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RELATED TO THE CANADIAN FIRE WEATHER INDEX

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PACIFIC FOREST RESEARCH CENTRE • CANADIAN FORESTRY SERVICE • VICTORIA, B.C.

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BY

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CONTENTS

ABSTRACT

Fire behavior, measured in mature lodgepole pine stands in central British Columbia, is described for various levels of the Canadian Fire Weather Index.

Test fires were conducted on plots of approximately 1/20 acre, using central point ignition and strip ignition. Rate of spread, flame length, frontal flame depth, crown fuel involvement and spotting probabilities are described along with fire impact on the site.

Three guidelines for initial attack dispatching in this fuel complex are suggested in terms of Fire Weather Index levels.

INTRODUCTION

Prediction of forest fire behavior has been a goal of fire research since the pioneering days of fire science in the 1930's. Many of the physical laws governing how fire behaves have been described over the past four decades, aided by laboratory and field modeling techniques. The problem remains, however, of how to incorporate physical laws into predictive tools usable in the field for decision making by forest land managers concerned with fire control and use.

The Forest Fire Behavior System of the Canadian Forestry Service (Can. For. Serv. 1970 b) is a current approach being developed to provide guidelines of fire behavior to various levels of fire management personnel. The first phase of this system consists of a fire danger rating scale called the Fire Weather Index (Can. For. Serv. 1970 a). This index has been adopted by most Canadian fire control agencies.

The present study was undertaken to develop a technique for quantifying initiating fire behavior in standing timber fuel types (Lawson, 1972). Fire behavior is described for the first hour following ignition in lodgepole pine (*Pinus contorta* Dougl. var. *latifolia* Engel.) stands. Values of various component modules of the Fire Weather Index are related to expected fire behavior. Such fire behavior parameters as initial spread rate, spotting and crowning potential, fire intensity, fuel consumption and short term fire impact on the site are considered.

FIELD PROCEDURE

Study Area

The experimental burns were conducted over three fire seasons, 1968, 1969 and 1970, on a study area about 40 miles north of Prince George, B.C. in the north-central interior plateau. Forests in this area are transitional between montane types to the south and subalpine types to the north and fall into the Montane Transition or M4 classification of Rowe (1959).

Locations of the three test fire sites and weather station are shown in Fig. 1. The two dry pine sites are essentially mature pure lodgepole pine with a scattered low understory of pine, white spruce, (*Picea glauca* (Moen.) Voss), alpine fir (*Abies lasiocarpa* (Hook.) Nutt.) and Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco). The dry sites are open and parklike, the north site stand being denser and shorter than that of the south site. Stand characteristics are given in Appendix I. Surface fuels consist of needle litter, moss and *Cladonia* reindeer lichen, with a low shrub layer of dwarf huckleberry (*Vaccinium* spp.). Dead down branch and log material is scattered. Surface fuel loadings are listed in Appendix II.

The fresh pine site has a more moist environment and appears to be a seral stage of a developing spruce-alpine fir climax forest. The stand is predominantly pine, but about 20% of the basal area is composed of Douglas-fir, spruce, alpine fir, birch (*Betula papyrifera* Marsh var. *subcordata* (Rhydb.) Sarg.) and aspen (*Populus tremuloides* Michx.). Because the soil is not as excessively drained, the moss layer is more lush than on the dry sites, and the highly flammable reindeer lichen is sparse. Again, huckleberry is the dominant low shrub layer, forming a complete cover about one-foot high.

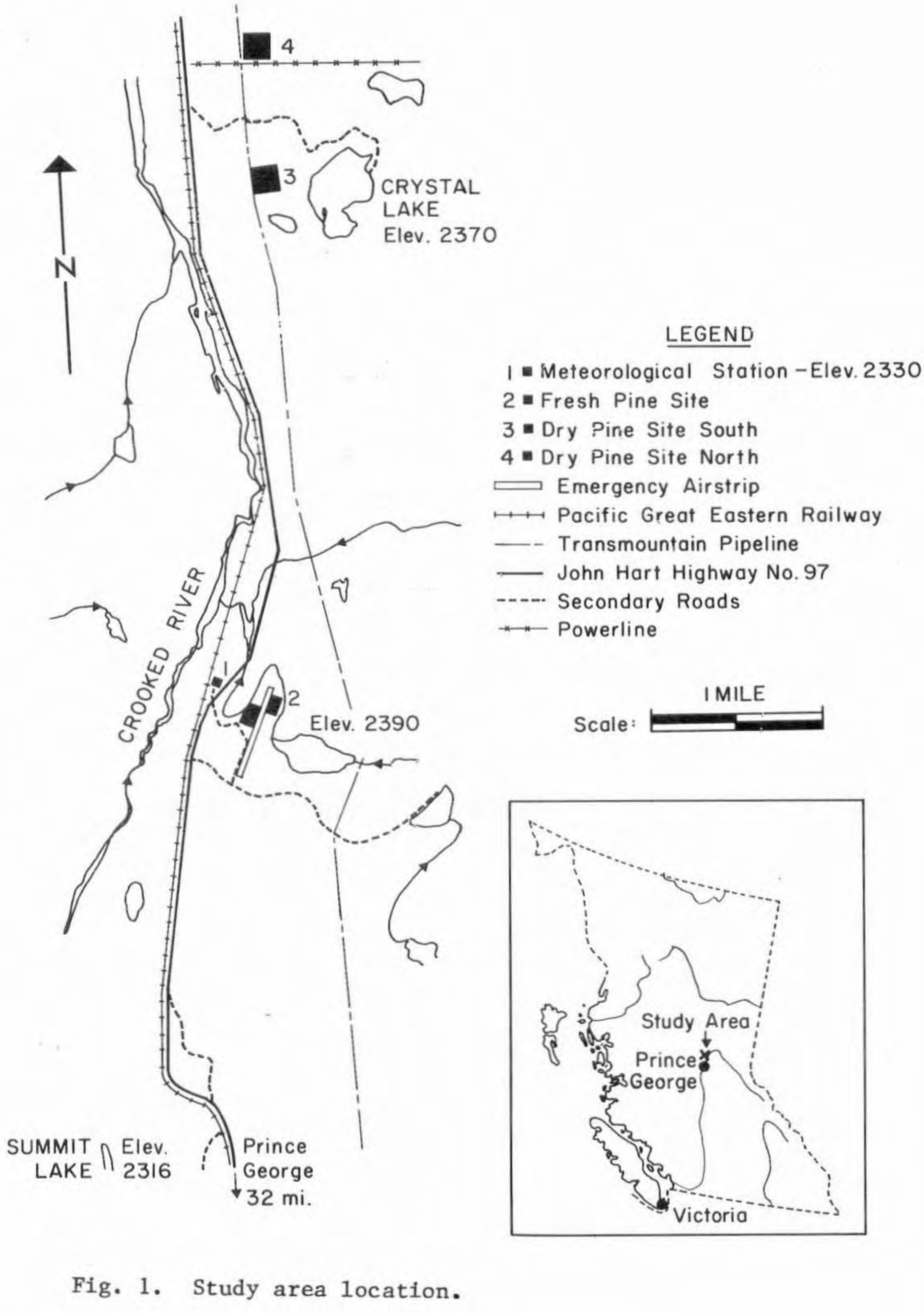

Fig. 1. Study area location.

Test Fire Methodology

Plot design

Two different plot designs were used for the test fires. A 50-foot diameter centrally-ignited circular plot was used for 20 of the test fires and a 50-foot square plot, edged ignited, was used for the other eight fires.

Fuel inventory

Standing and surface fuels were measured or sampled for each site and plot. Organic layer loadings were determined by vertically-stratified square-foot samples. Twig, branch and down-log fuel loadings were sampled on each plot, using a line intersect sampling technique (Van Wagner, 1968). All trees were measured for height and diameter and mapped as to location on the fire plots. Crowning susceptibility was rated on the most probable five trees per plot, based on fuels at the base and fire-carrying fuels on the boles up to the green crown.

Fuel moisture

Destructive samples from several fuel strata were taken on all rainless days to determine trends in fuel moisture content. On test fire days, moisture content samples were taken from the fire plots just prior to burning. Surface litter, upper and lower duff horizons, dwarf shrubs, several size classes of down branchwood and logs, and tree needles were sampled for moisture. Oven drying was used to determine moisture contents.

Weather and Fire Weather Index

Temperature, relative humidity, rainfall and wind velocity at 33 feet were continuously recorded at a weather station established in a large clearing adjacent to the fresh pine site. Noon values of these variables are required for daily calculation of the Fire Weather Index, which was the principal indicator of fire behavior used. Rainfall, temperature and humidity were also monitored in a clearing adjacent to the dry pine sites so that the most accurate indices could be calculated for each burn. Local differences in rainfall between the two sites were common, because much of the summer precipitation in the region is from frequent small convective showers.

Several weather parameters were monitored at the time of each test fire. These included wind speed in the stand at a height of 3.5 feet adjacent to the fire. Also, temperature and relative humidity at the fuel surface were recorded prior to ignition.

Fire behavior and impact

Ignition of centrally-ignited fires on circular plots was accomplished by lighting a cubic-foot pile of small twigs at the plot center. Square plots were ignited with a drip torch along the windward edge with one ignition line only.

Rate of spread was measured by plotting the fire front positions at regular time intervals. Heading flame lengths and fire front depths were estimated at these intervals. A thermocouple grid provided auxiliary spread and residence times for some fires. Photographs were taken to document such aspects of fire behavior as sudden rapid advances of the fire front or excursions into the crowns.

Fire impact on the site was determined by measuring fuel quantities removed, and by observing mortality of regeneration and mature trees annually for four years following the burns.

Fire control precautions

Each test fire plot was protected by an 18-inch-wide mineral soil fire guard. Hand tools for a crew of four were available, and water under pressure was supplied to each site. Complete mop up of all hot spots followed each burn. Although some fires were conducted under high fire danger conditions, no control difficulties were experienced. All spot fires ignited outside the plot areas from aerial firebrands were easily handled by the research crew.

RESULTS AND DISCUSSION

Fire Behavior

General

The 28 test fires were conducted over a wide range of burning conditions and showed large differences in spread rate, as shown by the following tabulation.

Mean Heading Rate of Spread (fpm)	Mean Stand Wind Speed (mph)	Fuel Moisture Content (%)	Initial Spread Index (ISI)	Fire Weather Index (FWI)
0.4 to 6.5	0.8 to 3.3	7 to 28	5 to 14	14 to 35

Appendix III details the fire behavior and fire environment conditions for each test fire.

It was not possible to achieve a threshold of fire behavior above which sustained crown fire spread appeared probable on any of the three sites. Factors accounting for this were the limited maximum rate of energy release from the surface fuels, lack of sufficient vertical and horizontal continuity of aerial fuels, and low ambient wind speeds which prevailed during the tests. Single trees and groups of trees "candled" or flared up on all three sites, but the energy flux from the ground was insufficient to sustain fire advancement through the rather open canopies. Wildfire observations suggest that crown fire spread could occur in these types if open wind speeds exceed 15 mph, but such conditions could not be tested in this study.

Spread rates vary with ignition pattern

Rates of spread were higher for strip-ignited plots than for centrally-ignited plots. This is due to the initial difference in the shape of the flame front of strip-ignited fires, compared to centrally-ignited fires. Centrally-ignited fires can only spread outward against their own convective activity during the early growth stage. During this period, flames lean inward toward the plot centre, away from the unburned fuel. The effect of wind gradually overcomes this spread-retarding convective inflow effect. The doughnut-shaped fire then begins to develop the single linear fire front characteristic of strip-ignited fires immediately after ignition. Except for the brief initial period in which the gasoline-diesel fuel mix is involved, the spread rate exhibited by the strip head fire is effectively the steady-state fire behavior condition for the surface fuel complex.

Figure 2 shows the early growth stage, ten minutes after ignition, on a centrally-ignited fire. Spread is being retarded by inward convection and flames are sloping away from the unburned fuel. Figure 3 shows an advanced stage of spread on a centrally-ignited fire, 30 minutes after ignition. It is essentially behaving in equilibrium with the fire environment at this stage, and has produced a single elongated front similar to the type of front produced immediately after ignition of a strip head fire (Fig. 4).

Spread rates for centrally-ignited fires were adjusted upward to compensate for the retarded early growth period. This adjustment enabled all fires to be considered as approaching the steady-state condition for spread through surface fuels, the condition of most concern to fire control planning, along with potential of crowning and spotting.

The upward adjustment of spread rates of centrally-ignited fires

Fig. 2. Initiating behavior of centrally-ignited fire.

Fig. 3. Advanced behavior of centrally-ignited fire.

Fig. 4. Ignition of strip head fire.

was made from an empirical curve fitted to the relation between spread rate and time from ignition (Fig. 5). Multiple curvilinear regression by successive approximation (Ezekiel, 1930) was the analytical technique used. This regression was corrected for the effects of wind (Fig. 6) and moisture content (Fig. 7) on spread. As Fig. 5 shows, no further growth in spread rate was apparent after 48 minutes following ignition, so spread rates for later times were assumed to be steady-state and were not corrected.

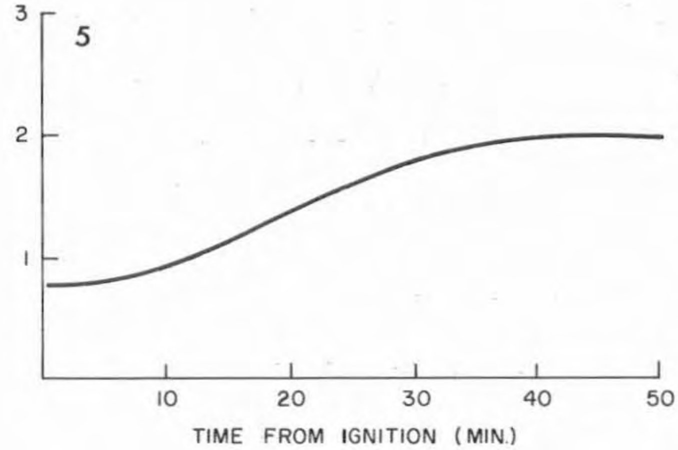

Fig. 5. Relation of spread rate to time from ignition for centrally-ignited fires.

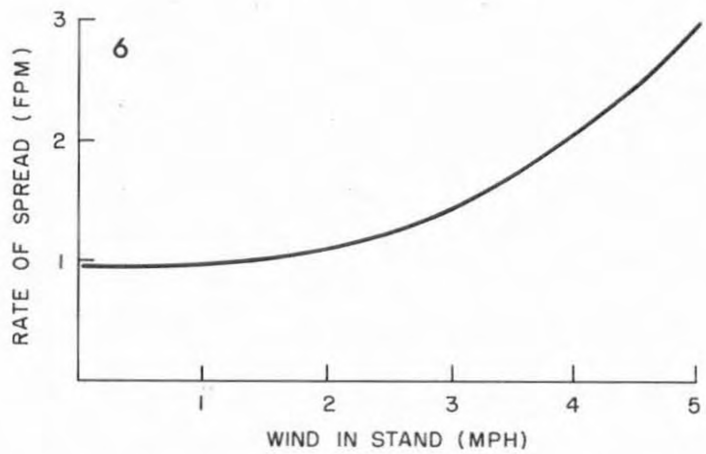

Fig. 6. Relation of spread rate to wind for centrally-ignited fires.

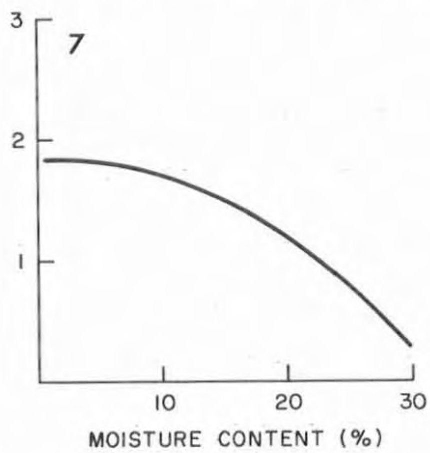

Fig. 7. Relation of spread rate to duff moisture content for centrally-ignited fires.

Mean spread rates for each plot were determined by averaging the rates for each time interval, using the above adjustment procedure for centrally-ignited plots. No corrections were made to strip-ignited plot spread rates. Appendix III lists the plot mean adjusted spread rates for the centrally ignited fires.

Fuel consumption and fire intensity

Although the duff layers were thin and down branch and log-type fuels were light on these sites, fuel depletion was not complete even when fuels were quite dry. Appendix IV shows that initial duff depths ranged from 0.9 inch to 1.8 inches, while consumption ranged from 0.21 inch to 0.65 inch and did not exceed 50% of the initial depth on any plot. In terms of loading, total fuel consumption of organic layer plus debris did not exceed 0.3 lb/ft^2 (6.5 T/ac) on any fire (Appendix IV) and was generally less than 30% of the initial fuel loading. Fuel consumption was highly variable among plots and was not well correlated with fire danger indices due, in part, to the highly variable initial loadings of dead-down debris.

Fire intensity is the product of spread rate, heat yield per unit mass of fuel consumed, and fuel quantity consumed by the heading fire front. Intensities were derived after Byram (1959), who developed an expression of energy output per unit time per unit length of fire front and used the units Btu/sec/foot. Because the intensity calculation refers only to fire frontal energy, appropriate deductions from total fuel consumption were made to allow for dead-down fuel which burned out after passage of the main fire fronts. In contrast to Byram, however, no deductions in heat yield of the fuel were made for incomplete combustion or radiation losses, because these small fires were judged to be highly efficient. The adjusted spread rates were used in the intensity calculations. The intensities calculated for these fires were less than 125 Btu/sec/foot (Appendix III), and fall at the low end of the range from 100 to 1000 Btu/sec/foot suggested by Byram (1959) as representing the majority of wildfires.

Fire Behavior Related to Fire Weather Index

Aspects of fire behavior in these stands considered to be most important from the initial attack viewpoint were rate of spread during initial stages, size of fire front, i.e., flame zone length and frontal depth, and probability of vertical growth into aerial fuels. Predictions of these variables were desired in terms of the Fire Weather Index (FWI) and its components.

Adjusted spread rates of centrally-ignited fires were pooled with strip fire spread rates. Multiple linear regression analysis was run to determine relationships of spread rate to components of the Fire Weather Index and to selected weather variables. As Appendix V shows, FWI alone was the best single variable associated with spread rate. No additional variable in combination could account for more of the variability in spread rate without increasing the error factor (standard error of estimate).

Figure 8 shows the relationship of spread rate to FWI. Each plot was typed as to its dominant fire carrying fuel, as indicated in this figure. However, there was insufficient evidence that separate rate of spread curves were required for each fuel. Certainly pure *Cladonia* fuel beds would produce higher spread rates than pure moss beds, but the fuels on operational sized areas tend to be admixtures of these fuels and needle litter, so a single spread curve seems appropriate.

Figures 9 and 10 show the relationship of heading flame length to spread rate and to depth of the fire front, respectively. These figures include data points from Russian studies (Vonskii, 1957) in similar pine stands, which correlate well with the present study results.

Spotting probability is virtually certain from firebrands thrown ahead of the fire front if Fine Fuel Moisture Code (FFMC) exceeds 90. To have mobile firebrands produced on these surface fires, candling or flaring of aerial fuels must be attained. Probability of candling trees is certain when FWI exceeds 20, as long as sufficient bridge fuels exist on the tree boles to transport fire up to the live crowns.

No thresholds for crown fire spread can be suggested from this study. However, it is reasonable to expect that under certain wind velocity conditions, horizontal heat transfer sufficient to move fire through the crowns would be attainable.

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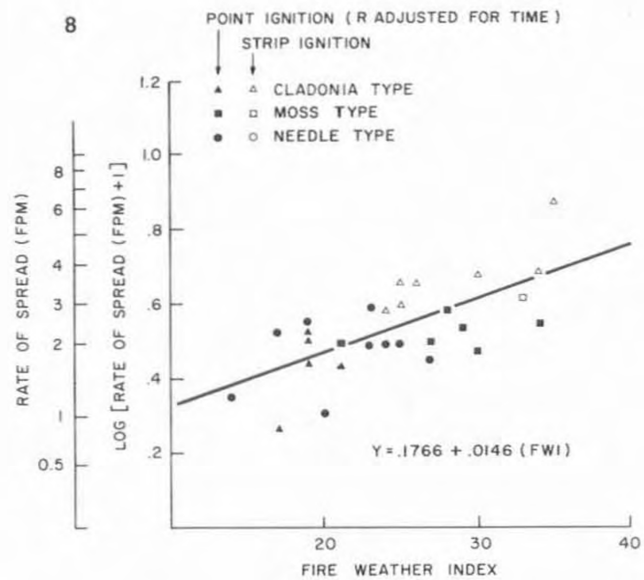

Fig. 8. Relation of spread rate to Fire Weather Index.

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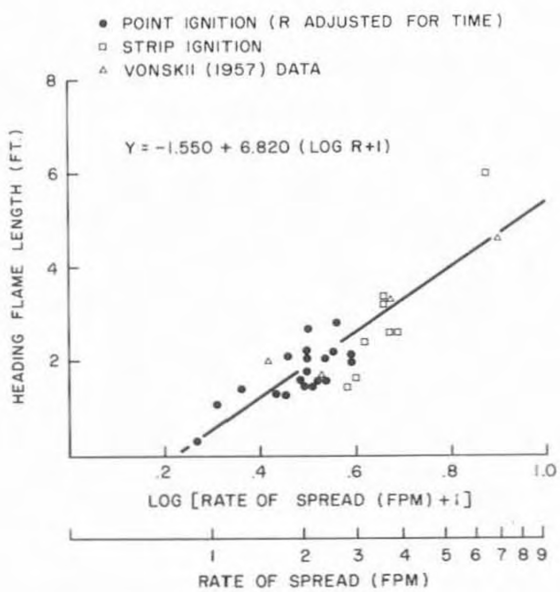

Fig. 9. Relation of heading flame length to spread rate.

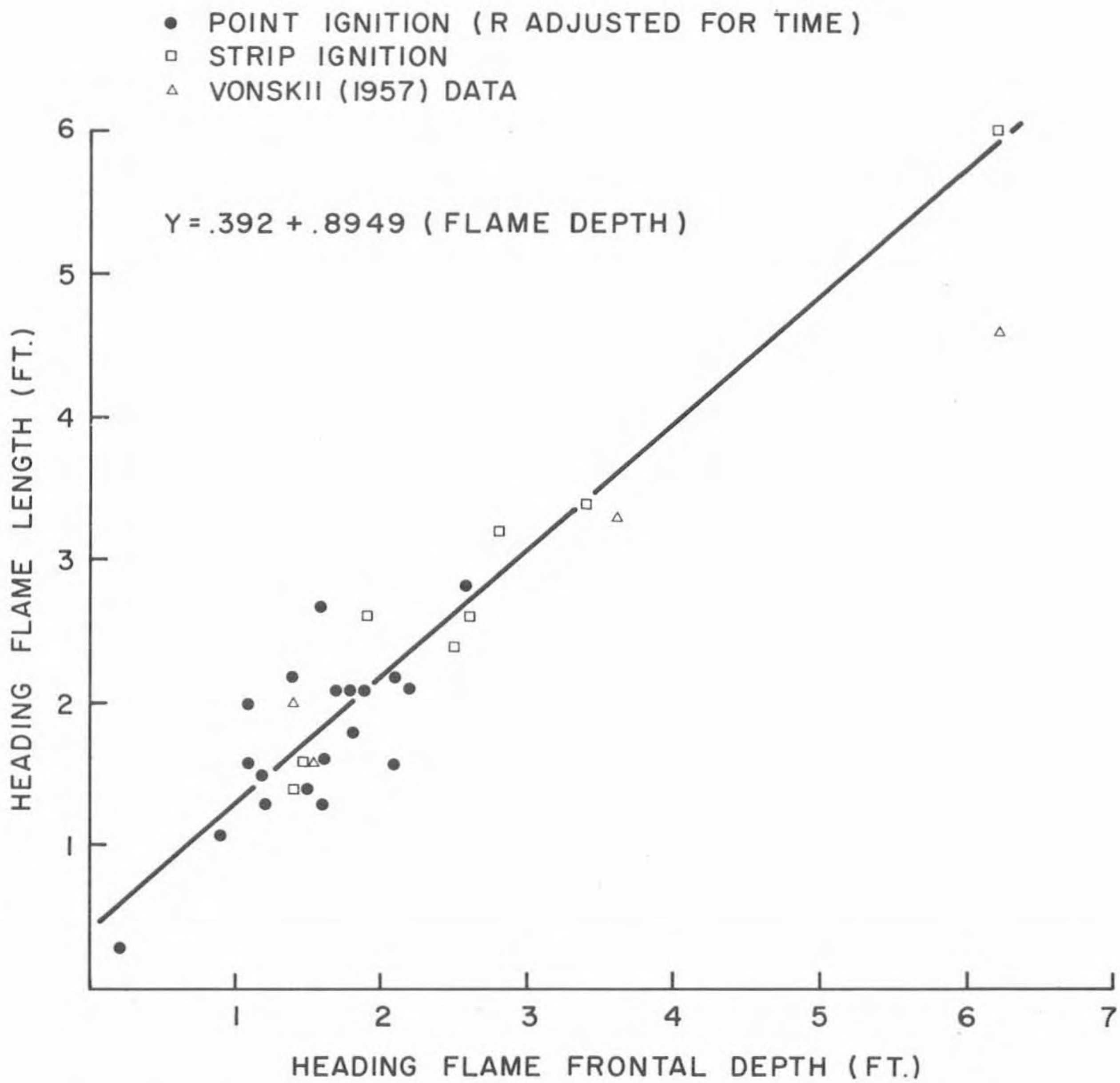

Fig. 10. Relation of heading flame length to head fire frontal depth.

Fire Impact on the Site

The study fires were low energy fires, none of them consuming more than half the duff layer or exposing more than isolated patches of mineral soil. Most of the advance regeneration was killed, and mature tree damage was sufficient to produce high bark beetle-induced mortality, two, three and four years following the fires, Appendix IV. Mature tree mortality ranged from zero to 83%, with fire being the primary damage agent and *Ips* spp. of pine engraver beetles ultimately causing tree mortality. Mortality generally increased with fire energy output, with scorch height and with FWI. No tendency was observed for insects to invade adjacent healthy trees outside the fire plots.

Implications for Fire Management

Dispatching suppression forces for initial attack on fires in mature lodgepole pine stands with low surface fuel loadings and low probability of crown fire spread can be aided by knowledge of probable spread rates and fire energy output. The following guidelines are presented to represent three possible action levels, based on significant fire behavior changes that could be expected in this fuel type. The guidelines are presented in terms of component index levels of the Fire Weather Index and predict limits of fire behavior to be expected.

Guideline 1 - low hazard

FWI $\leq$ 20	Spread rate $\leq$ 2.5 ft/min
ISI $\leq$ 6	Frontal flame length $\leq$ 2.5 ft
FFMC $\leq$ 90[1/]	Frontal flame depth $\leq$ 2.5 ft

Probability of crown involvement and spotting 50%. Control easy to achieve, using direct attack with hand tools. Spread rate slow.

Guideline 2 - moderate hazard

FWI 21-29	Spread rate 2.0-3.6 ft/min
ISI 7-11	Frontal flame length 1.5-3.5 ft
FFMC 91-93	Frontal flame depth 1.0-3.0 ft

Probability of crown involvement and spotting 100%. Control moderately easy to achieve, using direct attack with hand tools. Spread rate slow to moderate. Spotting ahead increases perimeter requiring control work.

Guideline 3 - high hazard

FWI 30-35	Spread rate 2.5-6.5 ft/min
ISI 12-14	Frontal flame length 2.0-6.0 ft
FFMC 94-96	Frontal flame depth 2.0-6.5 ft

Probability of crown involvement and spotting 100%. Control difficulty increases as upper end of index values reached. Indirect attack and suppression equipment in addition to hand tools probably required. Spread rate moderate to high, with spotting and crown fuel involvement frequent.
Higher ISI levels due to high wind velocities may produce crown fire spread.

1/ At FFMC $\leq$ 85, there is only 50% probability of ignition in this fuel type, but ignition probability rises to 90% at FFMC of 90. R.N. Russell, Ignition guides for spruce and lodgepole pine stands in the Prince George region, in process.

The descriptive terms for the hazard levels are relative to this particular fuel type, but even at the high hazard conditions defined by Guidelines 3, control work is relatively easy, due to the low energy output of initiating fires in such light fuels.

When the above guides are applied to the study fires, at least 83% of the fires in each of the three index categories are correctly predicted in terms of the fire behavior limits for spread, flame length and flame depth.

A final implication for forest management after fire in these stands concerns insect problems directly related to fire damage. Even though low intensity surface fires kill very few mature pines directly, bark beetles can be expected to invade fire-weakened trees and kill a large proportion within three to four years. This suggests early salvage of timber should be undertaken, even if a fire appears to be of low intensity and bole and crown scorch appears minimal. The high degree of insect-induced mortality on these small plots is probably not indicative of the amount of mortality to be expected on large burn areas, since the small plots concentrate the insect population in a relatively few trees. However, one should be prepared for potential insect problems shortly after fire in lodgepole pine stands.

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APPENDIX I. Standing fuel characteristics

	Dry Pine South	Dry Pine North	Fresh Pine
Number of live trees per acre	322	374	454
Number of standing snags per acre	101	71	44
Basal area per acre (ft^2)	102	80	102
Total gross vol. per acre (ft^3)	3400	2160	3300
Mean lodgepole dbh (in.)	7.5	5.9	7.4
Mean lodgepole age (yrs)	100	77	74
Percent of basal area in lodgepole	97.5	99	82
Percent of basal area in Douglas fir	0.4	0	9
Percent of basal area in spruce	2.0	1	5
Percent of basal area in alpine fir	0.1	0	4
Mean height of lodgepole (ft)	67	48	63
Mean height to base of green crown (ft)	32	22	37
Mean crown length (ft)	34	26	24
Mean No. branches/tree<¼" on boles to ht of 10ft	4.1	6.9	8.4
Mean tot. No. branches/tree on boles to ht of 10ft	15.2	18.0	22.3
Pine regeneration No. per acre	2000	2300	130
Pine regeneration mean height (ft)	3	3.5	6
Douglas fir regeneration No. per acre	4	0	400
Douglas fir regeneration mean height (ft)	8	0	4
Spruce regeneration No. per acre	90	20	250
Spruce regeneration mean height (ft)	5	3	5
Alpine fir regeneration No. per acre	140	0	725
Alpine fir regeneration mean height (ft)	3	0	4
Total regeneration per acre	2234	2320	1505
Mean regeneration ht (ft)	3	3.5	4

APPENDIX II. Surface fuel loadings and bulk densities by site

	Dry Pine South	Dry Pine North	Fresh Pine
Loading of herbs and low shrubs (lb/ft^2)	.008	.010	.006
Depth of herbs and low shrubs (in.)	6	6	12
Loading of fine surface litter (lb/ft^2)	.011	.007	.009
Loading of upper organic layer (lb/ft^2)	.139	.128	.128
Depth of upper organic layer (in.)	.77	.85	.86
Bulk density of upper organic layer (g/cm^3)	.035	.029	.029
Loading of total organic layer (lb/ft^2)	.333	.229	.386
Depth of total organic layer (in.)	1.2	1.2	1.4
Bulk density of total organic layer (g/cm^3)	.053	.037	.053
Loading of surface branch fuel 0-½ in. (lb/ft^2)	.008	.005	.007
" " " " " 1/2-1 in.	.003	.002	.002
" " " " " 1-2 in.	.013	.005	.003
" " branch and log fuel 2-3 in.	.016	0	.008
" " log fuel greater than 3 in.	.087	.052	.016
Total surface fuel loading (lb/ft^2)	.468	.303	.428

APPENDIX III. Fire behavior and fire environment data

Plot[1/] No.	Mean Heading R.O.S. Uncorrected for growth (fpm)	Mean Heading R.O.S. Corrected for Growth (fpm)	Mean Head Fire Intensity (Btu/sec/ft)	Heading flame length (ft)	Heading flame depth (ft)	Stand wind (mph)	Open[2/] wind (mph)	Air temp at 4 ft (°F)	R.H. at 4 ft (%)	Surface litter M.C. (%)	Upper Organic layer M.C. (%)	DANGER INDICES: Fine Fuel Moisture Code	DANGER INDICES: Duff Moisture Code	DANGER INDICES: Initial Spread Index	DANGER INDICES: Fire Weather Index
109	0.9	1.3	14	1.4	1.5	0.8	2	78	29	9.8	17.4	90	37	5	14
205	0.4	0.9	7	0.3	0.2	2.2	4	65	52	17.4	28.4	90	44	6	17
108	1.9	2.4	34	1.6	2.1	2.1	4	78	32	9.6	18.1	90	43	6	17
110	1.4	1.8	35	1.3	1.6	2.3	4	75	30	13.5	12.8	90	47	6	19
111	1.5	2.2	32	2.7	1.6	1.5	3	80	17	14.7	13.4	92	38	7	19
107	1.7	2.6	44	2.8	2.6	2.7	5	71	45	14.3	18.4	90	50	6	19
112	1.9	2.4	37	1.6	1.6	1.9	4	74	25	10.8	6.9	90	45	6	19
106	0.8	1.1	15	1.1	0.9	1.9	4	81	25	8.8	19.1	91	47	7	20
118	1.3	1.8	22	1.3	1.2	2.5	5	76	23	10.8	6.9	91	45	7	21
211	1.5	2.2	31	2.2	1.4	2.9	6	80	19	14.7	16.0	91	40	8	21
114	1.5	2.1	36	1.8	1.8	2.3	4	78	22	14.0	11.6	91	65	7	23
103	2.0	2.9	26	2.0	1.1	2.3	4	83	22	11.7	11.7	96	34	13	23
429	1.6	2.1	33	2.1	1.9	2.4	4	72	18	11.0	17.6	91	92	7	24
124*	2.8	2.8	31	1.4	1.4	2.6	5	82	14	10.9	10.9	93	68	9	24
426	1.5	2.2	20	1.5	1.2	2.8	6	72	22	17.6	14.0	92	70	9	25
430*	3.0	3.0	20	1.6	1.5	2.4	4	72	22	6.6	12.3	93	70	9	25
432*	3.6	3.6	68	3.2	2.8	2.4	4	76	26	15.6	11.9	91	99	7	25
433*	3.6	3.6	47	3.4	3.4	2.2	4	72	16	9.3	7.9	92	92	8	26
428	1.4	2.1	29	1.5	1.2	2.1	4	78	26	14.3	10.2	92	99	8	27
113	1.4	1.9	44	2.1	1.7	2.0	4	78	21	14.0	11.6	93	65	9	27
105	2.1	2.9	26	2.1	2.2	2.2	4	78	22	9.2	10.4	94	76	10	28
121	1.8	2.5	20	2.1	1.8	2.4	4	81	16	12.7	11.0	94	82	10	29
427	1.4	2.0	24	1.6	1.1	2.5	5	74	16	9.1	9.9	93	96	9	30
431*	3.8	3.8	67	2.6	1.9	2.7	6	74	18	9.1	16.8	92	96	9	30
120*	3.2	3.2	21	2.4	2.5	2.3	4	82	15	10.3	9.8	95	82	12	33
122	1.9	2.5	34	2.2	2.1	3.2	6	74	14	7.1	8.5	95	72	14	34
123*	3.9	3.9	37	2.6	2.6	3.3	8	73	14	7.1	8.5	94	72	14	34
119*	6.5	6.5	125	6.0	6.2	2.8	6	79	21	8.8	13.5	95	76	14	35

1/ Plots numbered in 100's are Dry Pine South, in 200's are Fresh Pine, and in 400's are Dry Pine North.
* Asterisks indicate strip head fire ignition.
2/ Open winds derived from stand winds for danger index calculation from relationships in Cooper (1965).

APPENDIX IV. Fuel consumption and fire impact

Plot[1/] No.	Initial Organic Layer Depth (in)	Initial Organic Layer Weight (lb/ft^2)	Initial Debris Weight 0-0.5" Diam. (lb/ft^2)	Initial Debris Weight >0.5" Diam. (lb/ft^2)	Total Initial Debris Weight (lb/ft^2)	Total[2/] Initial Fuel Weight (lb/ft^2)	Organic Layer Consumption Depth (in)	Organic Layer Consumption Weight (lb/ft^2)	Debris Consumption 0-0.5" Diam. (lb/ft^2)
109	1.4	.332	.008	.015	.023	.363	.35	.059	.007
205	1.8	.452	.006	.083	.089	.547	.30	.050	.002
108	1.6	.390	.008	.259	.267	.665	.42	.071	.007
110	1.4	.332	.005	.263	.268	.608	.57	.096	.004
111	1.2	.298	.006	.017	.023	.329	.44	.074	.006
107	1.6	.390	.011	.056	.067	.465	.60	.101	.010
112	1.5	.373	.009	0	.009	.390	.55	.092	.009
106	1.8	.473	.012	.092	.104	.585	.33	.055	.012
118	1.5	.373	.009	.002	.011	.392	.40	.068	.009
211	1.1	.242	.007	0	.007	.255	.52	.087	.007
114	1.3	.315	.007	0	.007	.330	.65	.109	.006
103	1.2	.298	.007	.032	.039	.313	.30	.050	.007
429	1.1	.257	.004	0	.004	.271	.51	.086	.003
124*	1.1	.257	.004	.161	.165	.430	.27	.045	.004
426	1.2	.298	.006	.028	.034	.342	.21	.035	.005
430*	1.2	.298	.004	0	.004	.312	.20	.034	.004
432*	1.4	.332	.007	.437	.444	.786	.37	.062	.007
433*	1.0	.241	.005	.001	.006	.257	.47	.079	.004
428	1.3	.315	.005	.002	.007	.330	.50	.084	.005
113	1.7	.432	.006	.356	.362	.802	.54	.091	.006
105	1.1	.257	.004	.004	.008	.273	.30	.050	.003
121	1.2	.298	.007	.009	.016	.322	.21	.035	.007
427	1.3	.315	.003	0	.003	.328	.42	.071	.003
431*	1.6	.390	.007	0	.007	.407	.65	.109	.006
120*	1.2	.298	.008	.151	.159	.465	.18	.030	.008
122	0.9	.224	.012	.392	.404	.636	.24	.040	.011
123*	0.9	.224	.005	.004	.009	.241	.30	.050	.005
119*	1.1	.257	.012	.358	.370	.635	.35	.059	.012

1/ Plots numbered in 100's are Dry Pine South, in 200's are Fresh Pine and in 400's are Dry Pine North.
* Asterisks indicate strip head fire ignition.
2/ Includes herbaceous fuel loading and consumption of .008, .006 and .010 lb/ft^2 for Sites 1,2 and 4 respectively

APPENDIX IV. Fuel consumption and fire impact (cont'd)

Plot[1/] No.	Debris Consumption > 0.5" Diam. (lb/ft^2)	Total Debris Consumption (lb/ft^2)	Total[2/] Fuel Consumption (lb/ft^2)	Fuel[2/] Consumed By Heading Front (lb/ft^2)	Mean Scorch Height (ft)	No. of Candling Trees	Mature Tree Mortality to Oct. 72 (%)	Advance Regeneration Mortality to Oct. 72 (%)
109	0	.007	.074	.074	.8	0	15	97.5
205	0	.002	.058	.058	0	0	0	0
108	.044	.051	.130	.099	.6	1	11	100
110	.092	.096	.200	.138	1.7	0	6	100
111	.017	.023	.105	.101	2.4	4	20	99.4
107	.018	.028	.137	.121	1.3	1	5	97.5
112	0	.009	.109	.109	2.7	3	33	100
106	.092	.104	.167	.098	1.2	1	0	100
118	.002	.011	.087	.086	6.3	10	54	100
211	0	.007	.100	.100	3.1	4	45	100
114	0	.006	.123	.123	6.9	6	73	100
103	0	.007	.065	.065	1.5	1	32	100
429	0	.003	.099	.099	1.6	2	16	100
124*	.060	.064	.117	.078	2.6	1	38	100
426	.024	.029	.072	.063	1.4	0	14	99.3
430*	0	.004	.046	.046	4.5	2	31	97.0
432*	.166	.173	.245	.134	5.2	1	71	99.4
433*	0	.004	.093	.093	4.8	5	54	100
428	0	.005	.099	.099	1.4	1	40	98.0
113	.184	.190	.289	.162	5.3	7	29	100
105	.002	.005	.063	.063	1.3	3	20	100
121	.006	.013	.056	.055	2.5	4	57	100
427	0	.003	.084	.084	1.9	2	15	100
431*	0	.006	.125	.125	2.7	2	17	98.3
120*	0	.008	.046	.046	3.3	4	64	100
122	.104	.115	.163	.095	1.8	1	4	100
123*	.004	.009	.067	.067	2.9	1	25	100
119*	.182	.194	.261	.137	5.9	2	83	100

1/ Plots numbered in 100's are Dry Pine South, in 200's are Fresh Pine and in 400's are Dry Pine North.
* Asterisks indicate strip head fire ignition.
2/ Includes herbaceous fuel loading and consumption of .008, .006 and .010 lb/ft^2 for Sites 1,2, and 4 respectively.

APPENDIX V. Regression equations for prediction of fire behavior parameters from Fire Weather Index components and fire environment variables.

Y Dependent	X Independent	Inter-cept	Regr. Coef.	SEE	R^2	Mean Y	Mean X
$\log_{10}$(ROS+1)	Fire Weather Index	.1766	.0146	.094	.446	.534	24.6
"	Initial Spread Index	.2785	.0296	.100	.396	.534	8.6
"	Fine Fuel Moist. Code	-3.015	.0385	.104	.317	.534	92.2
"	Wind in stand	.2523	.1202	.110	.230	.534	2.35
"	Relative Humidity	.6765	-.0662*	.113	.198	.534	22.9
"	Org. Layer M.C.	.6857	-.0116*	.113	.190	.534	13.0
"	Fine Fuel Moist. Cont.	.7141	-.0156*	.116	.149	.534	11.5
Flame Length	$\log_{10}$(ROS+1)	-1.550	6.820	.338	.684	2.1	.534
"	Front Flame Depth	.392	.8949	.349	.886	2.1	1.9
"	$\log_{10}$(Intensity (Hwr))	-2.494	3.206	.633	.626	2.1	1.43
Front Flame Depth	$\log_{10}$(ROS+1)	-1.802	6.922	.655	.639	1.9	.534

Note: All regressions significant at .01 level by F-test except those noted * which are significant at .05 level.

Regressions include all 28 test fires (strip and point ignition) with point source fire ROS adjusted for growth with time.