THE MAY 1968 FOREST CONFLAGRATIONS IN CENTRAL ALBERTA

A review of fire weather, fuels and fire behavior

by

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A. D. Kiil and J. E. Grigel[1]

INTRODUCTION

In 1968, Alberta experienced an extremely severe spring forest fire season. During the 15-day period from May 16 to 31, 250 fires burned more than 950,000 acres of forest land. The suppression of these fires involved over 100 aircraft, retardant planes and helicopters, 580 bulldozers and an army of about 5,000 firefighters. Firefighting costs exceeded 4 million dollars.

Most of the forest conflagrations occurred in a 150-mile semi-circular strip across central Alberta. This area borders on a transition zone from forest to prairie where land clearing and debris-burning is prevalent. Hundreds of settler fires were burning adjacent to this forest zone before and during the peak fire period and many of these subsequently spread into the forested zone. The largest single conflagration, a 330,000-acre blaze south of Lesser Slave Lake, had as its source several settler fires in the agricultural zone which united and was swept in a northwesterly direction by the high winds.

The peak of the 1968 debris-burning season in agricultural areas coincided with an unusually long period of hot and dry weather. On May 16 a large air mass settled over central Canada and resulted in strong south-easterly winds over much of central Alberta. This air mass

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was the single most important cause of fuel drying and the extremely rapid fire spread.

The common forest associations in central Alberta include pure stands of aspen (*Populus tremuloides*) and balsam poplar (*P. balsamifera*), with mixtures of aspen, balsam poplar and white spruce (*Picea glauca*) on the well-drained uplands. Lodgepole pine (*Pinus contorta* var. *latifolia*) and jack pine (*P. banksiana*) occur in pure stands or mixed with black spruce (*Picea mariana*) or white spruce (Rowe, 1959). Of the land administered by the Alberta Forest Service about 75 per cent is forested, the remainder being mainly agricultural and grassland. About 45 per cent of the forested area is classified as coniferous, 35 per cent as mixedwood and the remaining 20 per cent as deciduous (Anon, 1961). Young and immature forest cover types predominate, reflecting the high rate of fire occurrence and damage during the past few decades. Average volume per acre on presently forested area exceeds 1,500 cubic feet (4" dbh and over). Some common forest cover types are shown in Figures 1 to 4.

This report documents synoptic and local weather, indicates the nature and condition of forest fuels, and describes some important aspects of fire behavior and effects. The identification and measurement of individual fuel and weather factors in fire behavior is basic to prediction of critical fire conditions. Much of the information about fire weather, fuels and fire behavior relates to burning conditions in the huge fire south of Lesser Slave Lake but similar conditions appear to have been present for all fires in the zone of high fire occurrence. The blaze south of Lesser Slave Lake, however, epitomizes the upper limit of fire behavior and should be valuable as a case study of extreme

Figure 1. View of typical lodgepole pine stand.

Figure 2. Interior of typical lodgepole pine stand.

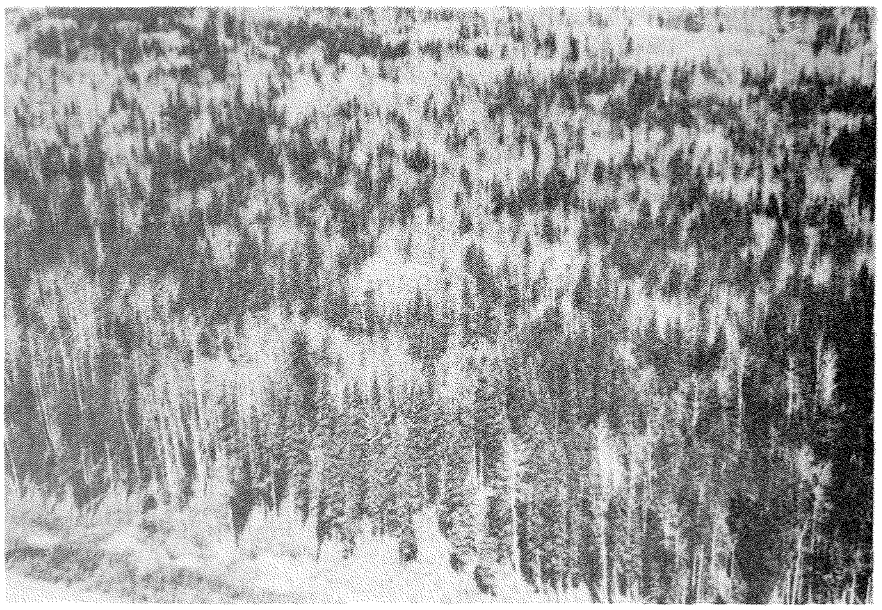

Figure 3. Aerial view of spruce-aspen stand.

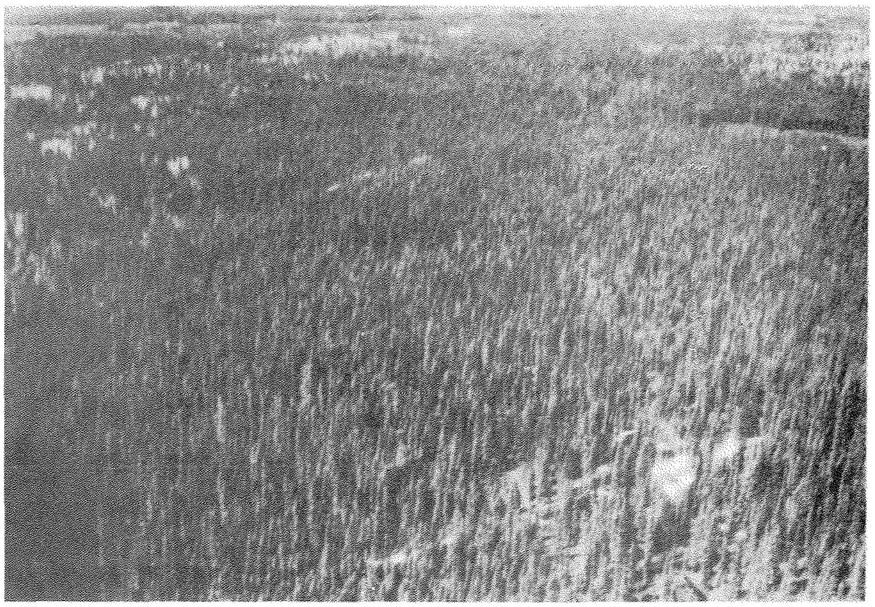

Figure 4. Aerial view of black spruce stand.

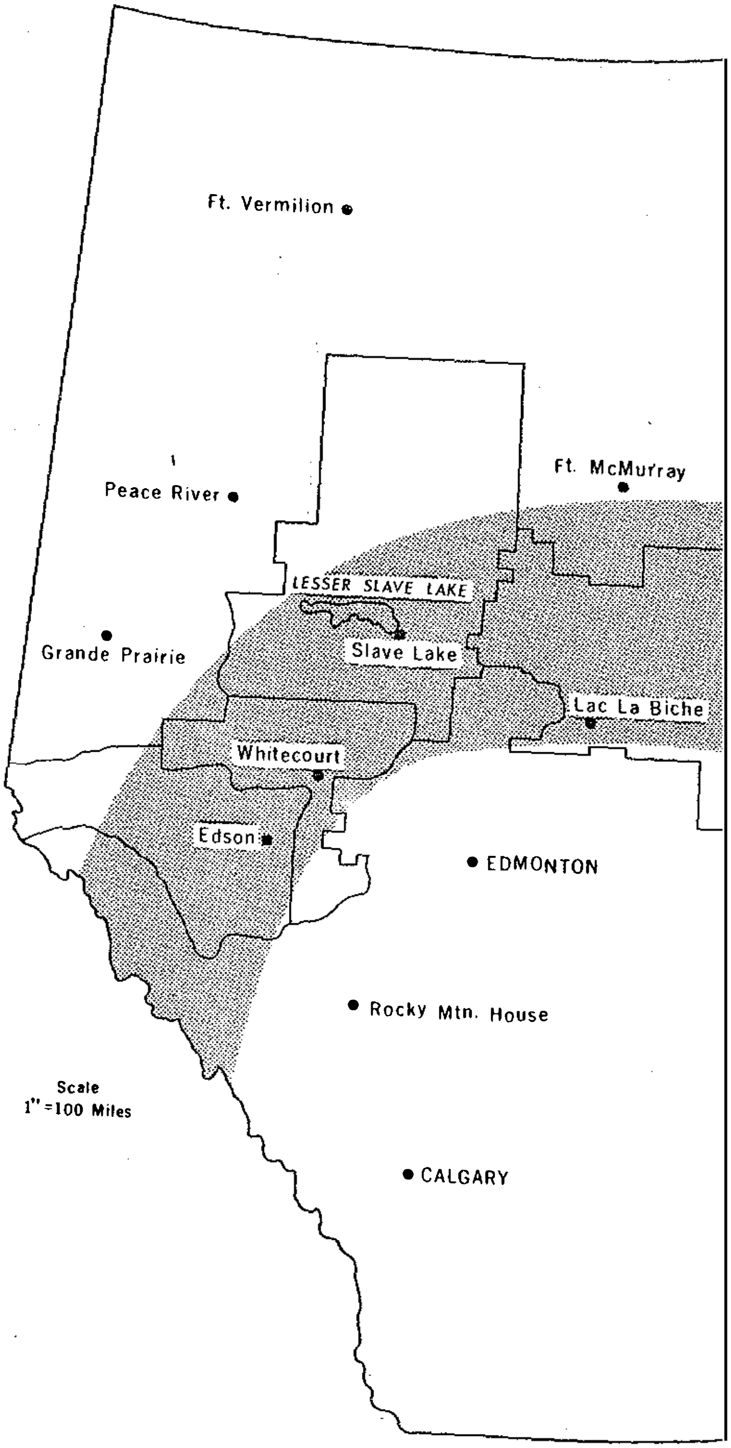

Figure 5. Map of the Province of Alberta showing the zone of high fire incidence.

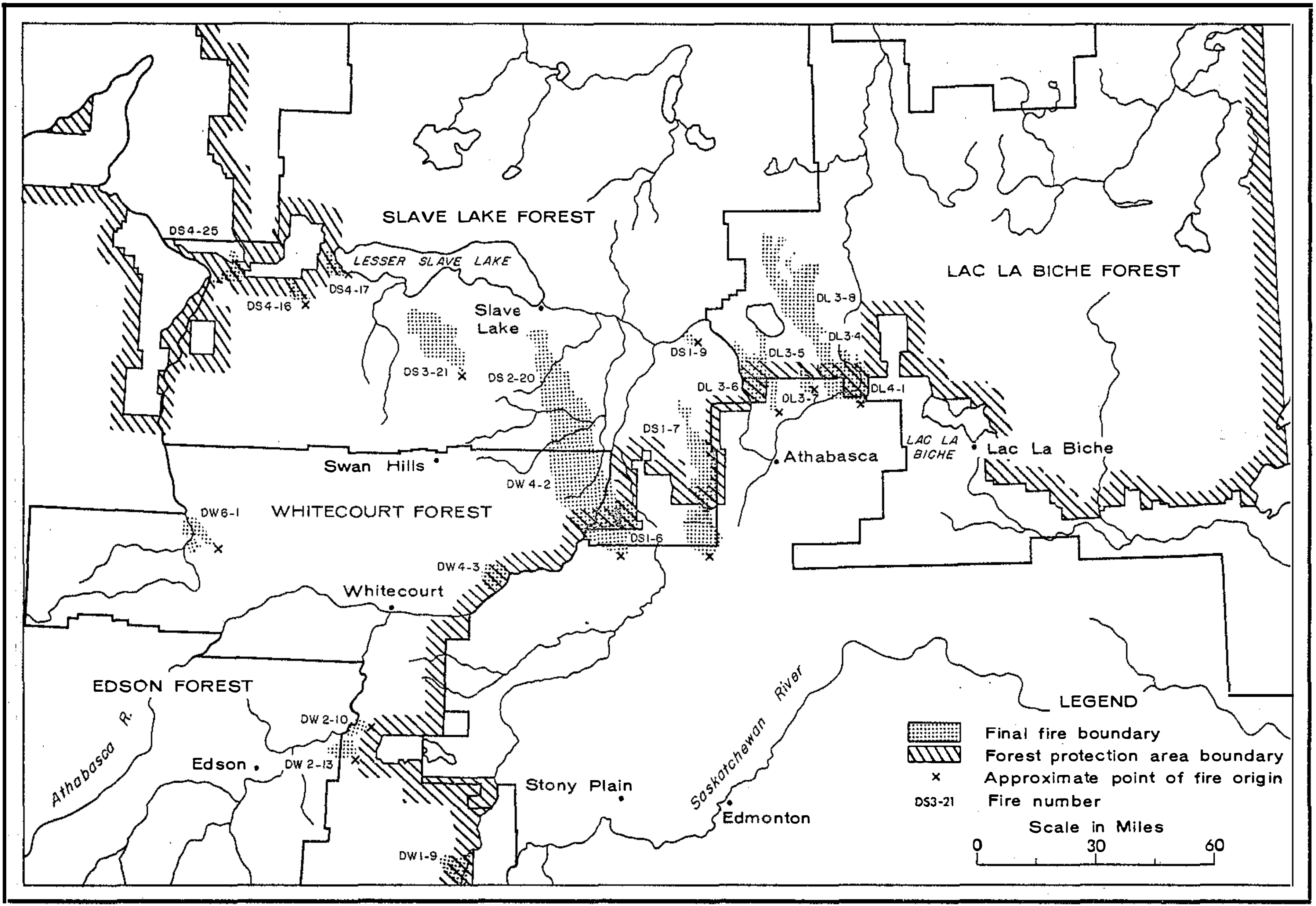

Figure 6. Location of May 1968 fires over 500 acres in size.

burning conditions in central Alberta.

FIRE INCIDENCE

The region of highest fire incidence is located in the Edson, Whitecourt, Slave Lake and Lac La Biche Forests, about 100 miles north, northwest, and west of Edmonton (Figs. 5 and 6). The area contains some agricultural land and land in the process of being cleared for settlement but most of it is forested and administered by the Alberta Forest Service. The forested area of Alberta is divided into 10 Forests for administrative purposes, each Forest being responsible for fire control activities within the boundaries of the protected zone.

A total of 131 fires burned over 732,000 acres, an average of 559 acres per fire (Table I). Of the total forested area of about 52,000 square miles, 1,145 square miles, or 2.2%, was burned.

TABLE I. NUMBER OF FIRES, AREA BURNED AND PER CENT OF AREA BURNED IN EACH FOREST FOR THE PERIOD MAY 16 TO 31, 1968.

Forest	No. of fires	Area burned (acres)	Per cent of forested area burned
Edson	21	88	Negligible
Whitecourt	35	196,948	3.5
Slave Lake	49	310,154	2.2
Lac La Biche	26	225,779	2.9
Total	131	732,969	2.2

Set fires associated with land-clearing operations are common throughout Alberta and thousands of acres are treated annually. During the middle of May, smoke from hundreds of such settler fires could be observed throughout central Alberta. Settler fires presented no special suppression problems for the Alberta Forest Service until weather and fuel conditions became favorable for rapid spread about May 18. All fires exceeding 500 acres made their major runs during the seven-day period from May 18 to 24. Alberta Forest Service fire-fighting personnel and facilities were taxed in that period to an extent never before experienced. On May 23 alone the fire[2] in Whitecourt and Slave Lake Forests burned over 150,000 of its final 330,000 acres during a 10-hour period between 1300 and 2300 hours. Burning on a 10 to 15-mile front, it spread at an average rate of 4 miles per hour through a wide variety forest cover types. The forest fire situation in Alberta remained critical until the end of May when rains suppressed existing fires and reduced the hazard. Mop-up operations continued for several weeks.

Preliminary estimates by the Alberta Forest Service indicate that the value of salvageable trees in the Lesser Slave Lake fire alone amounts to 36 million dollars.

FIRE WEATHER

Weather Prior to Burning Period

The forested region under consideration, along with a large part of Alberta, experienced severe drought conditions during the

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[2] Henceforth referred to as the Lesser Slave Lake fire.

summer of 1967 (Fig. 7). Warm, dry weather continued into autumn, at which time a number of deep-burning ground fires occurred. Several of these, although under control, continued to burn during winter. Freezing conditions occurred before precipitation was able to replenish the ground moisture supply. Snowfall was below normal during the 1967-68 winter (Fig. 8) and in addition much of it was removed by frequent chinooks. A prolonged mild spell in early spring evaporated most of the remaining snow cover so that the normal wetting of forest fuels by the melting and infiltration of moisture from accumulated snow did not occur. By early May, almost all of central Alberta was free of snow and drying was accelerated by warm winds. Precipitation was relatively low during the first two weeks in May, so that by the middle of May the light surface fuels had reached a highly flammable state.

Weather During Period of Fires

During this period of extreme fire hazard, weather over much of the Prairie Provinces was dominated by a stagnant high pressure mass originated over frozen sea and land areas in the Arctic; hence, the system was cool and very dry as it moved south. Having reached Saskatchewan and Manitoba, the dry air mass became blocked. It circulated slowly in a clockwise direction. Low humidities, high temperatures and persistent winds of 15 to 45 miles per hour prevailed.

Large-scale subsidence, or settling of a mass of air, subsequently occurred[3]. This subsidence was so extensive that a strong,

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[3] Subsiding air may originate at great heights, in extreme cases at or near the tropopause. At the point of origin this air is very cold, but it has a high potential temperature. Because of the extremely low initial temperature, the air contains little water vapor. As it lowers, this air heats by compression. Since its potential temperature at the point of origin is high, and since it tends to heat at the adiabatic rate, the result is a warm, exceedingly dry air mass when the air reaches lower levels.

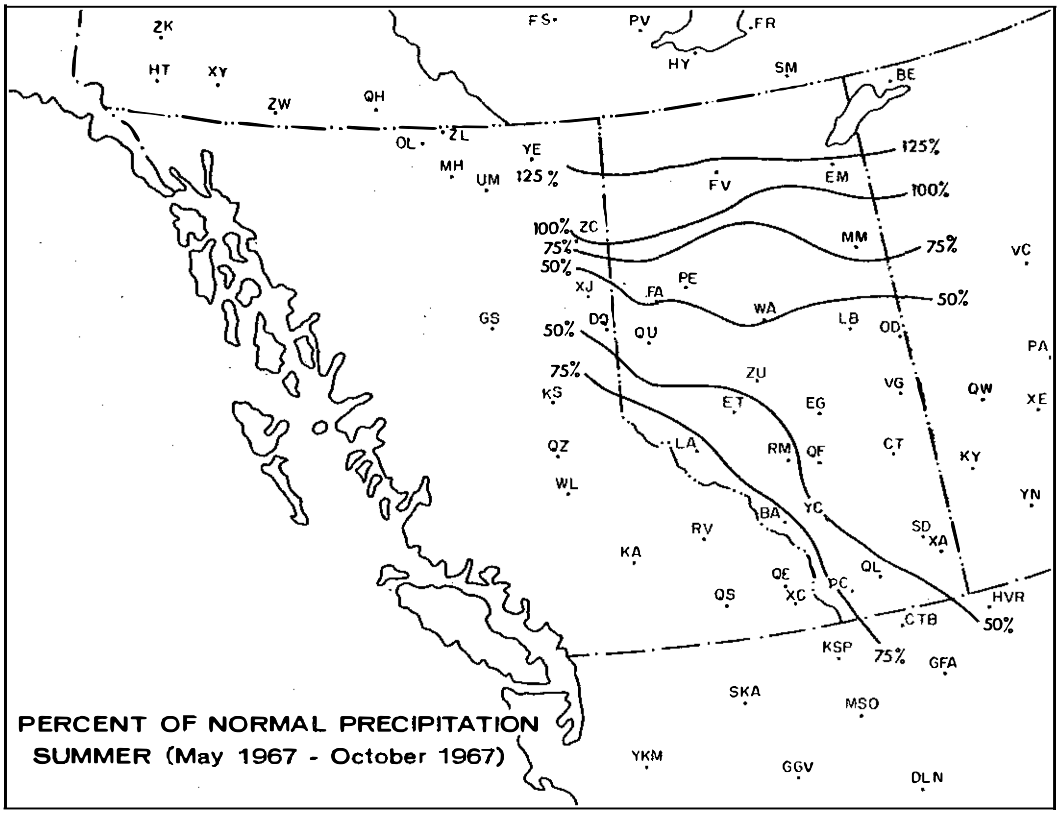


Figure 7. Percent of normal precipitation for Alberta during summer (May 1967 - October 1967). Note below normal rainfall in central region.

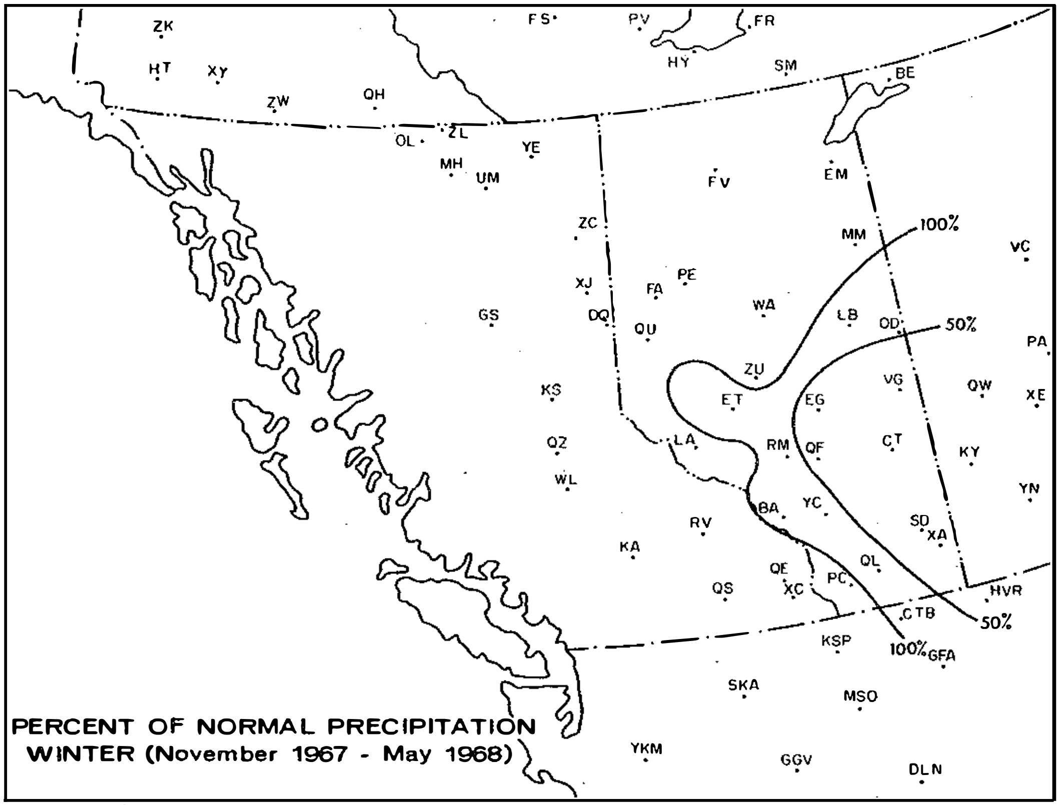


Figure 8. Percent of normal precipitation for Alberta during winter (November 1967 - May 1968). Note below normal precipitation in central region.

southeasterly flow of warm dry air occurred at ground level over all of central Alberta. This weather block persisted for nearly seven days during which high southeasterly winds continued day and night.

On May 19 and 20, the effect of the southeasterly winds was noticeable on the numerous fires burning in central Alberta. Figure 9 shows the surface weather chart for May 20 when large areas were burned in the Edson and Whitecourt Forests. By May 22, two frontal lines were established in Alberta (Fig. 10). A cold air mass from the Yukon had moved into Alberta and stalled in a line from north of Fort McMurray to Grande Prairie and south of Fort St. John, B.C. Further to the south, a second front in a line from Fort McMurray to Wagner, Whitecourt, Edson and south to Calgary marked the southern boundary of a cool moist Pacific air mass that was trying to push eastward from the interior of British Columbia. This Pacific air mass was unable to penetrate further eastward because of the strong southeasterly flow from the stagnant high over central Alberta. Areas in the western region of the burning belt were influenced by the cool moist air from British Columbia and resulted in reduced fire intensities. However, the areas to the east of the frontal line remained under the influence of high southeasterly winds.

On May 23 the cold air mass from the Northwest Territories was unable to penetrate any further south, and moved north and east. Also, the cool moist air mass from the British Columbia interior was able to penetrate overnight only as a shallow surface layer as far east as Whitecourt. Daily surface heating burned off this shallow layer and the cold front proper retreated to its original position along the Rockies. However, this shallow layer of cool moist Pacific air modified the fire

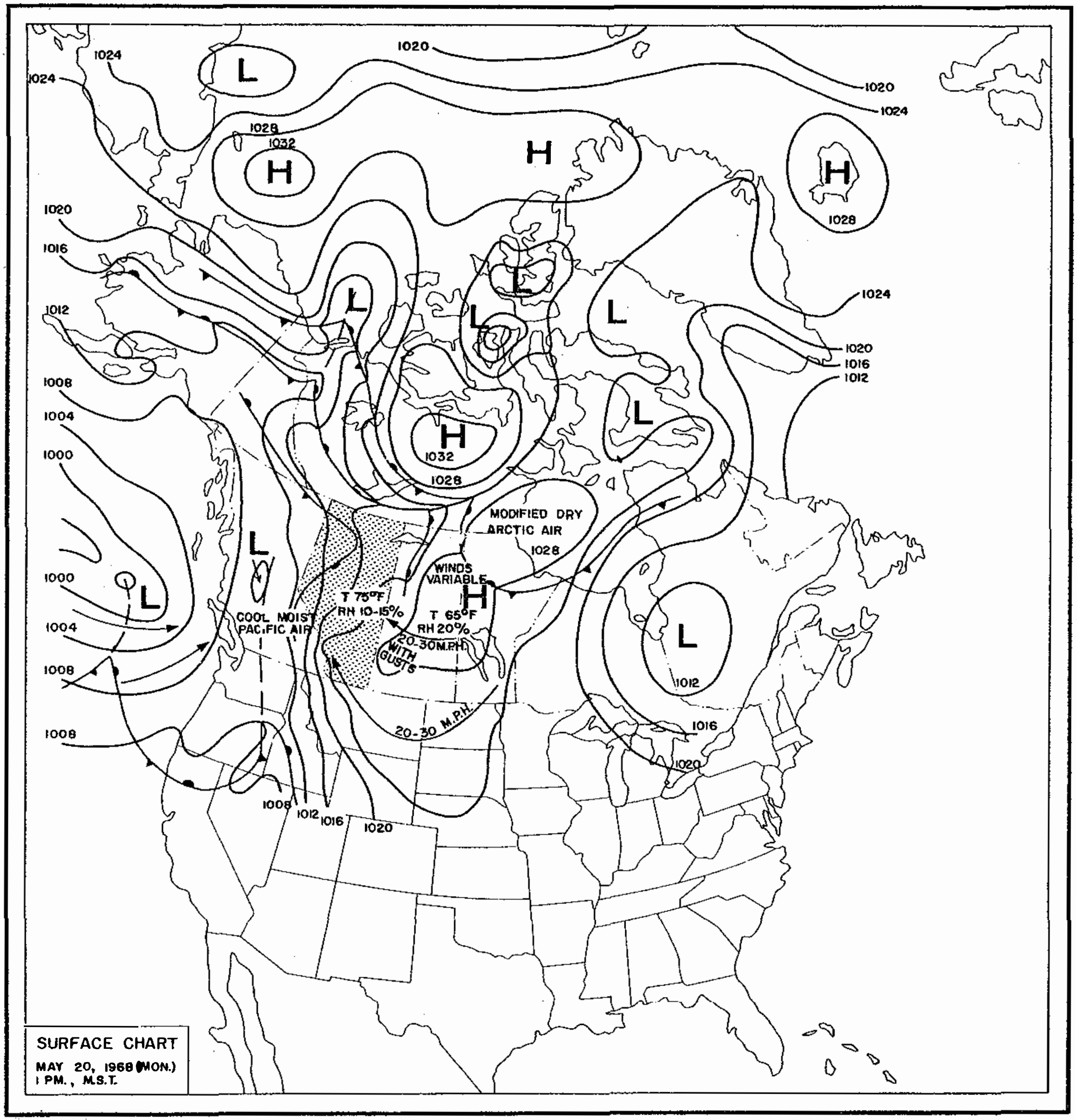


Figure 9. Surface weather chart, 1:00 P.M., M.S.T., May 20, 1968 (Monday). Note high temperature, low relative humidity and strong southeasterly winds over central region of Alberta.

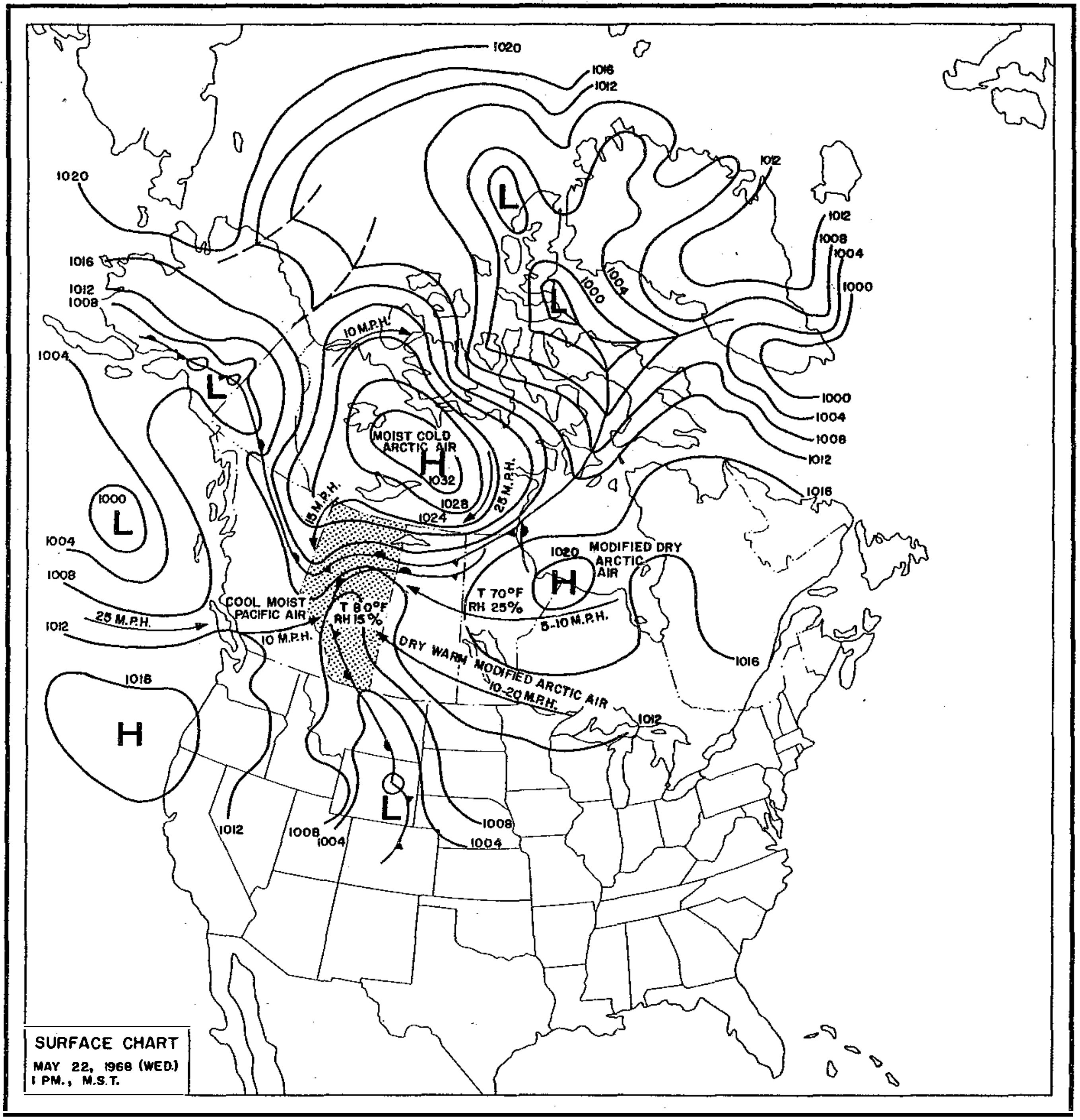


Figure 10. Surface weather chart, 1:00 P.M., M.S.T., May 22, 1968 (Wednesday). Cool moist Pacific air covers west-central Alberta, but warm, dry air from blocked high still covers east-central region. Note moist cold Arctic air mass in Northwest Territories.

weather to the extent that the forward advance of the fires generally did not penetrate beyond the frontal line -- with the exception of the large Lesser Slave Lake blaze. Since the inversion layer over central Alberta was only several hundred feet deep, it did not cover the top of the Swan Hills. Thus the fires burning at the higher elevations beyond the front, i.e. the Lesser Slave Lake fire, were still under the influence of the southeasterly flow of warm dry air. The retreat of the high pressure area in the extreme north and the deepening of the low pressure area along the foothills allowed the dry, southeasterly flow of air to surge northwest (Fig. 11). Strong southeasterly winds gusting to 45 miles per hour fanned the fires burning in the Slave Lake and Lac La Biche Forests and caused phenomenal rates of fire spread.

Forest Fire Danger Rating Tables

Forest fire danger rating tables provide an objective rating of forest fuel flammability. The Alberta Forest Service uses the Spread and Buildup Indexes of the United States National Fire Danger Tables to gauge fire hazard. The Spread Index is derived from measurements of temperature, relative humidity, and wind speed, and applies only to the time at which these measurements are taken. Spread Index reflects the relative forward rate of fire spread in fine fuels, i.e. grass and surface litter. The Buildup Index indicates the moisture content of medium fuels, i.e. top 3 to 4 inches of duff. Because these fuels require longer periods of time to dry than fine fuels, the Buildup Index is not as sensitive as the Spread Index. The Spread and Buildup indexes are combined through the use of hazard charts to rate the potential fire danger in classes from low to extreme. In addition, the Soil Moisture Index,

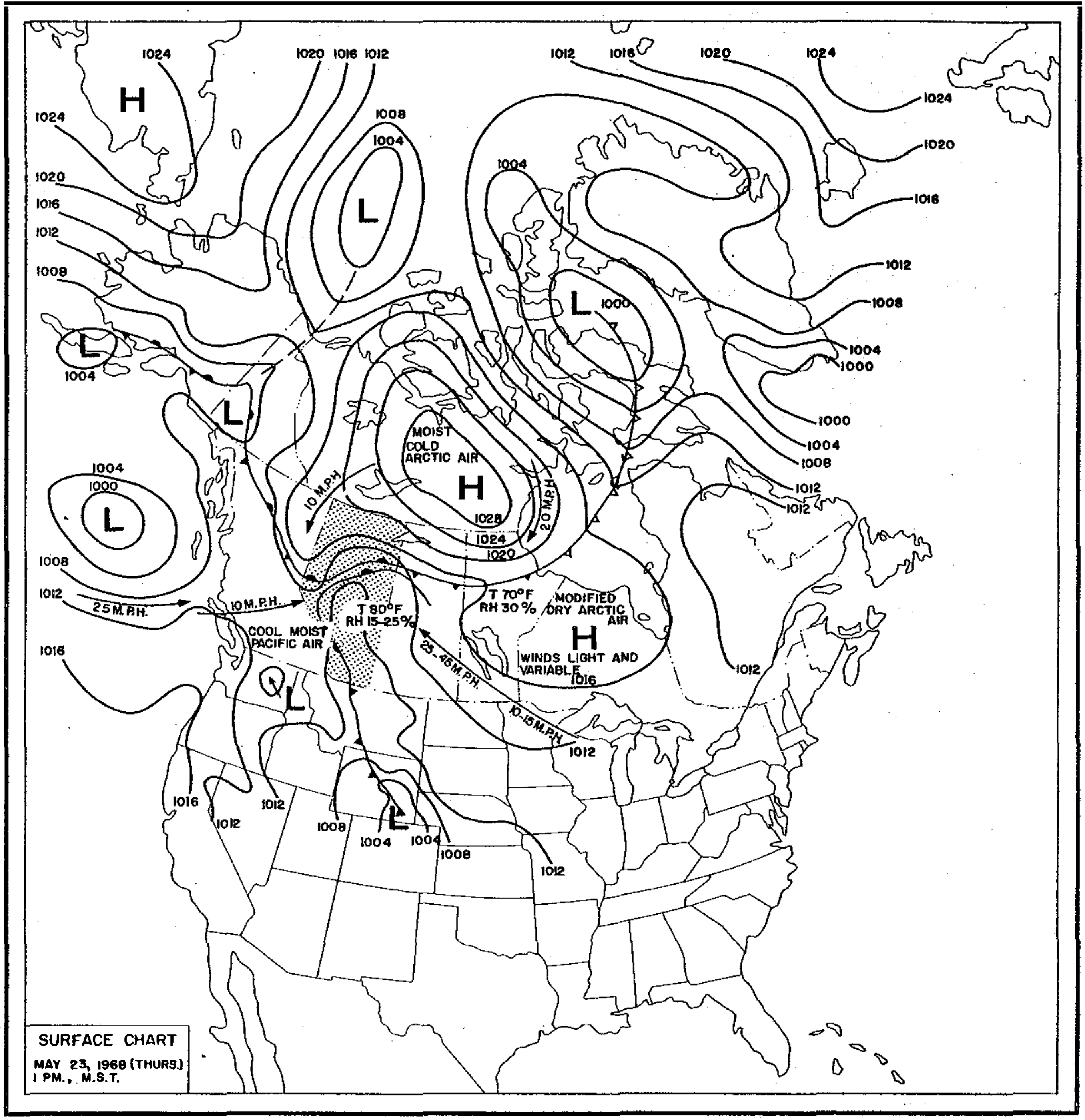


Figure 11. Surface weather chart, 1:00 P.M., M.S.T., May 23, 1968 (Thursday). Moist cold Arctic air mass has moved eastward allowing warm, dry air from blocked high pressure area to surge northwest.

which provides a relative measure of the loss and gain of soil moisture over an extended period, indicates the overall moisture supply of the heavy fuels.

The presence of the blocked high pressure system caused temperatures to rise to the high 70's and low 80's, relative humidities to drop to the high 10's and low 20's, and winds to remain in the 15 to 30 miles per hour range throughout the week of May 18th. The Spread Index recorded at fire danger stations in the burning region remained higher than 20 as shown in Figure 12. A Spread Index of greater than 20 indicates extreme rate of fire spread.

The Buildup Index before and during the critical burning period is shown in Figure 13. An index value greater than 26 indicates a high to extreme fire danger in deciduous and mixedwood stands during the spring when warm, dry days with light to moderate winds exist. Fires occurred when the Buildup Index was approaching its highest point of the period. The fire hazard charts which combine the Spread and Buildup Indexes into a general fire danger rating indicated that the fire potential remained in the very high and extreme classes throughout the week of May 18.

The increase in fire potential from 1967 to 1968 is illustrated by the Soil Moisture Index (Fig. 14). The soil recovered very little moisture during the winter and spring of 1967-68 and prevented the index from dropping to its normal spring-time level. The soil held only 3.4 inches of the total possible 8 inches of moisture at the time of the spring fire outbreak (Fig. 14). Thus, the occurrence of a moderately high Soil Moisture Index, a high Buildup Index and a very high to extreme

Figure 12. Spread Index and wind speed in forested region of central Alberta, May 15 - 30. Average of 7 fire danger rating stations in area.

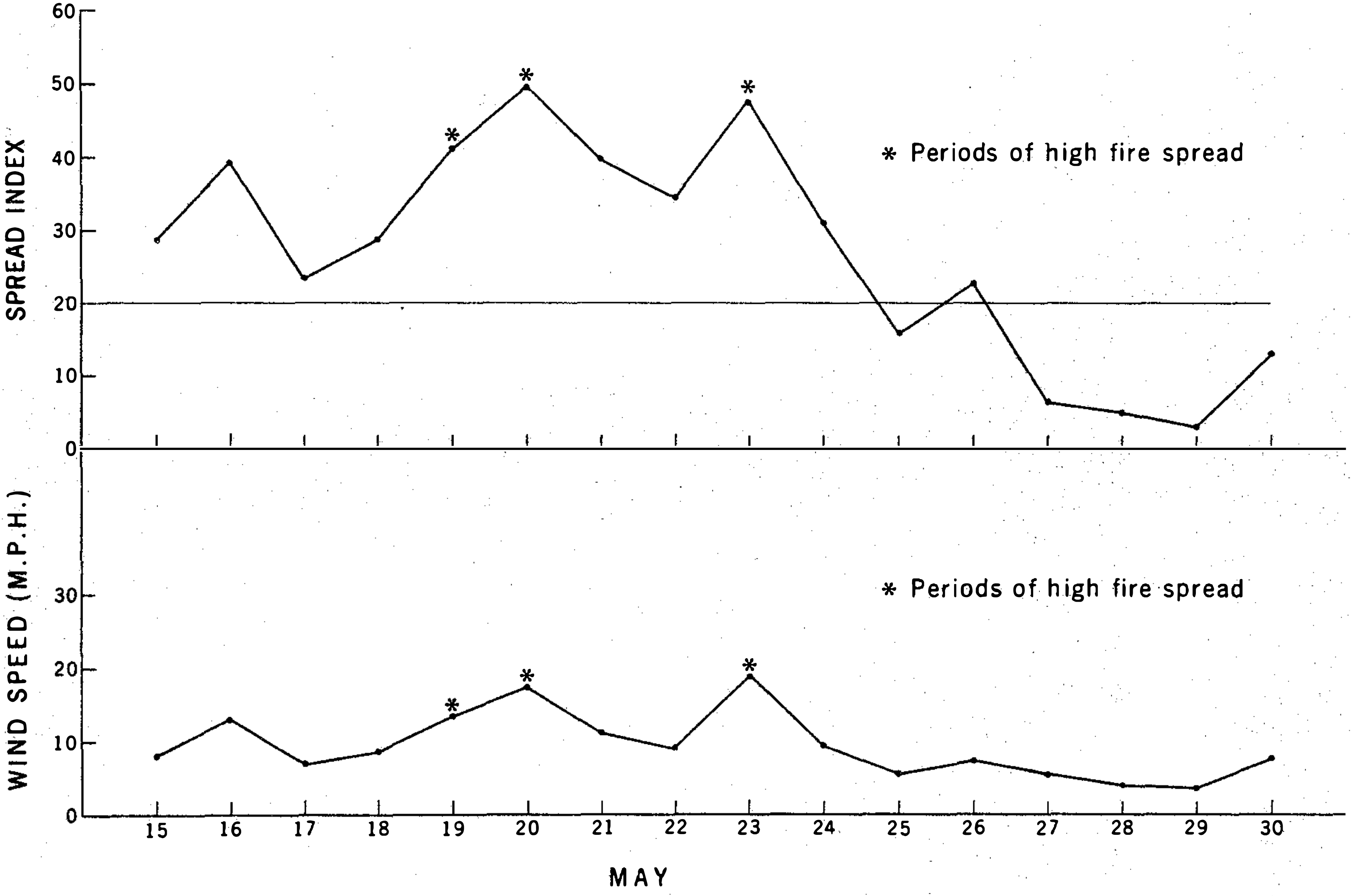


Figure 13. Buildup Index in forested region of central Alberta, May 15 - 30, 1968. Average of 7 fire danger rating stations in area.

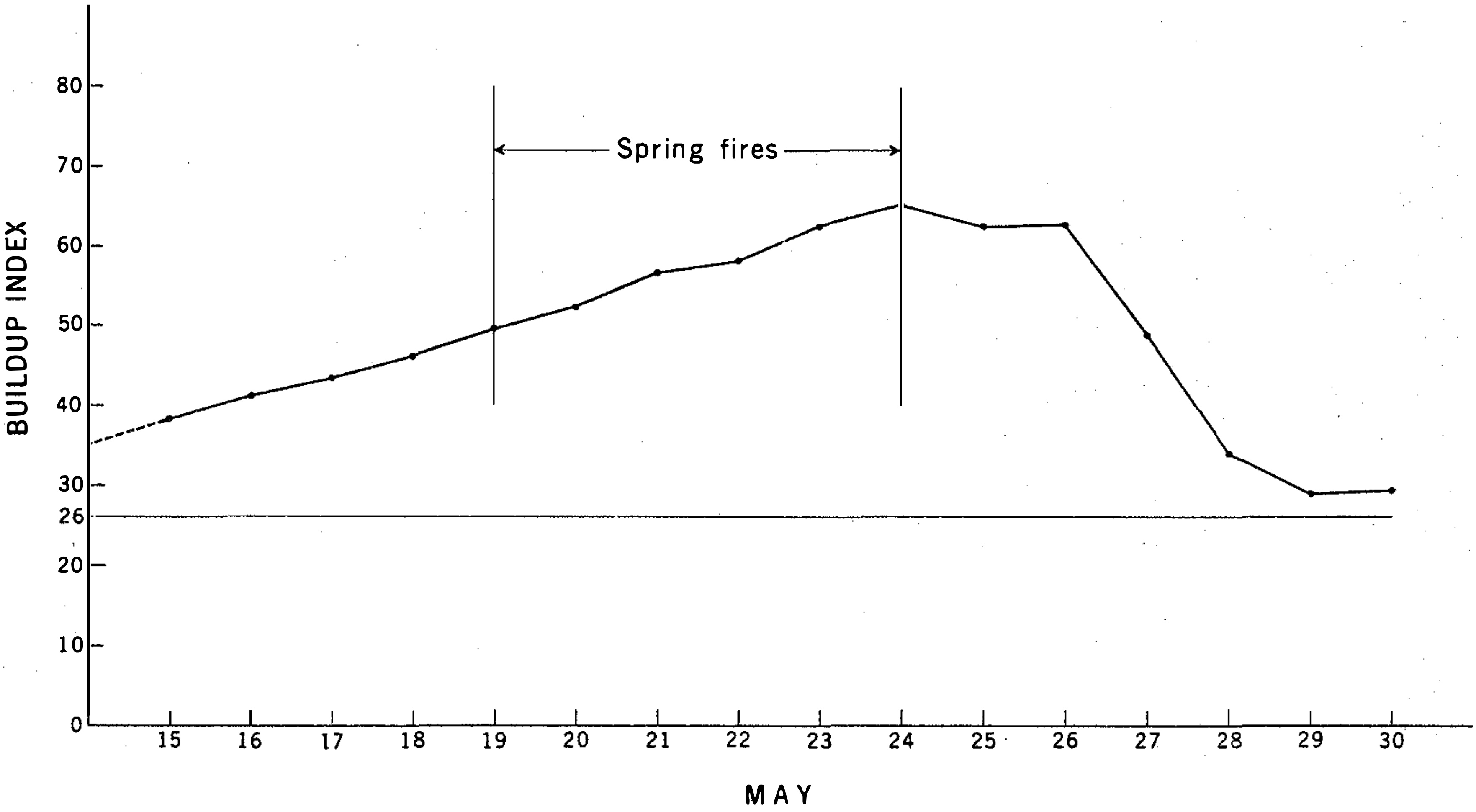
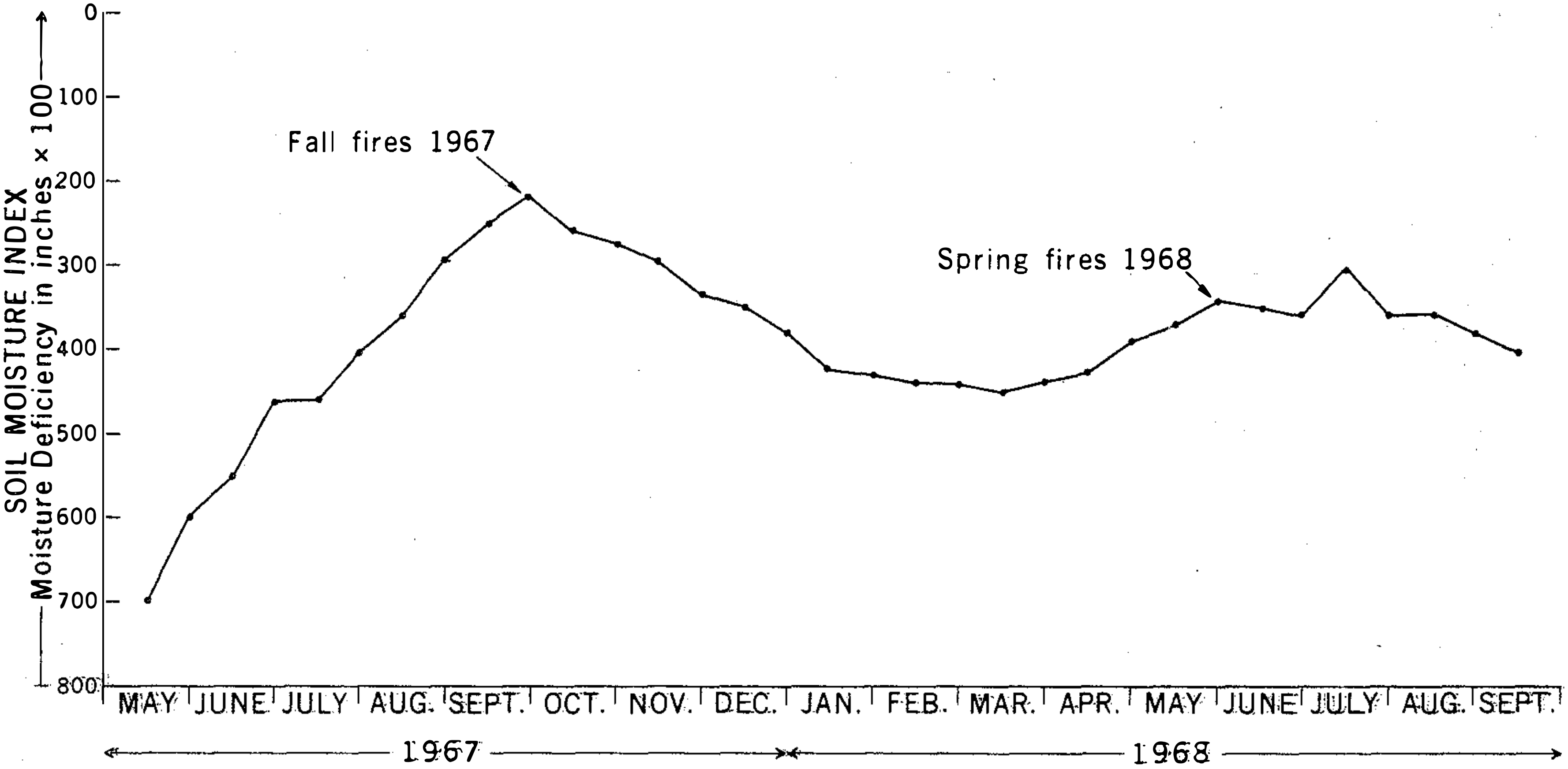


Figure 14. Soil Moisture Index in central Alberta, 1967 - 1968. Average of four stations in fire area.



Spread Index indicated critical burning conditions, borne out by subsequent events in the field.

During the critical period, relative humidities remained low throughout the day and the constant subsidence prevented recovery at night. Thus, burning conditions remained critical for extended periods of time. Table II shows the hourly relative values recorded at Whitecourt on May 20th.

TABLE II. HOURLY RELATIVE HUMIDITY RECORDED AT WHITECOURT, ALBERTA, MAY 20, 1968.

Hour	R.H.%	Hour	R.H.%	Hour	R.H.%	Hour	R.H.%
0000	31	0600	44	1200	16	1800	18
0100	31	0700	40	1300	17	1900	21
0200	33	0800	32	1400	17	2000	23
0300	39	0900	25	1500	16	2100	24
0400	39	1000	21	1600	16	2200	30
0500	40	1100	19	1700	14	2300	30

FUELS

Fuel Condition

The stage of seasonal development of vegetation is important in fuel availability for burning, fuel-moisture relationships and ultimately, fire behavior. In central Alberta, the vegetative growth usually starts during the middle of May but a general greening of the forest landscape does not occur for several weeks. In 1968, aspen and poplar leaves were about 25 per cent developed by the third week in May compared to 10 or 15 per cent for understory vegetation. The relative absence of green vegetation in hardwood and mixedwood stands increased the exposure of forest fuels to the desiccating effects of the atmosphere. This drying pattern increased the ground surface fuels available for burning in hardwood and mixedwood stands to a level comparable to that in pure conifer stands with the result that fire could spread with equal ease through the entire landscape.

Fuel Weight

Fuel weight is a measure of potential fire intensity. Forest stands in Alberta commonly contain more than 100 tons of potentially combustible woody material but only a small fraction of this total is likely to be consumed by even the "hottest" forest fire. Low-intensity fires generally consume only the top litter layer; high-intensity fires sometimes burn off all litter plus the entire organic soil mantle.

Fuel weight data is fragmentary but preliminary work in Alberta gives an indication of the range of fuel loadings in the major forest cover types (Table III).

TABLE III. ESTIMATED FUEL LOADINGS FOR SELECTED FOREST STANDS IN CENTRAL ALBERTA.

Fuel	Aspen	Pine	Pine-Spruce	Spruce-Poplar	Black Spruce
			Ovendry weight in tons per acre		
Crowns	4	10	12	8	8
Lesser vegetation	2	1	2	3	1
Litter	4	5	5	4	5
F layer	10	15	15	15	20
H layer	5	2	10	10	20
Total	25	33	44	40	54

The values in Table III do not include the weight of stems as these are not usually consumed by even the hottest wildfire. Crown weight refers to the combined weights of foliage and branchwood, except in the case of hardwoods. Lesser vegetation consists primarily of shrubs such as alder, cranberry, Labrador tea and wild rose.

Aside from total fuel weight, the other principal features of the forest for fire propogation include (1) a measure of fine fuels which determines, to a large extent, the fuel consumed in the burning zone and (2) a measure of the surface area available for radiational heating. Only little quantitative information about these aspects of the fuel complex is available but visual observation of fire behavior has provided some clues about the role of these factors in fire behavior. In relation to crown fires, the level and range of energy output by surface fires is relatively insignificant between different fuel types. The potential for crowning, however, is dependent on the surface fire being able to develop a level of energy output sufficient to bring the foliage to ignition. Black spruce crowns, because of their vertical and horizontal continuity, are highly susceptible to crowning and are usually completely consumed. Lodgepole pine stands do not have good vertical continuity but once fire crowns, horizontal fuel continuity is usually sufficient to maintain a continuous and fast-spreading crown fire. Mixedwood stands of spruce and poplar are frequently uneven in the distribution of the various fuel components and do not facilitate crowning. Hardwood stands are highly variable between seasons and normally are not susceptible to crowning.

Fuel Moisture

The amount of moisture contained in fuels determines whether ignition is possible and what is the extent of fuel consumption. The exceptionally low fuel moisture values for early spring are attributed to (1) the long drying days in late May, (2) the abundance of fine cured vegetation from the previous year, (3) the absence of shade-giving green vegetation, (4) low overnight humidities and (5) a carry-over moisture deficiency in heavy fuels.

The moisture content of cured vegetation, surface litter and the top few inches of moss was generally less than 20 per cent of oven-dry weight and some fine fuels dried to within 5 or 10 per cent. The moisture content of other fuel components was highly variable, depending on fuel size and condition. Table IV summarizes moisture content levels in duff fuels and live foliage.

TABLE IV. MOISTURE CONTENT OF GROUND AND AERIAL FUEL COMPONENTS BASED ON SAMPLES TAKEN BETWEEN MAY 18 AND 26, 1968.

Fuel	Aspen-poplar	Pine	White spruce	Black spruce
	Moisture content as per cent of ovendry weight			
Foliage	334	95	79	79
F layer	190	135	143	137
H layer	131	80	99	no data

The values in Table IV mean little until compared with the water-holding capacities of these fuels. The F and H layers become saturated only when their moisture content approaches or exceeds 300 per cent of ovendry weight. A fully saturated duff layer under a mature lodgepole pine stand weighs about 80 tons per acre, comprising 20 tons of organic material and 60 tons of water. Generally the F layer has a greater water-holding capacity than the H layer.

It is interesting to speculate on the effect of long-term drought on the moisture content of foliage and duff layers in May. Following a wet spring, the summer and fall of 1967 were hot and dry and resulted in a substantial moisture deficiency in deep duff fuels (Fig. 14). By late fall, the moisture content of the full organic layer often averaged between 50 and 100 per cent of ovendry weight. The moisture levels increased as a result of snowmelt in spring but the recovery from this source is not believed to have been complete. The relatively low moisture levels in F and H layers (Table IV) can be partially attributed to the carry-over moisture deficiencies from the previous summer and fall.

Moisture content of conifer needles ranged from 79 to 95 per cent of ovendry weight (Table IV), compared to over 300 per cent for new hardwood leaves. Foliage moisture is undoubtedly an important factor in the threshold level of crowning and rate of fire spread, but these levels are presently not known. The moisture content of pine and spruce needles in Alberta is generally between 75 and 100 per cent during the dormant part of the year, increasing to over 100 per cent near the middle of the growing season. Site, tree age, age of foliage and duff moisture content are some other factors which may affect foliage moisture but these relationships are not known. It would appear, however, that the moisture content of pine and spruce foliage was 5 to 15 per cent lower than is normal during spring.

At the time of the May fires, ground frost was general under moss in nearly all black spruce stands and in some mixedwood and pine stands. It is therefore conjectured that the presence of frost in the ground greatly reduced transpirational moisture losses, and this, in combination with the desiccating effects of the atmosphere, may have resulted in abnormally low foliage moisture levels near the middle of the afternoons. This in turn may have increased the release of combustible gases from the crowns and increased the rate of flaming combustion.

FIRE BEHAVIOR AND EFFECTS

General

Being dynamic, a forest fire is highly changeable from start to finish and this makes it difficult to identify and measure the required parameters. On fires such as those discussed here, measurement of fire characteristics is practically impossible owing to rapid fire spread, spotting of firebrands ahead of the main front, and heavy smoke. The following account of fire behavior is therefore based primarily on post-fire observation and measurement of fuels, reconstruction of synoptic and local weather conditions, and accounts by fire control personnel directly involved in fire-fighting operations.

The unprecedented outbreak of fires is attributed primarily to (1) the large number of settler fires burning or smouldering adjacent to and in the four Forests, (2) the presence of a weather pattern with extremely dry air and high southeasterly winds and (3) the presence of large volumes of highly flammable fuels. Arctic high pressure systems are common over western Canada in spring but they usually remain for only a few days.

Although the fires burned or smouldered both day and night, they did not "blow up" or crown until about noon. Conditions for this are dependent on relative humidity, air temperature, wind and fuel moisture but the threshold limit is not known. Nearly all of the larger fires did develop a vertical or crowning character where winds in excess of 15 mph occurred. The periods of highest fire activity frequently coincided with days of high and gusty southeasterly winds. Average noon surface wind speeds exceeded 15 mph on May 19, 20 and 23 but gusts of over 40 mps were not uncommon (Fig. 12). Edson and Whitecourt Forests experienced numerous fires on May 19 and 20 whereas May 23 was most fateful for the Slave Lake and Lac La Biche Forests. The high surface winds on these days were instrumental in carrying burning firebrands ahead of the main fire front, causing development of pseudofronts.

An analysis of the wind profile for the days on which major fire runs occurred shows that a low-level jet wind most likely caused the high rate of fire spread (Figs. 15 and 16). These profiles were plotted from data recorded at Stony Plain, located 70 miles from the fire areas. Extreme wind conditions prevented measurement of wind speeds for May 23. Similar but less severe wind conditions occurred on May 22.

Extreme fire behavior is most likely to be associated with those low-level jet winds for which the height of the jet maximum is 1,500 feet or less above the surface, or elevation, of the fire (Davis 1959, pp. 107-112). The most intense fires have occurred when the wind speed at the jet maximum is 18 mph or more. The wind speed at the jet maximum was 33 mph on May 19 and 24 mph on May 22. Although the low-level jet wind had a pronounced effect on the fires in both the Edson-Whitecourt and Lesser Slave Lake Forests, its influence on the behavior of the fires in the latter locality was much greater because of the low height (1,000 feet) of the jet maximum[4].

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[4] The difference in elevation between the weather station and fire areas necessitates that only the profile which is above the elevation of the fires be considered significant. Where the large fire runs occurred in the Edson and Whitecourt Forests on May 19, the elevation is between 500 to 1,000 feet above the elevation of the weather station. Thus, the maximum wind speed occurred between 3,000 and and 3,500 feet above the fires (Fig. 15). Similarly, the elevation of the Lesser Slave Lake fire is approximately 1,200 feet higher, therefore the maximum wind speed was about 1000 feet above the blaze (Fig. 16).

Figure 15. The wind profile over Stony Plain, Alberta, for 5:00 p.m., May 19, 1968.

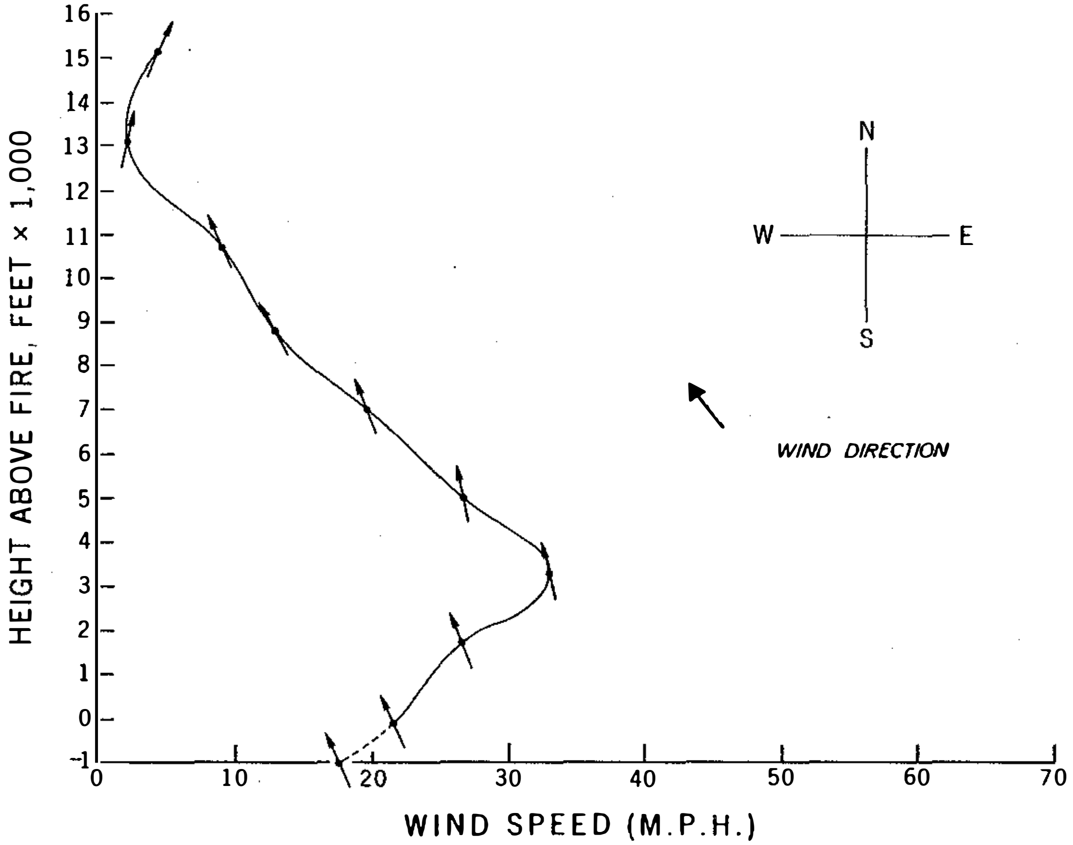
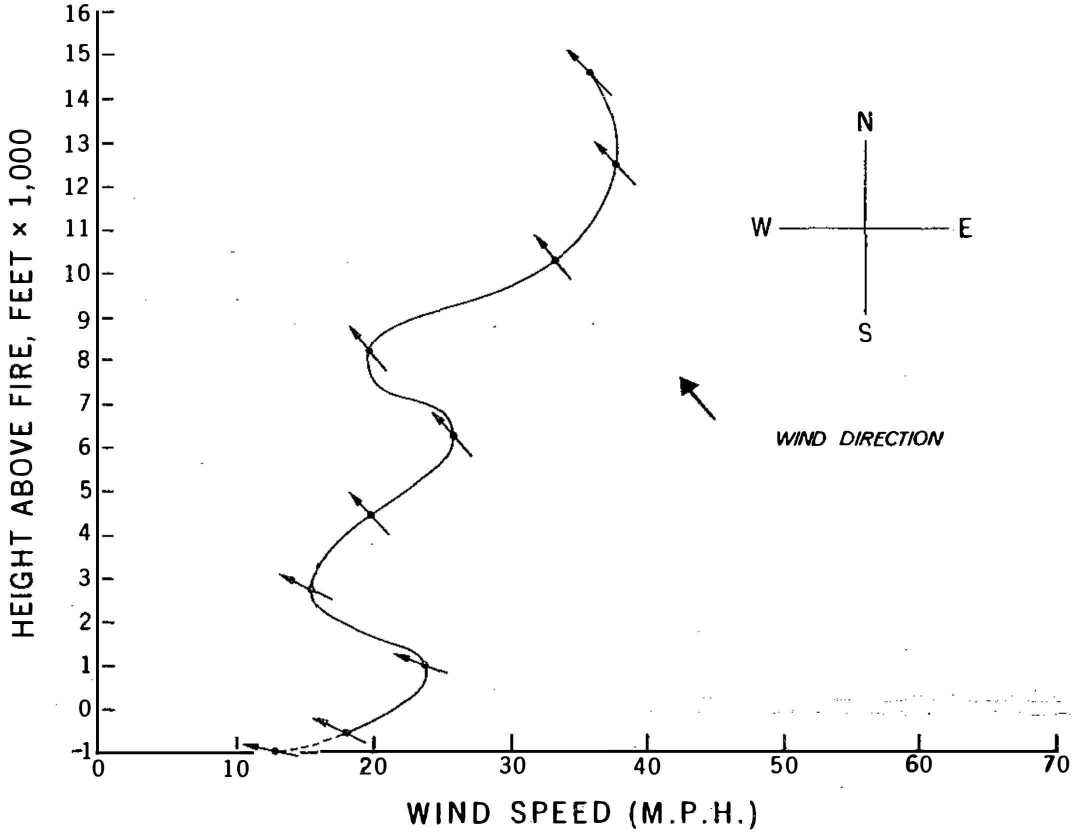


Figure 16. The wind profile over Stony Plain, Alberta, for 5:00 p.m., May 22, 1968.



This wind no doubt contributed to the transport of firebrands and preheating of fuels ahead of the fire. During the major run of the Lesser Slave Lake fire, a relative humidity of 6 per cent was recorded at the Flat Top tower situated in the path of the fires. The convection column above this fire was over 5 miles high and firebrands were reported to have landed several miles ahead of the fire.

Two striking characteristics of the fires were "runs" and whirlwinds (Figs. 17 and 18). Several areas were seen where thousands of trees had been felled by the force of wind generated by the fire or scattered in a circular pattern up to several hundred feet in diameter. Fires had made "runs" thousands of feet long, with no particular pattern in relation to topography.

Observations of the Lesser Slave Lake fire area gave an indication of the wind force at the fire front. Fifteen to 20-inch white spruce and poplar trees were "snapped" 10 to 15 feet above ground level. The bending moment at the point of failure for a 20-inch white spruce is about 4,000,000 inch-pounds (Smith, 1968). The fire released about 11 kilotons of energy every minute during its 10-hour "run" on May 23. Similar rates of energy release were reported for the 1967 Sundance fire in Idaho (Jones and Johnston, 1968).

Considering the variety of forest cover types in the fire area, fire spread appears to have been surprisingly uniform. Crowning was particularly common in pure black spruce and pine stands but occurred also in mixedwood stands. Consumption of ground fuels was variable from stand to stand but the energy from this source was sufficient to ignite and consume practically all lesser vegetation and crown fuels

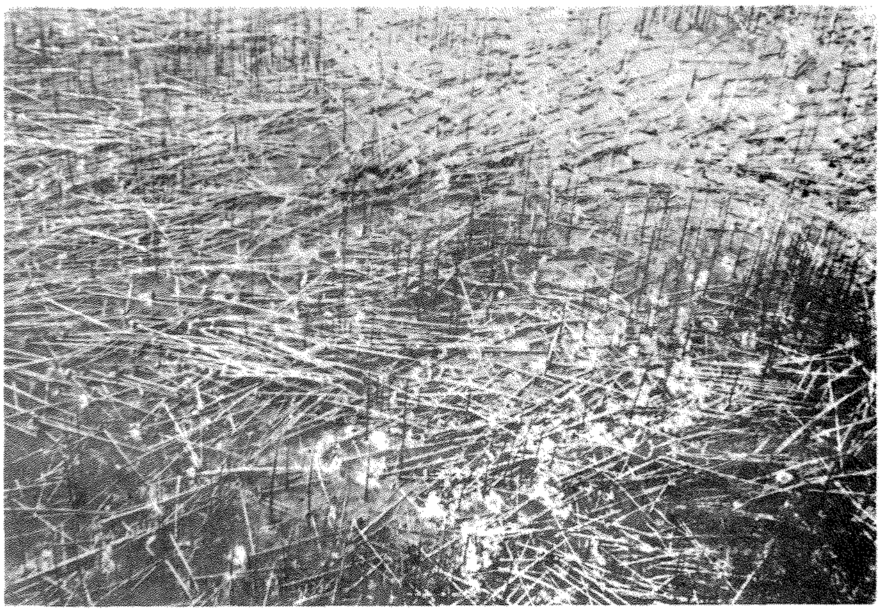


Figure 17. Aerial view of burned-over conifer stand. Circular pattern of felled trees in area right of centre is attributed to fire whirlwind.

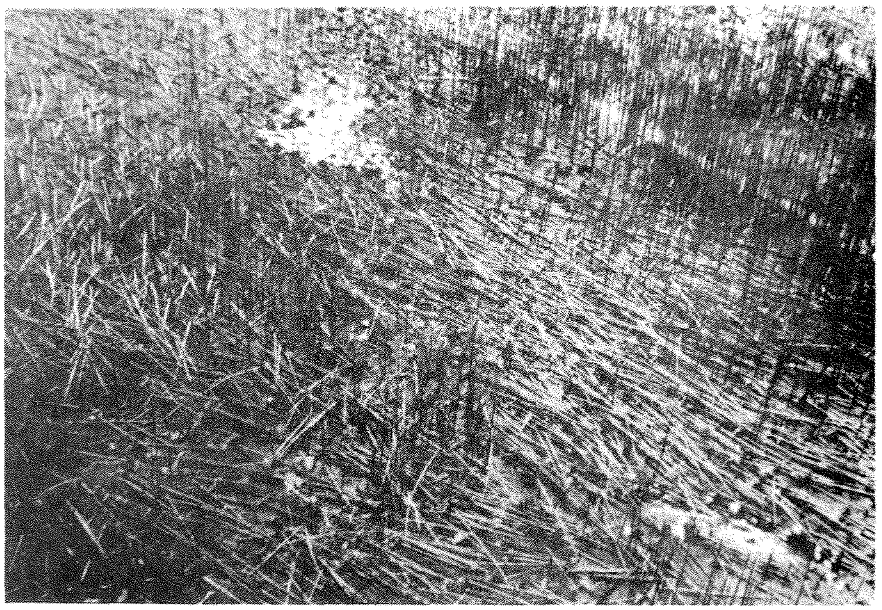


Figure 18. Aerial view of part of Lesser Slave Lake fire showing fire felled trees.

less than ½-inch. Data from earlier studies suggested the following amounts of fuel were consumed on an ovendry weight and square foot basis: deciduous stand, 0.41 pounds; mixedwood stand, 0.63 pounds; and coniferous stand, 1.1 pounds. In terms of aerial fuel consumption, crown fires in black spruce and lodgepole pine stands were most destructive. All foliage and much of the branchwood were usually consumed. Mineral soil exposure was common in lodgepole pine but not in black spruce stands. Even though depth of burn was sometimes in excess of 6 inches, mineral soil exposure was not possible owing to the deep duff layer and the presence of ice in the lower layer. In hardwood stands, practically all litter to a depth of 2 or 3 inches was consumed by the fire but mineral soil exposure was infrequent. Depth of burn, ranging from less than an inch to 6 inches and more, was most variable in mixedwood stands. Consumption of needles and fine branches was not as extensive in these stands as in the pure conifer stands. Burned areas are illustrated in Figures 19 to 22.

Total fuel consumption (both at the fire front and subsequent smouldering) appears to have been significantly greater than would be the case after only a week or two of hot and dry weather. Although Spread and Buildup Indexes in Figures 12 and 13 indicate that conditions were favorable for rapid fire spread, it is not likely that the low moisture levels in the deep duff layers had a direct effect on rate of fire spread. It is possible, however, that the deep-duff moisture deficit (Fig. 14) may have had an indirect effect on the moisture content of the surface fuels and crown foliage.

One month after the fires, green vegetation was general in all burned areas (Fig. 23). The species and distribution of this vegetation

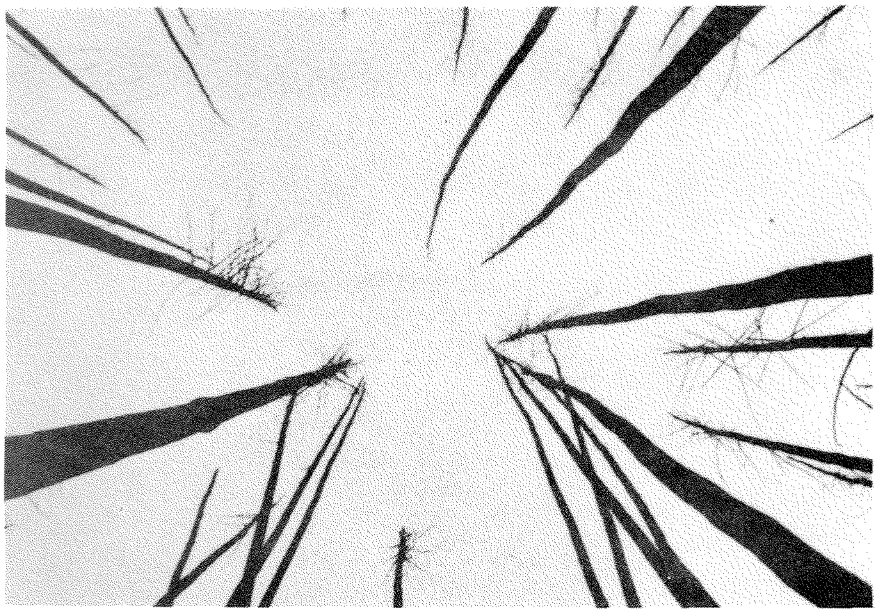


Figure 19. Post-fire view of black spruce crowns.

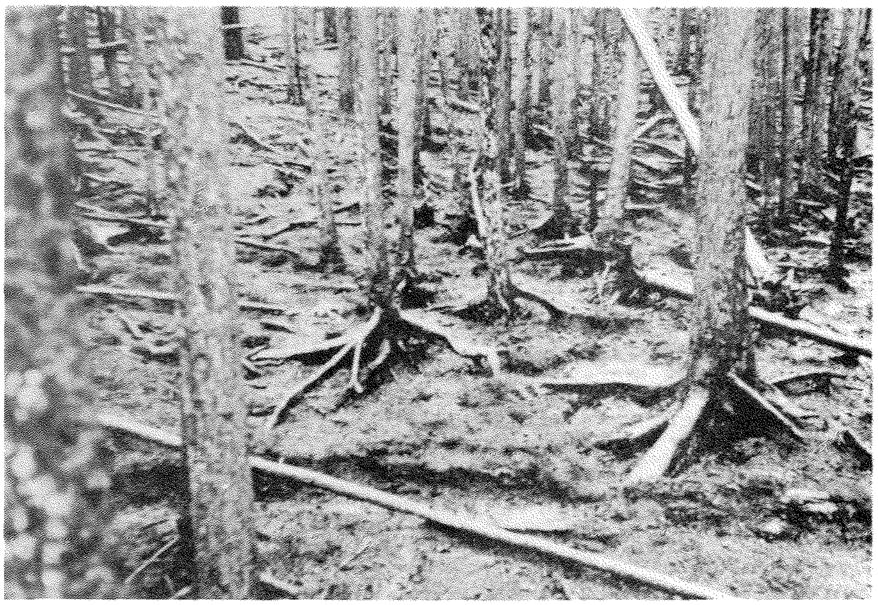


Figure 20. Duff consumption in black spruce stand.

Figure 21. Post-fire view of crowns in mixedwood stand.

Figure 22. Burned-over mixedwood stand one month after fire.

varied with pre-fire cover types, site and other factors but usually included fireweed and grasses. Large quantities of charred lodgepole pine cones were noted on the ground but many of these may have fallen during the passage of the fire front (Fig. 24).

Fire Intensity

Fire intensity for the Lesser Slave Lake fire was calculated, based on an average heat yield value of 6,000 btu/lb, forward rate of spread of 4 mph (6 ft/sec) and fuel consumption levels of 0.41, 0.63 and 1.1 lb/sq. ft. (as described earlier). The results in btu/sec/ft of fire front were as follows: deciduous stand, 14,760; mixedwood stand, 22,680; coniferous stand, 39,600.

The forward rate of fire spread of 4 mph represents a 10-hour average and is among the highest values ever recorded. Rates at least twice as high undoubtedly occurred, particularly in pure conifer stands. This level of spread is difficult to explain by normal processes of radiation, convection and conduction. Convectional and wind transport of firebrands far ahead of the fire front must have been a major factor contributing to the unusually high forward rate of spread.

Figure 23. New vegetation under lodgepole pine stand one month after Lesser Slave Lake fire.

Figure 24. Close up of post-fire ground surface fuels in pine-spruce stand in Lesser Slave Lake fire one month after fire.

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