FIRE HISTORY AND FIRE REGIMES

OF THE CENTRAL WESTERN

CASCADES OF OREGON

by

PETER DOMINIC ADRIAN TEENSMA

A DISSERTATION

Presented to the Department of Geography
and the Graduate School of the University of Oregon
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Approved:_______________________________
Dr. Carl L. Johannessen

Fire history is documented for an 11,000 hectare (27,110 acre) area, including H. J. Andrews Experimental Forest. Fire scar and tree origin data were collected mainly from stumps at 359 sites. Thirty-five fire events are mapped from 1482 to 1952. Mean fire return intervals (MFRI) are derived from data at individual sites, about 5 hectares in size (12 acres), rather than from the corrected master fire chronology.

Fire frequency is higher than the generally accepted level. Both catastrophic fires and underburning were part of the pre-fire suppression fire regimes. The MFRI of partial or complete stand-replacing fires is 166 years, and the MFRI of all fires is 114 years.

Mean fire return intervals vary considerably between

different landscape positions. Sites with south aspects or on ridges, at higher elevations, or exposed to east winds, have the shortest MFRI (for all fires, less than 100 years). Fire is least frequent at lower elevations, in valley bottoms, on north aspects, and where protected from east winds (MFRI, all fires, 150 years or more).

Natural fire rotation is shortest prior to Anglo-settlement (1772-1830), at 78 years, increases to 87 years after settlement (1851-1909), then increases dramatically to 587 years with fire suppression. Aboriginal burning supplemented lightning ignitions, but the extent of aboriginal burning could not be determined. Presumably, aboriginal burning was ecologically important within at least parts of the study area, e.g., meadows and huckleberry fields. In the absence of logging, the decrease in fire frequency due to fire suppression would greatly influence forest composition and structure, and fuel loading characteristics.

No single fire regime adequately describes the spatial and temporal pattern of fire observed here. The study does not exclude fire regimes described previously for the region, rather it includes fire regimes described for other regions.

Further distinction between the frequencies of stand-replacing fires and lower intensity fires is necessary. Future research methods should take into account more extensive underburning than reported here. The methods used in this study may have been too conservative in that they may have discarded a considerable amount of evidence for underburning.

VITA

NAME OF AUTHOR: Peter D. A. Teensma

PLACE OF BIRTH: Den Hague, The Netherlands

DATE OF BIRTH: August 21, 1956

UNDERGRADUATE AND GRADUATE SCHOOLS ATTENDED:

University of California, Los Angeles
University of Oregon, Eugene, Oregon

DEGREES AWARDED:

Bachelor of Arts, 1978, University of California, Los Angeles
Master of Arts, 1981, University of Oregon, Eugene, Oregon
Doctor of Philosophy, 1987, University of Oregon, Eugene, Oregon

AREAS OF SPECIAL INTEREST:

Fire History and Fire Ecology
Fire Management
Biogeography

PROFESSIONAL EXPERIENCE:

Teaching Assistant, Department of Geography, University of Oregon, 1979-1982, 1984

Teaching Assistant, Map Library, University of Oregon Library, 1982-1983

Research Assistant, Department of Forest Science, Oregon State University, 1983-1987

Forestry Technician, United States Bureau of Land Management, Alaska, 1985

Forestry Technician, United States Forest Service, Willamette National Forest, 1985-1987

AWARDS AND HONORS:

Cum Laude, University of California, Los Angeles, 1978
Special Departmental Honors, University of California, Los Angeles, 1978

PUBLICATIONS:

"Forest Fire History of the H. J. Andrews Experimental Forest, Willamette National Forest, Oregon." Teensma, P. D. In: Program and Abstracts of the Eighth Biennial Meeting of the American Quaternary Association, 1984.

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CHAPTER I

INTRODUCTION

Description of the fire history and the corresponding fire regimes of the western slopes of the Cascade Mountains are necessary for an understanding of the forest ecology of the region. Fire history analysis of a portion of the region will allow the characterization of fire regimes. The relationships between fire history and behavior and the landscape are strong, but complex. Spatial and temporal analyses of fire history patterns reveal that fire does not occur in random patterns on the landscape (Wright, 1974; Romme and Knight, 1981). The dominant disturbance agent prior to pre-fire suppression was fire, therefore an understanding of fire, its frequency, geographic patterns, and other attributes is essential to a more complete comprehension of the ecological processes that characterize Douglas-fir forests in the Pacific Northwest.

It is hypothesized that aspect, elevation, orientation of landforms on the landscape, and place in time have significant effects on fire behavior and hence fire history. The orientation of a drainage basin, for instance, may affect the boundaries of a single burn by influencing direction of spread, intensity, and the resulting size, as well as determine the relative susceptibility of forests stands to fire. The cumulative effects of landform and landscape position can be measured in terms of fire history. As a result of topography alone, fire may have a variable behavior over the landscape, and documented fire history patterns should not be uniform over the landscape.

Fire history patterns are equally unlikely to be uniform over time. Land-use, attitudes towards the use of fire, and the natural occurrence of fire, have varied significantly over the five centuries of fire history presented. Cultural uses of the landscape are categorized in four time periods, and a measure of fire frequency is employed to compare the fire history of these cultural periods.

Specific objectives of the study include:

1. Consider the types of fires and their frequency (i.e., fire regime) that have occurred in the study area.

2. Estimate fire frequencies by historical periods (i.e., pre-Anglo, early settlement, pre-fire suppression, and fire suppression eras).

3. Test the hypothesis that fire history is not geographically random, but rather landscape dependent.

4. Document the spatial patterns of fire and the fire regimes of different drainages with varying

environmental characteristics, during the period of time prior to fire suppression.

5. Further refine a methodology of analyzing fire history that can be applied to small areas of study, as well as to investigations of larger areas within the Douglas-fir forests of the Pacific Northwest.

Fire history data were collected from 1983 to 1984, and were graciously supplemented by data collected earlier by Peter Morrison (Morrison and Swanson, 1987; Morrison, personal communication). Fire scar data and tree origin date were collected primarily from Douglas-fir (*Pseudostuga menziesii*) stumps in clearcuts. The data are tabulated into a corrected master fire chronology and mapped by individual fire years. Statistical comparison of fire frequencies are then used to test hypotheses of the non-randomness of fire over the landscape and over time. Possible fire regimes are presented to explain some of the differences in fire frequency.

Many additional insights were gained by observing fire behavior and the effects of numerous wildfires, some within or adjacent to the study area, and by observing fire behavior in slash burning operations. Discussions with experienced fire fighting professionals proved valuable as well, adding the insights of many years' observations of fire that could not have been discovered from the data collected from the field by any means.

A glossary of fire history terminology is included as Appendix A. Several terms used throughout the text have more than one meaning in the fire history literature, therefore clear definitions of terms are necessary to prevent their misinterpretation in the contexts of this study.

CHAPTER II

PHYSICAL ENVIRONMENT

Location

The study area is located in the McKenzie River watershed within the Willamette National Forest east of Eugene, Oregon (Figure 1). The size of the study area is 11,000 hectares (27,110 acres), 6,400 hectares (15,815 acres) of which lie within the H. J. Andrews Experimental Forest (HJA) (Figure 2). The study area includes the entire Lookout Creek drainage, and portions of the Blue River and Deer Creek drainages to the north and east of the Lookout Creek drainage, respectively.

Physiography

The study area is situated at middle to upper elevations in the central western Cascades, ranging from about 370 to 1600 meters (1200 to 5300 feet). The topography is generally steep and dissected with sharp ridges dividing the larger sub-drainages. Lookout Ridge, oriented east-west, defines the southern boundary of the study area; and Frissell Ridge, oriented

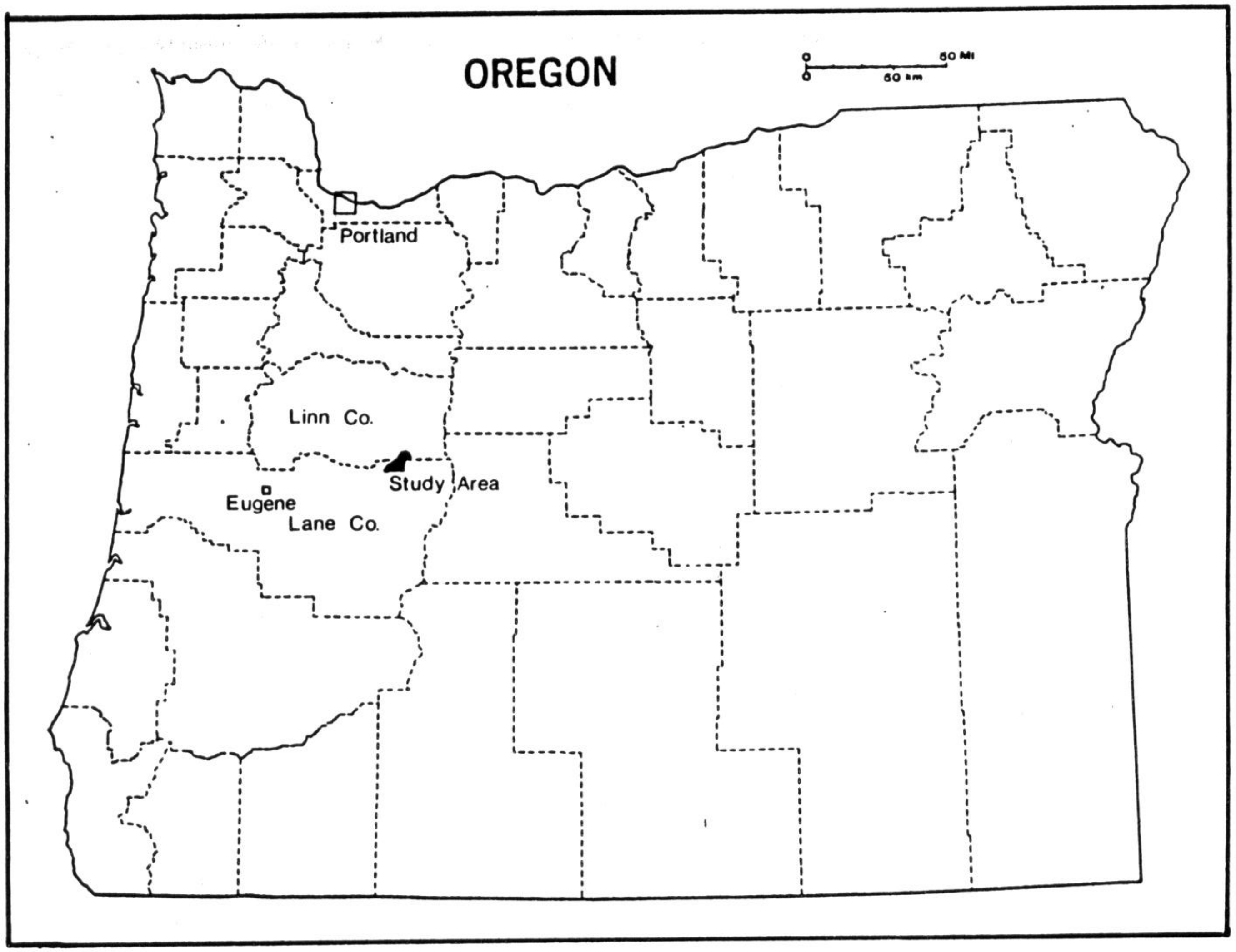


Figure 1. Location of Study Area.

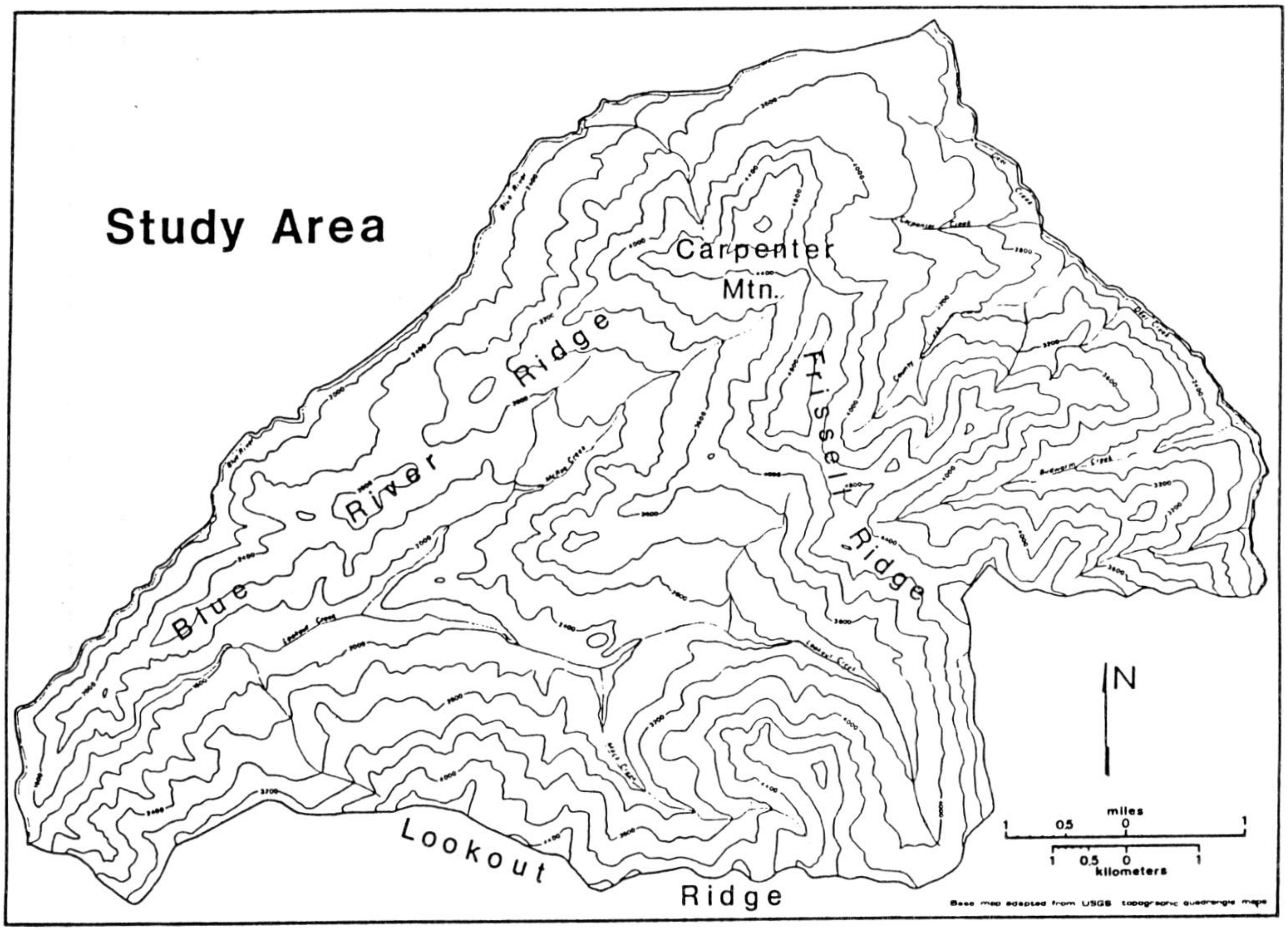


Figure 2. Study Area Map.

southeast-northwest, divides the Lookout Creek drainage from the Deer Creek drainage, and Blue River Ridge, oriented northeast-southwest, divides the Lookout Creek drainage from the Blue River drainage (Figure 2). Major breaks in topography were chosen as the boundaries of the study area, which is of sufficient size that it encompasses a wide variety of slope aspects and drainage orientations.

Geomorphology

The geologic history of the study area consists of periods of volcanism as recent as about 3.5 million years ago, with periodic glaciation, and continuous weathering and erosion (Swanson and James, 1975). Soils resulting from these processes are shallow, have high infiltration capacity, and are moderately erodible, resulting in extensive shallow soil mass movement and slow, deep-seated mass movement (Dyrness, 1967; Swanson and James, 1975). These erosional processes have formed complex topography with a mixture of steep slopes and areas of hummocky ground of moderate slope. The soils are well-drained, but retain about 30 centimeters (12 inches) of water in the first 120 centimeters (48 inches) of depth for storage during periods of summer drought (Dyrness, 1969).

Weather and Climate

Temperature and Precipitation

The climate is classified as Mediterranean, characterized by wet, mild winters and dry, warm summers. The temperature varies from an average annual value of 9.5 degrees Celsius (49.1 degrees Fahrenheit) at 450 meters (1500 feet) elevation on Lookout Creek, to 5.5 degrees C (41.9 degrees F) at 1300 meters (4300 feet) on Carpenter Mountain (Waring, et al., 1978; Emmingham and Lundburg, 1977; Bierlmaier, 1986). Extremes at the main meteorological station on Lookout Creek (450 meters elevation [1500 feet]) are -20 degrees C (-4 degrees F) and 44 degrees C (112 degrees F) (Bierlmaier, personal communication). Mean annual precipitation varies from 239 centimeters (94 inches) at 450 meters (1500 feet) elevation to nearly 400 centimeters (160 inches) at 1300 meters (4300 feet) (Waring et al, 1978; U.S. Army Corps of Engineers, 1956). Nearly 75 percent of the annual precipitation occurs between November and March (Figure 3). The winter snowline varies considerably, but a significant snowpack generally accumulates above 1200 meters (4000 feet) and persists until early May. The precipitation record at the HJA extends from 1952 to the present, 35 years of record. A longer precipitation record (1902-1913 and 1931-present) has been maintained at the nearby McKenzie Bridge (United

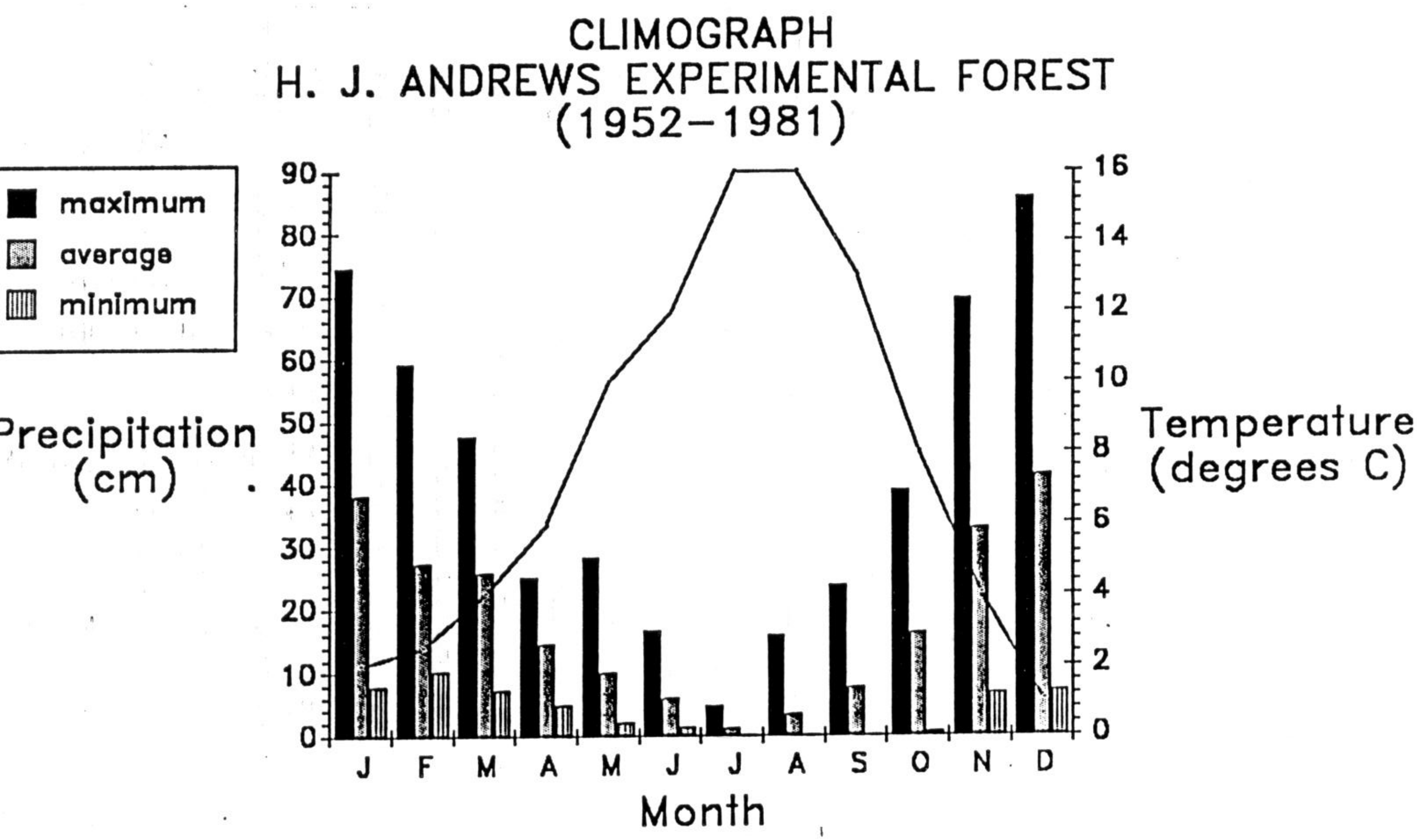


Figure 3. Climograph of H. J. Andrews Experimental Forest.

States Forest Service) Ranger Station, and considerably longer temperature and precipitation records exist for Eugene (United States National Weather Service Forecast Office), 80 kilometers (50 miles) west. Annual precipitation in the study area is quite variable, with a standard deviation of 37.9 centimeters (14.92 inches) at the central climatic station in the HJA.

Synoptic Climatology

In the most general terms, the weather of the Pacific Northwest is governed by the position of the Polar Jet Stream, flowing into or south of the region during much of the winter, and flowing well north of the region most of the summer. Availability of moisture from organized storms (warm, cold, or occluded fronts) is critical to cumulative drought patterns and fire weather. During most of the year, strong high pressure located offshore produces cool or cold and dry weather, while the addition of moisture brings overcast conditions or precipitation, when accompanied by lifting or cooling mechanisms. With strong high pressure located over the region, weather conditions are warm and dry. Isolated convective storms may be locally significant during the summer drought.

Only 25 percent of the average annual precipitation occurs from April through October, and much of this may fall during brief periods lasting only a few days each.

Strong high pressure cells over the eastern Pacific Ocean and over the Northern Rocky Mountains direct the jet stream into Canada and usually prevent intrusions of subtropical moisture from the desert southwest. Rainless periods of two to four weeks typically occur from two to four times each summer (Table 1). The longest recorded rainless period in the study area was 79 days in 1967, periods over 30 days have occurred 25 times in 30 years, and periods over 14 days have occurred 70 times.

Droughts have often been broken by two related mechanisms that contribute to fire activity. First, a thermal low-pressure cell may develop over northern California or just off-shore, and occasionally from Northern California to the Willamette Valley. This low pressure cell, which produces the warmest temperatures over the region, circulates subtropical moisture into the region from California and Nevada, triggering lightning, occasionally with little or no precipitation. Second, the same low-pressure cell, or a low pressure trough extending south along the Washington-Oregon coast from the Gulf of Alaska, establishes a strong off-shore pressure gradient, resulting in strong, dry, easterly winds. The first mechanism may provide the ignition source, while the second may greatly accelerate the rate of spread of any ensuing fire, depending on persistence of the pressure gradient and the arrival of related fronts or bands of showers that

Table 1. Drought Periods at H. J. Andrews Experimental Forest, 1952-1981 (compiled from data on file, H. J. Andrews Experimental Forest office).

Year	Length of Drought (14 days or more)	Total Drought Days (of periods 14 days or more)
1952	42,22	64
1953	35,32,24,15	106
1954	23,20,19	57
1955	47,15,14	76
1956	69,28	97
1957	42,21,18	81
1958	57	57
1959	35,15	50
1960	41,31,17,15	104
1961	28,24,20	68
1962	38,31,19,16	104
1963	46	46
1964	14	14
1965	19,19,18,17	73
1966	43	43
1967	78,14	92
1968	16	16
1969	79	79
1970	64,16	80
1971	21,20	41
1972	52,19,14	85
1973	34,22,17	73
1974	40,20,19	79
1975	33,22,18	73
1976	29,14	43
1977	15,14	29
1978	31,16	47
1979	34,33,17	84
1980	38	38
1981	48,15	63

shift inland. Similar weather conditions initiate and affect major wildland fires throughout the intermountain west (Brotak, 1983; Finklin, 1981).

The meteorology of east winds in the Northwest, and their drying effect was first described accurately and scientifically in 1886 (Bowerman, 1886) and their effects were probably known to aboriginals for millennia. A thorough study of east wind occurrences and prevailing weather patterns (Cramer, 1957) indicates that no years are completely free of east wind, but that they vary considerably in intensity, elevation, location and month of occurrence. For the range of elevations of the study area, the east winds peak in intensity from September to November, coinciding with the transition from the end of the long summer drought to the beginning of the period of significant rainfall.

Microclimatology

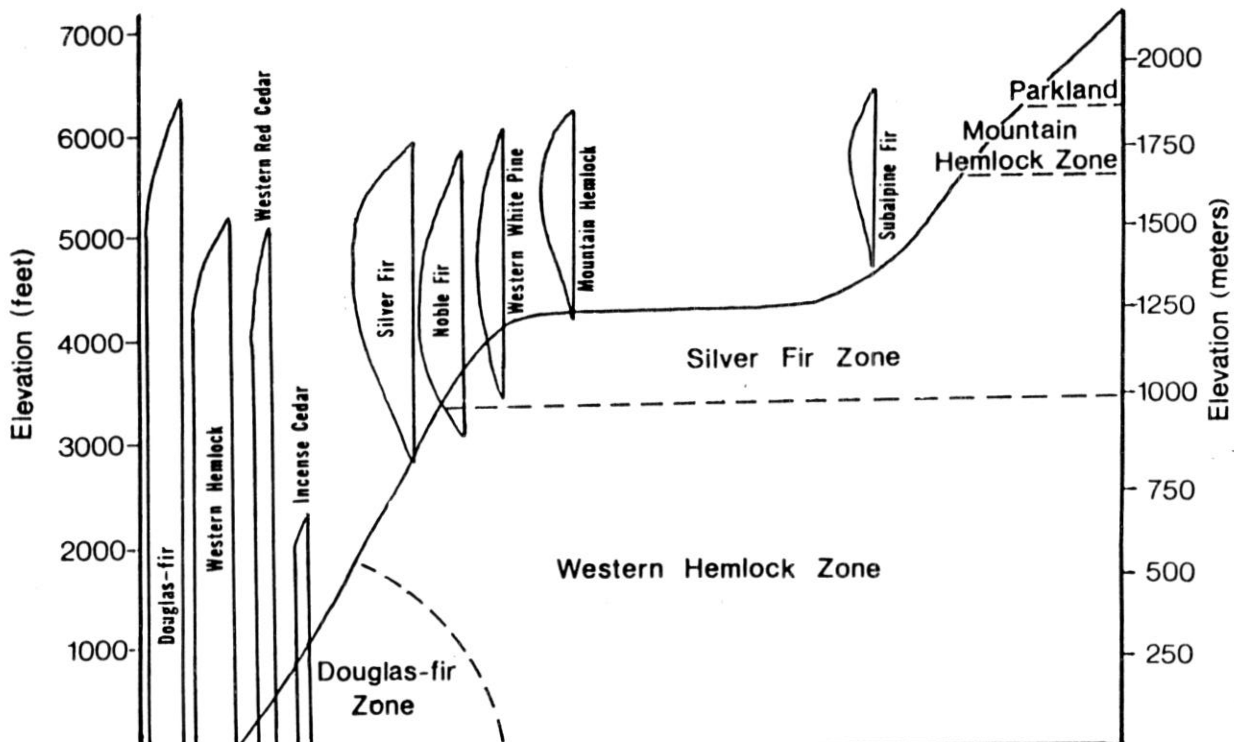
Position of the landscape, both in absolute and relative terms, markedly affects microclimate. Precipitation generally increases and temperature decreases with elevation. The strength and duration of diurnal upslope and downslope winds vary with aspect and size of drainage area because of relative differences in solar insolation. The diurnal winds are most important in determining the direction and rate spread of individual fires, while the amount of solar insolation itself contributes to the characteristics of the vegetation and fuels, thereby affecting the rate of spread and burning intensity. East-facing slopes are the most prone to east wind conditions, especially in the exposed higher elevations of ridge tops, and the east slopes and crest of Frissell Ridge.

CHAPTER III

VEGETATION

General Forest Composition

The forest vegetation of the area has been studied extensively since establishment of the H.J. Andrews Experimental Forest by the U.S. Forest Service in 1948. Climax vegetation is classified into two major and one minor zone. The Pacific Silver Fir Zone ranges upward from 1200 meters (4000 feet), the Western Hemlock Zone from 350 to 1200 meters (1200 to 4000 feet), and the Douglas-fir Zone occupies some of the driest sites between 350 meter and 750 meter (1200 and 2500 feet) (Franklin and Dyrness, 1973; Hemstrom et al., 1982) (Figure 4). Dominant tree species within the Silver Fir Zone are Pacific silver fir (Abies amabilis), Douglas-fir (Pseudotsuga menziesii), noble fir (A. procera), western hemlock (Tsuga heterophylla), subalpline fir (A. lasiocarpa), and western white pine (Pinus monticola) (Dyrness, Franklin and Moir, 1974; Hemstrom, Logan and Pavlat, 1985). Within the Western Hemlock Zone the dominant tree species are western



Notes: Relative abundance of species is indicated by bar thickness.
Adapted from Hemstrom et al., 1982:11.

Figure 4. Vegetation Zonation.

hemlock, Douglas-fir, grand fir (*A. grandis*), western red cedar (*Thuja plicata*), and incense-cedar (*Calocedrus decurrens*). Finally, within the Douglas-fir Zone they are Douglas-fir, incense cedar, and sugar pine (*Pinus lambertiana*). Theoretically, Douglas-fir would gradually be replaced by the reproduction of more tolerant species in the Pacific silver fir and western hemlock zones (Franklin and Hemstrom, 1981), but the time since the last disturbance event has not been great enough for complete replacement in stands within the study area, although a few sites approach this climax status in the HJA Forest.

Effects of Fire on Individual Species

The ecological role of fire in each zone, and in each of the plant habitat types within these zones, is dependent primarily on the physical characteristics of the individual species, which determines species response to fire, and secondarily on the response of one species in relation to the others (Davis, Clayton and Fischer, 1980). Fire affects the species present differentially, some responding with very high mortality rates, while others suffer little or no mortality. Species with low mortality can become dominant or replace those with higher mortality. The ecological role of fire is further dependent on fire intensity, which is referred to as fire severity in ecological terms. Fire intensity is the heat output of a fire, while fire severity is the ecological impact of a fire. Higher intensity fires cause greater or complete mortality among all species. Lower intensity and recurrent fires, or underburns, can prevent the establishment of shade tolerant tree species, thereby tending to maintain a species composition, in absence of other causes of mortality.

Douglas-fir is the most fire resistant tree species in the study area, largely due to its thick bark (Minore, 1979). Its foliage flammability is ranked as high or higher than other species present and it is also ranked high in supporting epiphytes, both factors increasing crown fire susceptibility (Minore, 1979), given appropriate fire behavior conditions. Rooting depth is ranked moderate, providing resistance to low and moderate intensity fires.

A pair of experimental fires in a 60 year old Douglas-fir stand, under prescribed conditions with flame lengths generally between 0.5 and 1.0 meters (2 to 3 feet), caused 38 to 72 percent mortality, with the greatest concentration of mortality occurring where flame lengths were the longest (Ward, 1977). Within a given fire intensity, as measured by scorch height, post-fire survival of Douglas-fir is strongly related to diameter at breast height (Bevins, 1980). When 60 percent or more of the crown is scorched, mortality exceeds 50 percent (Norum, 1977).

The Tillamook Fire of 1933 is regarded as the most catastrophic fire in Oregon's recorded history, yet even that extreme fire event did not result in 100 percent mortality, as Isaac and Meagher (1938:6) report:

> . . . except for the Cedar Butte double burn, there were few large areas entirely devoid of seed trees. Green trees were numerous, as isolated trees, in groups, and on unburned 'islands.' They were found in greatest numbers in the northeast corner, where the fire progressed slowly, but were also scattered sparingly throughout the southern and western portions. The green islands naturally contained a mixture of all the tree species present before the fire, but the single green trees were almost all Douglas[-]fir.

They stated that mortality had increased since earlier observations, and was expected to continue, but that survivors would persist in large numbers nonetheless. The problems of revegetation associated with the reburns of the Tillamook Burn and the Yacolt Burn are sometimes used as examples to highlight prolonged periods of tree establishment after wildfire. These two examples can serve as guides without regeneration data from wildfire, but they may be extremes in a range of possibilities.

In addition to fire resistance, Douglas-fir is also a pioneer tree species in postfire succession. Seed survival in the soil is possible under light to moderate burning intensities (Isaac, 1943), but these light burns are not as likely to create canopy openings. Seed dissemination from survivors and from surrounding unburned stands is a much more common mechanism of regeneration.

Dispersal distances up to 185 meters (600 feet) are common, while distances up to 800 meters (2,700 feet) have been recorded (Isaac, 1943:20-21). Another seed source described in the same report is the crop of cones in fire-killed trees, which may shed their seeds if the fire occurred in late summer or early fall.

Western hemlock is a later successional species than Douglas-fir, except occasionally within the Pacific silver fir zone. Older individuals are relatively fire resistant, but this species has shallow roots, and even hot ground and surface fires with extensive duff consumption can cause mortality (Minore, 1979; Franklin et al., 1981; Volland and Dell, 1981). Foliage flammability and epiphyte receptivity to firebrands are both high. Western hemlock is very fire susceptible under almost any burning conditions.

Older individuals of sugar pine are somewhat resistant to fire. Bark is relatively thick, but has a high resin content. Subalpine fir has the lowest resistance to fire of the conifers within the study area, largely due to its very thin bark. Its distribution is very limited. Pacific silver fir, grand fir, noble fir, western white pine, western red cedar, and incense cedar rank between Douglas-fir and western hemlock in their fire resistances, although older individuals of both cedars are apparently more resistant than those of the other species (Minor, 1979).

Fire and Successional Processes

Fire, as a primary agent of disturbance, has important influences on successional pathways (Franklin, 1982). Underburns strongly influence forest composition by removing fire-intolerant, understory trees species, such as western Hemlock, the true firs, and western red cedar, which are recognized elements of the climax vegetation of the study area (Franklin and Hemstrom, 1981; Stewart, 1986). In areas with frequent underburning, early successional species may predominate for an extended period of time (Franklin and Hemstrom, 1981). Without frequent underburning, and without catastrophic disturbance, shade-tolerant species may become dominant. Repeated underburning and partial, patchy burns probably add considerable complexity to species composition as well as stand age-class structure.

The types, magnitudes, and frequency of disturbance trigger various responses in the vegetation, which itself is variable. The pattern of disturbance by fire should be integrated with other types of perturbations, resulting in a unique disturbance history for each individual stand. While this study does not address types of disturbance other than fire, the importance of, and interaction with other disturbance mechanisms are recognized.

Effects of Fire on Fuel Loading

In many forest ecosystems, fuel loading, defined as the accumulation of biomass (both dead and live), increases after fire. Fine fuels (small diameter) may be augmented by the increased abundance of shrubs and herbaceous vegetation. Stands are more open, and fuels are desiccated more rapidly due to the change in microclimate: solar radiation is increased and fuels are more exposed to wind, which can dramatically increase the rate of desiccation as well as the rate of spread of a fire (Rothermel, 1983). Snags from the former forest facilitate both emission and reception of flying embers, thereby increase the stand's susceptibility to fire.

Old growth Douglas-fir stands typically contain considerably higher volumes of both live and dead biomass than other Pacific Northwest vegetation types (Maxwell and Ward, 1980). High intensity fire in the old-growth forests of the study area tends to create more fuels than it consumes. However, much of the increase is in the form of large size-classed fuels, which do not contribute much to fire behavior and fire intensity under most circumstances (National Wildfire Coordinating Group, 1981). While large fuels increase by the largest amount, the medium and small size-classes, e.g., partially consumed crowns and needles, may also increase significantly.

Fire may recur because:

> . . . wildfires in these forests rarely consume much of the wood. Trees die and become snags and down logs, but several subsequent fires are necessary to consume a majority of this woody debris. Even the tree foliage often escapes burning. Numerous examples of reburn, at least during historic times, suggests that young stands (e.g., 25-75 years) are more susceptible than later forest stages (Franklin and Hemstrom, 1981:217-218).

The extensive and frequent reburns of the Tillamook Burn in northwest Oregon, and the Yacolt Burn in southern Washington, are often used as examples of natural fire regimes following infrequent catastrophic fire. However, both fires resulted from unnatural causes, the build-up of logging slash over extensive area, and multiple ignition points during a prolonged drought. Other large fires in the region since the 1840s did not result in multiple reburns. The Tillamook and Yacolt Burns may provide insights to some of the fires of the past, but they should not, without clear evidence, be viewed a "typical" fire regime.

The first Tillamook Fire in 1933 did present direct evidence of one other factor related to fuel loading and reburn potential: insect attack. Isaack and Meagher (1938) report that between 1935 and 1937 Douglas-fir beetle (<u>Dendroctonus</u> <u>pseudostuga</u>) caused the mortality of numerous Douglas-fir seed trees that had survived the fire itself. The trees had been able to reproduce before the infestation reached epidemic levels, but then became part of the fuelbed for ensuing fires, adding large quantities of fine fuels from tree crowns (especially needles and small branches).

Extensive areas filled with snags were created throughout the Tillamook Burn. The fuels were not available immediately after the original fire, but ". . . a large amount of inflammable material is constantly being added to the surface debris. Moreover, after the snags shed their bark, the sapwood weathers and dries and becomes increasingly inflammable at nearly all seasons of the year" (Isaac and Meagher, 1938:8). Natural reproduction, without intervening reburns, could be expected to shade the fuels sufficiently to reduce the probability of reburns after about 35 years (McArdle, 1931 in Isaac and Meagher, 1938).

CHAPTER IV

METHODS

Data Collection Techniques

Preliminary data collection was begun in July, 1982. Evaluation of these data indicated a higher than anticipated fire frequency, and a complex spatial pattern of burns. Further data collection was undertaken in the summers of 1983 and 1984 in a progressively smaller study area to increase the sampling density to more accurately interpret the complex fire history of the area.

Site Selection

Sample sites were selected from 1959 (United States Department of Agriculture, Forest Service, 1:12,000, black and white) and 1982 (U.S.D.A., Forest Service, 1:12,000, color) aerial photographs. Several criteria were used in site selection. Stand age-class boundaries were presumed to be fire boundaries, and sample sites were selected within and outside the recognizable stand types as well as at, or near, boundaries. Areas with numerous age-classes were sampled at a higher density than stands with simple age-structure. Most sites are located within clearcuts, therefore, the distribution of clearcuts across the landscape strongly influenced the distribution of sample sites. With few exceptions, sample sites are distributed fairly well over the sample area. There are 329 sample sites within the study area, and an additional 30 sites immediately adjacent to it (Figure 5).

Sites were marked in the field on both sets of aerial photographs (1959 and 1982) and on 15 minute United States Geological Survey topographic quadrangle maps. The elevation, slope, and aspect of each site was recorded in the field. Some site aspects were later adjusted to reflect general hillslope (five hectare size-patch) aspects rather than very site specific aspects. The distribution of sites by elevation and aspect is given in Table 2. A set of 600 randomly selected grid-points was prepared on a topographic map overlay to obtain a non-biased estimate of the actual distribution of elevations and aspects within the study area (Table 3). A Chi-square comparison of the sample sites with these random points indicates that they are not statistically significantly different ($p=0.05$) (Tables 26 and 27, Appendix B). Although not distributed uniformly across the study area, the sample sites are a representative sample of the landscape.

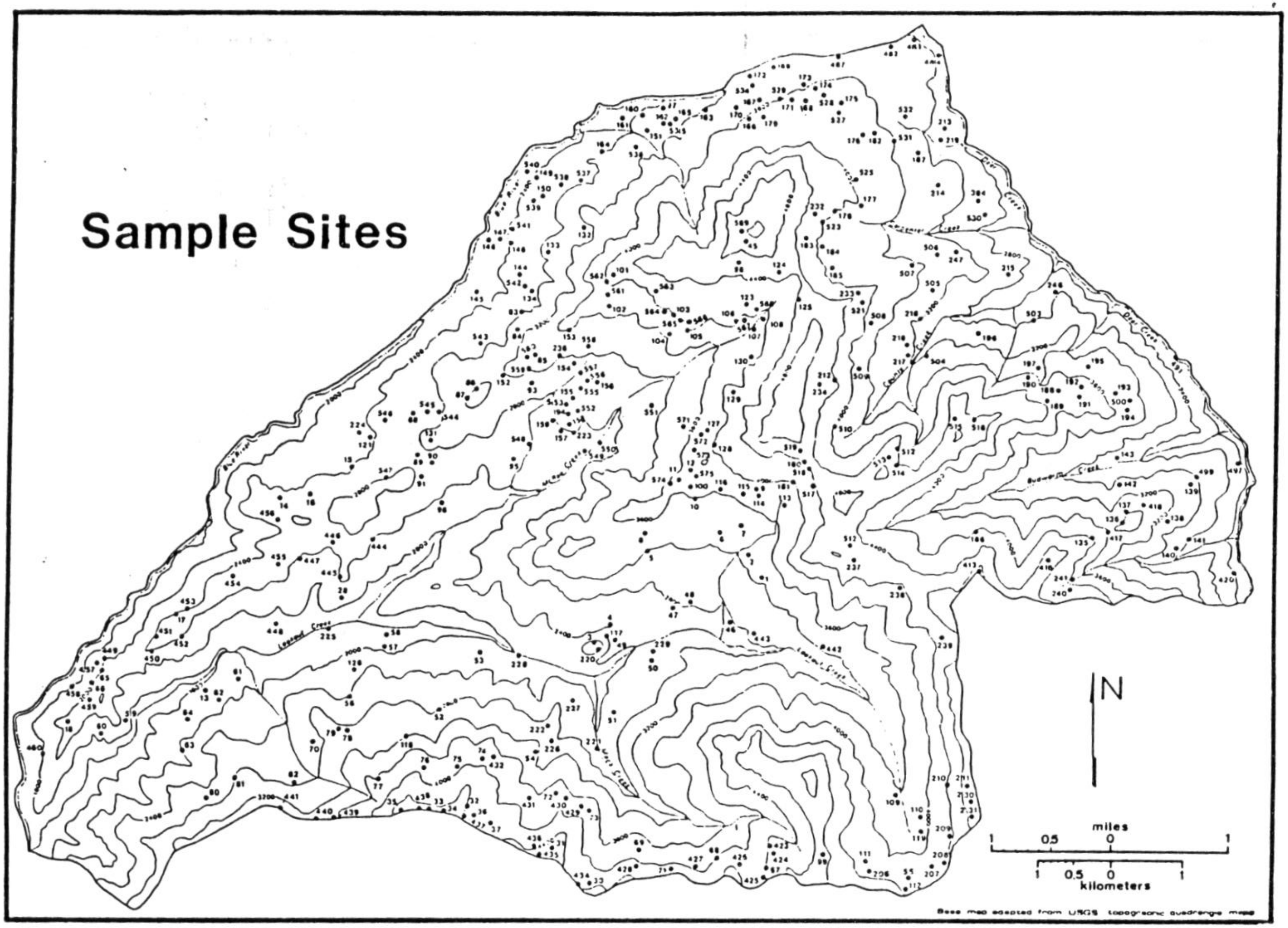


Figure 5. Location of Sample Sites.

Table 2. Distribution of Sample Sites.

Elevation Classes

Meters (feet)	Number of Sites	Percent
< 762 (< 2,500)	50	15
762- 914 (2,500-2,999)	69	21
915-1,066 (3,000-3,499)	70	21
1.067-1,219 (3,500-3,999)	65	20
1,220-1,371 (4,000-4,499)	53	16
> 1,371 (> 4,500)	22	7
TOTAL	329	100

Aspect

Direction	Number of Sites	Percent
North	37	11
Northeast	26	8
East	31	9
Southeast	26	8
South	29	9
Southwest	31	9
West	40	12
Northwest	48	15
Ridgetop	42	13
Valley Bottom	19	6
TOTAL	329	100

Table 3. Study Area Aspect and Elevation Distribution.

Elevation Classes

Meters (feet)	Number of Sites	Percent
< 762 (< 2,500)	102	17
762– 914 (2,500–2,999)	130	22
915–1,066 (3,000–3,499)	107	18
1,067–1,219 (3,500–3,999)	98	16
1,220–1,371 (4,000–4,499)	117	19
> 1,371 (> 4,500)	46	8
TOTAL	600	100

Aspect

Direction	Number of Sites	Percent
North	77	13
Northeast	49	8
East	48	8
Southeast	55	9
South	48	8
Southwest	50	9
West	80	13
Northwest	92	15
Ridgetop	69	12
Valley Bottom	32	5
TOTAL	600	100

Stump and Tree Selection

Four onsite criteria were used in the selection of individual stumps and trees. First, annual growth rings had to be distinguishable and countable. Pitch, soil debris, physical shattering (as from bucking and falling during lumbering operations), age, physical decay (either before or after cutting), and charring from slash burning made numerous stumps unusable for this study. Pitch pockets and rot cause difficulty in aging live trees with an increment borer. The second criterion for stump and tree selection was to obtain a representative sample of the tree ages in the stand, or at least a cross section of the principal age-classes. Size-classes approximated age-classes in many instances, but data were compared in the field to evaluate this relationship at each site and more than ten times the trees and stumps used in this study were examined to ensure that no major age-class would be excluded. The third criterion was to attempt to include the oldest age-class or individual. This is difficult to accomplish under most conditions, but obtaining a record from the oldest member would establish the longest possible record at that site. Finally, individual trees or stumps were chosen to include a large number of fire scar dates (see "fire scar," Appendix A).

As direct evidence of fire, fire scar dates are preferable to origin dates in reconstructing fire history

Tree origin dates were used where scar dates were not available, primarily to represent additional older age-classes not represented by scar dates. Scar dates are more difficult to obtain from live trees, especially from older trees with deeply buried fire scars. Some of the youngest age-classes could not have contained any fire scar dates, because they post-date the most recent fires.

The number of stumps or trees sampled per site varies between one and 23, and averages 6.5 (Table 4). A total of 2158 trees were sampled within the study area, yielding 2022 origin dates and 708 scar dates. Another 147 trees were sampled at the 30 sites immediately adjacent to the study area, and were used delineate fire boundaries at the edges of the study area.

Dating Techniques

Data From Stumps

Data were obtained principally from stumps, but supplemented with data from live trees where clearcuts were not available or too old to be useful. Clearcuts are numerous in and around the study area, and using stumpsproved more advantageous than using live trees. The dating methods are similar to those described by Arno and Sneck (1977) and Morrison and Swanson (1987). Tree rings were counted on stumps from the bark to the pith using a

Table 4. Numbers of Sites, Trees Sampled, Scar Dates, and Origin Dates.

	Number in	
	Study Area	Study Area and Fringe
Sites	329	359
Origin Dates	2,022	2,157
Scar Dates	708	751
Total Dates	2,730	2,908
Trees Sampled	2,158	2,305
Average Number of Dates Per Site	8.3	8.1

pointer, and a marking pen was used to mark every 50th ring and label every one-hundredth ring. Sections where the growth rings were very narrow could sometimes be avoided by moving around the circumference of the stump along a particular ring, to a point where the rings were more widely spaced. The most difficult sections were counted two or three times to confirm the count. The tops of stumps were cleaned and scraped prior to counting the rings, and the positions of fire scars, or other types of recognizable scars were noted.

The total count, stump height, stump diameter, bark thickness, growth rate of the inner three rings, and growth rate of the inner inch were recorded for each tree sampled. A subjective rating of the accuracy of the count was noted for both origin and scar dates, and only the more accurate counts were used in subsequent data analysis. Scars were also classified by their presumed cause, and those assumed to be fire scars were further rated as to the certainty that they were, in fact, fire scars. Other factors scarring Douglas-fir trees included tree fall, windthrow, frost cracks, lightning, root rot, animal damage, and beetle damage. Careful observation and experience allow an investigator to differentiate between the various origins of scars (Arno and Sneck, 1977; Mitchell, Martin, and Stuart, 1983). Those scar dates with any ambiguity of either date (count) or origin were excluded from analysis.

A few cross-sections were also sampled with chainsaw. The sections were then sanded and counted in a manner similar to that used with increment cores described below.

Data From Live Trees

Live trees sampled were cored with an increment borer at breast height. Cores were placed into plastic straws, taped at both ends, labeled, and frozen at the end of each day. Trees were often sampled from different radii, and the counts compared for accuracy. The diameter of each tree was measured with a diameter tape and the bark thickness was measured in the groove between bark plates with a ruler. Cores were later counted under a light and a 40-power stereo-dissecting microscope, aided by dissecting needles. Phloroglucinol was used to stain some of the cores with narrower rings, but was generally not needed. Every tenth growth ring was marked.

The limitations of using live trees were 1) the time involved in collecting each sample, 2) the low probability of obtaining a fire scar and recognizing it as such, 3) the inability to compare ages in the field to ascertain the range of age-classes (although some cores were counted prior to placement in their holders), 4) the difficulty in coring the center of large trees due to oblique coring angles, and 5) the difficulty in reaching the center of the tree due to the large radii of old-growth Douglas-fir trees with a moderate-length (56 centimeter [22 inch]) increment borer. A small number of trees were sectioned with a chainsaw. This method allows the removal of fire scars from live trees for laboratory analysis by cutting a narrow wedge from the scarred face of the trunk (Arno and Sneck, 1977).

Ring Count Conversions

Fire scar and origin ring counts were converted to calendar year counts. Fire scar counts from live trees could simply be subtracted from the year sampled to get a scar date. Age at breast height was adjusted by the formulae (from Frederick C. Hall, Region 6 Ecologist, U.S.F.S., reported in Morrison, 1984:26):

$$Age = 0.185 \times CH/RW + CY, \quad \text{for } RW >= 2 \text{ millimeters}$$

$$Age = 0.185 \times CH/2 + CY, \quad \text{for } RW < 2 \text{ millimeters}$$

where:

Age = age at core (or stump) height (years)

CH = core (or stump) height (centimeters)

RW = average ring width of inner three rings (millimeters)

0.185 = a constant

CY = counted years

The age obtained from the appropriate formula was then added to the ring count and that sum subtracted from the year sampled to get the origin date. For example, a 100-centimeter-tall stump cut in 1980, with 200 counted years and an average ring width of 5 mm (for inner three rings) would require the following calculation:

$$Age = 0.185 \times 100/5 + 200 = 3.7 + 200 = 203.7 = 204$$

Then to obtain the origin date:

$$Origin\ date = 1980 - 204 = 1776$$

These correction-factor formulae were developed for Douglas-fir only, and other species would have different average growth rates as seedlings (i.e., would have different constants in their formulae). Species other than Douglas-fir were corrected by the same formulae, but are presumably older than the estimated age, and were used very sparingly where no other data were available.

The determination of origin and scar dates from stumps required an additional step beyond that of cored trees: the year the trees were harvested needed to be determined. In most cases, the clearcut units could be identified in records of the United States Forest Service Total Resource Inventory (TRI) system or the HJA administrative records. The harvest year could then be used in the same manner as the sample year of core dates. The corrections from the formulae were added to the counts, and this sum subtracted from the harvest year to obtain origin dates. Scar dates were obtained by subtracting the scar counts from harvest dates.

Mapping Techniques

The first step in mapping a fire is the determination of a fire date or episode (period of several years) from fire scar and origin data. Definition of the amount of data necessary to qualify as a mappable fire event is highly subjective, but essential. Errors in counting, missing or added rings, season in which the fire occured, and inaccurate harvest records cause temporal scattering of fire scar and tree origin data. Missing or added rings are not thought to be a significant source of error in Douglas-fir in this region (Means, personal communication). Inaccuracies in the data and the low incidence of records of numerous fires on individual trees combine to inhibit the construction of the type of "corrected master fire chronologies" suggested by Arno and Sneck (1977). Spatial scattering of probable records of fire events from the raw data must also be reconciled.

Determination of Fire Years

Several criteria were set for evaluating the occurrence of fire. Arno and Sneck (1977) and McBride (1983) recommend that an inventoried fire be recorded at a minimum of two sites in close proximity, to imply that it was spreading and not a spot fire, and that regeneration occurred after that fire. The criteria used in this study ...ch more stringent, and are modified from Morrison and

Swanson (1987). These criteria are minimum standards only; the majority of cases greatly exceed them.

1. Ten or more sites (including those immediately adjacent to the study area) must have scars or regeneration dating from the fire.

2. Both scar and origin dates must be present for all fires. It is recognized that older individuals of similar age, predating the earliest scar date, may have originated from an early fire, but only those that have corresponding scar dates will be considered in this study. Regeneration needs to be present for all but the more recent fires (1910 to present), when historical records or aerial photographs clearly support the presence of that fire. The occurrence of fire is determined by scar dates. Origin dates can only be used to sustain a suspected record, not establish one.

3. Only the dates rated most accurate, and those scars most probably caused by fire are used. The less reliable one-third of the scar data set, as judged in the field while sampling, has been discarded.

4. Temporal clustering of scar dates must be established. The clustering for later periods of time is narrow, while for earlier periods it may be wider. Due to this temporal dispersion and the decrease in records over time, fewer records are required to establish older fire events. Specifically, for the period 1800-1900 fire scars

from twelve sites must be recorded within a four-year period. From 1700 to 1800 fire scars must have been present at eight sites within a four-year period. From 1600 to 1700 six sites must contain a record of fire scars over a four-year period. From 1500 to 1600 fire scars must be present at four sites within a four-year period. Prior to 1500 data are more sparse, and two documented fires are established by individual means: 1) the 1482 fire has two scar records within two years, and 2) the 1435 fire has only one scar date (which lies just beyond the boundary of the study area). The interpretation of only these two fires are supported exclusively by regeneration dates.

5. The sites with fire scars, or at least the majority of them, must have geographic affinity. At least some of those with a record of fire must be adjacent to one another to determine the existence of a fire. The mapped "fire" need not be one contiguous area. There may be several clusters of geographic affinity for the same "fire." The term "fire" is used to include cases of a single, contiguous fire as well as cases of multiple fires occurring at the same period in time throughout the study area, possibly connected by underburning not observed in the study.

The Mapping Process

The process of mapping individual fires was reiterative. First, the record at each site was evaluated using the above criteria. The record of each site was then matched with its neighbors in increasingly larger sets of sites, similar to the fire chronology tables outlined by Arno and Sneck (1977) to correct discrepancies in the data. Somwe adjacent sites had scar dates that appeared offset uniformly by a few years, and the dates of one of the sites could be adjusted to correct an apparent error in year of harvest.

Finally, the record of fire was tabulated in a form similar to Appendix D. Data from the table were then mapped. When one site had a record of fire and an adjacent site did not, a line was drawn midway between the sites as the fire boundary. Sites which had no trees capable of recording an individual fire because the fire pre-dated the establishment of the stand, were ignored in the mapping of that fire event. Scar dates, origin dates, the combination of both, the oldest origin dates per site, and sites that have records that pre-date a given fire, but do not record it, are mapped by fire year at a scale of 1:24,000. Discrepancies became evident during the mapping. The criteria for determining the presence of fire, while stringent, allowed various combinations of fire patterns, both temporally and spatially. Reiteration of the mapping process to eliminate conflicting fire boundaries and fire dates produced maps and tables that appeared more internally consistent. Reiteration progressed until a "best fit" was found. Many origin dates could not be attributed to any specific fire event. Fire scars that were not associated with others, either spatially or temporally, were not used in further analysis. The process, while following some rigid guidelines, has an inevitable degree of subjectivity.

Statistical Techniques

The maps were plotted at a scale of 1:24,000 on a U.S. Geological Survey base (on file at the Pacific Northwest Research Station, Reseach Work Unit 4302, Forestry Sciences Laboratory, Corvallis, Oregon), and then reduced to their present scale. Measurements of each fire are expressed in hectares burned, to the nearest 2-hectare (5-acre) increment, and was obtained by a radial planimeter. Fires typically burned in more than one contiguous area. The hectares burned for each mapped unit was determined individually. Then the individual units were added together for a total area burned per fire year. A second method was employed in estimating the area burned for each fire episode: the ratio of sites recording an individual fire event, to the number of sites capable of recording that fire event, was multiplied by the size of the study area (Morrison and Swanson, 1987). This method is referred to as the "mapped-area-estimate ratio."

Natural fire rotation (Appendix A), in years, was determined for various periods of time. Natural fire rotation is calculated by the following formula (Heinselman, 1973):

$$NFR = \frac{\text{Size of Study Area}}{\text{Burned Area/Length of Time Period}}$$

Natural fire rotation requires areal data; other measures of fire frequency are derived from point or site specific data.

Mean fire rotation intervals (MFRI) (Appendix A) were compiled from site specific data. The average period of time between fire years, or the mean fire free interval, for the composite of all records at each individual site is termed the mean fire return interval. Mean fire return intervals are especially useful where data are either too complex or too sparse (spatially) to be adequately mapped.

Various sets of mean fire return intervals, such as, by elevation-classes and aspect, were tested by one-way analysis of variance (ANOVA) to determine if they were statistically different (Sokal and Rohlf, 1981). Subsets of those sets that were found to be significantly different (e.g., north and east aspects, within the set of aspects) were then compared to each other using the Tukey-Kramer Method of comparison of means, a minimum significant difference (MSD) test (Snedecor and Cochran, 1967; Sokal and Rohlf, 1981).

CHAPTER V

RESULTS

Cultural-Historical Fire History Patterns

Four time periods were chosen to reflect occupancy and land-use by different cultural groups, 1) pre-1830, as pre-Anglo, with only very limited white contact near the end of this period, 2) 1831-1850, as a transition period between aboriginal and white settlement, at the end of which aboriginals were displaced and finally removed entirely, 3) 1851-1909, the pre-fire suppression period, dominated by Anglo mining and sheep grazing activities, and 4) 1910-1986, the fire suppression period, when suppression and prevention efforts became effective in reducing the acreage burned.

Natural Fire Rotation (NFR, defined in Appendix A) for each of these four periods was estimated by two procedures, based on mapped fire areas measured by 1) a polar planimeter, and 2) the mapped-area-estimate ratio. The results from the two methods are averaged in further analysis because it is assumed to produce better estimates of the true NFRs for reasons discussed in Chapter VI.

Natural Fire Rotations reflect a significant difference in fire frequency between cultural periods (Table 5). The NFR is 96 years for the pre-Anglo period, the longest period of record. The NFR of the transition period is 33 years, a frequency three times greater than the preceding period. The pre-suppression period also has a higher fire frequency, with a NFR of 87 years. The NFR (40 years) for the entire period of white influence and dominance prior to fire suppression (1831-1909) is less than one-half of the NFR for the pre-Anglo period (NFR = 96 years), indicating more prevalent fire following that time period. An explanation of the significance and biases inherent in these NFRs follows in Chapter VI. Fire were least frequent during the suppression era (1910-1986), with an NFR value of 587 years, roughly an order of magnitude greater than the entire preceding period of record (1435-1909) (NFR = 91 years). The effect of fire suppression has apparently reduced the areal extent of fire by one order of magnitude compared to the period of 1435 to 1909.

Spatial Fire History Patterns

Fire history patterns were analyzed at three landscape scales: (1) the entire study area, (2) physiographic subdivisions of the study area, and (3) individual sites. At the study area level (10,970 hectares [27,110 acres]), a wide range of topographic and

Table 5. Natural Fire Rotation by Period.

Cultural Period	Interval (range of dates)	Estimated by Ratio	Estimated by Planimeter	Average
Pre-Anglo	1435-1830	102	89	96
Transition	1831-1850	36	30	33
Pre-fire Suppression	1851-1909	102	71	87
Suppression	1910-1986	768	587	587
"Natural Fires"	1435-1909	95	80	88
Immediate Pre-Anglo	1772-1830	86	69	78
Total for Length of Record	1435-1986	108	91	100

site characteristics are incorporated into a limited set of descriptors of fire history, and the results are averages over a wide range of possible fire regimes. The second level, subdivisions of the study area covering 1,820 to 3,270 hectares (4,500 to 8,080 acres) each, allows an analysis of fire history more sensitive to topographic influences on drainage basin-scale wind patterns. At the third level, the individual sites of approximately one hectare (2.5 acres), fire history may be analyzed with respect to specific environmental factors, such as elevation and aspect. Small fires are most sensitive to specific site characteristics, medium-sized fires are most sensitive to drainage basin and general winds, while large fires may generate their own winds and are largely insensitive to "external" environmental factors. Therefore the analysis of fire history at various spatial scales is an appropriate approach to examining the natural fire regimes within this study area.

Fire History Patterns of the Entire Study Area

Overall Fire Record

Thirty-six individual fires (spatial sets of fires in the same year) and fire episodes (temporal clusters of fires), during the period 1435 to 1952, were mapped at a scale of 1:24,000 (Appendices C and D). The episodes ranged from 1 to 40 years in length (the 1952 fires were mapped from historical records and aerial photographs, but not from field data) (Table 6). Lengths of the episodes increased sharply for earlier centuries until about 1700, and then remain similar. Average episode lengths are as follows: 1900-1986, 2 years; 1800-1899, 7 years; 1700-1799, 14 years; 1600-1699, 27 years; and 1435-1599, 23 years. Fire-free intervals, the length of time from the inferred fire year within a fire episode to the next, also increased for earlier centuries: 1900-1986, 7 years; 1800-1899, 7 years; 1700-1799, 17 years; 1600-1699, 34 years; and 1435-1599, 29 years. These two sets of figures probably reflect the grouping of the earliest individual fire events (fire years) into the sets of events which have been termed "fire episodes," while later fire events remained more clearly distinguishable from one another, and more likely represent individual fire years.

A number of sites with both scar and origin records in close physical proximity and with close temporal clustering, would be an ideal indicator of a fire event or episode, but does not always occur, even for historically documented fires. The potential number of sites with records of fire events diminishes progressively into the past (Table 7), as later fire episodes and other mortality factors have erased the evidence of previous episodes by stand removal. Where scar dates and regeneration from that fire episode were not simultaneously available, the record

Table 6. Fire Dates and Fire Episodes.

Fire Year	Fire Episode	Episode Length (years)	Fire Free Interval (years)
1435	1410-1450	40	NA
1482	1470-1494	24	47
1532	1520-1543	23	50
1551	1548-1556	8	19
1566	1562-1574	12	15
1591	1579-1605	26	15
1623	1612-1641	29	32
1663	1646-1677	31	40
1692	1683-1701	18	29
1717	1705-1729	24	25
1747	1735-1751	16	30
1757	1753-1760	7	10
1764	1761-1771	10	7
1780	1773-1787	14	16
1796	1789-1798	9	16
1801	1799-1805	6	5
1809	1806-1811	5	8
1813	1812-1816	4	4
1820	1817-1824	7	7
1830	1826-1832	6	10
1836	1833-1838	5	6
1839	1838-1843	5	3
1849	1844-1852	8	10
1857	1853-1861	8	8
1868	1863-1872	9	11
1878	1875-1881	6	10
1885	1882-1887	5	7
1893	1888-1896	8	8
1902	1898-1904	6	9
1907	1905-1910	5	5
1914	1912-1918	6	7
1921	1921-1923	2	7
1930	1929-1930	1	9
1932	1931-1932	1	2
1935	1935-1936	1	3
1952	1952	0	17

Table 7. Sites Capable of Having a Fire Record by Fire Episode.

Fire Year	Fire Episode	Number of Sites With a Record of Fire	Number of Sites Sites Capable of Having a Record of Fire
1435	1410-1450	32	68
1482	1470-1494	156	169
1532	1520-1543	103	199
1551	1548-1556	42	208
1566	1562-1574	60	219
1591	1579-1605	45	221
1623	1612-1641	42	221
1663	1646-1677	55	228
1692	1683-1701	9	229
1717	1705-1729	44	238
1747	1735-1751	49	247
1757	1753-1760	41	260
1764	1761-1771	12	261
1780	1773-1787	33	265
1796	1789-1798	30	268
1801	1799-1805	10	269
1809	1806-1811	20	273
1813	1812-1816	42	280
1820	1817-1824	33	291
1830	1826-1832	23	293
1836	1833-1838	56	302
1839	1838-1843	36	308
1849	1844-1852	81	317
1857	1853-1861	35	320
1868	1863-1872	26	321
1878	1875-1881	14	322
1885	1882-1887	26	324
1893	1888-1896	51	326
1902	1898-1904	29	328
1907	1905-1910	4	328
1914	1912-1918	14	329
1921	1921-1923	4	329
1930	1929-1930	6	329
1932	1931-1932	2	329
1935	1935-1936	7	329
1952	1952	0	329

of fire was established by scar dates alone, corroborated by origin dates. Establishment of the fire record by regeneration was necessary only for the earliest two fire episodes, 1435 and 1482, and even these two fires had scar records to supplement the record of regeneration (Table 8). The 1435 fire episode had no scar record within the study area, although one scar date was found immediately adjacent to the study area, across Blue River.

The acreage burned during each fire episode was determined by two methods (Table 9). Both methods are approximations of the actual area burned. The areas measured by planimeter on mapped burns are accurate for episodes from 1893 to 1952 because aerial photographs could supplement mapped data, but are more subjective for earlier episodes. The ratio method was used as an alternate method of calculating burned areas by the proportion of sites burned, and was less likely biased by interpretation. The 1435 fire episode had too few sites to draw presumed fire boundaries, and only the ratio method could be used to calculate burned area. The 1952 fires were not recorded at any sample sites, because the sampling density was too low and did not target them specifically. In this case, the area could be measured by planimeter, but not estimated by the ratio method. The areas calculated by the two methods are strongly correlated (r-squared=.94), although the planimeter method usually estimated a larger area burned

Table 8. Number of Sites with Fire Scar Dates and Origin Dates, by Fire Episode.

Fire Year	Number of Sites with Scar Dates	Number of Sites with Both Scar and Origin Dates	Number of Sites with Origin dates	Total Number of Sites with a Record of Fire Year
1435	0	0	32	32
1482	2	4	150	156
1532	16	8	79	103
1551	5	3	34	42
1566	8	4	48	60
1591	13	2	30	45
1623	28	6	8	42
1663	30	4	21	55
1692	5	0	4	9
1717	22	6	16	44
1747	26	9	14	49
1757	15	8	18	41
1764	7	1	4	12
1780	20	1	12	33
1796	18	2	10	30
1801	6	1	3	10
1809	14	1	5	20
1813	22	5	15	42
1820	11	4	18	33
1830	14	3	6	23
1836	28	7	21	56
1839	12	12	12	36
1849	41	21	19	81
1857	15	8	12	35
1868	17	4	5	26
1878	10	2	2	14
1885	20	2	4	26
1893	32	8	11	51
1902	16	4	9	29
1907	3	0	1	4
1914	10	0	4	14
1921	4	0	0	4
1930	6	0	0	6
1932	2	0	0	2
1935	6	0	1	7
1952	0	0	0	0

Table 9. Area Burned by Fire Episode.

Fire Year	Ratio-estimated Area in Meters (feet)	Measured Area in Meters (feet)
1435	5,165 (12,758)	NA
1482	10,130 (25,025)	10,525 (26,000)
1532	5,680 (14,032)	6,610 (16,325)
1551	2,215 (5,474)	2,105 (5,200)
1566	3,005 (7,427)	2,990 (7,390)
1591	2,235 (5,520)	1,500 (3,700)
1623	2,085 (5,152)	3,340 (8,245)
1663	2,650 (6,540)	3,415 (8,430)
1692	430 (1,065)	515 (1,275)
1717	2,030 (5,012)	2,875 (7,105)
1747	2,175 (5,378)	2,360 (5,835)
1757	1,730 (4,275)	2,295 (5,665)
1764	505 (1,246)	1,215 (2,995)
1780	1,365 (3,376)	1,565 (3,860)
1796	1,230 (3,035)	1,535 (3,790)
1801	410 (1,008)	305 (755)
1809	805 (1,986)	1,515 (3,735)
1813	1,645 (4,067)	2,386 (5,895)
1820	1,245 (3,079)	1,000 (2,470)
1830	860 (2,128)	1.065 (2,635)
1836	2,035 (5,027)	1,885 (4,655)
1839	1,280 (3,169)	1,970 (4,860)
1849	2,805 (6,927)	3,480 (8,595)
1857	1,200 (2,965)	1,970 (4,860)
1868	890 (2,196)	820 (2,020)
1878	475 (1,179)	325 (805)
1885	880 (2,175)	1,500 (3,705)
1893	1,715 (4,241)	3,360 (8,295)
1902	970 (2,396)	955 (2,360)
1907	135 (330)	45 (105)
1914	470 (1,154)	605 (1,495)
1921	135 (330)	340 (845)
1930	200 (494)	435 (1,070)
1932	65 (165)	10 (30)
1935	235 (577)	30 (75)
1952	NA	20 (44)

(slope of regression line, b=1.06).

Study Area Fire Frequency

Several of the numerous indices of fire frequency or recurrence are presented here. The natural fire rotation of the study area over the entire length of record is 91 years, and prior to fire suppression it is 80 years (see Table 5, Natural Fire Rotation Periods). These figures are derived from planimetric measurement of mapped fire boundaries. Several other analyses are based on point (site) specific data rather than areal measurements. These further analyses cover the period 1435 to 1909. The period 1910 to 1986 was excluded because of the presumed effects of fire suppression. These effects themselves are worthy of future detailed analysis.

The average number of fires at individual sites within the study area is 3.8 (Table 10). There are an average of 2.4 age-classes at each site, an indication that most the sites had two or three fires that were of sufficient severity to cause at least partial stand mortality and regeneration. The sites averaged one stand replacement or partial stand replacement fire every 166 years. Fires of sufficient intensity to cause scarring, but lacking the severity to cause mortality, defined as underburns, were recorded less frequently than the higher intensity (severity) fires. The sites recorded an averaged

Table 10. Study Area Fire Frequency Indicators.

Measure of Fire Frequency	Value	Range
Average Number of Fires Per Site	3.8	(1-15)
Average Number of Age-classes Per Site	2.4	(1-8)
Average Number of Underburns Per Site[1]	1.5	(0-11)
Mean Fire Return Interval (All Fires) (Years)[2]	114	(14-428)[3]
Mean Fire Return Interval (Stand-replacing or Partial Stand-replacing Fires) (Years)[2]	166	(24-428)[3]

1 Sites Recording Underburns Have Fire Scars, but No Regeneration for That Fire.
2 MFRI is Calculated at the Site Level.
3 Sites with 2 or More Records Only.

of 1.5 underburns. The total mean fire return interval (MFRI, defined in Appendix A) fire frequency, included both intensity types, averaged 114 years.

Fire History of Physiographic Units

More detailed analyses of effects of topography on fire history can be made by dividing the study area into four physiographic units (Figure 6), which are supplemented by data from two nearby units (Morrison and Swanson, 1987). The subdivisions were chosen to reflect contrasts in environmental conditions that influence fire history. Sites in the South Lookout unit are oriented primarily north and northwest, with a high proportion of ridgetop sites, generally under 1820 meters (4500 feet) elevation (Tables 11 and 12). Sites in the North Lookout unit are mainly oriented to the southeast, south, southwest and west, also with a high proportion on ridgetops, but with numerous sites above 1820 meters (4500 feet). In the County Creek unit, sites generally face the east, range in the middle elevations, but are not common on ridgetops. The sites in the Blue River unit are oriented to the west and northwest, and are located in the lower elevations, with few sites on ridgetops.

Data from Morrison and Swanson (1987) are incorporated in the physiographic analyses to provide two additional units of similar scale. Sites in their Cook-

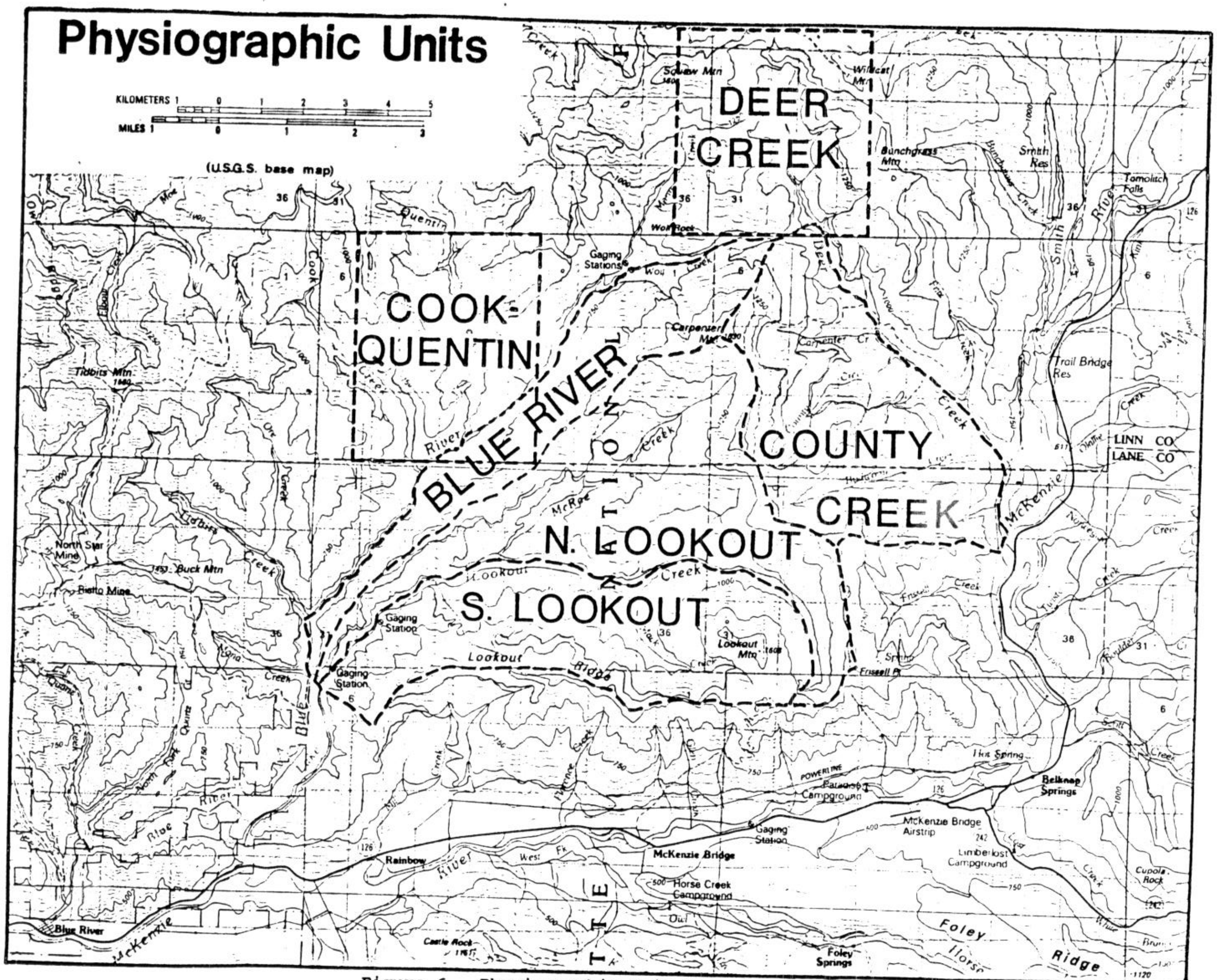


Figure 6. Physiographic Unit Location Map.

Table 11. Environmental Characteristics of Physiographic Units: Aspects.

	Physiographic Unit					
	Blue River	County Cr.	N. Lookout	S. Lookout	Deer Creek	Cook-Quentin
Area, Hectares (Acres)	1,820 (4,500)	3,150 (7,780)	3,270 (8,080)	2,730 (6,750)	1,940 (4,795)	1,940 (4,795)
Aspect, Sites (%)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
North	8 (11)	9 (11)	4 (3)	16 (26)	3 (5)	1 (2)
NE	0 (0)	18 (23)	2 (2)	6 (10)	6 (9)	2 (3)
East	0 (0)	24 (31)	3 (3)	4 (6)	10 (16)	5 (9)
SE	0 (0)	12 (15)	14 (12)	0 (0)	3 (5)	13 (23)
South	1 (2)	2 (3)	26 (22)	0 (0)	13 (20)	7 (12)
NW	2 (3)	1 (1)	27 (23)	1 (2)	10 (16)	8 (14)
West	23 (32)	0 (0)	15 (13)	2 (3)	8 (13)	5 (9)
NW	29 (40)	0 (0)	4 (3)	15 (25)	1 (2)	3 (5)
Ridge	6 (8)	6 (7)	19 (16)	11 (18)	4 (6)	12 (21)
Valley	3 (4)	7 (9)	3 (3)	6 (10)	5 (8)	1 (2)
	72 (100)	79 (100)	117 (100)	61 (100)	63 (100)	57 (100)

Table 12. Environmental Characteristics of Physiographic Units: Elevation Classes.

	Physiographic Unit					
	Blue River	County Creek	North Lookout	South Lookout	Deer Creek	Cook-Quentin
Elevation in M (Ft)	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
< 762 (< 2,500)	20 (28)	4 (5)	14 (12)	12 (20)	0 (0)	12 (21)
762- 914 (2,500-2,999)	28 (39)	9 (11)	18 (15)	14 (23)	0 (0)	21 (37)
915-1,066 (3,000-3,499)	15 (21)	24 (31)	22 (19)	9 (15)	8 (13)	21 (37)
1,067-1,219 (3,500-3,999)	9 (12)	22 (28)	24 (21)	10 (16)	24 (38)	3 (5)
1,220-1,371 (4,000-4,499)	0 (0)	15 (19)	25 (21)	13 (21)	31 (49)	0 (0)
> 1,371 (> 4,500)	0 (0)	5 (6)	14 (12)	3 (5)	0 (0)	0 (0)
	72 (100)	79 (100)	117 (100)	61 (100)	63 (100)	57 (100)

Quentin unit have in southerly aspects, with high a proportion of sites in lower to middle elevations and on ridgetops (Tables 11 and 12). In their Deer Creek unit, sites are oriented in similar aspects, but range from middle to high elevation, and rarely on ridgetops.

Fire frequency data from these six units can be categorized into four groups. Three of the six units, County Creek, North Lookout, and Cook-Quentin, have very similar fire frequencies, and more refined differentiation between them would depend on which measure or measures of fire frequency were judged most critical (Tables 13, 14, and 15). The two indices that probably are the most significant in evaluating relative fire frequencies, the average stand replacement (or partial stand replacement) MFRIs and the composite MFRIs (both lower and higher severity), are particularly similar among the three units. County Creek, North Lookout, and Cook-Quentin units have the highest fire frequencies, with stand-replacement mean fire return intervals (MFRI) ranging between 132 and 150 years, and composite mean fire return intervals between 96 and 100 years.

The unit with the next shorter mean fire return interval, Blue River, has a similar composite MFRI of 114 years, but has a somewhat higher stand replacement MFRI (190 years). South Lookout has an intermediate composite MFRI (160 years) and stand replacement MFRI (223 years).

Table 13. Fire Occurrence Characteristics of Physiographic Units.

Measure of Fire Occurrence	Physiographic Unit					
	Blue River	County Creek	North Lookout	South Lookout	Deer Creek	Cook-Quentin
Average Number of Fire Per Site	4.0	3.5	4.2	3.0	2.1	3.3
Average Number of Age-classes Per Site	2.4	2.2	2.6	2.0	1.6	2.2
Average Number of Underburns Per Site	1.7	1.5	1.7	1.1	0.5	1.1
Mean Fire Return Interval (all fires)	114	99	100	160	239	96
Mean Fire Return Interval (stand-replacing or partial stand-replacing)	190	132	145	223	276	150

Table 14. Minimum Significant Differences of MFRI (Stand-replacing or partial stand-replacing fires), by Physiographic Unit.

Physiographic Unit		Cook-Quentin	County Creek	North Lookout	Blue River	South Lookout	Deer Creek
		Minimum Significant Difference					
Cook-Quentin	Obs. Diff.	--	56.32	52.77	57.76	60.01	59.55
County Creek		17.31	--	47.26	52.77	55.23	54.72
North Lookout		5.10	12.21	--	48.96	51.60	51.06
Blue River		39.69	57.00*	44.79*	--	56.69	56.20
South Lookout		72.36*	89.67*	77.46*	32.67	--	58.52
Deer Creek		121.64*	138.95*	126.74*	81.95*	49.28*	--

note: * indicates a statistically significant difference (p=0.05).

Table 15. Minimum Significant Differences of MFRI (All fires), by Physiographic Unit.

Physiographic Unit		Cook-Quentin	County Creek	North Lookout	Blue River	South Lookout	Deer Creek
	Observed Diff.	Minimum Significant Difference					
Cook-Quentin		--	46.50	43.56	47.68	49.54	49.16
County Creek		4.50	--	39.01	43.56	45.59	45.18
North Lookout		3.20	1.30	--	40.42	42.60	42.15
Blue River		18.00	13.50	14.80	--	46.40	46.40
South Lookout		64.40*	59.90*	61.20*	46.80*	--	48.31
Deer Creek		137.10*	132.60*	133.90*	119.10*	72.70*	0.00

note: * indicates a statistically significant difference (p=0.05).

The unit with the lowest fire frequency using any of the five indices is Deer Creek. It has a composite MFRI of 239 years and a stand replacement MFRI of 279 years. The fire frequencies of this unit are roughly one-half of the County Creek, North Lookout, and Cook-Quntin units.

Fire frequencies vary considerably between the physiographic units. Some of these differences may be attributed to the variations of aspects and elevations of sites between the units.

Fire History Based on Site Variables

Mean Fire Return Intervals by Elevation

Individual site fire frequencies vary considerably from those for the study area. The composite site MFRI is 114 years and the stand replacement MFRI is 166 years, but standard deviations are 96 and 118 years, respectively (Appendix D). Some of the variation in fire frequency can be attributed to elevation and aspect, which influence ignition and spread (Tables 16 and 17).

Differences between mean fire return intervals by aspect classes were found to be statistically significant in a one-way analysis of variance [ANOVA], (p=0.05; Appendix B). A separate ANOVA (p=0.05) indicated a statistically significant trend of shorter mean fire return intervals at higher elevations.

Table 16. Mean Fire Return Intervals by Aspect.

Aspect	Number of Sites	Mean Number Age-classes	Mean Number Underburns	MFRI (Stand-replacing type)	MFRI (all Fires)
N	37	2.30	1.89	131	198
NE	26	2.31	2.12	120	159
E	31	2.06	1.19	110	154
SE	26	2.23	0.88	122	151
S	29	3.28	1.72	93	124
SW	31	2.52	1.32	107	162
W	40	2.40	2.10	102	174
NW	48	2.42	1.19	143	205
R	42	2.26	1.69	74	115
B	19	1.53	1.21	150	227

notes: 1) MFRI = Mean Fire Return Interval, derived at the site level.

Table 17. Mean Fire Return Intervals by Elevation.

Elevation in meters (feet)	Number of Sites	Mean Number of Age-classes	Mean Number of Underburns	MFRI (stand-replacing type)	MFRI (all fires)
< 762 (< 2,500)	50	2.28	1.28	153	209
762- 914 (2,500-2,999)	69	2.38	1.48	121	170
915-1,066 (3,000-3,499)	70	2.11	1.51	123	186
1,067-1,219 (3,500-3,999)	65	2.37	1.78	109	171
1,220-1,371 (4,000-4,499)	53	2.64	2.02	81	125
> 1,371 (> 4,500)	22	2.55	0.73	72	81

Note: 1) MFRI = Mean Fire Return Interval, derived at the site level.

are the longest for lower elevation sites (less than 1,010 meters [2,500 feet]), 153 and 209 years, respectively, and the shortest for higher elevations (greater than 1,820 meters [4,500 feet]), 72 and 81 years, respectively. Intermediate elevations tend to follow the same gradient of increasing fire frequency with elevation (Table 17), although differences between some of the means are not statistically significant, as determined by the Tukey-Kramer method of comparisons of means (Tables 18 and 19) (Sokal and Rohlf, 1981:244-245,251-252).

Fire Return Intervals by Aspect

The interpretation of fire frequency by aspect is more complex than by elevation. Composite MFRIs are shortest for ridgetop sites followed south aspects (Tables 18 and 19). Stand replacement MFRIs are also shortest for ridgetops and south aspects, but in this case, the mean MFRIs are not significantly different statistically (Table 17). The longest MFRIs for both composite and stand replacement types were at north, northwest and valley bottom sites. The MFRIs of the five remaining aspects (west, southwest, southeast, east and northeast) are more difficult to rank. Based on a MFRI for stand replacement or partial stand replacement type fires only, aspects are ordered by the group: southeast, east, northeast, and southwest (these four are statistically very similar),

Table 18. Minimum Significant Differences of MFRI (All fires), by Elevation Classes.

Elevation in meters (feet)		< 762	762-914	915-1,066	1,067-1,219	1,220-1,371	> 1,371
	Observed Difference	Minimum Significant Difference					
< 762 (< 2,500)		--	14.88	14.83	15.07	15.79	20.50
762- 914 (2,500-2,999)		32.34*	--	13.59	13.85	14.63	19.62
915-1,066 (3,000-3,499)		30.24*	2.10	--	13.80	14.59	19.58
1,067-1,219 (3,500-3,999)		44.15*	11.81	13.91*	--	14.83	19.76
1,220-1,371 (4,000-4,499)		71.35*	39.01*	41.11*	27.20*	--	20.32
> 1,371 (> 4,500)		80.458	48.11*	50.21*	36.30*	9.10	--

note: * indicates a statistically significant difference.

Table 19. Minimum Significant Differences of MFRI (Stand-replacing and partial stand-replacing fires) by Elevation Classes.

Elevation in meters (feet)	< 762	762-914	915-1,066	1,067-1,219	1,220-1,371	> 1,371
	Observed Difference / Minimum Significant Difference					
< 762 (< 2,500)	--	11.74	11.70	11.89	12.46	16.17
762- 914 (2,500-2,999)	38.49*	--	10.72	10.92	11.54	15.47
915-1,066 (3,000-3,499)	23.18*	15.31*	--	10.88	11.51	15.45
1,067-1,219 (3,500-3,999)	37.62*	0.87	14.44*	--	11.70	15.59
1,220-1,371 (4,000-4,499)	83.13*	44.64*	59.95*	45.51*	--	16.03
> 1,371 (> 4,500)	127.24*	88.75*	104.06*	89.62*	44.11*	--

note: * indicates statistically significant difference.

Mean Fire Return Interval, Stand-replacing (or partial stand-replacing) Fires (bars connect elevations with MFRI that are not significantly different)

Elevation Range, in Meters (feet)

	< 762 (< 2,500)	762-914 (2,500-2,999)	914-1,066 (3,000-3,499)	1,067-1,219 (3,500-3,999)	1,220-1,371 (4,000-4,499)	> 1,371 (> 4,500)
MFRI (yrs)	209	170	186	171	126	82

Mean Fire Return Interval, All Fires (bars connect elevations with MFRI that are not significantly different)

Elevation Range, in Meters (feet)

	< 762 (< 2,500)	762-914 (2,500-2,999)	914-1,066 (3,000-3,499)	1,067-1,219 (3,500-3,999)	1,220-1,371 (4,000-4,499)	> 1,371 (> 4,500)
MFRI (yrs)	153	121	123	109	82	73

Figure 7. Comparison of Mean Fire Rotation Intervals by Elevation.

followed by west aspects (Table 19). The rank order differs when based on the mean fire return interval of all types of fires. West has the shorter MFRI, followed by the group southwest, east, northeast, and southeast (individual aspects of the group are difficult to distinguish statistically).

Some of the patterns of variation in MFRI between physiographic units, aspects, and elevation are, therefore, statistically significant. Further analysis of MFRI by aspect and elevation within each of the physiographic units is presented in Chapter VI in the context of fire regimes, together with explanations of possible causes of the differences in fire frequencies.

Mean Fire Return Interval, Stand-replacing (or partial-stand-replacing) Fires
(bars connect aspects with MFRI that are not significantly different)

Aspect	Ridge	South	West	SW	East	NE	SE	North	NW	Valley
MFRI (years)	116	124	178	162	154	159	151	198	207	227

Mean Fire Return Interval, All Fires
(bars connect aspects with MFRI that are not significantly different)

Aspect	Ridge	South	West	SW	East	NE	SE	North	NW	Valley
MFRI (years)	74	94	105	107	110	121	122	132	148	150

Figure 8. Comparison of Mean Fire Return Intervals by Aspect.

Table 20. Minimum Significant Differences of MFRI (All fires) by Aspect.

Aspect		Ridge	South	West	SW	East	NE	SE	North	NW	Valley
		Minimum Significant Difference									
Ridge	Observed Difference	--	14.05	12.30	13.78	13.78	14.52	14.52	13.12	12.86	16.09
South		20.00*	--	13.69	15.04	15.04	15.72	15.72	14.43	14.20	17.18
West		31.12*	11.12	--	13.41	13.41	14.17	14.17	12.73	12.46	15.78
SW		33.21*	13.21	2.09	--	14.78	15.48	15.48	14.17	13.93	16.96
East		36.08*	16.08*	4.96	2.87	--	15.48	15.48	14.17	13.93	16.96
NE		46.52*	26.52*	15.40*	13.31	10.44	--	16.14	14.89	14.66	17.57
SE		47.91*	27.91*	16.79*	14.70	11.83	1.39	--	14.89	14.66	17.57
North		57.65*	37.65*	26.53*	24.44*	21.57*	11.13	9.74	--	13.28	16.43
NW		74.17*	54.17*	43.05*	40.96*	38.09*	27.65*	26.26*	16.52*	--	16.22
Valley Bottom		76.16*	56.16*	45.04*	42.95*	40.08*	29.64*	28.25*	18.51*	1.99	--

note: * indicates a statistically significant difference.

Table 21. Minimum Significant Differences of MFRI (Stand-replacing or partial stand-replacing fires) by Aspect.

Aspect		Ridge	South	West	SW	East	NE	SE	North	NW	Valley
		Minimum Significant Difference									
Ridge	Observed Difference	--	11.30	9.89	11.08	11.08	11.68	11.68	10.56	10.34	12.94
South		8.50	--	11.01	12.09	12.09	12.64	12.64	11.61	11.42	13.82
West		62.25*	53.75*	--	10.79	10.79	11.40	11.40	10.24	10.02	12.69
SW		46.42*	37.92*	15.83*	--	11.89	12.45	12.45	11.40	11.20	13.64
East		38.35*	29.85*	23.90*	8.07	--	12.45	12.45	11.40	11.20	13.64
NE		43.52*	35.02*	18.73*	2.90	5.17	--	12.98	11.98	11.79	14.13
SE		35.25*	26.75*	27.00*	11.17	3.10	8.27	--	11.98	11.79	14.13
North		82.56*	74.06*	20.31*	36.14*	44.21*	39.04*	47.31*	--	10.68	13.21
NW		91.27*	82.77*	29.02*	44.85*	52.92*	47.75*	56.02*	8.71	--	13.04
Valley Bottom		111.71*	103.21*	49.46*	65.29*	73.36*	68.19*	76.46*	29.15*	20.44*	--

note: * indicates a statistically significant difference.

CHAPTER VI

DISCUSSION

Methods

The sample size of this study compares favorably with previous fire history studies. There are 329 sample sites, 2022 origin dates, and 708 scar dates from 2158 trees within the study area. There are, on average, 19.6 trees sampled per square kilometer and 9.6 fire records (the sum of scar and origin dates) per square kilometer, which is supporting a high sampling density compared to the archetypal fire history studies (Table 22).

A large sample size alone does not yield an accurate study: the reliability and accuracy of the data and the analytical methods, in relationship to the complexity of the fire regimes themselves dictate the sample size necessary to obtain valid interpretations and conclusions. Nonetheless, a larger sample size over a larger area may improve the statistical testing of the hypotheses presented. Additional data immediately adjacent to the study area provide some basis for delimiting fire boundaries at the edges of the study area, and contribute

Table 22. Comparisons of Sample Size in Fire History Studies.

Investigator	Number of Trees Sampled Per Sq. km (mi)	Number of Scar and Origin Dates Per Sq. km (mi)	Study Area Size, Sq. km (mi)
Current Study	19.6 (7.6)	24.8 (9.6)	110 (42.4)
Morrison and Swanson (1987)	14.7 (5.7)	22.8 (8.8)	39 (15.1)
Hemstrom and Franklin (1982)	1.3 (0.5)	1.3 (0.5)	770 (297.2)
Tande (1979)	8.1 (3.1)	9.6 (3.7)	432 (166.8)
Kilgore and Taylor (1979)	12.1 (4.7)	36.6 (14.1)	18 (7.0)
Heinselman (1973)	0.8 (0.3)	0.9 (0.4)	3480 (1343)

supporting evidence for the existence of fire years, but are not essential to the latter. Data adjacent to the study area was not used in calculating NFRs and MFRIs.

Regeneration data are used conservatively throughout this study. Stand age structure analysis of two old-growth Douglas-fir sites in the H. J. Andrews Experimental Forest provide evidence of prolonged establishment (125 and 165 years) of Douglas-fir after suspected disturbance events (Franklin and Waring, 1979). The data do not indicate ". . . multiple peaks or waves of establishment--just a gradually increasing number of individuals followed by a broad-crested peak and gradually declining period of establishment," based on origin dates (Franklin and Waring, 1979:73). Franklin and Waring (1979) hypothesize circumstances that could explain this observation in the general case: "Multiple disturbances subsequent to the first one may have wiped out portions of young stands, creating open spaces for establishment of even younger cohorts; reburns of young Douglas-fir stands occur, with survival of individuals and small patches of trees" (Franklin and Waring, 1979:74). Their hypothesis is supported by this study and by personal observation in fire management activities. Although the question has not been specifically addressed in this study, the two stands were subject to underburning, and the addition of scar data presented in the current study could explain some of the subtle variation in rates of establishment. Nonetheless, regeneration dates are not used to date fire events because of the uncertainty regarding the length of establishment following disturbance, although regeneration dates support the definition of fire events. Fire events are dated by fire scars.

The accuracy of scar dates is much greater than of origin dates. In both cases, deviations from actual dates can occur from counting error, from added or missing growth rings, and from inaccurate harvest records of clearcuts. But origin dates have an additional source of error in the estimation of age at stump height. This is probably the greatest source of error, and adds to the unreliability of origin dates in dating fire events. Counting error is likely to be greatest in older dates because of the longer record to count, and because of the closely spaced growth rings often encountered in older individuals. The counting error with stumps is probably similar, but slightly more than the counting error with cores.

Cores were analyzed in a laboratory with a stereoscope, but growth rings may be very narrow. On stumps, while analyzed under less than ideal conditions, narrow growth rings can often be avoided by choosing a different radius to count. Several stumps of 480-year-old trees that were analyzed in the field were also cored wit an increment borer, and the counted ages varied by no mc than three years.

The record of fire becomes less distinct over time. Individual trees and portions of stands may survive a given fire event, but as more fires occur, fewer individuals persist and the remaining stands are reduced in size. While the record of earlier fires declines due to loss of information, the pattern of fire events, in a mosaic of overlapping burns, becomes increasingly complex. Individual fire events may have become indiscernible. Records of the oldest "fire events" become less definitive, and it is quite probable that a series of events over a period of time have been incorporated into single fire episodes. The summation of multiple events into a single event will result in overestimation of the actual area burned for that particular fire, but not for the sequence of fires. If several fires burned in close proximity in a short period of years, it is quite likely that reburns occurred at sets of sites or even large areas. The total acreage is underestimated in this case, and calculated natural fire rotation periods are longer than actual natural fire rotations. The summation of multiple events, e.g. reburns, into single events also causes the total number of fires at sites to be reduced, resulting in lower than actual mean fire return intervals.

Fires of very low intensity will not scar trees, or may scar a lower percentage of trees, or scar trees in only a small area. Many fires may not have been intense enough to be recorded in tree rings as fire scars, and others will simply be overlooked entirely. Hopefully, those fires that are overlooked are distributed evenly over the landscape. The lighter intensity fires, those without recorded fire scars, are probably not randomly distributed, but instead may be somewhat correlated to areas with lighter surface fuels, which were not sampled in this study. A fuel loading inventory is expected to be of limited value because current conditions would probably not reflect fuel loadings under "natural," or pre-fire suppression, fire regimes.

The Human Role

The impacts of humans on the fire history of the study area are not entirely clear. The only distinct human influence is the effect of fire suppression on the extent of fire, as measured by natural fire rotation. This measure of fire frequency increased in length by one order of magnitude following the advent of fire suppression (compared to the NFR of previous period). Because small fires were overlooked due to the sampling density and the mapping criteria, and because the earliest large fires probably represent more than one fire, the number of fires, of all sizes, in the pre-suppression period (pre-1910) cannot be determined. Therefore one cannot infer that the number of fires has also declined. However, the natural fire rotation has declined, indicating only that less area has burned in the current period of time (1910-1986) than in any preceding period evaluated.

The natural fire rotation of the pre-fire-suppression Anglo period (1851-1909) is the same, or a little longer, than a period of equal length (1772-1830) in the pre-Anglo period (pre-1830). The transition period (1831-1850) has the shortest natural fire rotation. Whether or not this is due to human influence cannot be ascertained. This period is very short, therefore particularly subject to climatic anomalies and chance variation.

A Brief Historical Chronology

Exploration and settlement of the Pacific Northwest extended over quite a long period of time. The Spanish may have sailed along the Oregon coast as early as 1542, but the first documented explorations of the Pacific Northwest by Anglos occurred in 1774 and 1775 (Velasco, 1985:16). From 1785 to 1820 more than 440 expeditions ventured into parts of the Northwest. A group of trappers from the Pacific Fur Company (Astoria, Oregon), led by Donald MacKenzie, traveled through the Willamette Valley in 1812, and named the McKenzie River (numerous citations in Williams, 1985; Velasco, 1985:17). At least three other expeditions travelled through the upper Willamette Valley during the mid-1810s (Williams, 1985). The first expedition into the McKenzie Valley may have taken place in 1834 (Williams, 1985). Diseases, such as smallpox and measles, were spread by the trappers and led to widespread epidemics as early as 1782, on the Oregon coast, and throughout the Willamette Valley by the early-1830s. By the 1830s between 75 and 90 percent of the population of western Oregon had succumbed to these epidemics (Velasco, 1985:18).

The Anglo settlement of the southern Willamette Valley began in the mid-1840s. Large numbers of cattle were brought into the Willamette Valley from California in 1837 (Williams, 1985), and later, in 1845, a number of sheep and cattle were brought into the valley (Oliphant, 1948). The first large scale migration of settlers into the Willamette Valley arrived in 1842 (Williams, 1985). A thorough search of government reports by Burke (1979) yielded records of substantial Anglo settlement in the McKenzie, Calapooyia, and South Santiam river valleys by the mid-1850s. Remaining aboriginal groups were moved to reservations from the early to the mid-1850s. (Williams, 1985; Velasco, 1985). In 1860, the McKenzie Valley became a travel route for trading cattle and supplies from the Willamette Valley to eastern Oregon and Idaho (Burke, 1979). Then in 1863, gold was discovered near Blue River (Velasco, 1985:71), but was not extracted in quantity until the late-1880s (Burke, 1979).

The Forest Reserve Act of 1891 lead the way for establishment of the Cascade Forest Reserve in 1893, parts of which later became the Cascade and the Santiam National Forests, and then later combined to form the Willamette National Forest in 1933 (MacDaniels, 1941). Early use of the Forest Reserve was limited mostly to berry picking and sheep grazing (Colville, 1898). While the forest rangers of the General Land Office were assigned to extinguish all fires in the Forest Reserves, they were given no training and were expected to provide even their own tools (Pyne, 1982). Fire control efforts became effective only after the 1910 fires in the northern Rocky Mountains, which burned over 2 million hectares (5 million acres) and left 85 persons dead (Pyne, 1982, 234, & 239-259). Advocates of fire suppression were then able to pass new forest and fire codes, to promote fire prevention and cooperative fire suppression legislation, and to secure appropriations for these efforts.

Aboriginal Land Use

At the time of Anglo contact the inhabitants of the study area were apparently of the Molala band (Beckham, 1976; Cox, archeologist, Willamette National Forest, personal communication). Little ethnographic information is known about the Molala, but archeological findings and resource availability suggest that they were at least similar to the Kalapuya of the Willamette Valley (Baxter, 1986). Population densities in the study area were relatively low (compared to the Willamette Valley) and probably decreased further due to the epidemics that decimated aboriginal groups in western Oregon by the mid-1830s. This decrease, combined with the pressures of an increasing Anglo population in the Willamette Valley may have resulted in a limited influx of Kalapuya into the study area in the 1840s. Archeological data suggest that small groups of Molala gathered nuts, berries, bulbs, roots, grass seed, and small game during most of the year, and congregated in moderately large groups during the large game hunts (of deer and elk) in the late fall (Baxter, 1986). Upland sites were not occupied for extended periods of time, but rather activities were carried out from year-round base camps on the McKenzie River and perhaps from lower reaches of the major tributaries (Cox, personal communication). Summer base camps in the study area may been established near the confluences of major streams, such as Lookout Creek and Blue River, Tidbits Creek and Blue River, and Deer Creek and McKenzie River. Resources in upland areas were used seasonally.

Aboriginal Use of Fire

Fire was widely used by the Kalapuya in the Willamette Valley, and probably used by the Molala in the study area as well. Vegetation analysis of the upper Middle Fork of the Willamette River (near Oakridge) indicates that the Molala there used fire as a management tool to maintain vegetation diversity and to maintain prairie and oak woodland ecosystems (Winkler, 1984). In the Willamette Valley, evidence for the use of fire is documented extensively (Morris, 1934; Habeck, 1961; Johannessen et al., 1971; Boyd, 1977), and widely supported by ecologists (Franklin and Dyrness, 1973). Frequent, large-scale burning was continued until Anglo settlement in the mid-1840s. Burning was accomplished from early August to late September according to journal accounts cited in Johannessen et al. (1971) and was used primarily for driving large game in annual hunts. Fire was also used extensively to maintain prairie ecosystems, to stimulate the growth of grasses, berry, and root crops, for protection against attack, and for protection against unwanted fire (Boyd, 1977).

The study area does not contain prairie ecosystems analogous to those of the Willamette Valley or the upper Middle Fork of the Willamette River. However, fire was evidently used to drive game just south of the study area along the McKenzie River. A descendant of Peter Runey, who bought Foley Hot Springs in 1882, stated that his grandfather could remember the valley bottom between what are now the towns of Blue River and McKenzie Bridge being burned "every few years" (Interview of William Runey, 1984). This could account for some of the fires that burned into the southern portion of the study area (Lookout Ridge). These fires may have been set in late-summer, coinciding with the game drives in the Willamette Valley. The open meadows in the vicinity of McKenzie Bridge were homesteaded by ranchers and stock raisers (Plummer, 1903). Secondary sources have reported the use of fire by Molala in the South Santiam watershed, the large drainage basin to the north of the study area:

> Repeatedly I [Surdam] have been told that the Indians used to burn off various sections from time to time. Early settlers all say, "Why you could see back here for a mile of two"...And again they would point out that one could see all over this or that hill. The reason for this burning...[was] to create grass land [sic] for the game and to keep down big forest fires. The territory would not be burned over every year but from two to three year intervals. All brush was kept down in this manner so one could see for a half-mile under the trees, however most places burned were also devoid of tree life (Surdam and Anderson, 1939:3b).

The same source reports that Indians from the Warm Springs Indian Reservation hunted, fished and picked berries in the headwaters of Cook, Quentin, and Deer Creeks annually (Surdam and Anderson, 1939:3b-3d). A site on Indian Ridge, 16 kilometers (10 miles) south of the study area, was also used for hunting and huckleberry picking by Indians from the Warm Springs Indian Reservation until the late-1920s (Henn, 1975). The archeological record at this site indicates that it was used seasonally for the same purposes in pre-Anglo times.

Meadows and berry fields in the study area were probably burned periodically as well. If the meadows were burned, they were probably fired in the spring or summer, when game is more abundant in the higher elevations. But there are no archeological, ethnographic, or ecological data to support a hypothesis of aboriginal burning of the meadows in the study area over a hypothesis of the natural existence of meadows (initiated and maintained by lightning ignitions). Archeological evidence indicates only that these meadows were hunted (Minor and Pecor, 1977; Cox, archeologist, Willamette National Forest, personal communication). Aboriginal use of huckleberry fields is established. Although fire is required to promote huckleberry, burning at higher elevations without woody fuels is difficult to accomplish, except during extreme fire weather (Minore et al., 1979). The burning of these fields by aboriginals was probably not limited solely to the fields themselves, and would help explain the high mean fire return interval of ridgetop sites.

The fire of 1849 may be ascribed to aboriginal burning with some degree of confidence. Anglo settlers occupied the Willamette Valley, but very few, if any, homesteads were located in the Cascade valleys of the Willamette National Forest at that time (Minor and Pecor, 1977). Morris (1934:318) cites from the Oregon Spectator (4 October 1849) that fires in the Cascades were very widespread at that date. Lightning ignitions cannot be entirely ruled out. But evidence of widespread fire in the Coast Range, where lightning fires are very uncommon, supports the human ignition hypothesis. Morris (1934: 318-322) provides evidence, including his own field notes, that indicate one or more fires burned more than 200,000 hectares (500,000 acres) of forest between the Siletz and Siuslaw Rivers in 1849. Oregon State records attribute 325,000 hectares (800,000 acres) to the fire or set of fires in the same drainages (Oregon State Forestry Department, 1977:3). Alternate hypothesis may be conceived, but the simplest is that fire ignited by aboriginals was much more extensive than usual that year, in both the Cascades and Coast Range, because it was an extreme drought year (the fourth driest on record, between 1600 and 1981, and the tenth consecutive drought year (Graumlich, 1985:182)).

Diversity of habitats would produce a diversity of resources for aboriginal use. A range of age classes between stands and within stands would help maintain diversity. From an aboriginal foragers' perspective, extensive stands of old growth could "become virtual resource deserts" (Uebelacker, 1986). Natural fires may have produced sufficient diversity, but could have required supplementation with human caused fire.

It may be argued that the role of aboriginals in the fire history of Pacific Coast Douglas-fir forests will never be determined. But additional archeological information will allow an evaluation of which areas were more heavily used, and during what time of year. Given a large sample size of fire scars, the mean fire return intervals of areas heavily utilized may be compared (on a paired basis, accounting for other variables influencing fire history), with areas that were more remote and less used (Barrett, 1981; Barrett and Arno, 1982). Furthermore, detailed analysis of fire scars can determine the season of burning.

In the Northern Rocky Mountains, aboriginal burning was practiced both in the spring and in the fall, but not in the summer (Barrett, 1981). In the study area, since lightning fires occur in the summer and fall, spring fire scars would likely be due to aboriginal burning.

Displacement of Kalapuya from the Willamette Valley into the study area could have decreased the natural fire rotation during the transition period, if they practiced burning to a greater extent than the Molala. The data support such a hypothesis, but the time period in question, 1831 to 1850, is much too short to draw any conclusions. Many alternate hypotheses could also explain the decrease in NFR, and the issue is raised here as a question rather than fact. It is even possible that aboriginal population levels decreased in the study area during this period of time.

Source of Ignition: Human or Natural?

In some ecosystems the question of ignition source with respect to fire history becomes almost irrelevant. Fires in chaparral ecosystems in Southern California are stand-replacement fires, with only slight variations in severity, so that their source is ecologically unimportant (Minnich, personal communication). It has been argued that ignition source makes no difference to the vegetation (Van Wagner, 1985). In Douglas-fir forests, however, burning intensity, represented by flame length and heat per unit area, varies by several orders of magnitude (Rothermel, 1983; Rothermel and Deeming, 1980).

Burning intensity varies from smoldering to "running" and "crowning," and fire severity correspondingly ranges from partial duff removal to entire stand replacement. In this context, source and timing of ignition can become important.

While lightning fires can occur as early as May, they are most common from mid July to mid September. Large fires could result from fires in any period of drought in the summer, but those burning by the end of the summer had the greatest chance of having their intensity increased by east-wind weather conditions. Aboriginal fires set in the spring or early summer, would have burned at much lower intensities than those set in the late summer or early fall. Fires set early in the year could be extinguished by rainfall before the typical summer drought. Those set in the late summer or fall would have occurred during the period of the year with the potential for the most extreme fire weather conditions. Since it has been established that people underburned the lowland prairies in the latter period, they may have burned the uplands during the early period. Frequent, low intensity burning at middle to high elevations could reduce the fuel loading substantially, so that the resource areas were significantly "fire-proofed" from potentially damaging natural fires (Barrett, 1981).

By manipulating fuel conditions during a period of the year more conducive to "controlled burning," similar to modern fire management practices, aboriginals could affect their environment significantly. In this context, the source of origin of fire, largely because of season of origin, does become important ecologically (Lewis, 1985). Furthermore, aboriginals may have increased the frequency of burning above the level attainable by natural origins alone. Frequent underburning, as commonly practiced in modern pine forest management in the southern and western United States, greatly reduces fuel loading, which results in substantially lower fire intensity and severity (Wright and Bailey, 1982). Frequent fires of low intensity will not scar Douglas-fir trees, and therefore will not even appear in the raw data of fire history investigations of this nature.

While the density of lightning strikes may seem sufficiently high to provide the calculated mean fire return intervals, many lightning strikes will not produce fires greater than 0.1 hectare (0.25 acre) in size, even without fire suppression. Aboriginals, by controlling the time of ignition and by the use of multiple ignition points, could promote the spread of fire better than chance alone. The supplementation of lightning fire occurrences by aboriginal fires is supported by data from montane forests in California (Lewis, 1973).

Pre-Suppression Land Use and Fire

The two most extensive land uses during the pre-suppression Anglo period (1851-1909), transportation and sheep grazing, both promoted fire to achieve their objectives economically. Burke (1979) has documented the effects of roadbuilding and transportation, especially the route across Santiam Pass, north of the study area. Old growth timber was commonly removed by burning (Colville, 1898). There are no reports of burning in building the route across McKenzie Pass, to the south of the study area, perhaps because the route was largely already an open landscape by aboriginal burning and by lava flows.

Burke (1979) has also documented the burning associated with sheep grazing, which was most extensive from the 1880s to the 1920s. Sheepherders are thought to have assumed the role of aboriginals in maintaining montane meadows (Vankat, 1977; Vale, 1981). Data compiled by Burke (1979:84) show that the Lookout Mountain allotment, which was comprised of about the southern three-quarters of the study area, had an average of 1500 sheep per year from 1912 to 1922. The Wolf Mountain-Big Marsh allotment, comprising the northern one-quarter of the study area and some adjacent land, had an average of 1123 sheep per year for the period of 1915 to 1925. Burke further reports that sheep grazing was of sufficient concern to warrant a special investigation by Frederick Colville during the late 1890s. Colville (1898) reported that sheep herders had burned extensive areas within the Cascade Forest Reserve, and that many areas were burned repeatedly. Data for the entire Willamette National Forest indicate that in 1901, there were about 5 times more sheep grazing on the forest than from the mid-1910s to the mid-1920s (Minor and Pecor, 1977:24). Whether there was a correspondingly larger number within the study area cannot be determined.

Prospectors were considered to be another source of fire during this time period (Burke, 1979). But in this case, fire was due mostly due to neglect of campfires and carelessness. By 1900, recreation had also increased and significantly increased the number of fires, which were also considered due mainly to carelessness. The 1902 fires probably resulted from unattended campfires or escaped slash burning. Morris (1934) reports that in September of 1902, more than 80 campfires and land-clearing fires in the Cascades spread into intense brush and timber fires due to extremely severe east wind conditions (Morris, 1934:332-337).

Summary of Human Impact on Fire History

The full impact of humans on fire history will be very difficult, but not impossible, to discern. Aboriginals probably increased the frequency of fire above some baseline natural level. The increase may have been significant at high elevations because of periodic burning of berry fields and meadows. An even more significant increase in fire frequency could be expected for lower elevation areas just south of the study area, in the McKenzie River valley, where lightning frequencies are lower and occupance was year around. Some of these fires probably burned over Lookout Ridge into the study area as they have in the historic period (Burke, 1979: Maps).

The natural fire rotation of the pre-fire-suppression Anglo period was slightly longer, but surprisingly similar to the pre-Anglo period. The similarity is due, in large part, to the 1893 fire, one of the larger fires in the study area during the entire period of record. The fire is also reported by Morrison and Swanson (1987) for both Cook-Quentin Creek and Deer Creek. It may not be coincidental that the Cascade Forest Reserve was established in the same year, and it is worthy to note that the sheep herders fought its establishment vehemently (Burke, 1979). Sheep grazing was (temporarily) prohibited within the Forest Reserve the following year (Minor and Pecor, 1977). The natural fire rotation apparently decreased during and after Anglo settlement, further suggesting an aboriginal role in the fire history of earlier periods.

Only fires of sufficient intensity to scar Douglas-fir trees or cause the mortality of groups or stands of trees are reflected in the data collected in this study. Periodic fires in montane meadows south of the study area are thought to have burned at such low intensity that the use of fire scars to document fire occurrence "...would likely underestimate the frequency of burns within the meadows" (Vale, 1981:63). Fires of lower intensity, which are expected with frequent underburning, almost certainly occurred in the study area during the pre-Anglo period, although no evidence for their occurrence is presented.

Climatic Influences

Climate obviously impacts the fire history of the study area for several reasons. Vegetation develops and fuels accumulate in response to long term climatic conditions, prevailing for decades, and in the case of Douglas-fir and Western Hemlock forests, centuries.

Drought over a period of years affect understory characteristics, seasonal droughts affect the moisture content of the largest fuels (snags and downed logs) as well as needle moisture content on live trees, while short term droughts, with durations of weeks or even days, affect the moisture contents of the medium and fine fuels, upon which the spread of fire ultimately dependents (Burgan, 1979; Pyne, 1984; Rothermel, 1983). Weather, in contrast to climate, is a significant factor in controlling fire behavior, and can also provide a source of fire ignition, lightning. The average frequency of lightning storms per year may be considered a climatic factor. The number of thunderstorm days averages about 5 per year in Eugene, and perhaps 10 per year in the study area (U.S. National Weather Service, 1986).

Lightning Fires

Lightning accounted for 46 percent of all fires reported in the Willamette National Forest (WNF) from 1945 to 1983 (data from fire reports on file at the Willamette National Forest Supervisor Office). The data show considerable variation of lightning fires from year to year, ranging from zero to 316. The study area had 59 reported lightning fires from 1910 to 1984 (Burke, 1979:Appendix B; data on file at WNF Supervisor Office). Two additional unreported, rainfall extinguished lightning fires, one 40 square meters (400 square feet) in size, the other 0.2 hectare (one-half acre) in size, were observed during the 1983 field season on Lookout Ridge. Probably many or most of the 61 suppressed lightning fires over the 75-year period also would have been extinguished by natural means before they reached significant size. Of these 61 fires, 6 ranged from 0.1 to 4 hectares (0.25 to 10 acres) in size, and only one exceeded 4 hectares (10 acres). Undoubtedly, many more lightning fires were not observed or reported.

The lightning fires are distributed mainly from the middle to the upper elevations; however fires were not recorded on any ridges, except for Lookout Ridge, which received 13 fires, a very high number. Parsons (1981:115) also reported the highest lightning fire density from the middle to the upper elevations, but not the highest elevations, and attributes the decrease in density of lightning fires at higher elevations to reduced fuel loading.

The number of lightning fires in the study area may be sufficient to produce the derived fire frequencies. Extrapolation of the historical lightning fire frequency over the entire period of record would result in about 450 lightning fires, as a crude estimate (due to extreme yearly variation). Hypothetically, this figure could have produced the 35 fires documented in this study.

Climate Record

The long term climate of the study area is best summarized by Graumlich (1985). Tree growth indices of Douglas-fir was obtained from Lookout Creek and extends to 1599 (Figure 9). Comparison of fire years to Graumich's growth indices shows that 13 of the 17 fires from 1599 to 1850 occurred during periods of below normal growth. However, for the period from 1851 to 1909, 6 of the 7 fires occurred during periods of above normal growth. From 1910 to 1952, the fires once again occurred during below normal growth, and by implication, during periods of drought.

The largest fires documented in this study, whether natural or human set, occurred mainly during periods of drought between 1600 to 1850. This was anticipated. Fires during the pre-suppression Anglo period (1851-1909), however, occurred almost exclusively during wetter than normal periods. This is entirely unexpected. Moderate length periods of drought obviously enhance the likelihood of larger fires, but are apparently not necessary, at least not with abundant sources of ignition. With fire suppression, drought again becomes prerequisite to large fires.

The growth indices of the two studies were evaluated to determine if climate could explain the decrease in length of the natural fire rotation for the period 1831-1850. The first half of this period was wetter than

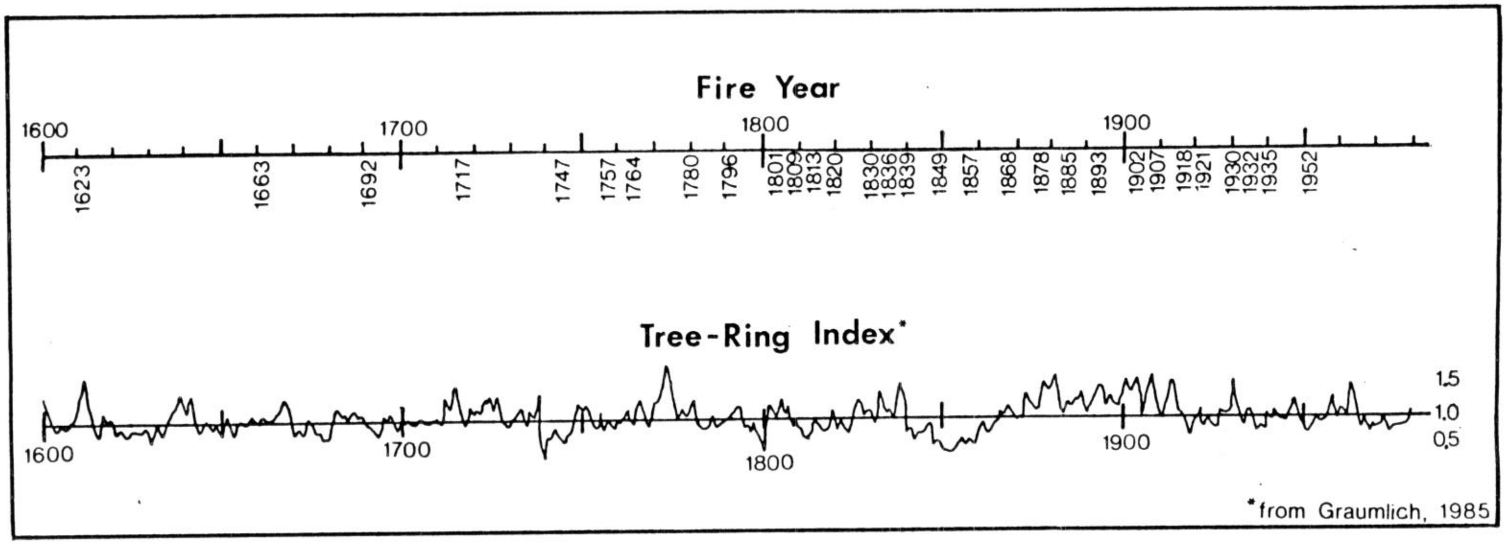


Figure 9. Climate History and Fire Years.

normal, and the second half was drier. The two fires that occurred during the wetter period together burned more than the one fire during the drier period. There is no conclusive evidence that climate caused the natural fire rotation period to be shorter than the other periods. My preferred explanation is that the period of record is too short, and that the anomalous NFR is due to chance or random variation of the very small number of fires represented by this period of time.

Most drought years reported in Graumlich (1985) do not have corresponding fire years in the data set presented here. Some fires were undoubtedly too small to be sampled, and records of others that were sampled at only a few sites were probably discarded due to the fire year determination and mapping criteria. But drought must be combined with ignition sources. Summer lightning storms in the study area often occur during wet years or are followed by moderate to heavy rainfall during dry years. The probability of ignition is greatly reduced in either case. Drought years without large fires, or large numbers of small fires, are also common during the historical period.

Fire History Patterns

Comparison with Other Fire History Studies

Individual Fire Years

Individual fire years are in correspond to those reported from surrounding areas. The fire years and episodes were documented and mapped independently from other studies, but are similar (Table 23). Morrison and Swanson (1987) sampled two areas adjacent to the study area employing similar methods and identified fires in many of the years. Stewart (1984) studied several small stands, 0.19 to 0.80 hectares (0.5 to 2.0 acres), about 21 kilometers (13 miles) northwest of HJA, and at somewhat higher average elevation (1,000-1,300 meter [3,300-4,300 feet]) and found some of the fire events reported here. Klopsch (1986) sampled Mount Hagan Research Natural Area, about 21 kilometers (13 miles) west of HJA, and Franklin and Hemstrom (1981) obtained their data from Bagby Research Natural Area, about 65 kilometers (40 miles) north of HJA.

Indices of Fire Frequency

The natural fire rotation interval derived in this study is similar to the natural fire rotation obtained by Morrison and Swanson (1987) for their Cook-Quentin study, but varies from the NFR of their Deer Creek study area. Composite and stand-replacement or partial stand-

Table 23. Comparison of Fire Years to Studies in Surrounding Areas in the Western Cascades.

Fire Year Reported This Study	Previously Reported Fire Year or Episode					Fire Year Reported This Study
	Morrison and Swanson (1987)	Stewart (1986)	Klopsch (1986)	Franklin and Hemstrom (1981)	Yamaguchi (1986)	
1907						1907
1902		1897				1902
1893	1893	1893	1895			1893
1885						1885
1878	1878	1877				1878
1868		1874			1868	1868
	1864					
1857	1855	1862	1855			1857
1849	1849/50					1849
1839	1840/41	1838				1839
1836	1834					1836
1830	1829					1830
1820		1823				1820
1813	1813					1813
1809	1807	1809-14			1809/10	1809
1801	1800	1803			1805/06	1801
1796	1796					1796
1780					1784	1780
	1769/72	1770				
1764					1766	1764
1757	1758					1757
1747		1732			1738/51	1747
1717				1717		1717
	1703					
1692	1689					1692
1663	1658	1662			1662	1663
1623					1622/25	1623
1591	1575				1595	1591
1566	1566				1562/73/78	1566
1551	1552	1543			1545	1551
1532	1532	1527			1528	1532
	1515					
1482	1475					1482
1435	1436	1427			1415	1435

note: "/" indicates multiple dates, at one site or more sites, while "-" indicates a range of possible dates.

replacement MFRIs determined for individual physiographic units of the study area fall within the range found by Morrison and Swanson for their two study areas.

The MFRI for the entire study area, 114 years, is longer than that reported for Japser National Park, Alberta, Canada, where MFRIs varied from 18 years for Douglas-fir forests to 74 years for subalpine forests (Tande, 1979). Differences in vegetation types and climate may account for much of the difference between the studies, but the methods used in this study contribute to a longer MFRI. The MFRIs derived by Tande (1979) refer to the intervals between fires occurring anywhere within the specific forest type, therefore will be higher by definition. The MFRI values described in this study, however, refer to the average intervals between fires at individual sites. The MFRI for the study area, for instance, was obtained by averaging the MFRI values obtained for each individual site.

When MFRI values are derived for areas, the value of the MFRI is dependent on the size of the area in question. The larger the area, the greater the chance that a fire occurred somewhere in that particular area. For this reason, MFRIs in this study were obtained for individual sites, that is, the MFRIs are site specific, and are not linked to the size of the area in question.

In forests more similar to those of the study area, Hemstrom and Franklin (1982:42) found NFRs of 465 years for their pre-Anglo era (1200-1850), 226 years for their early settlement era (1850-1900), and 2583 years since fire suppression (1900-1978). Hemstrom and Franklin (1982) note that in regions with infrequent, large fires, NFRs for relatively short time spans are not very meaningful. They further explained that none of the fire-frequency indices that they tested adequately described the fire regime of the forests of Mount Rainier National Park: all indices yield estimates that are too simplistic and are of limited use.

Some of the difference in NFR between the study area and Mount Rainier National Park may be explained by latitude alone. Decreased precipitation, increased solar radiation, longer drought periods, and more frequent lightning may all contribute to lower NFRs at more southerly latitudes. The data presented here supercede Franklin and Hemstrom (1981), who state, "The pattern of infrequent catastrophic, as opposed to frequent, light, burns is quite consistent . . ." in "limited data from elsewhere in the region . . ." (p. 217).

Stewart (1984, 1986) in an area 21 kilometers (13 miles) northwest of HJA, describes a different fire regime than Hemstrom and Franklin (1982). Stewart (1986) observes that fires occurred more frequently and were less destructive than had previously been characterized. In his earlier report, Stewart (1984) listed numerous fire dates that strongly coincide with the data introduced here (Table 23).

Reconciliation of Differences

It is quite likely that some of the fires in the study area were parts of much larger fires or fire episodes. These fires may have been so intense that very few, scattered trees survived as seed sources for regeneration following fire. Apparently, such an hypothesis might fit exceptional cases. Franklin and Hemstrom (1981) speculate that both multiple disturbances and lack of seed source are principal factors in delaying reestablishment after fire.

Observations of fires in the study area strengthen arguments for recurrent reburns, as reported by Klopsch (1985). The origin dates, and more importantly, the scar dates, indicate that numerous fires of low intensity (or at least parts of them were of low intensity) burned in many parts of the study area over the period of record. Tree origin data alone provide a weak record of reburn history, but when combined with scar dates, stronger interpretations can be made. Undoubtedly the number of these low intensity fires is underestimated, and if greater accuracy were employed in collecting scar dates, additional fire years could be documented and mapped. Repeated burning, much at low intensity, probably cause a significant amount of dispersion in stand age-classes.

Yamaguchi (1986) also reports multiple fires in the southern, western Cascades of Washington. Fire was most frequent during a 150 year period of initial stand development (1 fire per 40-50 years) and then decreased dramatically (1 fire per 125-150 years) (Yamaguchi, 1986:45-48). The fires were of sufficient intensity to cause scarring on Douglas-fir, but apparently did not cause new pulses of regeneration. Two to four fires were reported for each site during its first 150 years, comparable to the frequencies reported here. Yamaguchi (1986) notes that the fire frequency figures should be viewed as conservative, because not all fires were intense enough to cause scarring.

Other causes of wide ranging age-class structures are numerous, but are probably of lesser importance. High soil erosion rates from burned hillslopes is indisputable, and would likely increase substantially with the number of reburns and maintain open, poorly-stocked areas. Short-term climatic change is another possible cause. The same drought that allowed large, extensive fires may have inhibited the establishment of early seral tree species. Shrub and hardwood species may have been more tolerant to those climatic conditions, and may have provided competition to the conifer pioneers. Repeated burning favors grass and brush ecosystems even with constant climate. While these hypothesized causes may all be valid, and it is likely that they would have occurred in combination with one another, no convincing evidence for their widespread effect on delaying or prolonging reestablishment after fire has been presented to date.

The fire record presented here is conservative, and further evaluation of existing data may identify more numerous fires. While distinction was made between underburning and stand-replacing fires, further analysis should make clearer distinctions between intensities of fires. Data gathering and analysis both need to take into account the possibility of higher frequencies of underburning than reported here. Dendrochronological methods utilized by Yamaguchi (1986) could be applied here for greater precision in dating scars. Higher accuracy of scar dates would allow more fire years to be documented than presented in this study. Fires in the central western Cascades may be expected to be smaller, though more numerous than reported in this and previous studies on fire history, so that the total area burned over the period of record would likely increase above the documented levels. Hence, mean fire return intervals and natural fire rotations should be reduced below the indicated figures at most locations.

Proposed Fire Regimes

Description of a single fire regime for the entire study area would probably be too simplistic, unless the definition were very broad. The MFRI for the County Creek, McRae Creek, and Cook-Quentin physiographic units is about one-half of the MFRI of the Deer Creek unit. The MFRIs for elevation-classes vary by more than two-fold, and those of different aspects by almost that amount. The variation in fire frequency between locations on the landscape was significant prior to fire suppression.

The mean fire return intervals do not conform to the established classifications of fire regimes. Heinselman described seven types of fire regimes:

0. No (or very little) natural fire.
1. Infrequent, light surface fires (more than 25-year return intervals).
2. Frequent, light surface fires (1- to 25-year return intervals).
3. Infrequent, severe, surface fires (more than 25-year return intervals).
4. Short return interval, crown fires (25- to 100-year return intervals).
5. Long return interval, crown fires (100- to 300-year return intervals).
6. Very long return interval, crown fires (over 300-year return intervals) (1978:250-251).

Using these criteria, the fire regimes for the study area, including the two physiographic units of Morrison and Swanson (1987), generally consist of long return interval, crown fires, and some short return interval, crown fires. These are supplemented by either or both infrequent, light surface fires, and infrequent, severe, surface fires.

Kilgore (1981) presents a classification that is based on Heinselman (1978) and is very similar. The major difference is that the long return interval, crown fire category is modified to "variable regime: frequent, low-intensity surface fires and long return interval, stand-replacement fires (100- to 300-year intervals)" (Kilgore, 1981:60). Kilgore (1981:73) places Douglas-fir forests of the Pacific Northwest into this category.

Comparisons of MFRIs have been made among aspects, elevations, and physiographic units. Further distinctions between fire regimes may be made by analysis of MFRI by aspect and elevation within each of the physiographic units rather than for the entire study area (Table 24). While the trends in MFRI of the physiographic units by aspect and elevation are similar to the patterns described for the study area as a whole, some major differences should be noted. Mean fire return intervals of stand-replacing fire is compared by physiographic unit:

1. <u>Blue River</u>. Mean fire return interval is slightly shorter for west aspects compared to northwest aspects. Other aspects have sample sizes that are too small for comparison. Low to mid-elevation sites have the lowest MFRIs. The highest elevations of the unit appear to have longer MFRIs. The unit is characterized by long, unbroken slopes, with little variation in aspect. Since

Table 24. Comparison of MFRI of Stand-Replacing Fires by Aspect and Elevation within Physiographic Units.

	Physiographic Unit					
	Blue River	County Creek	North Lookout	South Lookout	Deer Creek	Cook-Quentin
	Mean Fire Return Interval, Stand-Replacing Fires (Number of Sites)					
Average	189 (72)	132 (79)	145 (117)	223 (61)	276 (63)	150 (57)
ASPECT						
North	201 (8)	107 (9)	143 (4)	262 (16)	342 (3)	218 (1)
Northeast	0 (0)	140 (18)	96 (2)	236 (6)	319 (6)	88 (2)
East	0 (0)	149 (24)	187 (3)	158 (4)	299 (10)	149 (5)
Southeast	0 (0)	122 (12)	175 (14)	0 (0)	168 (3)	183 (13)
South	89 (1)	84 (2)	128 (26)	0 (0)	236 (13)	181 (7)
Southwest	99 (2)	71 (1)	173 (27)	80 (1)	261 (10)	106 (8)
West	175 (23)	0 (0)	138 (15)	428 (2)	298 (8)	250 (5)
Northwest	188 (29)	0 (0)	250 (4)	227 (15)	179 (1)	107 (3)
Ridgetop	209 (6)	104 (6)	91 (19)	112 (11)	274 (4)	105 (12)
Valley Bottom	357 (3)	151 (7)	143 (3)	294 (6)	316 (5)	111 (1)
ELEVATION						
< 762 (< 2,500)	198 (20)	167 (4)	202 (14)	248 (12)	0 (0)	119 (12)
762- 914 (2,500-2,999)	148 (28)	122 (9)	127 (18)	301 (14)	0 (0)	171 (21)
915-1,066 (3,000-3,499)	238 (15)	149 (24)	156 (22)	267 (9)	311 (8)	126 (21)
1,067-1,219 (3,500-3,999)	223 (9)	120 (22)	168 (24)	243 (10)	301 (24)	302 (3)
1,220-1,371 (4,000-4,499)	0 (0)	130 (15)	134 (25)	104 (13)	247 (31)	0 (0)
> 1,371 (> 4,500)	0 (0)	100 (5)	78 (14)	67 (3)	0 (0)	0 (0)

there are no topographic barriers, fire frequency varies only by elevation. The north-end of the unit is extremely susceptible to east winds, which are channeled through a low pass north of Carpenter Mountain. East winds play a minor role at the south-end of the unit, but the entire drainage does experience northeast winds at times.

2. County Creek. This unit has the lowest MFRI for stand-replacing fires of all the units. Southeast aspect has a slightly lower MFRI than east or northeast, which are about equal. Other aspects are more limited in distribution. The entire unit is highly susceptible to east wind conditions, although the valley bottoms are least east-wind prone, and the ridgetops and highest elevations are most east-wind prone. Mean fire return intervals tend to shorten with elevation.

3. North Lookout. This physiographic unit has the most varied topographic characteristics of the six units. All elevation-classes and most aspects are well-represented here. Ridgetops clearly have the shortest MFRI, followed by south aspects. No trend is apparent among the other aspects. The distribution of MFRIs appears to be bi-modal. Apparently, the lowest and the middle elevations have the longest MFRIs, while the "lower" and higher elevations have shorter MFRIs. Human ignitions might have played a role in shaping this distribution: huckleberry fields and meadows cover parts of the higher elevations, while the lower

elevations could have received the most year-round use. The very lowest elevations, the moist riparian zone, probably did not burn as often, despite intensive aboriginal use. Alternative explanations would likely involve the influence of plant habitat types on fire frequency, but were not investigated in this study. Most of the unit is susceptible to east winds, especially the ridges. The valley bottoms are only very slightly influenced by east winds.

4. South Lookout. Few aspects are represented here, the trend follows that of the study area as a whole. Ridegtops burn most frequently, north aspects and valley bottoms the least. Mean fire return intervals tend to shorten with elevation. The unit receives almost no east winds, except for the ridges, which are highly susceptible. Since the unit is oriented to the north and receives little east wind, the MFRI for the unit is relatively long.

5. Deer Creek. South aspect has the shortest MFRI, followed by southwest. The other aspects represented with sufficient sample sizes have a uniformly long MFRIs. The are no low elevations sites within this unit. The MFRI appears to decrease with elevation, but the elevation range is fairly narrow. Slopes in this unit are relatively gentle, so that the effects of aspect and elevation are minimized. This unit is the least east wind prone. It is fairly high elevation overall, but with no high ridges.

6. Cook-Quentin. The terrain of the unit is similar to that of North Lookout. Most aspects are represented, and MFRIs follow the overall trend. One exception is west aspects, which have the longest MFRI of the unit. The lowest and middle elevations have the shortest MFRIs, while the "lower" elevations have a longer interval. The entire unit is susceptible to east winds, but the ridges are especially east-wind prone. Causes of the apparently anomalous distribution of fire frequency in this unit are probably based on its complex topography, its habitat types (related to topography), or patterns of aboriginal use.

Fire regimes are probably related to plant habitat type. Climatic wildfire zones (Furman, 1978) are based on the same environmental variables that have been used to characterize plant habitat types (Zobel et al., 1976): temperature, precipitation, and plant moisture stress. The sample size within the H. J. Andrews Experimental Forest, for which habitat-type mapping is available, is not large enough to differentiate statistically between the MFRIs of the individual habitat types. A classification system simplified by combining plant habitat types is necessary to preform analysis of variance on MFRIs to test if the differences between them is significant.

Variations in fire frequency due to aspect, elevation, exposure to east winds, aboriginal use, and plant habitat type warrant the use of more than one fire regime to describe the fire history of the study area. Further analysis of fire intensity and fire size by documenting a larger number of lower intensity fires and analysis of the interactions between fire and habitat type is necessary to more fully characterize the fire regimes typical of the area.

CHAPTER VII

CONCLUSIONS

While simple conclusions are appealing, single, simplistic interpretations of complex fire histories may be in error. There is no single characteristic fire regime in the study area, instead there may be several. This study provides a basis for reconstructing the fire regimes in the central western Cascades. The study does not exclude fire regimes previously described for the region, rather it includes fire regimes described for other regions. We are cautioned, "There seems to be a tendency to look for one ruling doctrine...In fact there are many causes and many aspects to successional phenomena" (Franklin, 1982:165). The data anaylsis and interpretations presented in this study should serve to expand the awareness of the extent and frequency of fire, and do not diminish the roles of other ecological processes.

Documentation and analysis of fire history in the central western Cascades disclosed several fundamental points:

1. Fire, as a primary agent of disturbance, performed an important role in shaping forest age-class

structure and species composition.

2. Both relatively infrequent catastrophic and more frequent underburning were part of the natural, pre-fire suppression fire regimes.

3. For the entire study area, the mean fire return interval (determined at the site level) of stand-replacing or partial stand-replacing fires is 166 years, and the MFRI of all fires (stand-replacing and underburns) is 114 years.

4. Mean fire return intervals vary considerably between landscape positions defined in terms of aspect, elevation, and exposure to winds. Slopes with south aspects or on ridges, at higher elevations, or exposed to east winds, have the shortest MFRIs. Fire is least frequent at lower elevation, in valley bottoms and streamsides, and where protected from east winds.

5. Natural fire rotation is shortest prior to Anglo-settlement (1772-1830) (78 years), increases in length to 87 years after settlement (1851-1909), then increases dramatically to 587 years with fire suppression (1910-1986).

6. Aboriginal burning supplemented lightning ignitions, but the extent of aboriginal burning and the impact on the fire history of the area was not determined. Presumably, aboriginal burning is ecologically important in some parts of the study area, e.g., huckleberry fields and high elevation meadows.

7. In the absence of logging, the decrease in fire frequency due to fire suppression would greatly influence forest composition and structure, and would also influence fuel loading characteristics.

8. Further distinction between the frequencies of stand-replacing fires and lower intensity fire is necessary. Refined analysis criteria may reveal more frequent underburning than reported here.

APPENDIX A

GLOSSARY OF FIRE HISTORY TERMINOLOGY

Differences in the use of fire history terms complicate comparisons of fire history studies. The necessity of standardization of terminology was recognized by fire history specialists in the late-1970s, and a committee of scientists was formed to strive towards this end at the Fire History Workshop in Tucson, Arizona, in October 1980 (Romme, 1980:135-137). Definitions are included here to provide the reader a clearer understanding of their meaning as used here. Most of the following fire history definitions are the product of this committee, but where no consensus was reached, or where alternate terms and definitions may be used, additional sources are listed. Fire behavior definitions are adapted from National Wildfire Coordinating Group (1981).

<u>Composite Fire Interval</u>. See <u>master fire chronology</u>.

<u>Cross-Dating</u>. Adjusting or correcting the chronology obtained from an individual source (tree or stump) by comparison with other records at the site or area. Repeated correction of individual records allows the

construction of a master fire chronology (see below).

Crown Fire. A fire that spreads between the crowns (canopies) of trees. It is classed as a high intensity fire. A further distinction is made between two types of crown fire. A "dependent" crown fire relies on the heat generated from a surface fire below it, and stops advancing when the intensity of that surface fire is reduced. A "running" crown fire, is independent of a surface fire below it, although it may have begun as a "dependent" crown fire. A running crown fire may partially or totally consume the crowns of trees without consuming the surface fuels below.

Fire Cycle. "...[T]he number of years required to burn an area equal to the whole area of the forest" (or other study area in question) (Van Wagner, 1978:221). This term is equivalent to Natural Fire Rotation (see below).

Fire Free Interval. See fire interval.

Fire Frequency. The number of fires in a specific unit of time in a specific area of question. Traditionally, this term has been used for point samples, and the term fire occurrence has been used for area samples. Romme (1980:136), however, recommends the use of the term "'fire frequency' for areas of all sizes (with the size of the area clearly specified." Fire frequencies for large area can be misleading, because the number refers only to the number of ignitions and not to the various sizes of burns.

Fire Intensity. This term is often interchanged with fire severity (below). In the narrowest sense, fire intensity refers specifically to units of heat output per unit of area, or heat output on a length of flame front (such as a fireline) over a specific length of time. Fire intensity can be measured while a fire is burning, but it is hard to estimate fire intensity retroactively. For this reason, fire history studies often estimate fire intensity by observing the ecological effects of fire, "[t]hus it is appropriate to call a stand-replacing fire a high intensity fire, and to call a fire that produces little mortality a low intensity fire, there being nothing to gain by introducing an additional term like fire severity" (Romme, 1980:137).

Fire Interval. The number of years between consecutive fires within a study area. It is the difference in years between two specific fires, in contrast to the mean fire return interval (see below), which is the arithmetic average number of years between a number of fire events at either one site or a set of sites.

Fire Occurrence. A single fire event in an area of study within a specific period of time. Occurrence is a binomial variable: an event either occurs, or it does not.

Fire Regime. The frequency and intensity of fire that is characteristic of an area (Heinselman, 1978). More than one set of frequencies and intensity classes may apply to a given area, so that an both frequent surface fires and infrequent crown fires could be descriptive of a particular fire regime (Kilgore, 1981).

Fire Resistant Tree. A species with a high probability of surviving a fire. It is protected by some combination of physical adaptations including thick bark, a crown that is high above the ground or not highly flammable, or roots that are not shallow.

Fire Rotation. See Natural Fire Rotation.

Fire Scar. A direct physical (heat) injury to one or more locations on the cambium layer of a tree, which causes an alteration of the pattern of the tree of annual rings (Figure 10). Damage to the cambium and crown may cause mortality, but can cause either growth rate increase or growth rate decrease following fire, depending on the amount of damage, time of year of occurrence, and alteration of the habitat (Fritts, 1976).

Fire Scar Susceptible Tree. Any tree that has already been scarred by fire, and has a wound that is not yet completely enclosed. The wound, especially with resin, increases the vulnerability of that tree to further scarring damage.

Fire Sensitive Tree. A species with a low tolerance to fire. It may be easily damaged or consumed by fire, and has a very low probability of survival.

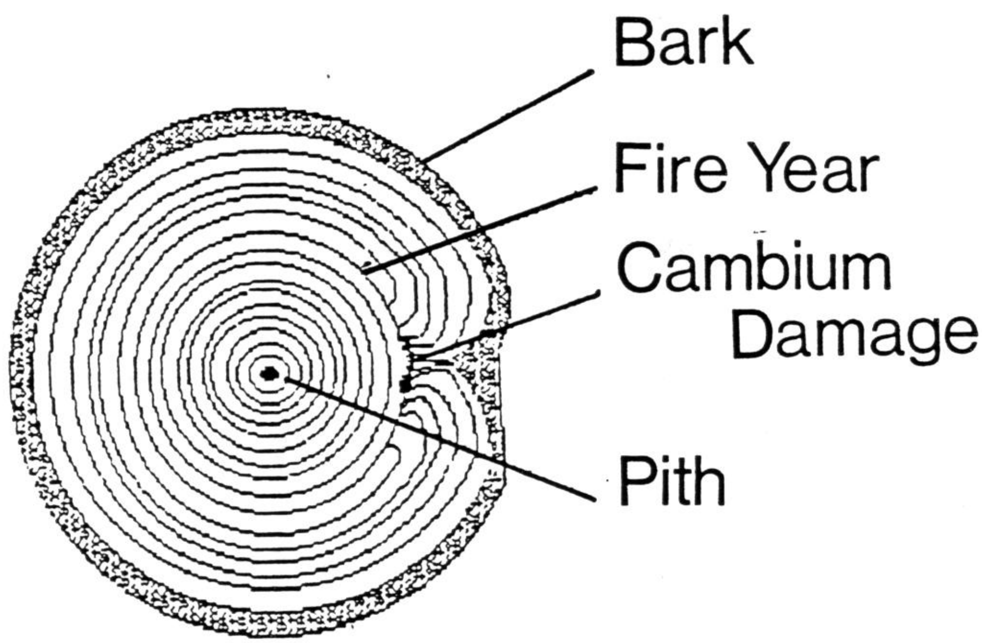


Figure 10. Stylized Example of A Fire Scar.

Fire Severity. The ecological impact of a fire, such as mortality of plant or animal species, changes in species composition, and other ecosystem characteristics. Often used synonymously with fire intensity (see above).

Master Fire Chronology. A chronological listing of documented fires in a study area. Also called a composite fire interval. The dates in a chronology have been adjusted by cross-dating (see above). Romme (1980:137) further defines the term:

> . . . this master fire chronology is compiled from several individual sources (e.g., individual trees, stumps, stands, or written fire records), and is then used to determine fire frequency, mean fire interval, and other fire history parameters; the size of the area must be clearly specified (no units).

Mean Fire Return Interval (MFRI). "Mean fire return interval is the average number of years between consecutive fires. It is defined by the formula:

MFRI = sum (i) (t (i+1) - t (i))/N

where (t (i+1) - t (i)) is the interval between any two consecutive fire years t (i), and N is the number of intervals for an area" (Tande, 1979:1917). Further, the sum (i), is the sum of the differences between individual fire years.

The MFRI is commonly derived by determining the interval length between any two consecutive fires occurring at any two points in the study area (Romme, 1980). One of the problems inherent with this type of calculation is that the interval between fires is dependent on the size of the area in question: the larger the area, the more sample points are included, and the greater the chance that a small fire anywhere in the study area will be included. Arno and Petersen (1983:1) describe this problem:

> Mean fire intervals calculated from a master fire chronology probably tend to be shortened as the study area becomes larger...This reduction of fire intervals with increasingly large sample area would result primarily because many fires burned only small portions of the area...it must be remembered that the data (including mean fire intervals) represent only the occurrences of fire somewhere within the sample area.

Arno and Petersen (1983) also note that the larger the area, the more diversity of habitat types (hence, environments) will be included within a single statistic. A wide range of sizes of study area impedes the comparison of MFRIs from one study with another. Determination of MFRIs from master fire chronologies may prove useful in other fire regimes, e.g., that of ponderosa pine in northern Arizona (Dieterich, 1980), or lodgepole pine in Jasper National Park, Canada (Tande, 1979), but would probably overestimate the fire frequencies of the study area.

At the other extreme, individual trees provide too little significant fire history information. Many trees in this area are not scarred repeatedly, so that no meaningful fire intervals can be derived from them. Instead of single trees, individual sites may provide the best estimate of fire return intervals in a manner similar to the use of small stands by Tande (1979), Arno (1980), Davis (1980), and Morrison and Swanson (1987).

Natural Fire Rotation. Synonymous with fire cycle (see above) and also sometimes called fire rotation (Heinselman, 1973). The natural fire rotation is that period of time that is required for an area equivalent (in size) to the study area in question to burn. It has been used to describe the period of time required for stand replacement fires to burn a given amount of area, but can be used to describe the extent of underburns as well (Romme, 1980:137).

Rate of Spread. The rate of forward movement or lateral expansion of a fire front.

Reburn. A subsequent fire in an area which has recently burned. Common where fire causes an increase in fuel loading, e.g., in an old growth forest, where incomplete consumption of organic material results in delayed mortality or slow decay of snags and other fuels.

Snag. A standing dead tree, from which the leaves and smaller branches have fallen.

Spot Fire. A fire set outside the perimeter of a larger fire by flying embers or other burning debris.

Stand-replacing Fire. A fire that causes high or complete mortality in an overstory stand of trees. Often referred to as a "high intensity" fire.

Surface Fire. Fire that burns the litter, duff, loose woody debris on the forest floor, and undergrowth vegetation, including seedlings of shade-tolerant species. Often mistakenly called a "ground fire," which burns materials, e.g., peat, beneath the surface.

Underburn. A low intensity fire that generally does not cause mortality in overstory tree species.

APPENDIX B

STATISTICAL SUMMARIES

Table 25. Chi-square Goodness of Fit Test Between Observed and Expected Elevation Frequencies.

Elevation Range in meters (feet)	Number of Sites Observed	Relative Expected Frequency	Absolute Expected Frequency	Ratio of Deviations to Expected Frequency
< 762 (< 2,500)	50	0.170	56	0.643
762- 914 (2,500-2,999)	69	0.217	71	0.056
915-1,066 (3,000-3,499)	70	0.178	59	2.051
1,067-1,219 (3,500-3,999)	65	0.163	54	2.241
1,220-1,371 (4,000-4,499)	53	0.195	64	1.266
> 1,371 (> 4,500)	22	0.077	25	0.360
Sum of Ranges	329	1.000	329	6.617

Chi-square ($p=0.05$) value for 4 d.f. is 9.448, therefore the difference between the observed frequency and the expected frequency (the sum of differences = 6.617) is not significantly different (at $p=0.05$) (Sokal and Rohlf, 1981:692-703).

Table 26. Chi-square Goodness of Fit Test Between Observed and Expected Aspect Frequencies.

Aspect	Number Observed	Rel. Expected Frequency	Abs. Expected Frequency	Ratio of Deviations to Expected Freq.
North	37	0.128	42	0.595
Northeast	26	0.082	27	0.037
East	31	0.080	26	0.962
Southeast	26	0.092	30	0.533
South	29	0.082	27	0.148
Southwest	31	0.083	27	0.593
West	40	0.133	44	0.364
Northwest	48	0.153	50	0.080
Ridgetop	42	0.115	38	0.421
Valley Bottom	19	0.053	18	0.056
sum of aspects	329	1.000	329	3.789

Chi-square (p=0.05) value for 8 d.f. is 15.507, therefore the difference between the observed frequency and the expected frequency (the sum of differences = 3.789) is not significantly different (at p=0.05) (Sokal and Rohlf, 1981:692-703).

Table 27. Analysis of Variance of Mean Fire Return Intervals (partial or complete stand-replacing fires) for Physiographic Units.

Source of Variation	Sum of Squares	df	Mean Square	F	p.
Between Groups	1,019,009	5	203,801.8	15.5937	< 0.001
Within Groups	5,789,783	443	13,069.5		
Total	6,808,792	448			

Table 28. Analysis of Variance of Mean Fire Return Intervals (all fires) for Physiographic Units.

Source of Variation	Sum of Squares	df	Mean Square	F	p.
Between Groups	987,884	5	197,576.8	22.1804	< 0.001
Within Groups	3,946,116	443	8,907.7		
Total	4,934,000	448			

Table 29. Analysis of Variance of Mean Fire Return Interval (partial or complete stand-replacing fires only) by Aspect.

Source of Variation	Sum of Squares	df	Mean Square	F	p.
Between Groups	352,926.7	9	32,214.1	2.9388	< 0.003
Within Groups	4,256,593.0	319	13,343.6		
Total	4,609,519.7	328			

Table 30. Analysis of Variance of Mean Fire Return Interval (all fires) by Aspect.

Source of Variation	Sum of Squares	df	Mean Square	F	p.
Between Groups	170,234.1	9	18,914.0	2.1197	< 0.03
Within Groups	2,846,625.9	319	8,923.6		
Total	3,016,860.0	328			

Table 31. Analysis of Variance of Mean Fire Return Interval (partial or complete stand-replacing fires) by Elevation.

Source of Variation	Sum of Squares	df	Mean Square	F	p.
Between Groups	179,400.4	5	35,880.2	4.0844	< 0.001
Within Groups	2,837,458.6	323	8,784.7		
Total	3,016,859.0	328			

Table 32. Analysis of Variance of Mean Fire Return Interval (all fires) by Elevation.

Source of Variation	Sum of Squares	df	Mean Square	F	p.
Between Groups	364,558.4	5	72,911.6	5.5479	< 0.0001
Within Groups	4,244,960.6	323	13,142.2		
Total	4,609,519.0	328			

Table 33. Analysis of Variance of Mean Fire Return Interval (partial or complete stand-replacing fires) by Habitat Type.

Source of Variation	Sum of Squares	df	Mean Square	F	p.
Between Groups	751,962.2	17	44,233.1	3.8927	< 0.001
Within Groups	1,863,552.8	164	11,363.1		
Total	2,615,515.0	181			

Table 34. Analysis of Variance of Mean Fire Return Interval (all Fires) by Habitat Type.

Source of Variation	Sum of Squares	df	Mean Square	F	p.
Between Groups	424,328.5	17	24,960.0	2.9054	< 0.001
Within Groups	1,408,931.5	164	8,591.0		
Total	1,833,260.0	181			

APPENDIX C

INDIVIDUAL FIRE AND FIRE EPISODE MAPS

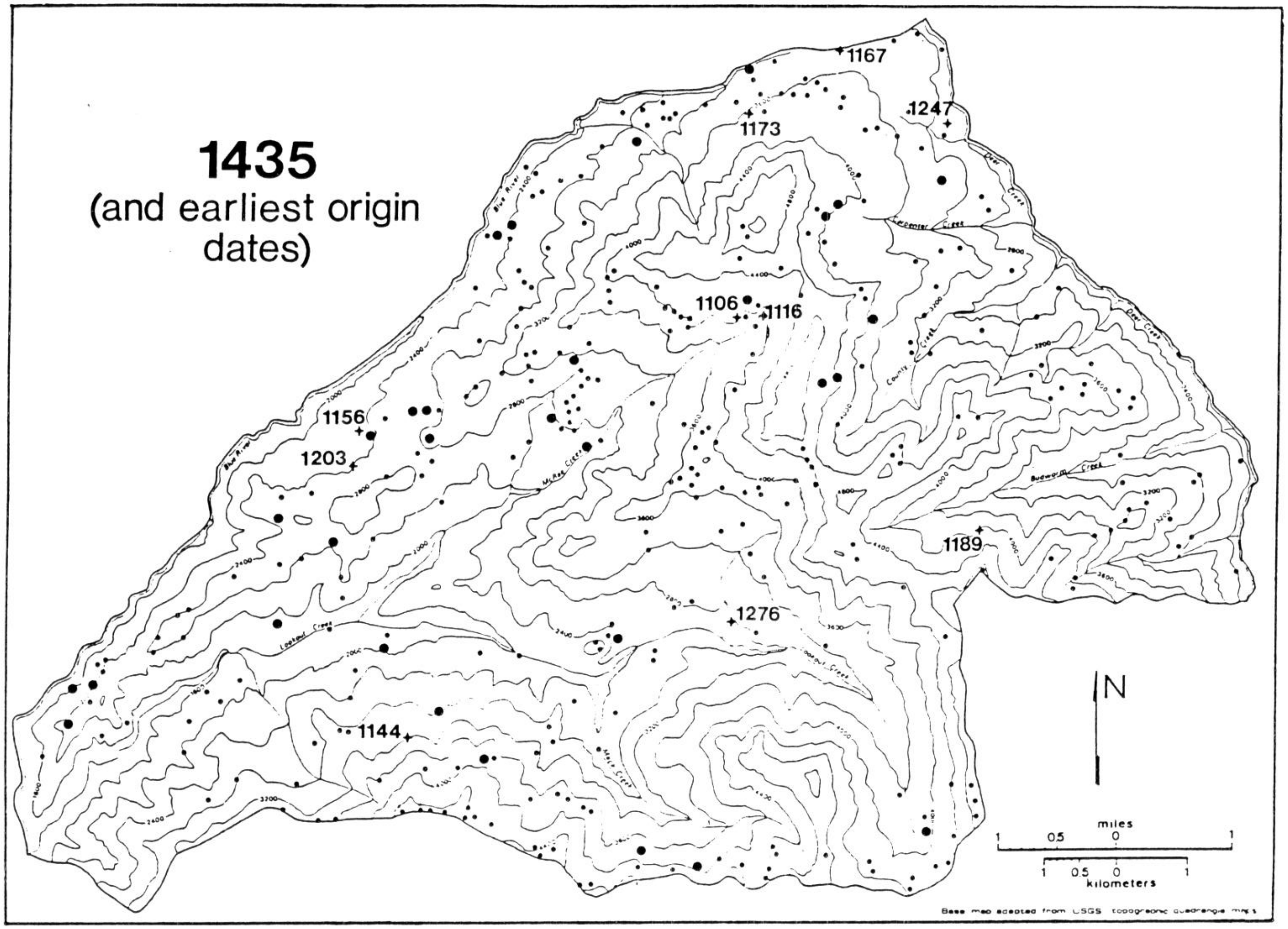


Figure 11. Fire Episode of 1435.

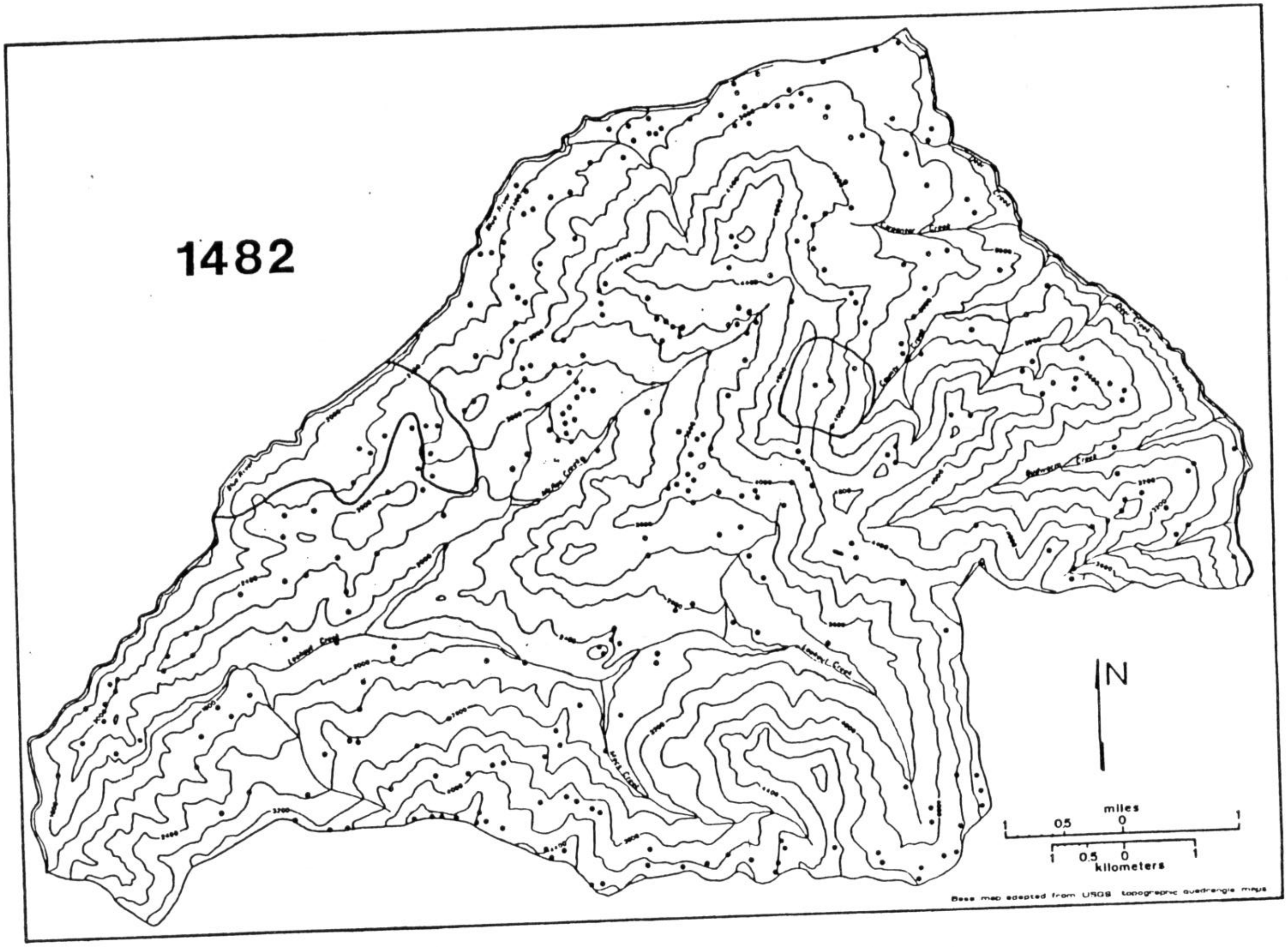


Figure 12. Fire Episode of 1482.

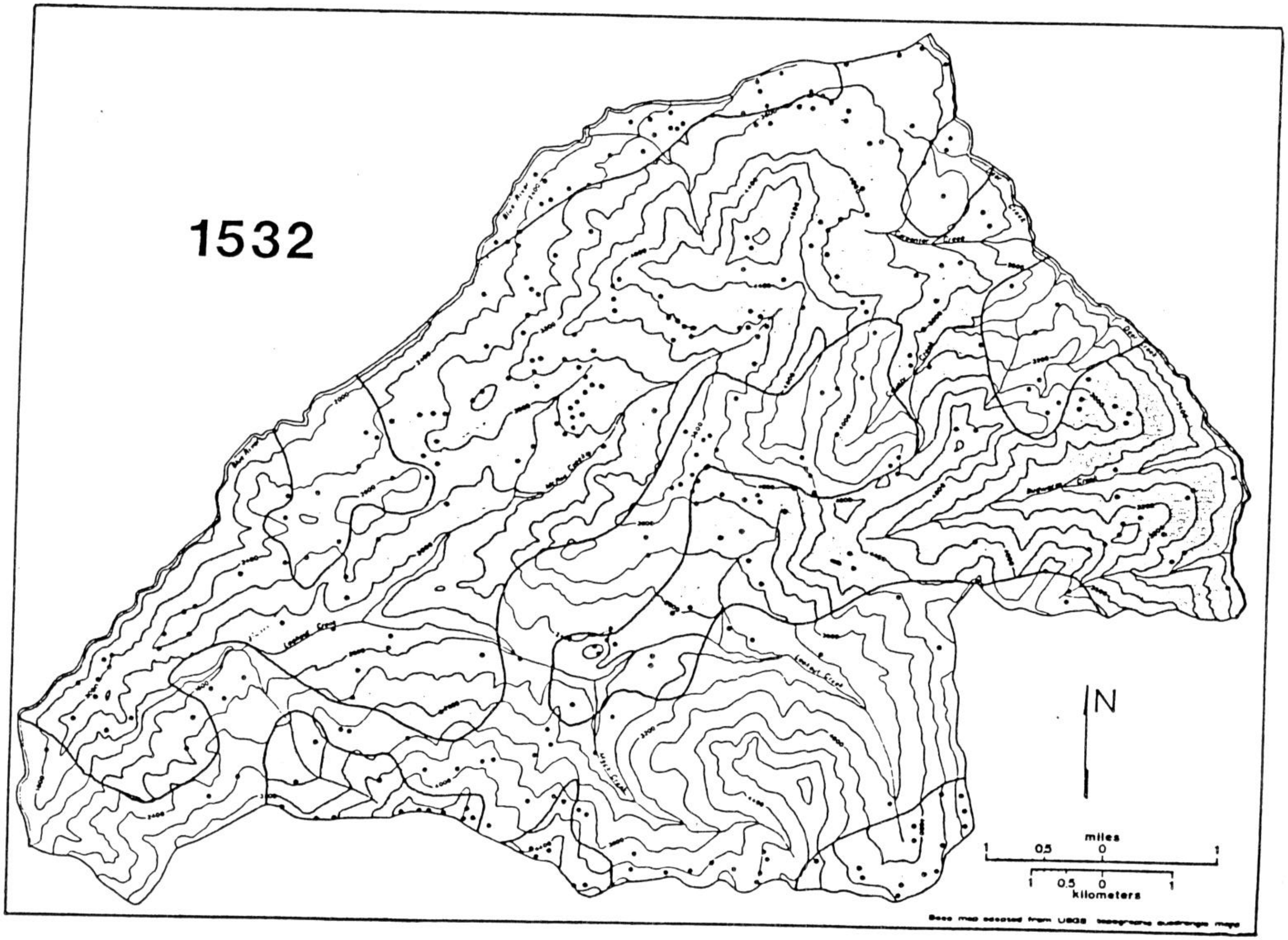


Figure 13. Fire Episode of 1532.

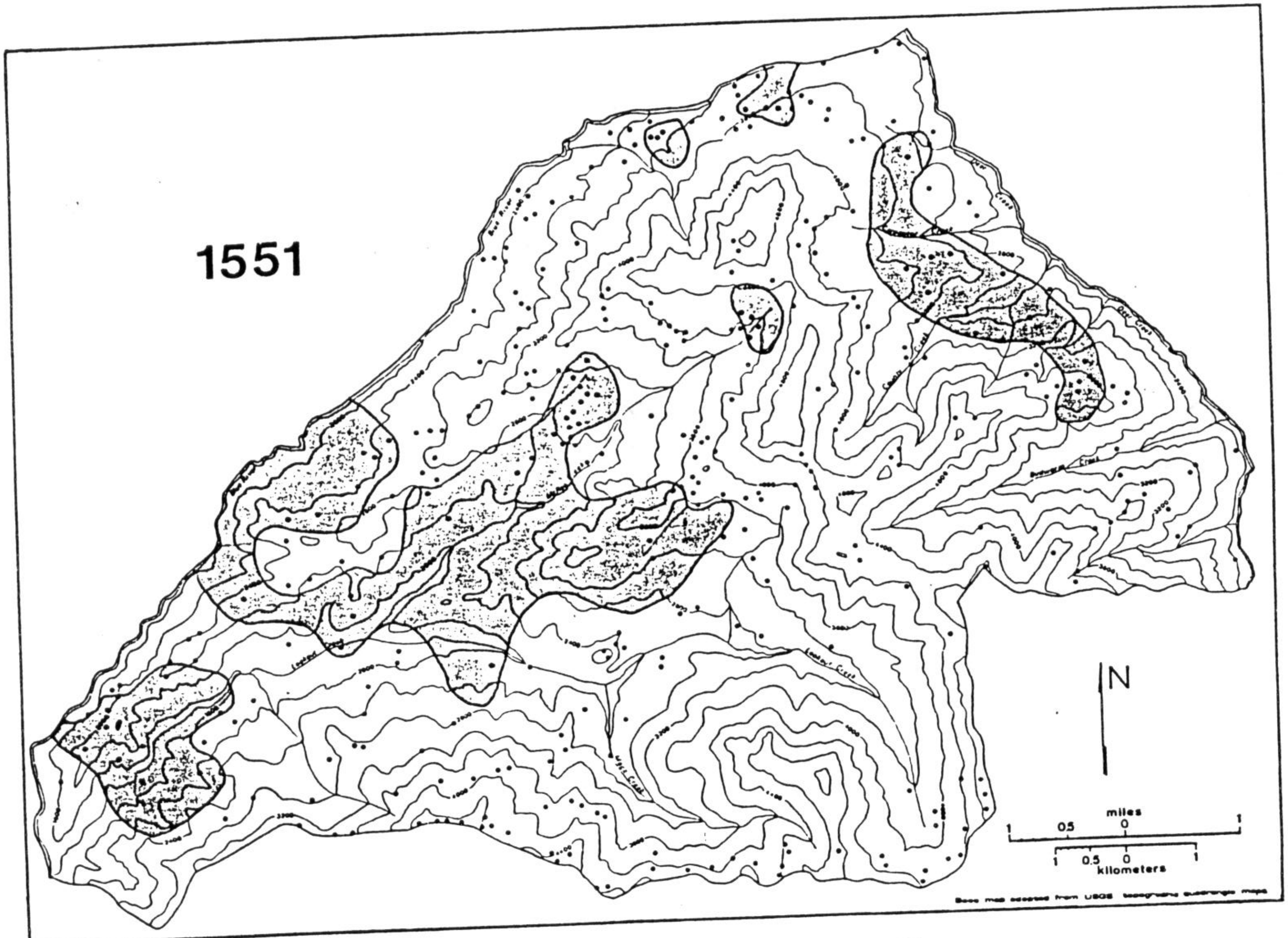


Figure 14. Fire Episode of 1551.

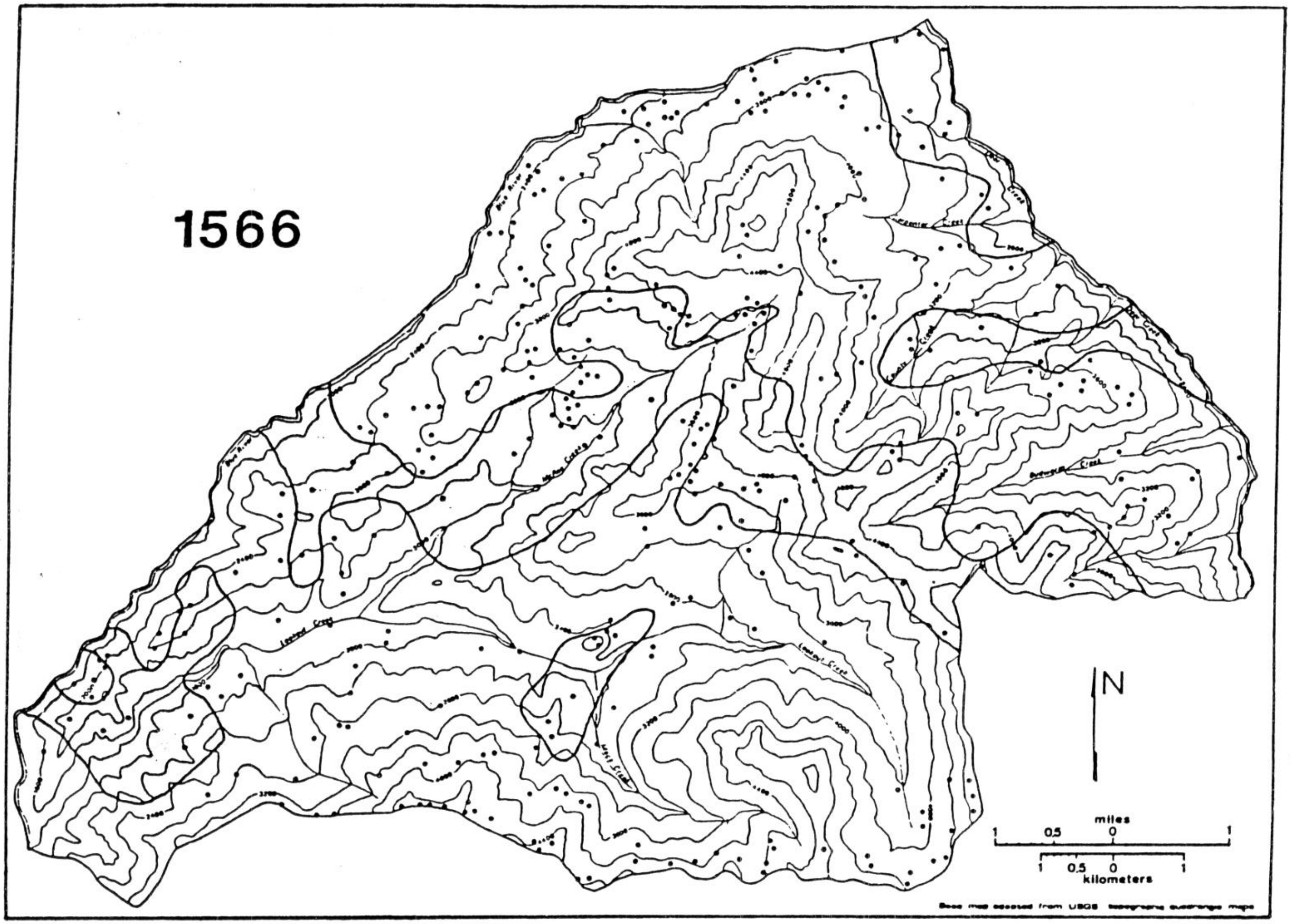


Figure 15. Fire Episode of 1566.

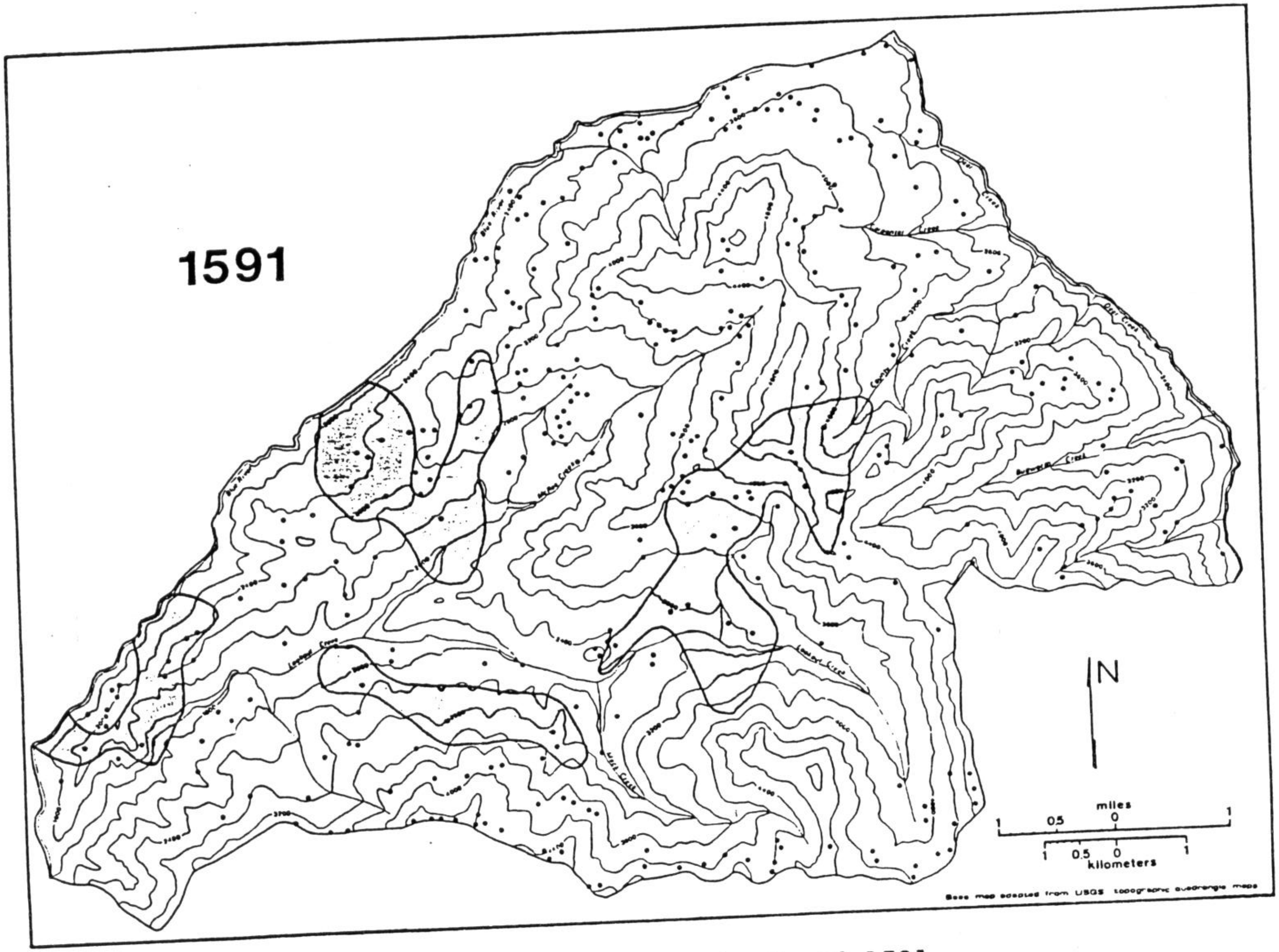


Figure 16. Fire Episode of 1591.

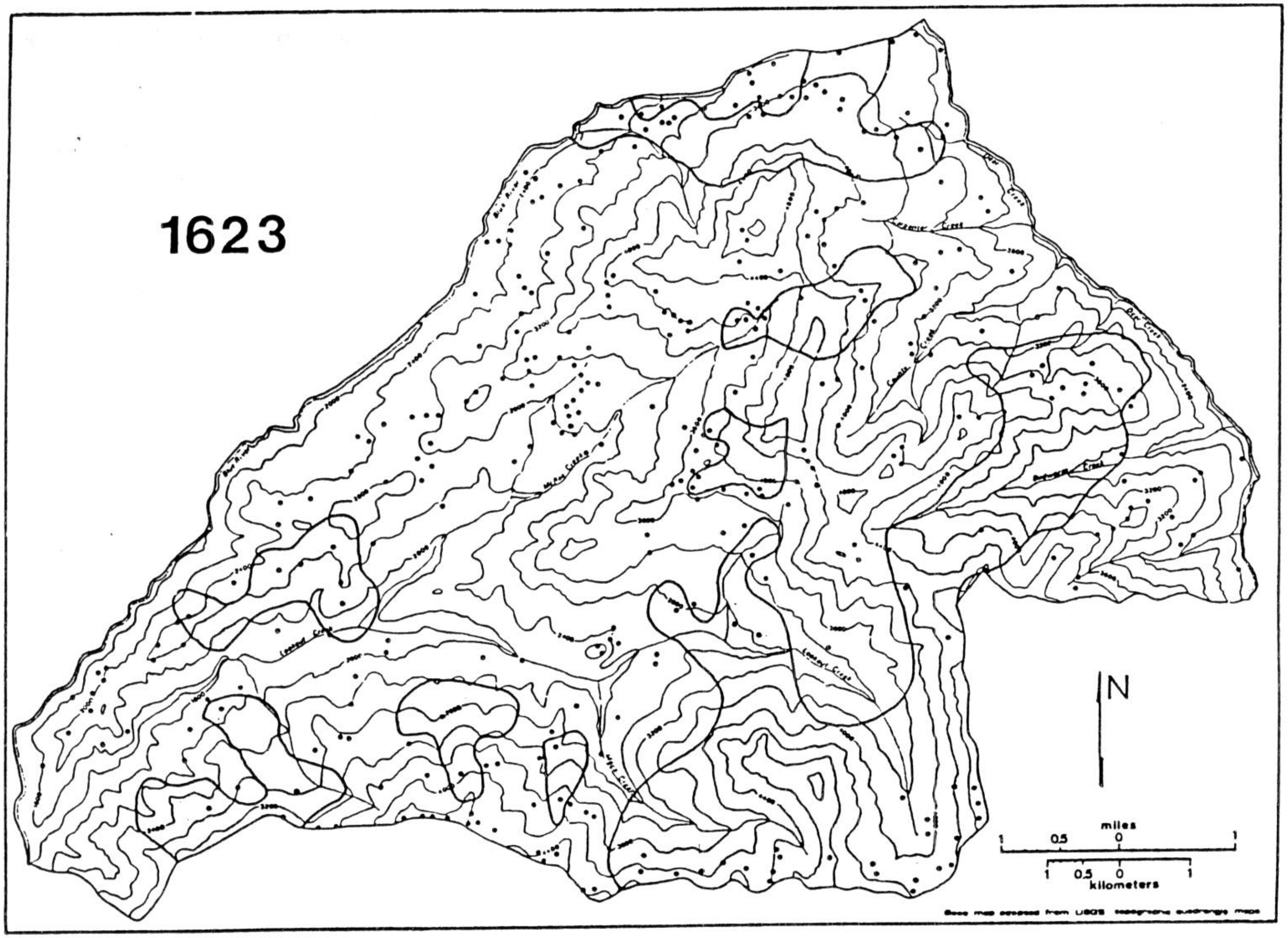


Figure 17. Fire Episode of 1623.

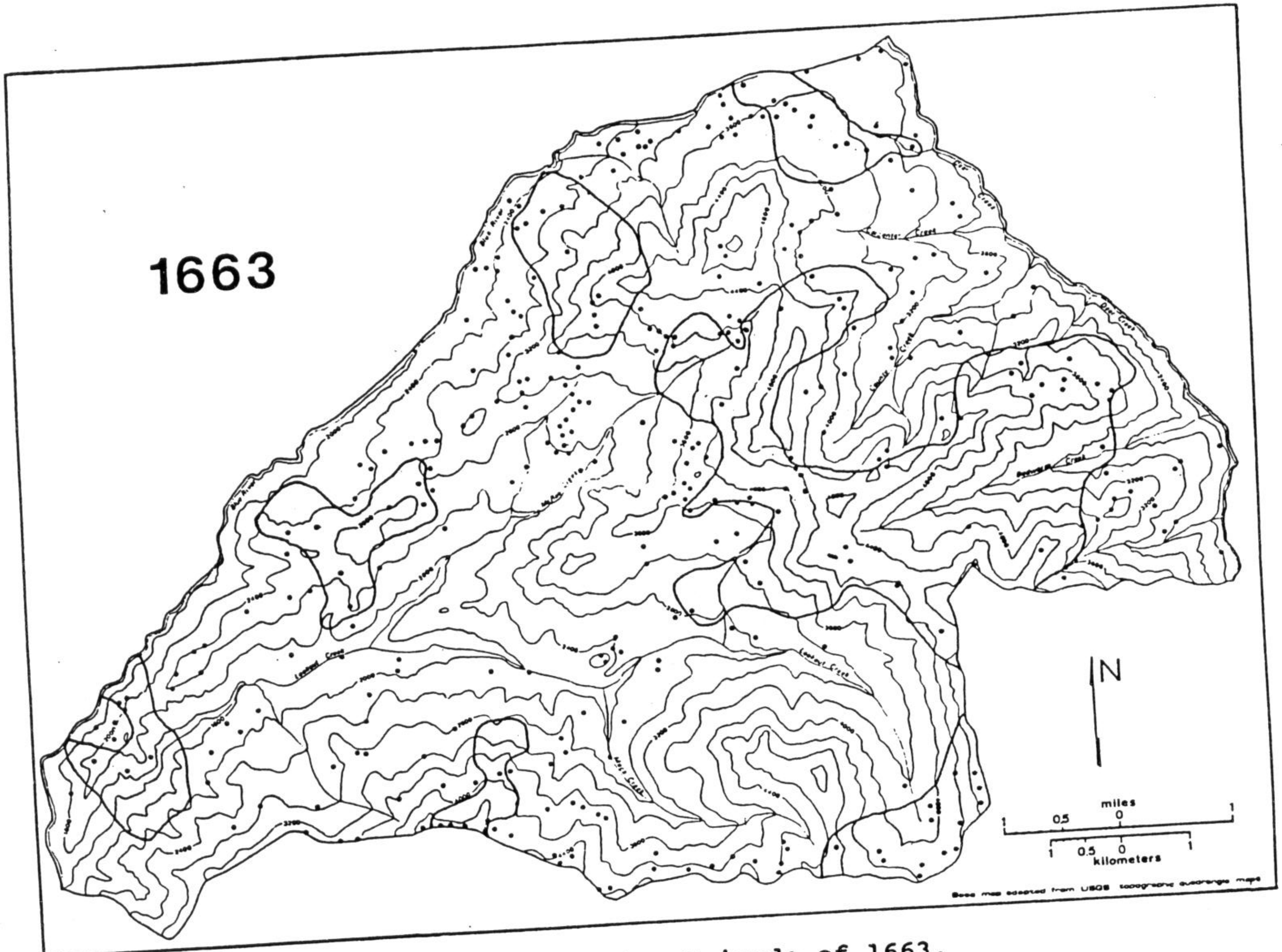


Figure 18. Fire Episode of 1663.

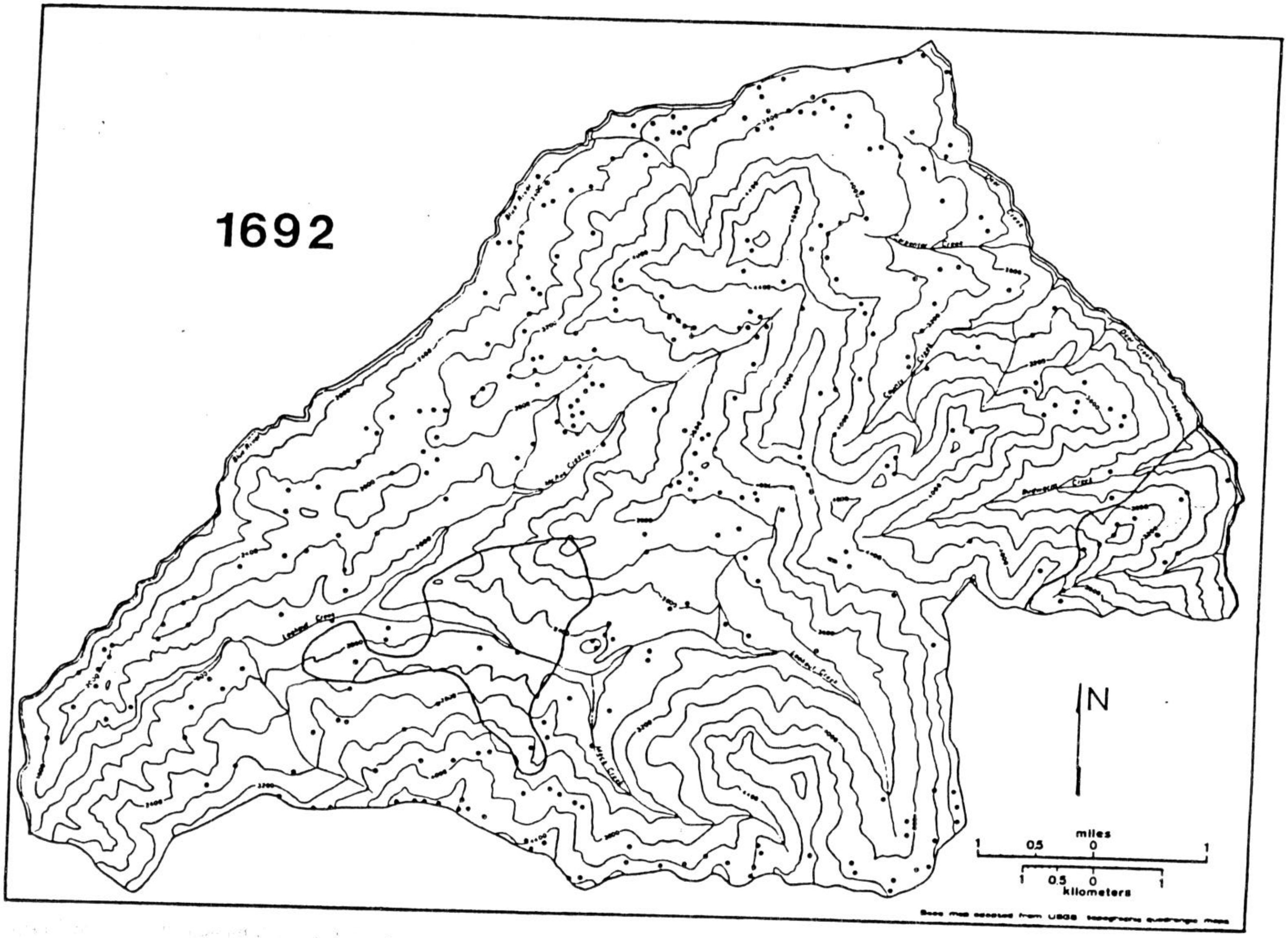


Figure 19. Fire Episode of 1692.

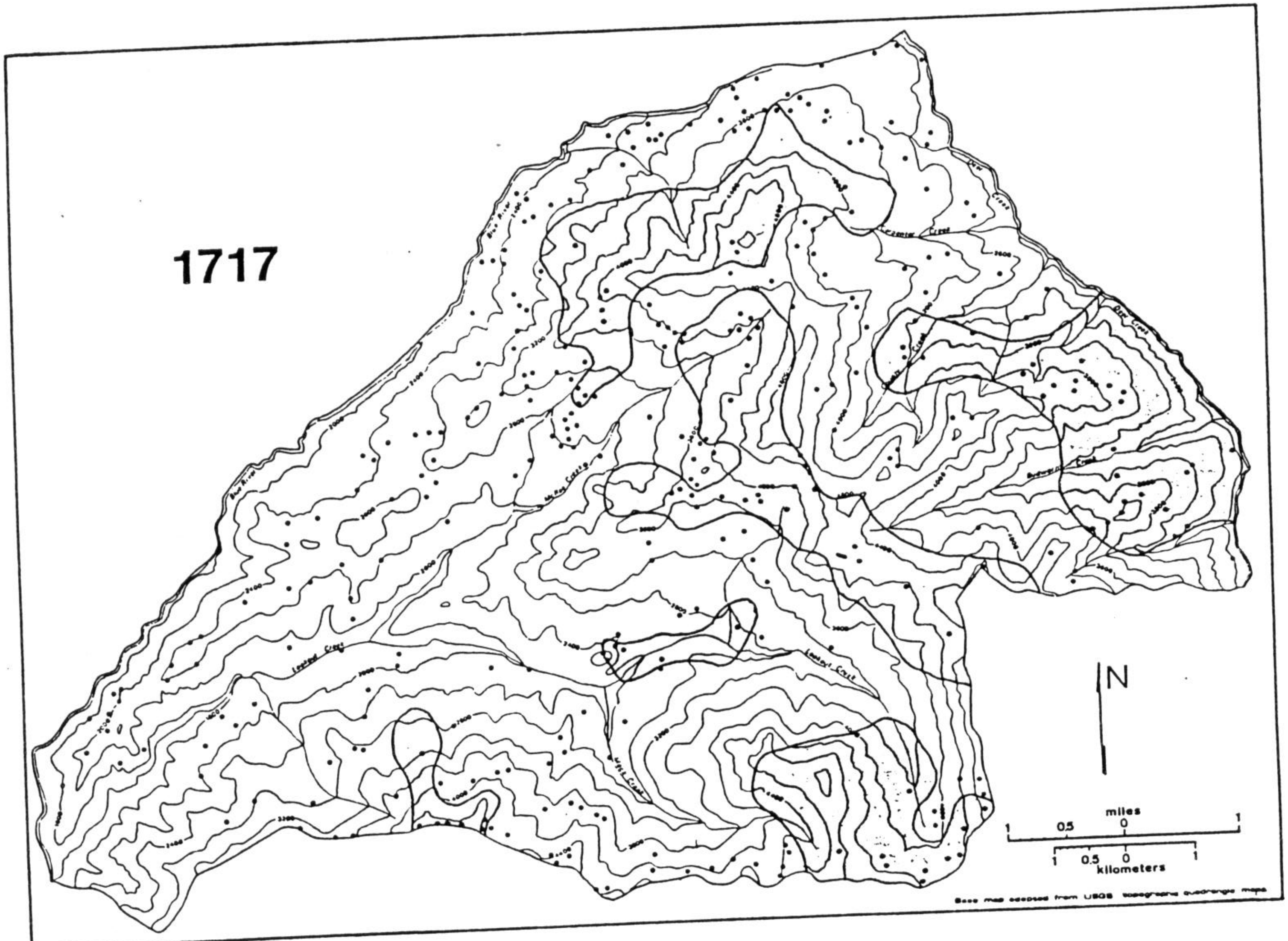


Figure 20. Fire Episode of 1717.

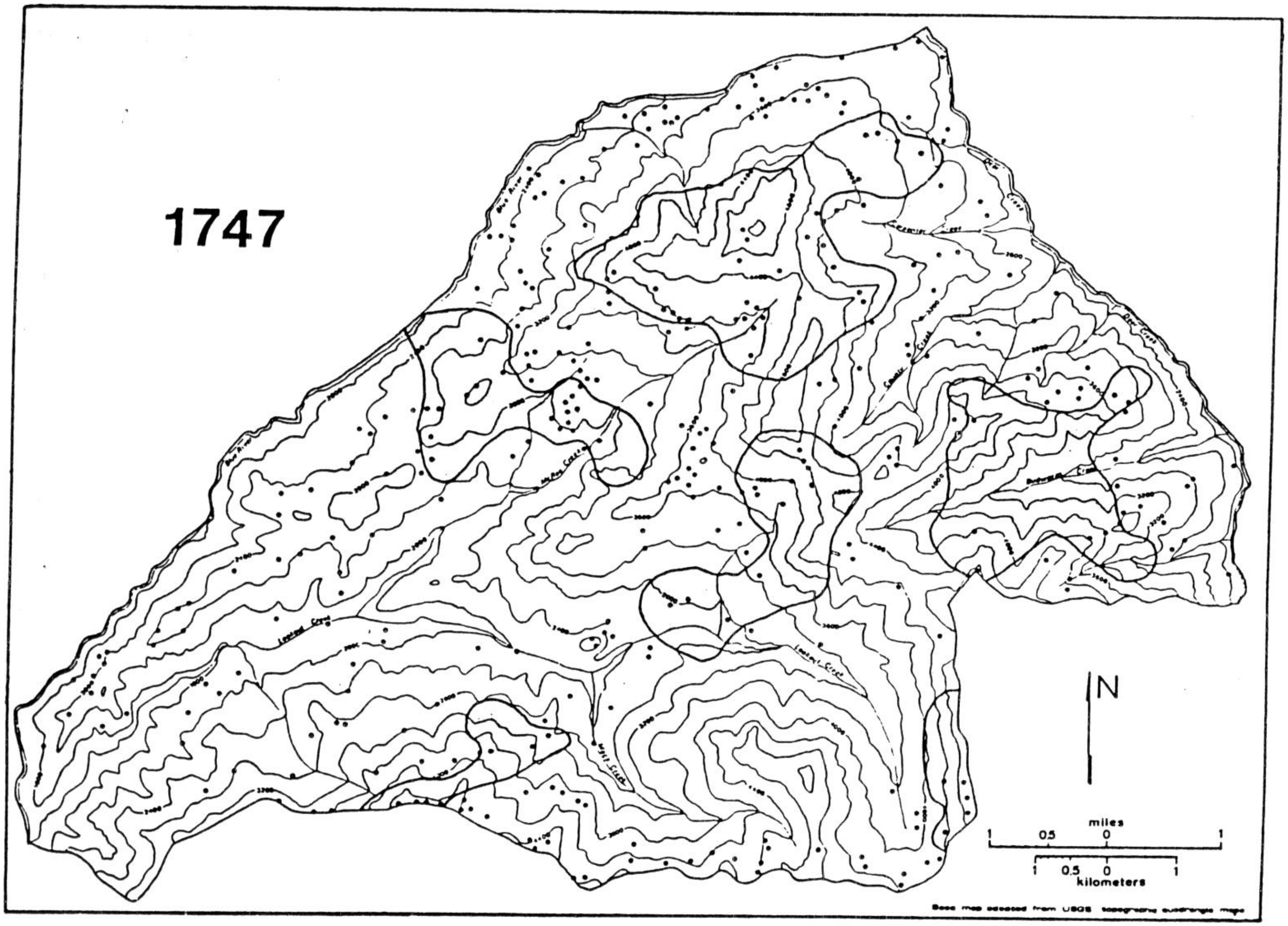


Figure 21. Fire Episode of 1747.

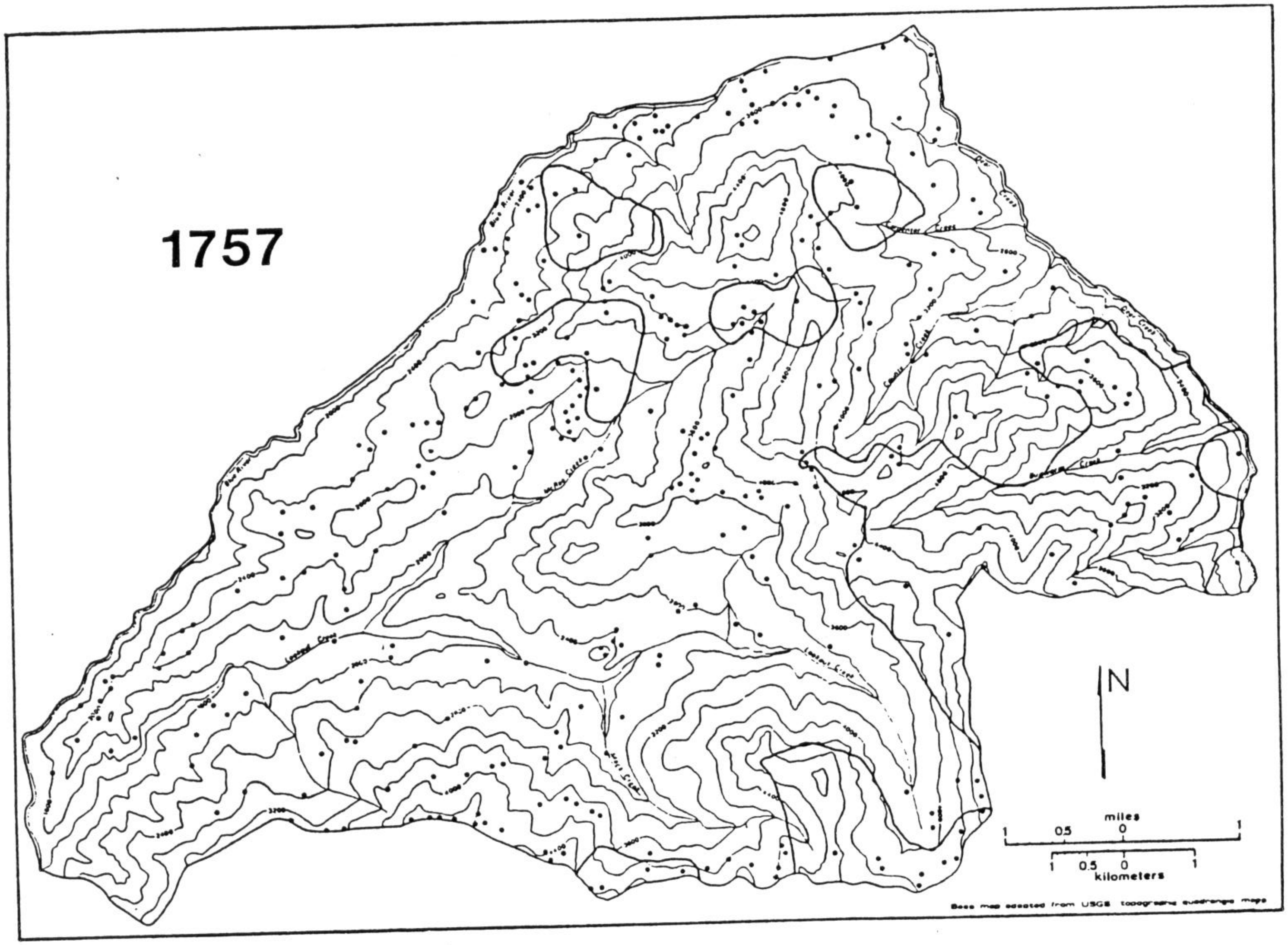


Figure 22. Fire Episode of 1757.

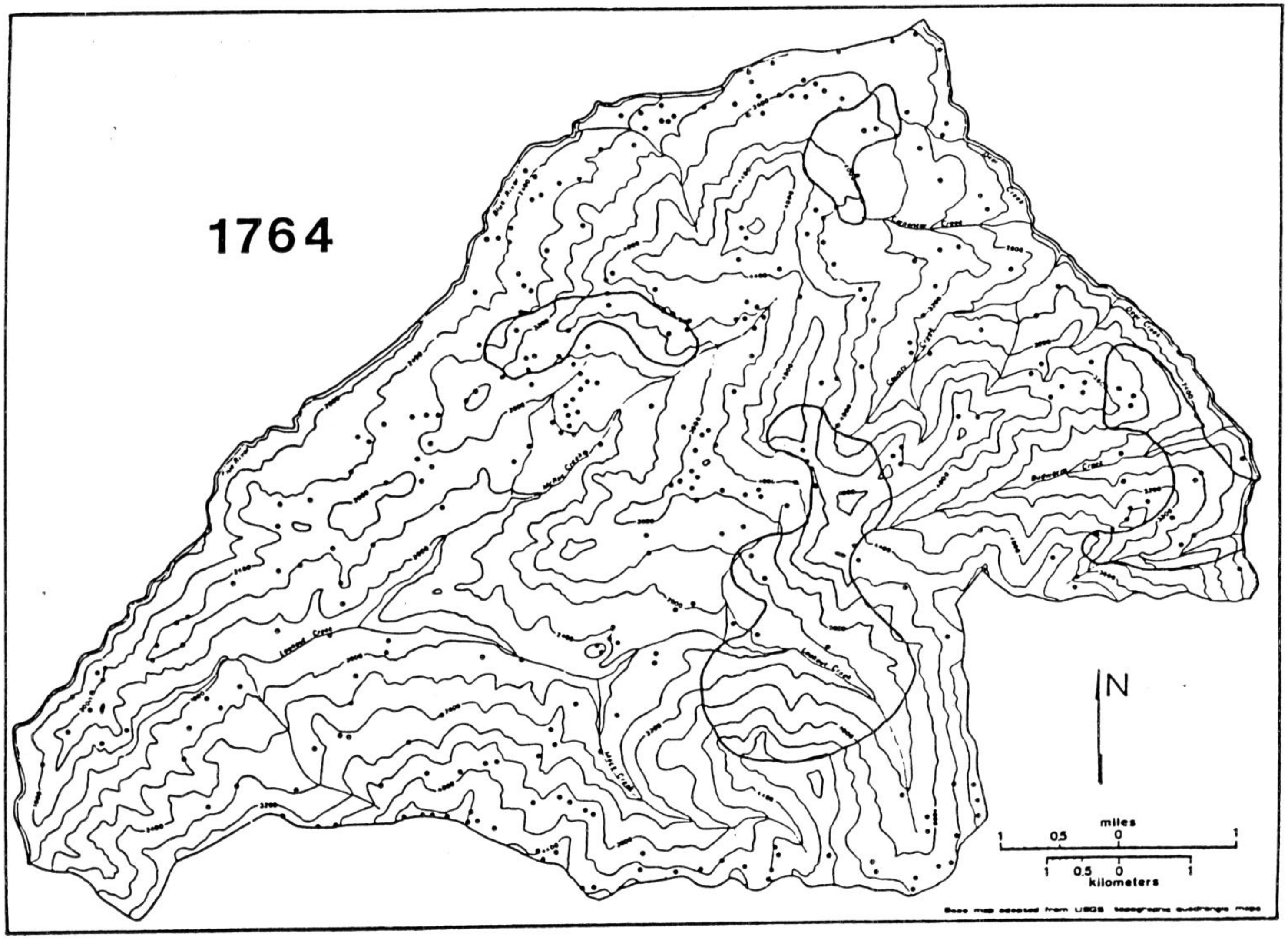


Figure 23. Fire Episode of 1764.

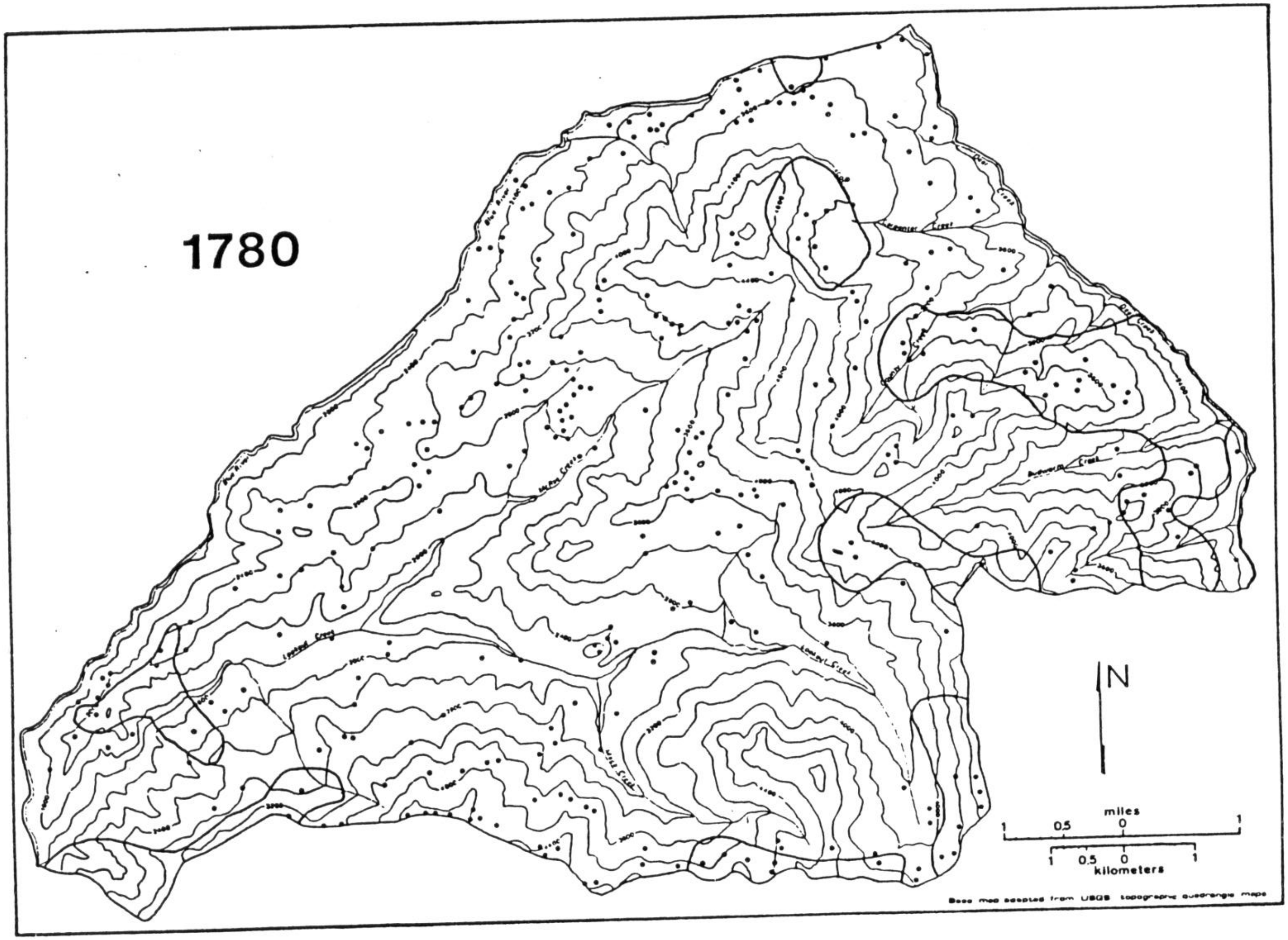


Figure 24. Fire Episode of 1780.

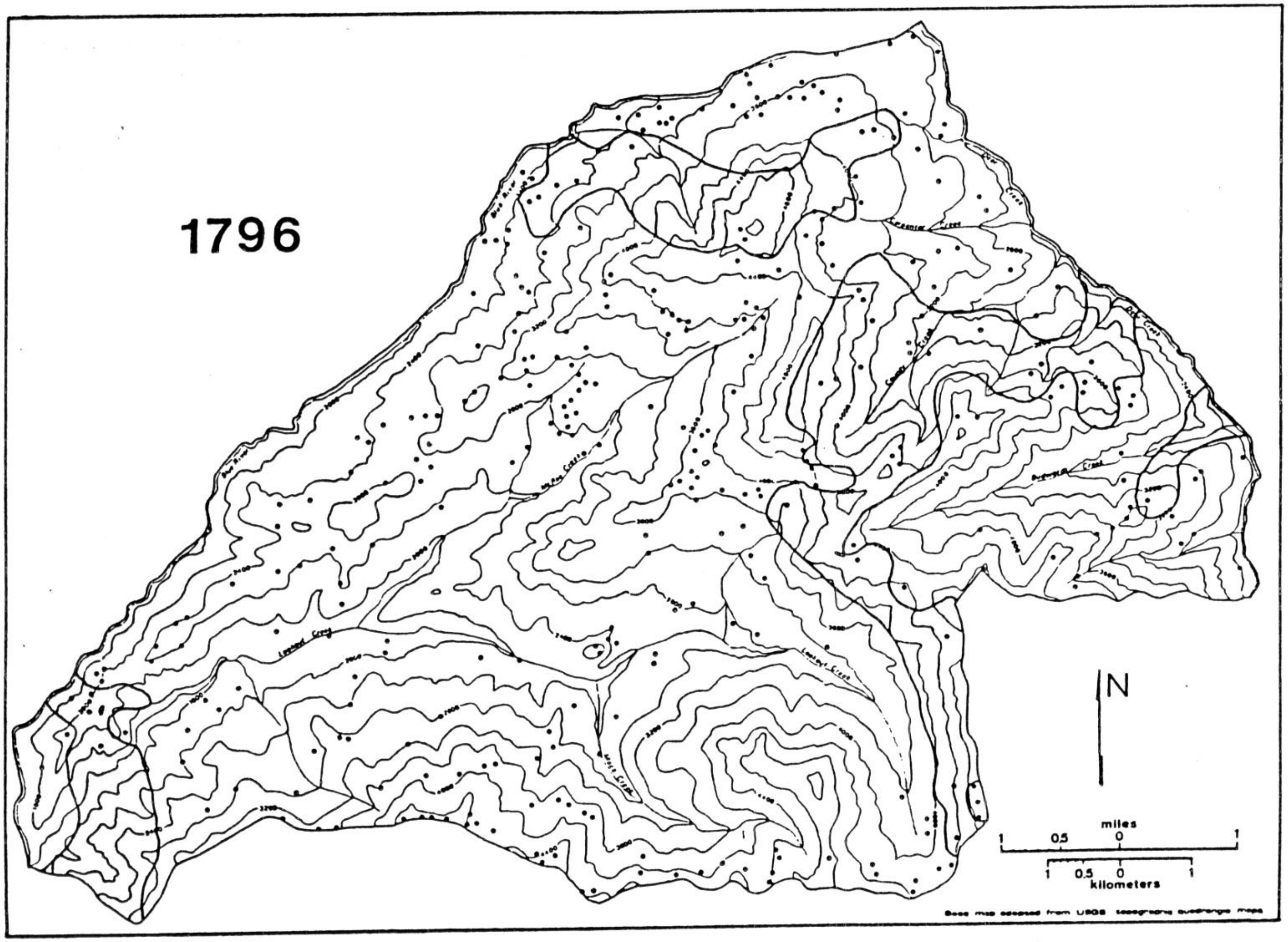


Figure 25. Fire Episode of 1796.

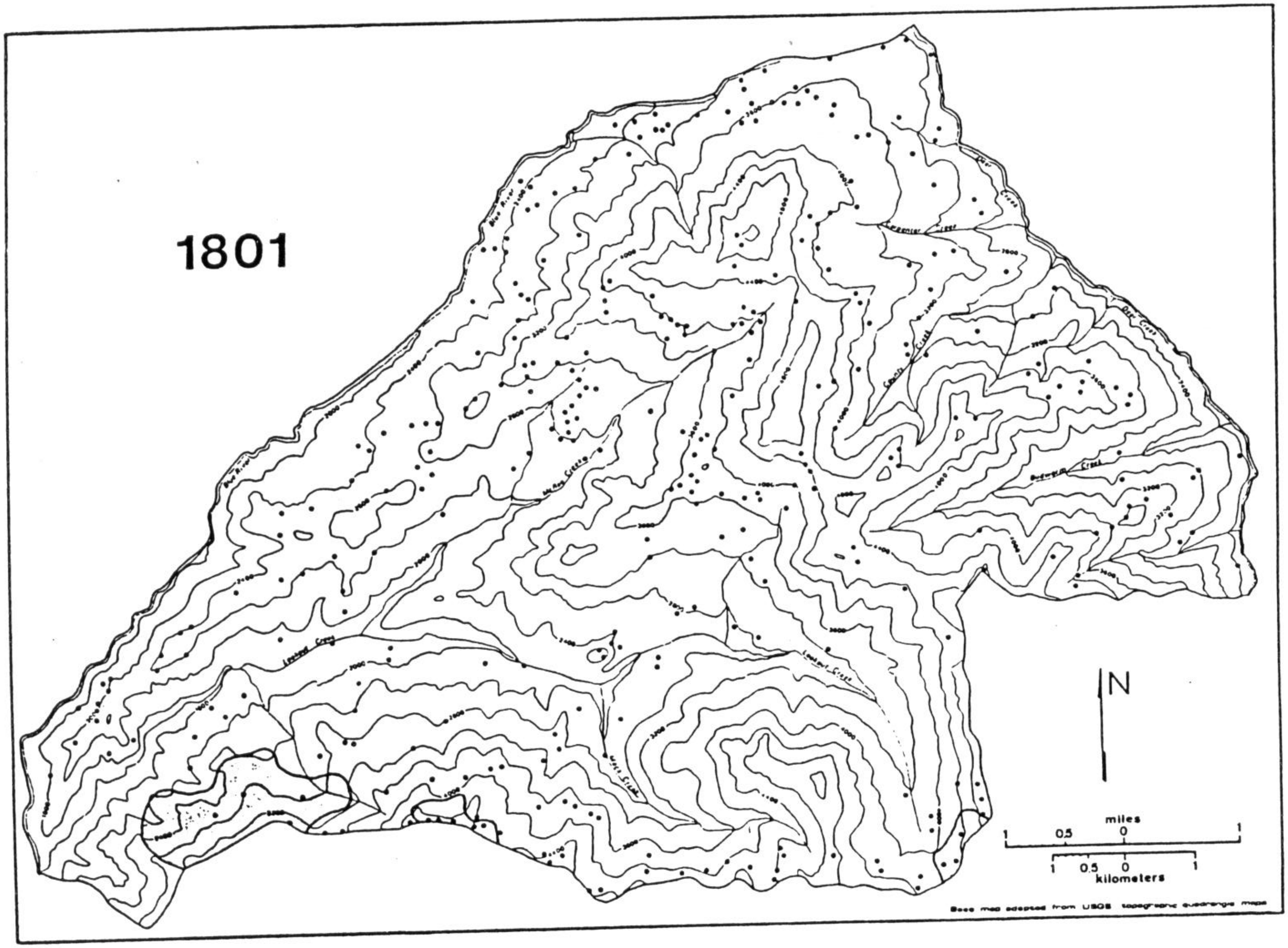


Figure 26. Fire Episode of 1801.

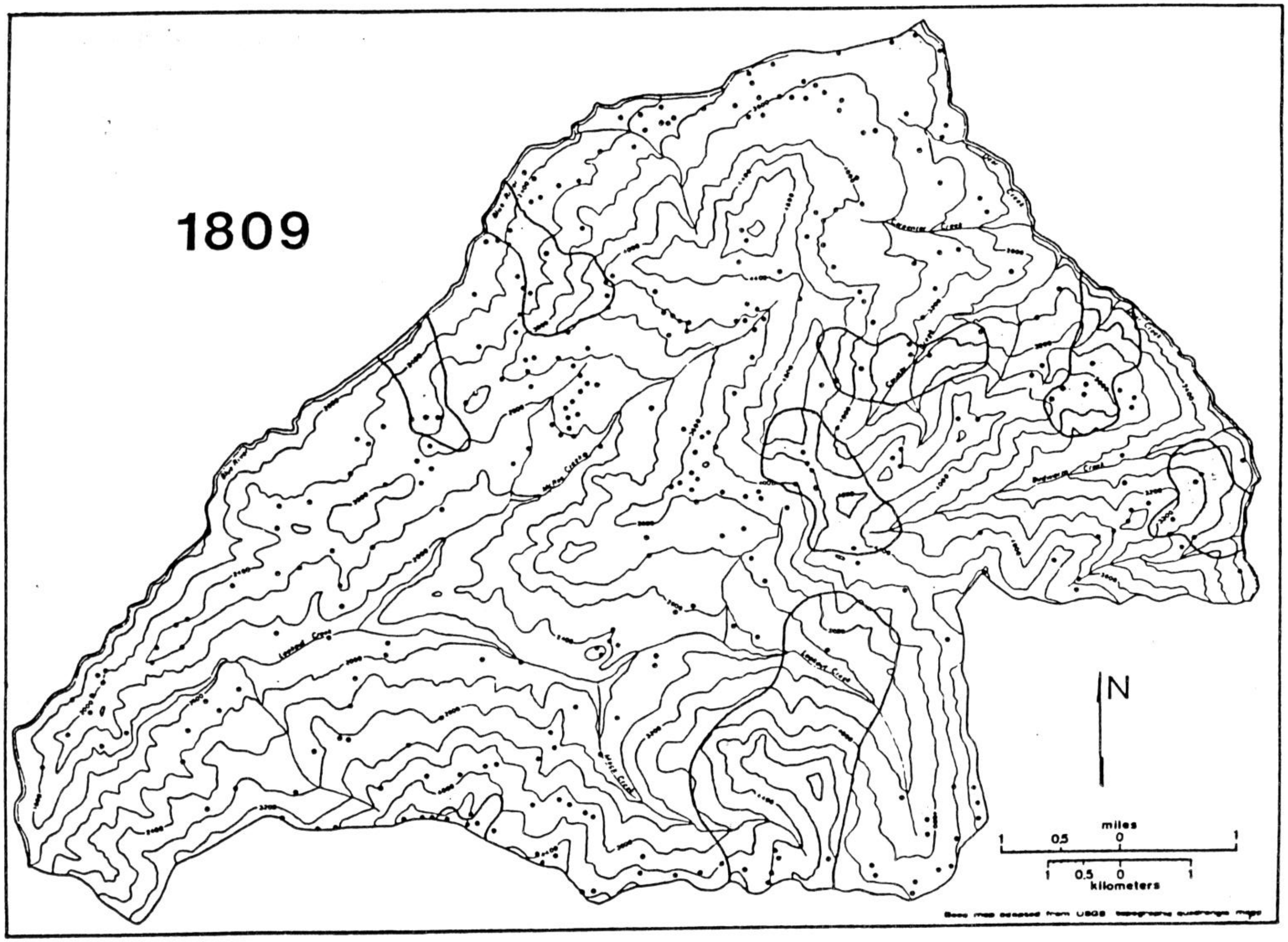


Figure 27. Fire Episode of 1809.

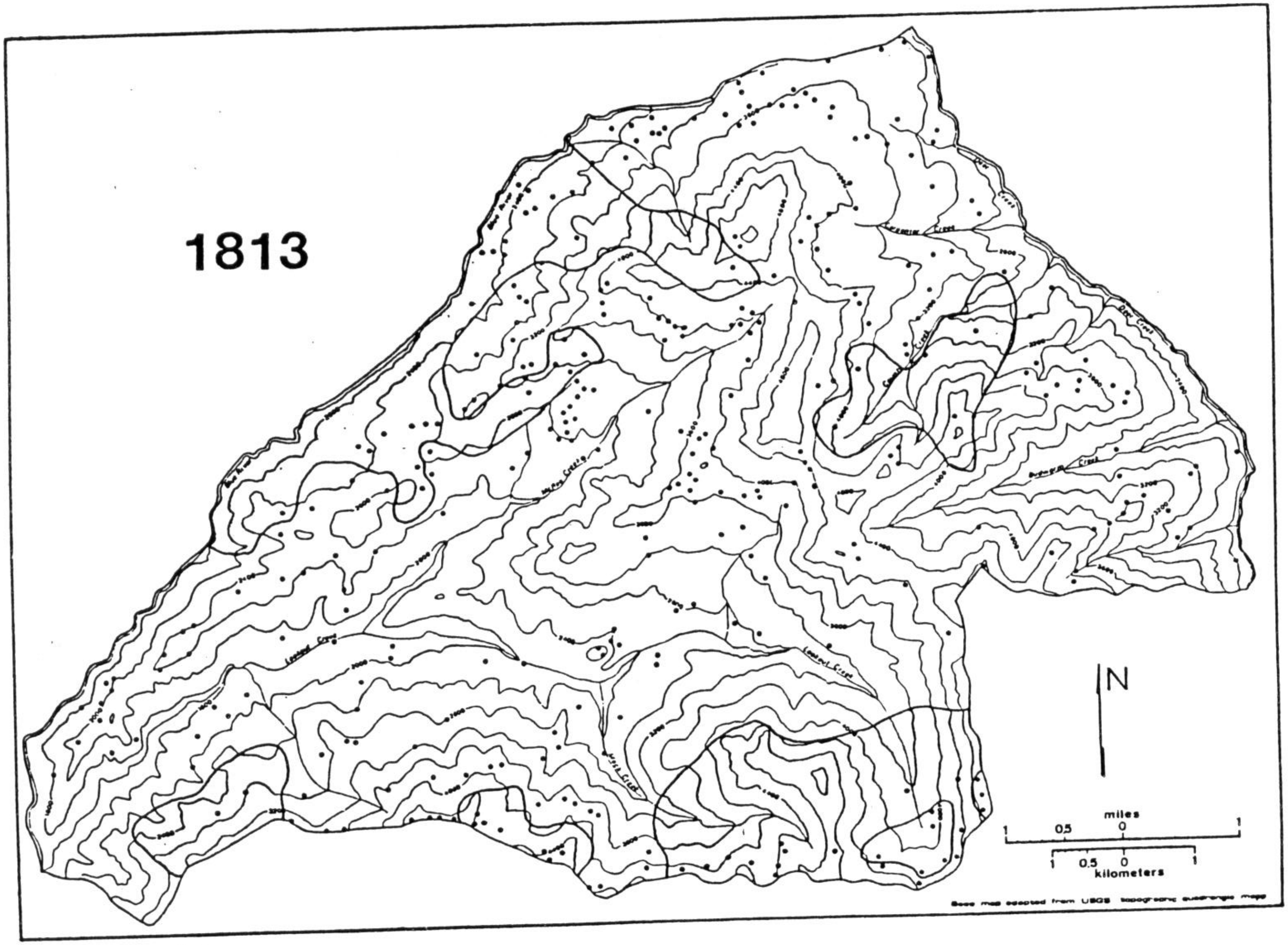


Figure 28. Fire Episode of 1813.

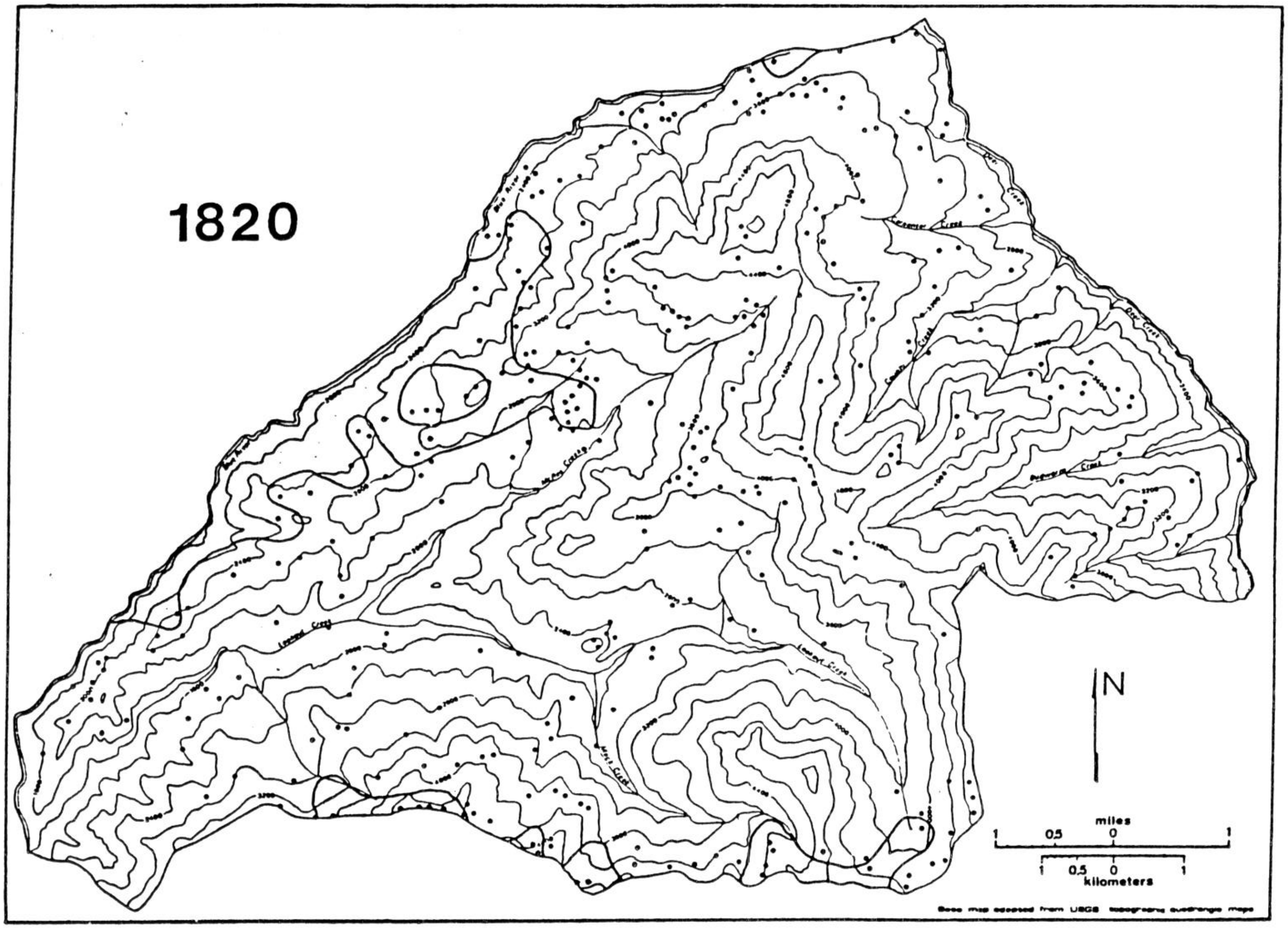


Figure 29. Fire Episode of 1820.

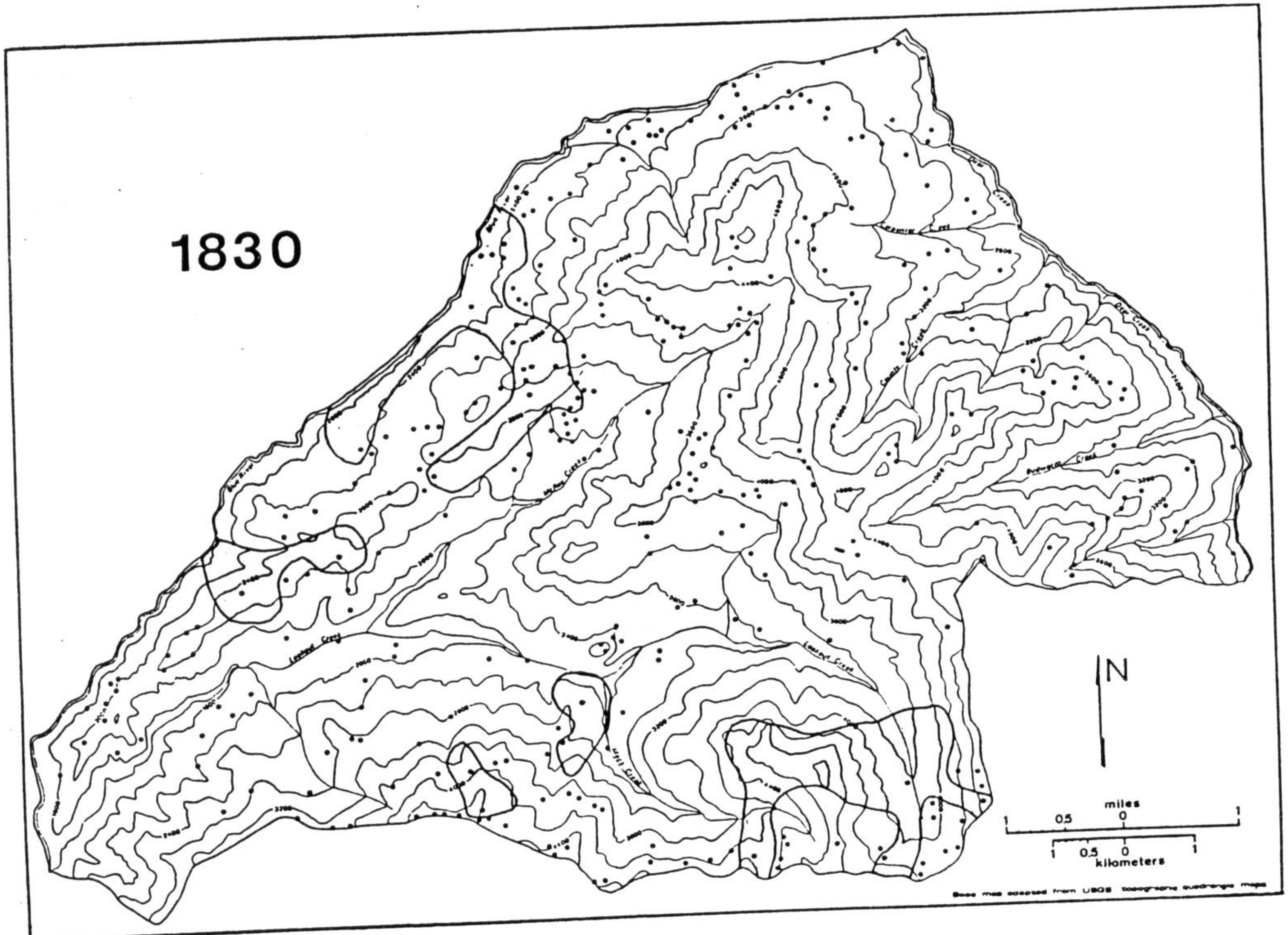


Figure 30. Fire Episode of 1830.

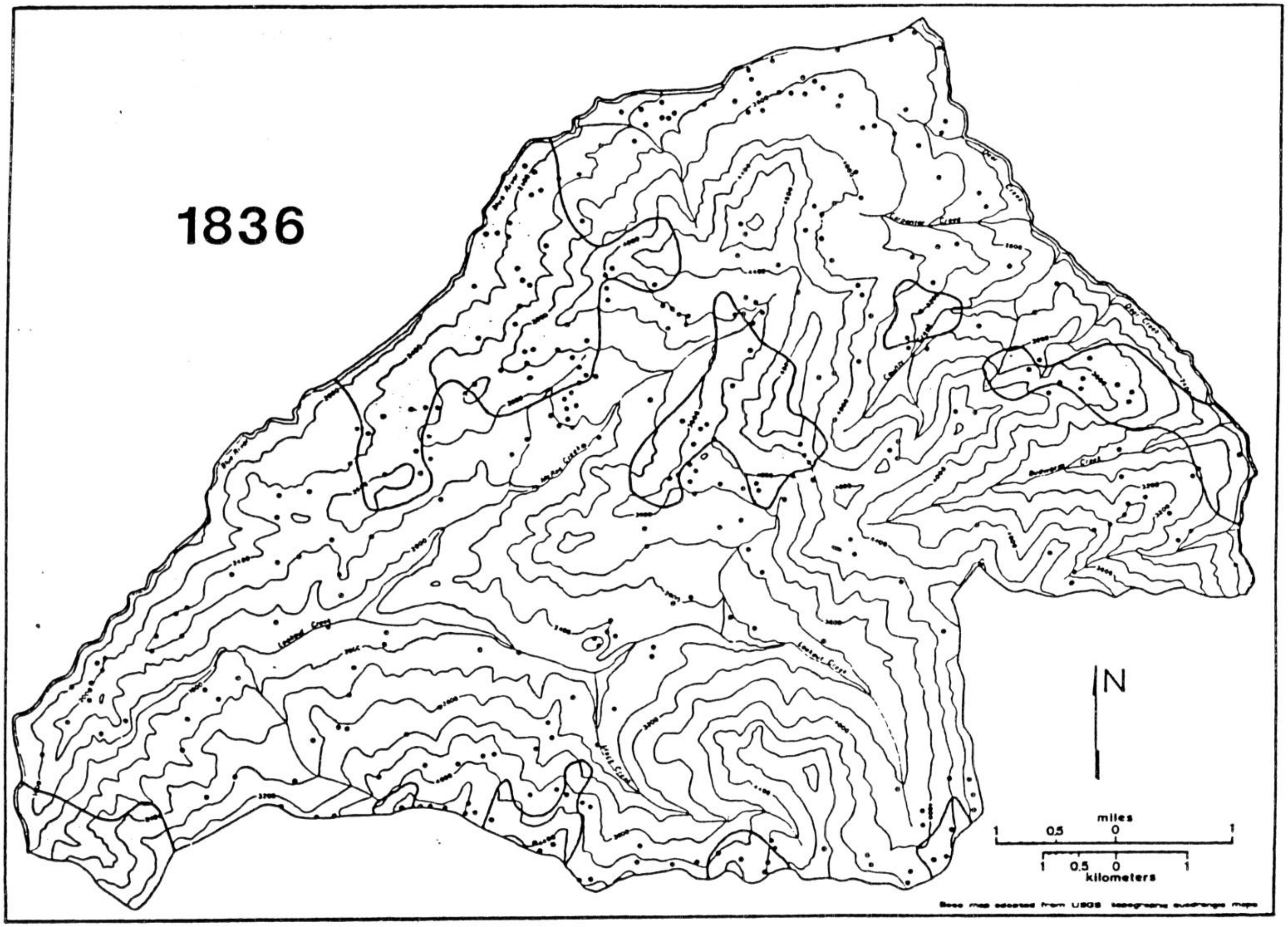


Figure 31. Fire Episode of 1836.

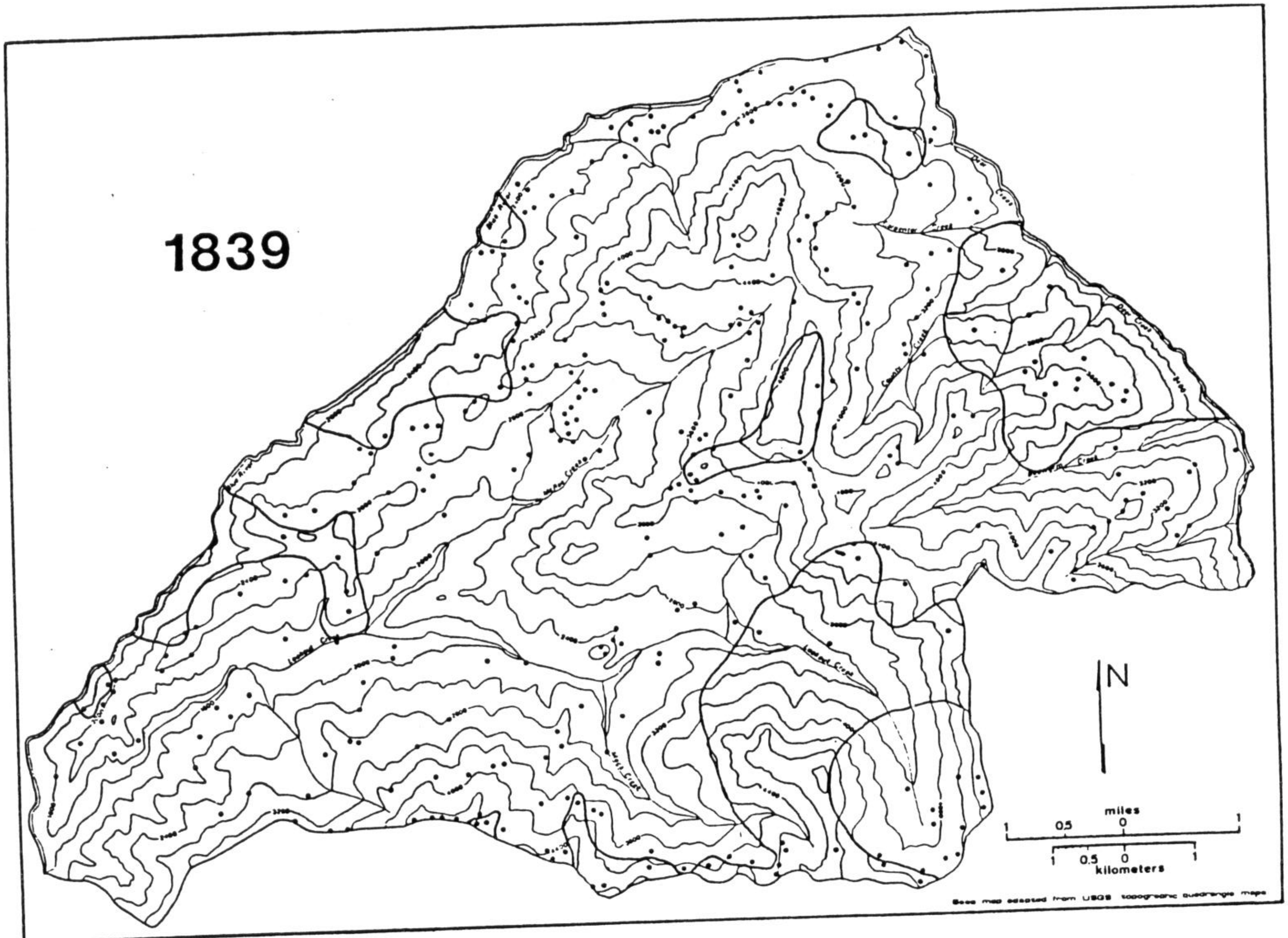


Figure 32. Fire Episode of 1839.

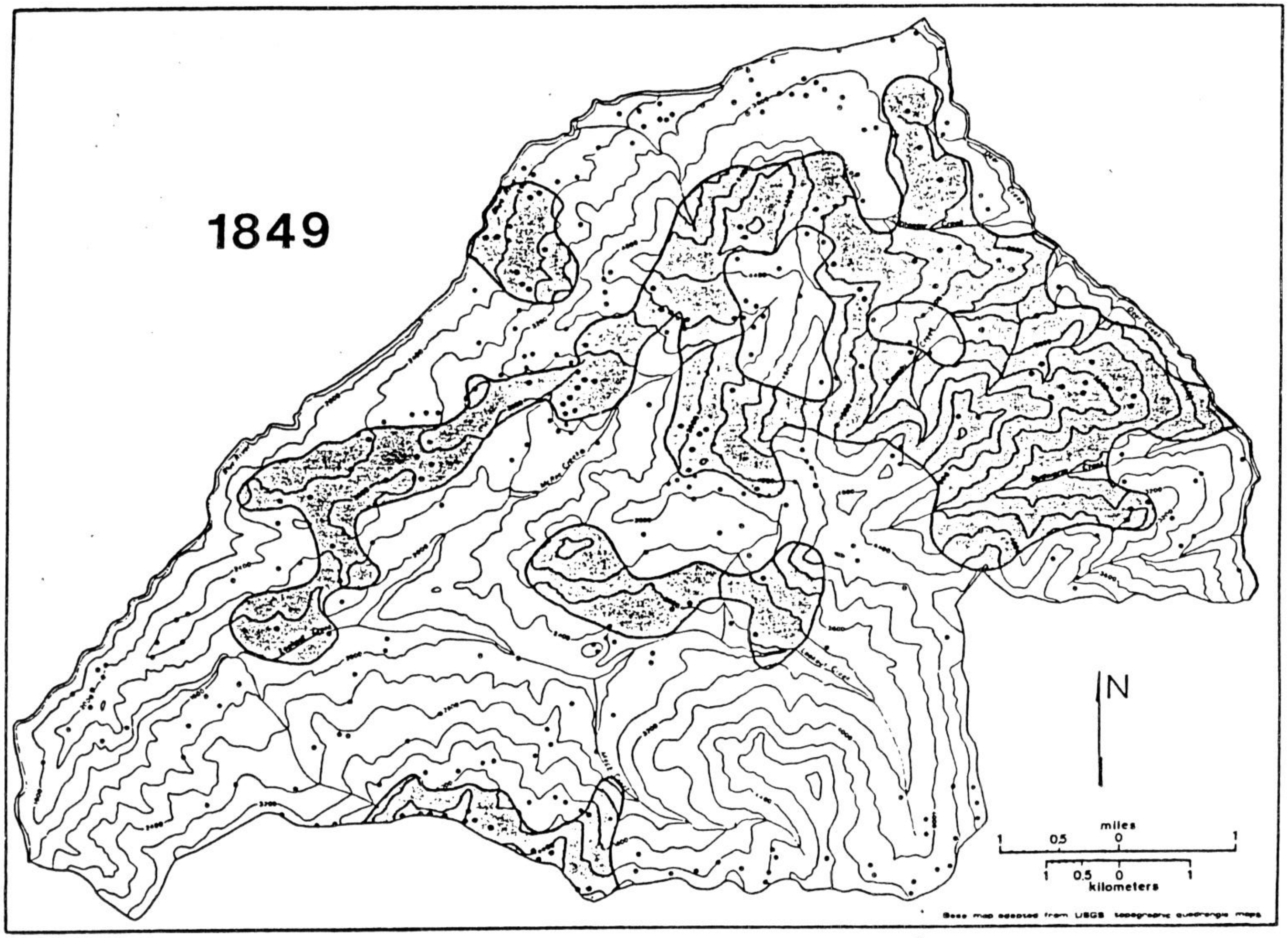


Figure 33. Fire Episode of 1849.

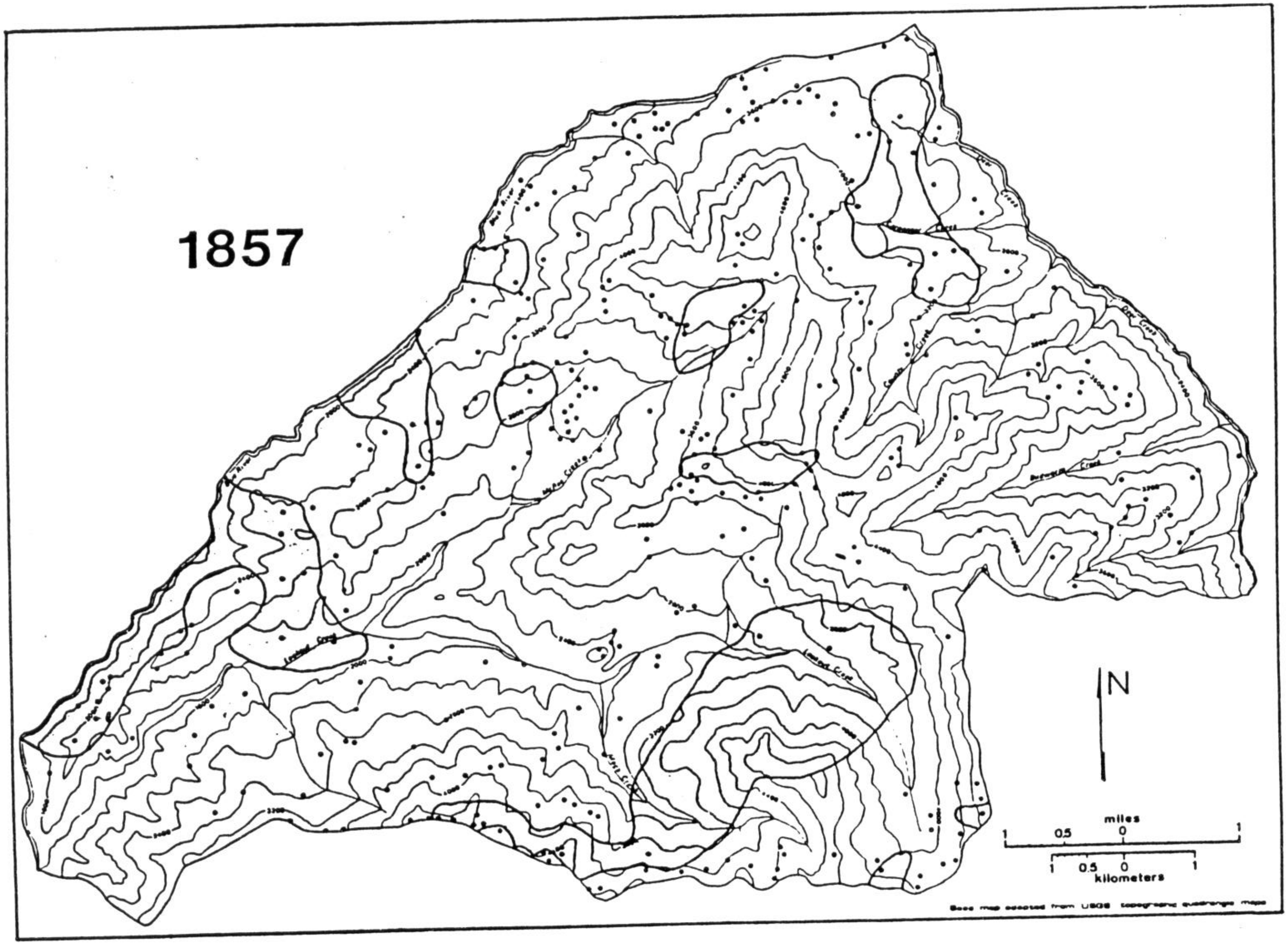


Figure 34. Fire Episode of 1857.

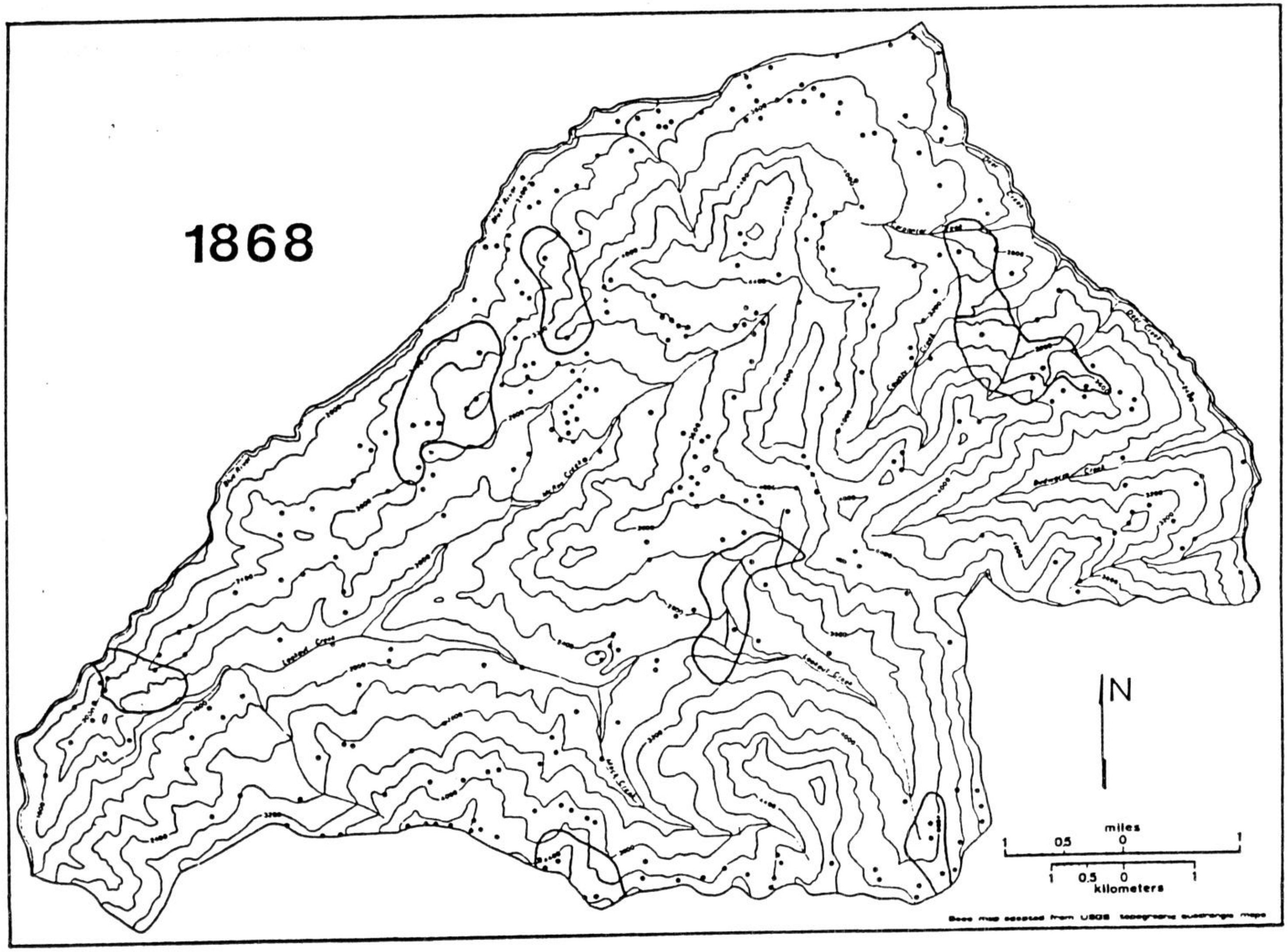


Figure 35. Fire Episode of 1868.

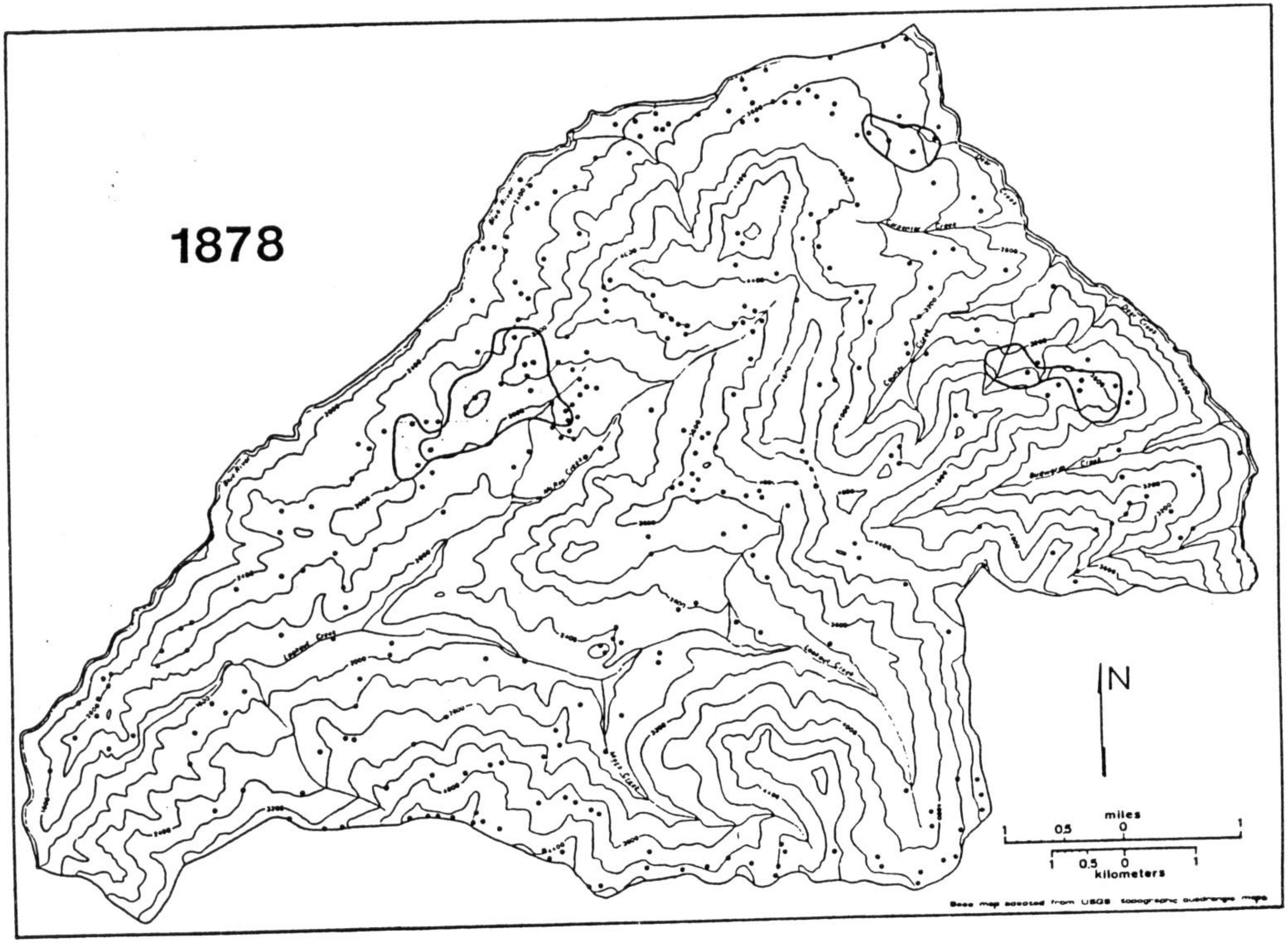


Figure 36. Fire Episode of 1878.

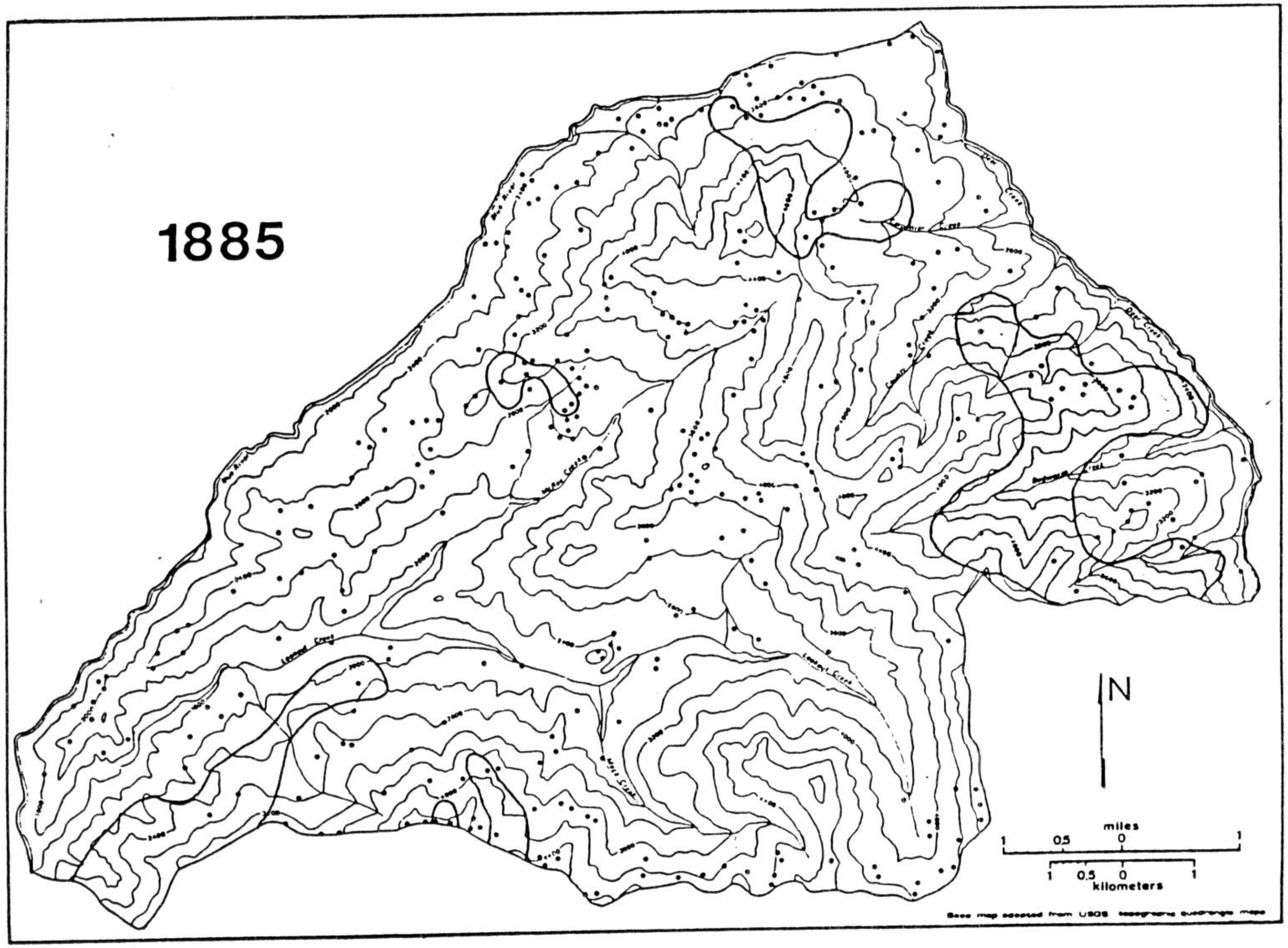


Figure 37. Fire Episode of 1885.

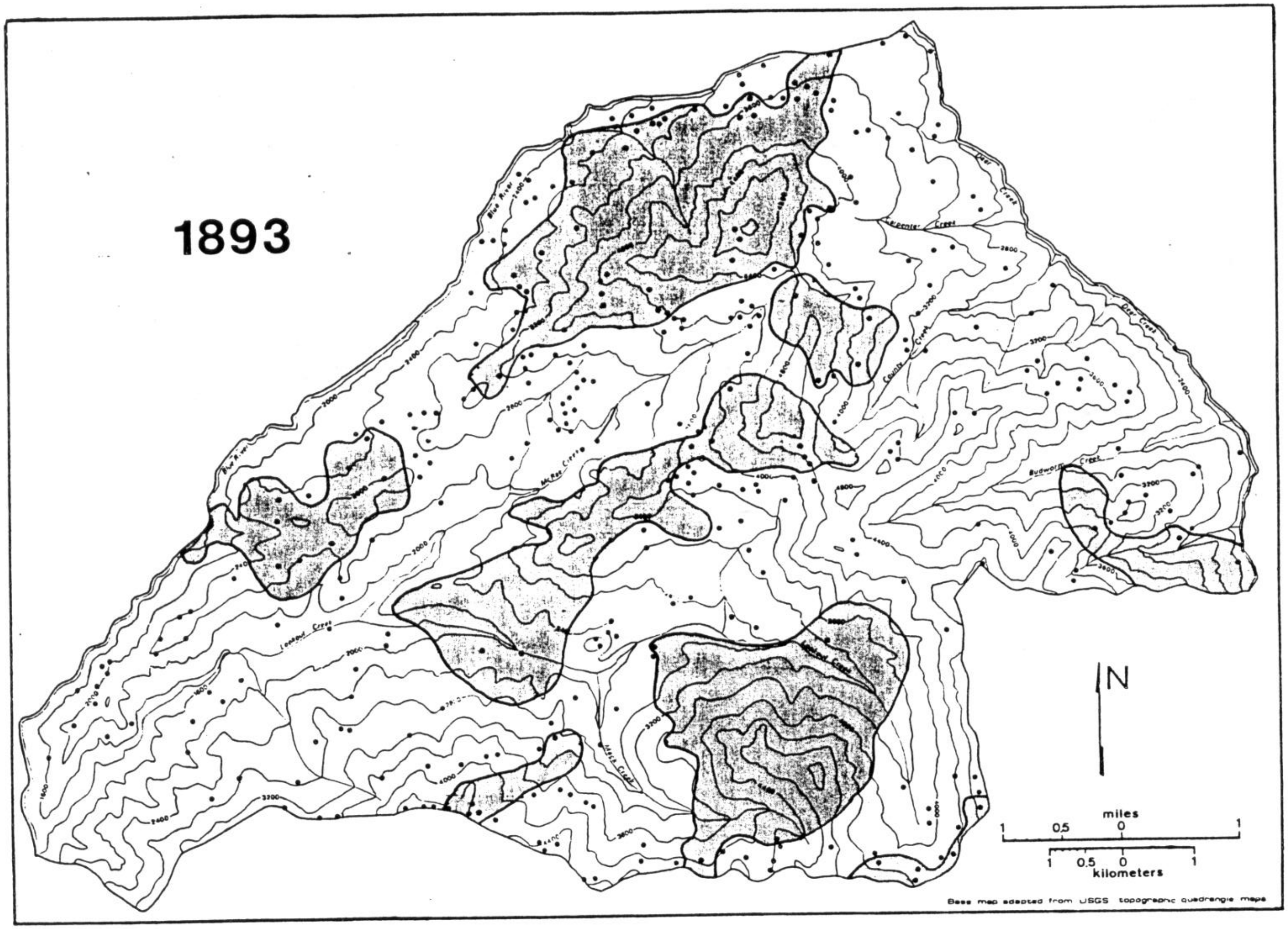


Figure 38. Fire Episode of 1893.

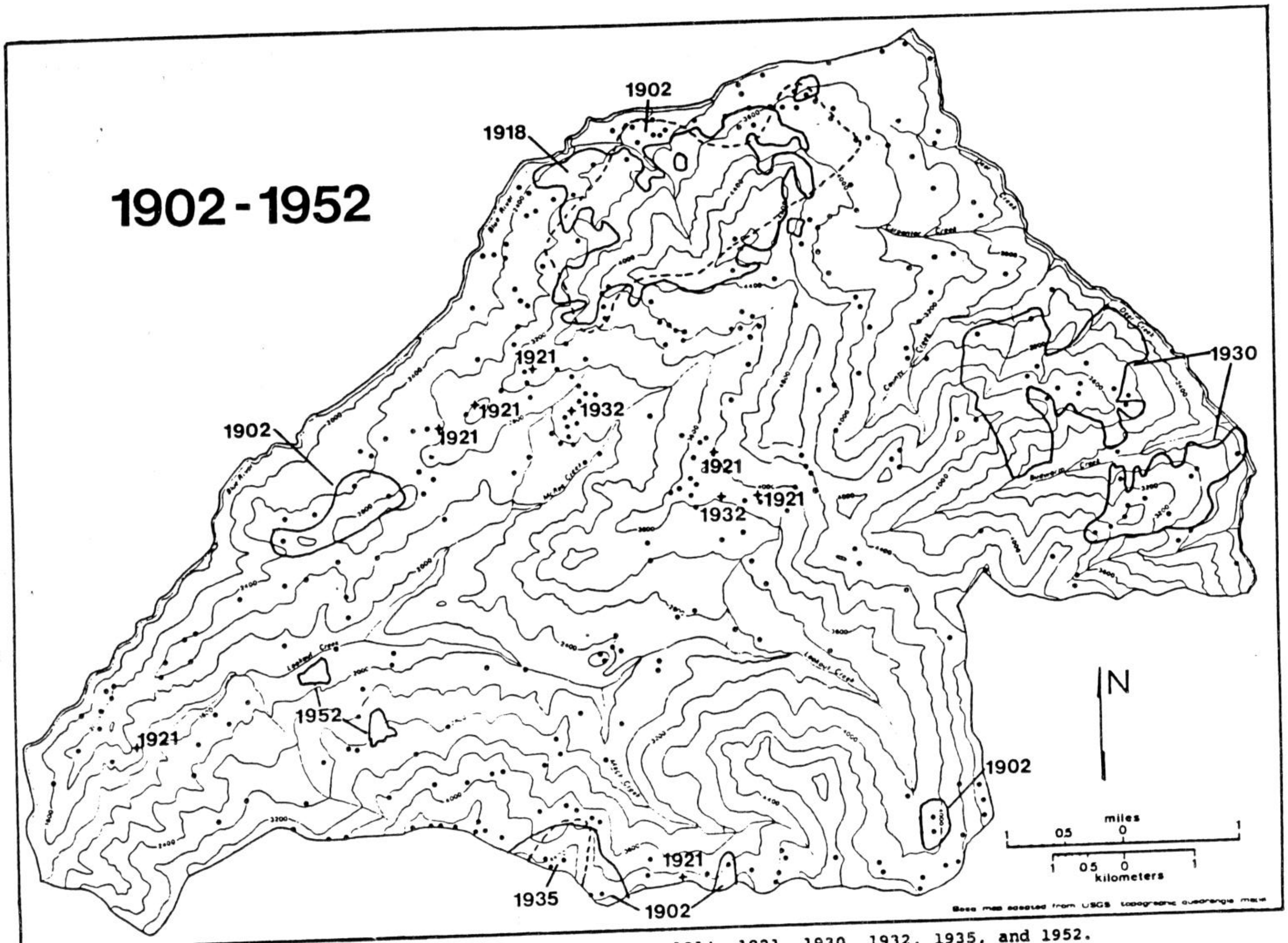


Figure 39. Fire Episodes of 1902, 1907, 1914, 1921, 1930, 1932, 1935, and 1952.

APPENDIX D

CORRECTED MASTER FIRE CHRONOLOGY

Table 35. Corrected Master Fire Chronology.

Note: S = scar date(s) recorded, R = regeneration (origin date(s)) recorded,
SR = both scar date(s) and regeneration recorded, "-" = no record of fire

SITE	OLDE	1435	1482	1532	1551	1566	1591	1623	1663	1692	1717	1747	1757	1764	1780	1796	1801	1809	1813	1820	1830	1836	1839	1849	1857	1868	1876	1885	1893	1902	1907	1914	1921	1930	1932	1935	SITE
1	-	-	-	R	-	-	-	-	R	-	-	S	-	-	-	-	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	1
2	-	-	R	-	-	-	-	SR	S	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	2
3	-	-	R	R	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3
4	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	4
5	-	-	R	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5
6	-	-	R	R	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6
7	-	-	-	-	-	R	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7
8	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	8
9	-	-	R	R	-	R	R	SR	R	-	-	R	-	-	-	-	-	-	-	-	-	-	-	R	S	-	-	-	-	-	-	-	S	-	-	-	9
10	-	-	R	-	-	R	R	-	R	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10
11	-	-	-	-	R	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11
12	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	SR	-	-	-	-	-	-	-	-	-	-	-	12
13	-	-	R	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13
14	-	-	-	R	R	-	-	-	S	-	-	-	-	-	-	-	-	-	SR	-	-	-	-	SR	S	S	-	-	S	-	-	-	-	-	-	-	14
15	1203	-	-	-	R	R	R	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	SR	-	-	-	-	SR	-	-	-	-	-	-	-	15
16	-	-	R	-	R	R	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	16
17	-	-	-	R	-	-	R	-	-	-	-	-	-	-	S	-	-	-	-	S	-	-	R	-	R	-	-	-	-	-	-	-	-	-	-	-	17
18	-	R	R	SR	R	S	SR	-	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	SR	-	-	-	-	-	-	-	-	-	-	-	18
28	-	-	R	SR	R	-	-	S	-	-	-	-	-	-	-	-	-	-	S	-	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	-	28
30	-	-	R	R	-	-	-	-	-	-	-	-	S	-	-	-	-	-	-	SR	-	-	SR	S	-	SR	-	-	S	S	-	-	-	-	-	-	30
31	-	-	R	R	-	S	-	-	-	-	-	-	-	-	-	-	-	-	S	-	-	SR	-	-	S	S	-	-	-	S	-	-	-	-	-	-	31
32	-	-	-	R	-	-	R	-	S	-	S	-	-	-	-	-	-	-	S	-	R	-	-	S	SR	-	-	-	R	-	-	-	-	-	-	-	32
33	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	R	-	-	-	-	-	-	SR	R	-	-	R	-	-	-	-	-	-	-	-	33
34	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	R	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	34
35	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	R	-	R	-	S	-	-	-	-	-	-	-	-	-	-	-	-	35
36	-	-	R	R	-	-	-	-	-	-	-	-	-	-	-	-	S	S	-	-	-	-	S	SR	-	-	-	-	R	-	-	-	-	-	-	-	36
37	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	S	-	-	SR	-	SR	-	-	-	R	-	-	-	-	-	-	-	-	37
38	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	R	-	-	-	-	-	-	-	-	38
39	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	SR	-	-	-	-	-	R	-	-	-	-	-	-	-	S	39
40	-	-	-	R	R	-	-	-	-	-	-	-	-	-	S	SR	-	R	S	-	-	-	-	S	-	-	-	-	S	-	-	-	-	-	-	-	40
41	-	-	R	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	SR	-	-	-	-	-	R	-	-	-	-	-	-	-	-	41
42	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	SR	-	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	42
45	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	R	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	45
46	1276	-	SR	-	-	-	S	R	-	-	S	R	-	-	-	-	-	-	-	-	S	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	46
47	-	-	R	R	-	-	R	-	R	-	-	R	-	-	-	-	-	-	-	-	-	-	-	S	-	-	S	-	-	-	-	-	-	-	-	-	47
48	-	-	-	R	-	-	S	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	48
49	-	R	R	SR	-	S	R	-	-	-	R	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	49
50	-	-	R	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50
51	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	51
52	-	R	-	R	-	-	R	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	52
53	-	-	R	S	R	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-	53
54	-	-	R	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	54
55	-	-	-	-	-	-	-	-	-	-	R	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	55
56	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	56
57	-	R	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	57
58	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	58
59	-	-	-	-	-	R	R	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	59
60	-	-	-	-	R	R	-	-	R	-	-	-	-	-	-	R	-	-	-	S	-	-	-	-	-	-	-	-	-	S	-	-	-	-	-	-	60
61	-	-	R	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	61
62	-	-	R	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	62
63	-	-	-	R	R	R	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	63
64	-	-	R	R	-	R	-	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	64
65	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	65
66	-	R	SR	S	S	-	-	-	-	-	-	-	-	-	-	S	-	-	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	-	66
67	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	67
68	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	R	-	-	-	-	-	-	-	S	-	-	-	-	-	-	68
69	-	R	R	-	-	-	-	S	-	-	S	-	-	S	-	-	-	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	-	69
70	-	-	R	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	70
71	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	R	-	-	-	-	-	-	-	SR	-	-	-	-	S	-	-	-	-	71
72	-	-	R	-	R	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	72
73	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	73
74	-	R	R	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-	-	74

OLDE	1435	1482	1532	1551	1566	1591	1623	1663	1692	1717	1747	1757	1764	1780	1796	1801	1809	1813	1820	1830	1836	1839	1849	1857	1860	1878	1885	1893	1902	1907	1914	1921	1930	1932	1935	SITE
-	-	R	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	75
-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	76
-	-	R	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	77
-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	78
-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	79
-	-	R	-	-	-	-	S	-	-	-	S	-	S	-	-	SR	-	R	-	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-	-	80
-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	81
-	-	R	R	-	-	R	S	-	-	-	-	-	-	S	-	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	82
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	83
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	S	-	-	-	-	-	-	-	-	-	84
-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	85
-	-	R	-	-	-	S	-	-	-	-	S	-	-	-	-	-	-	-	-	-	R	-	SR	-	-	SR	-	-	-	-	-	-	-	-	-	86
-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	S	S	-	-	-	-	-	-	-	-	-	87
-	R	S	S	-	-	R	-	-	-	-	-	-	-	-	-	-	-	R	-	-	R	-	-	S	S	S	-	-	-	-	-	-	-	-	-	88
-	-	R	R	-	-	S	-	S	S	S	-	-	-	-	-	-	-	S	S	-	S	-	-	S	S	S	-	-	-	-	-	-	-	-	-	89
-	R	-	R	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-	-	S	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	90
-	-	R	-	R	-	-	-	R	-	-	-	-	-	-	-	-	-	S	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	91
-	-	R	R	-	-	-	S	-	-	-	-	-	-	-	-	-	-	S	S	S	SR	-	S	SR	-	-	-	-	-	-	-	-	-	-	-	93
-	-	-	R	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	SR	-	-	-	R	-	-	S	-	-	-	-	-	-	-	-	-	94
-	-	R	-	SR	R	-	-	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	95
-	-	-	-	-	R	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	96
-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	97
-	-	-	-	-	-	-	-	-	R	-	SR	-	-	-	-	-	-	R	-	-	-	R	-	-	-	-	-	S	-	-	S	-	-	-	-	98
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	99
-	-	R	R	-	R	R	SR	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	100
-	-	-	-	-	-	-	-	R	-	-	SR	-	-	-	-	-	-	-	-	-	S	-	-	-	-	-	-	S	-	-	-	-	-	-	-	101
-	-	R	R	-	R	-	S	S	-	S	-	R	-	-	-	-	-	-	SR	-	-	-	-	-	-	-	-	S	SR	-	S	-	-	-	-	102
-	-	R	R	-	R	-	-	-	-	-	SR	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-	103
-	-	R	-	-	-	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	104
-	-	R	R	-	-	-	-	S	-	S	-	-	-	-	-	-	-	-	-	-	-	-	S	SR	-	-	-	-	-	-	-	-	-	-	-	105
-	-	R	R	-	SR	-	S	S	-	-	S	S	-	-	-	-	-	-	-	-	S	-	S	-	-	-	-	-	-	-	-	-	-	-	-	106
-	-	R	R	R	-	S	S	-	-	S	S	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	107
-	-	-	-	-	R	-	S	S	-	R	S	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	108
-	-	R	-	-	-	-	SR	-	-	S	-	-	-	-	-	-	-	S	-	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	109
-	-	R	R	-	-	-	S	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	S	-	-	-	-	S	-	-	-	-	-	110
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-	-	-	R	-	SR	-	-	S	-	S	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	113
-	-	-	R	-	R	R	-	-	-	S	S	-	-	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	114
-	-	R	S	-	R	R	-	-	-	-	-	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	115
-	-	-	-	R	R	R	-	-	-	R	-	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	S	-	-	-	116
-	-	R	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	117
1144	-	R	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	118
-	R	R	R	-	-	-	S	S	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	S	-	-	-	-	S	-	-	-	-	-	119
1156	R	-	-	R	-	R	-	-	-	-	-	-	-	-	-	-	-	S	-	-	R	-	R	-	-	-	-	R	-	-	-	-	-	-	-	121
1106	R	S	R	R	-	-	-	-	-	S	S	S	-	-	-	-	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	-	123
-	-	-	R	-	-	-	-	-	-	-	SR	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	124
-	-	-	-	-	-	-	-	R	-	-	SR	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-	125
-	-	R	R	-	-	R	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-	-	126
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-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	SR	-	-	-	-	-	-	-	S	-	-	-	-	131
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-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	R	-	-	-	-	-	-	-	-	-	-	133
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-	-	-	-	-	-	-	-	-	-	SR	-	-	-	R	-	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	137
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-	-	-	-	-	-	-	-	-	-	-	-	-	R	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	S	-	-	139
-	-	-	-	-	-	-	-	-	-	-	-	R	-	R	-	-	-	-	-	-	-	-	-	-	S	-	S	S	-	-	-	-	-	-	-	140

SITE	OLDE	1435	1482	1532	1551	1566	1591	1623	1663	1692	1717	1747	1757	1764	1780	1796	1801	1809	1813	1820	1830	1836	1839	1849	1857	1868	1878	1885	1893	1902	1907	1914	1921	1930	1932	1935	SITE
141	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	141
142	-	-	-	-	-	-	-	-	-	-	R	-	SR	-	-	-	-	-	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	142
143	-	-	-	-	-	-	-	-	-	-	R	-	SR	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	143
144	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	R	-	-	R	-	-	-	-	R	-	S	-	-	-	-	144
145	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	S	-	-	-	-	145
146	-	-	-	R	-	R	-	-	-	-	-	S	-	-	-	-	-	-	S	S	SR	-	-	S	SR	-	-	-	-	-	-	-	-	-	-	-	146
147	-	R	R	S	S	-	-	-	-	-	-	-	-	-	-	-	-	-	S	-	-	S	-	S	-	-	-	-	-	-	-	-	-	-	-	-	147
148	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	S	-	-	SR	-	SR	-	-	-	-	-	-	-	-	-	-	-	-	148
149	-	-	R	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	S	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	149
150	-	-	R	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	R	-	-	S	-	SR	-	-	-	R	-	-	-	-	-	-	-	-	150
151	-	-	R	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	SR	-	-	-	-	-	-	-	151
152	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	S	-	-	-	-	S	S	-	R	-	-	-	-	-	-	152
153	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	R	-	-	R	-	-	-	-	-	-	-	153
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155	-	-	-	R	R	-	R	-	-	-	-	S	-	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	-	S	-	155
156	-	-	-	R	R	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	156
157	-	-	R	SR	SR	R	-	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	157
158	-	-	-	R	-	SR	S	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	158
159	-	R	R	S	SR	S	-	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	S	-	159
160	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	S	-	-	-	-	-	-	160
161	-	-	R	-	-	-	S	S	-	-	-	-	-	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	161
162	-	-	R	-	S	R	SR	SR	-	-	-	-	-	-	S	-	-	-	-	-	-	R	-	-	-	-	-	-	-	SR	-	-	-	-	-	-	162
163	-	-	R	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	SR	R	-	-	-	-	-	-	163
164	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	R	-	-	-	-	164
165	-	-	R	-	R	-	S	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	SR	-	-	-	-	-	-	165
166	-	-	R	R	-	R	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	SR	R	-	S	-	-	-	-	166
167	-	-	R	-	R	-	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	S	-	-	S	-	-	-	-	167
168	1173	-	-	R	-	-	-	-	S	-	-	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	S	-	-	-	-	-	-	168
169	-	-	R	-	-	-	-	-	S	-	-	-	-	-	-	S	-	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	169
170	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-	-	170
171	-	-	R	SR	R	S	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	171
172	-	-	R	S	-	-	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	172
173	-	-	R	-	-	-	-	S	S	-	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	-	SR	S	-	-	-	-	-	-	173
174	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	174
175	-	-	R	R	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	175
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177	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	R	-	-	S	-	-	-	-	-	-	-	-	177
178	-	R	R	SR	-	-	-	-	-	-	-	-	S	S	S	S	-	-	-	-	-	R	-	SR	-	S	-	-	-	-	-	S	-	-	-	-	178
179	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	R	-	-	-	-	-	-	179
180	-	-	R	-	-	-	R	-	SR	-	S	S	SR	-	-	S	-	S	-	-	-	S	SR	-	S	-	-	-	SR	-	-	-	-	-	-	-	180
181	-	-	-	-	-	R	R	-	SR	-	-	S	-	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	181
182	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	182
183	-	-	-	-	-	-	-	-	-	-	-	R	-	-	SR	-	-	-	-	-	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-	-	183
184	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	184
185	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	185
186	1189	-	R	R	-	-	-	S	-	-	-	S	-	-	-	-	-	-	-	-	SR	-	-	SR	-	-	-	S	-	-	-	-	-	-	-	-	186
187	-	-	-	-	R	SR	-	S	-	-	-	S	-	-	-	-	-	-	-	-	-	-	S	SR	-	-	R	-	-	-	-	-	-	-	-	-	187
188	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	R	R	-	S	S	-	-	-	-	-	-	-	-	188
189	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	S	-	-	-	-	-	-	-	-	189
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191	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	S	SR	-	-	-	-	-	-	-	-	191
192	-	-	R	R	S	-	-	S	S	-	-	-	SR	-	S	S	-	S	-	-	-	S	SR	S	-	S	-	S	-	-	-	-	-	-	-	-	192
193	-	-	R	R	-	-	S	S	S	-	R	S	S	SR	S	-	-	-	-	-	-	S	-	S	-	-	-	S	-	S	-	-	-	S	-	-	193
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195	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	195
196	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	SR	-	R	-	S	-	S	-	-	-	-	-	-	196
197	-	-	R	-	-	R	-	S	S	-	S	-	S	-	S	-	-	-	-	-	-	-	R	S	-	S	-	S	-	-	-	-	-	S	-	-	197
206	-	-	-	-	-	-	-	-	-	-	-	-	R	-	S	-	-	-	S	S	S	-	-	-	S	-	-	-	S	-	-	-	-	-	-	-	206
207	-	-	R	R	-	-	-	-	-	-	-	-	S	-	S	-	S	-	-	-	-	SR	-	-	-	S	-	-	-	-	-	-	-	-	-	-	207
208	-	-	-	-	-	-	-	-	-	-	R	-	-	S	S	-	S	-	-	-	-	-	-	R	-	-	-	-	S	S	S	-	-	-	-	-	208
209	-	-	R	R	-	-	S	S	S	-	SR	S	SR	-	S	S	S	S	SR	-	-	SR	-	S	-	-	-	-	-	-	-	-	-	-	-	-	209
210	-	-	-	-	-	-	-	-	-	-	-	R	-	-	S	S	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	210
211	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	211

1435	1482	1532	1551	1566	1591	1623	1663	1692	1717	1747	1757	1764	1780	1796	1801	1809	1813	1820	1830	1836	1839	1849	1857	1868	1878	1885	1893	1902	1907	1914	1921	1930	1932	1935	SITE
R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	SR	-	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	212
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R	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	SR	-	-	-	-	-	-	-	-	-	-	-	-	214
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-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	R	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	438

SITE	OLDE	1435	1482	1532	1551	1566	1591	1623	1663	1692	1717	1747	1757	1764	1780	1796	1801	1809	1813	1820	1830	1836	1839	1849	1857	1868	1878	1885	1893	1902	1907	1914	1921	1930	1932	1935	SITE
439	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	439
440	-	-	R	-	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	440
441	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	441
442	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	SR	-	-	-	S	-	-	-	-	-	-	-	442
443	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	S	-	-	-	443
444	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	444
445	-	-	R	R	R	-	-	-	R	-	-	-	-	-	-	-	-	-	-	S	-	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	445
446	-	R	R	-	-	-	-	S	S	-	-	-	-	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-	446
447	-	-	R	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	S	-	-	-	S	-	-	-	-	-	-	-	447
448	-	R	R	SR	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	S	S	-	-	-	-	-	-	-	-	-	-	-	448
449	-	-	-	R	-	R	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	449
450	-	-	R	S	R	-	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	SR	-	-	-	R	-	-	-	-	-	-	450
451	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	451
452	-	-	R	R	-	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	452
453	-	-	-	R	-	R	R	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	453
454	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	454
455	-	-	-	R	-	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	S	-	-	-	-	-	-	-	455
456	-	R	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	SR	-	-	SR	-	-	-	-	-	-	S	-	-	-	-	-	-	456
457	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	R	-	-	-	-	-	-	-	-	-	-	-	457
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459	-	-	R	R	R	-	-	-	-	-	-	-	-	-	S	S	-	S	-	-	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	-	459
460	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	460
461	-	-	R	R	-	SR	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	461
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469	1146	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	469
470	-	-	R	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	470
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473	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	473
474	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	R	-	-	-	-	-	-	-	-	-	-	-	474
475	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	SR	-	S	-	-	-	-	-	-	-	-	-	-	-	475
477	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	S	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	-	477
479	1167	S	R	-	S	S	SR	-	-	-	S	-	R	-	S	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	479
481	-	-	R	R	-	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-	481
482	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	482
483	-	-	-	-	-	R	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	483
484	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	484
489	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	R	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	-	489
491	-	-	-	R	-	R	-	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	-	491
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499	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	499
500	-	-	R	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	S	S	-	-	-	-	-	-	-	-	-	-	-	-	-	500
503	-	-	R	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	S	R	-	-	-	-	-	-	-	-	-	-	-	-	503
504	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	504
505	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	SR	S	-	-	-	-	-	-	-	-	-	-	-	505
506	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	506
507	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	507
508	-	R	R	-	-	-	-	-	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-	508
509	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	509
510	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	SR	-	-	SR	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	510
512	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-	SR	-	-	-	-	-	-	-	-	-	-	-	-	512
513	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	513
514	-	-	R	R	-	S	-	-	S	-	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	514
515	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	515
516	-	-	-	-	-	-	-	-	R	-	-	SR	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	516
517	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	517
518	-	-	-	-	-	-	R	-	-	-	-	SR	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	518
519	-	-	-	-	-	-	R	-	-	-	-	SR	-	R	-	-	-	S	-	-	-	S	S	-	-	-	-	-	S	-	-	-	-	-	-	-	519
521	-	-	-	-	-	-	-	-	R	-	-	R	-	-	-	R	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	521
523	-	R	SR	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	SR	-	-	SR	-	-	-	-	-	-	-	-	-	-	-	-	523
525	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	525
527	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-	-	527

OLDE	1435	1482	1532	1551	1566	1591	1623	1663	1692	1717	1747	1757	1764	1780	1796	1801	1809	1813	1820	1830	1836	1839	1849	1857	1868	1878	1885	1893	1902	1907	1914	1921	1930	1932	1935	SITE
-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-	528
-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	529
-	-	-	R	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	530
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	R	-	-	-	-	-	-	-	-	-	-	-	531
-	-	R	R	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	S	SR	-	-	-	-	-	-	-	-	-	-	-	532
-	R	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	534
-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-	535
-	R	SR	-	-	-	-	-	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	-	SR	-	-	-	-	-	-	536
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	537
-	-	-	-	-	-	-	-	R	-	-	-	SR	-	-	R	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	538
-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	S	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	539
-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	SR	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	540
-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	S	-	S	S	-	SR	SR	-	-	-	-	-	-	-	-	-	-	-	-	541
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	S	-	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	542
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	R	-	-	-	R	-	-	-	-	-	-	-	-	-	-	543
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	544
-	R	-	R	-	-	-	-	-	-	-	S	-	-	-	-	-	S	SR	-	-	S	-	-	-	S	-	-	-	-	-	-	-	-	-	-	545
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	546
-	-	R	-	-	R	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	S	-	S	-	-	-	-	S	S	-	-	-	-	-	-	547
-	-	-	R	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	548
-	R	R	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	549
-	-	-	-	-	-	-	-	-	-	-	R	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	550
-	-	R	R	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	551
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	552
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-	-	553
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	555
-	-	R	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	S	-	S	-	-	-	-	-	-	-	-	-	-	-	-	556
-	-	R	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	S	-	S	-	-	-	-	-	-	-	-	-	-	-	-	557
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	558
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	R	-	R	-	-	-	-	559
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	560
-	-	R	-	R	-	-	-	S	-	S	-	-	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	SR	-	-	-	-	-	-	-	561
-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-	562
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	R	-	-	-	-	-	-	-	563
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	564
-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	565
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	S	S	-	-	-	-	-	-	-	-	-	-	-	566
-	-	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	567
1116	-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	568
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	569
-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	S	-	R	-	-	-	-	-	-	-	-	-	-	-	-	571
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	S	-	SR	-	-	-	-	-	-	-	-	-	-	-	-	572
-	-	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	573
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	574
-	-	R	R	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	S	-	-	-	-	-	-	-	-	-	-	-	-	-	575
OLDE	1435	1482	1532	1551	1566	1591	1623	1663	1692	1717	1747	1757	1764	1780	1796	1801	1809	1813	1820	1830	1836	1839	1849	1857	1868	1878	1885	1893	1902	1907	1914	1921	1930	1932	1935	SITE

APPENDIX E

INDIVIDUAL SITE MEAN FIRE RETURN INTERVALS

Table 36. Individual Site Mean Fire Return Intervals.*

SITE	ELEV	ASP	#F	#A	#U	FI1	FI2	REC	HABT	UN
1	3250	SW	4	2	2	95	189	378	9	3
2	3300	W	5	2	3	86	214	428	11	3
3	2400	N	3	2	1	143	214	428	5	3
4	2450	S	2	2	0	214	214	428	11	3
5	3150	SE	2	2	0	214	214	428	10	3
6	3300	SW	3	3	0	143	143	428	10	3
7	3400	S	2	2	0	172	172	344	10	3
8	3400	S	2	2	0	180	180	359	10	3
9	3900	S	9	8	2	48	54	428	17	3
10	3600	S	5	5	0	86	86	428	6	3
11	3700	S	2	2	0	180	180	359	9	3
12	3900	SW	3	3	0	143	143	428	9	3
13	1600	B	2	2	0	214	214	428	5	5
14	2500	N	8	4	4	47	95	378	99	4
15	2350	NW	6	6	0	60	60	359	99	4
16	2500	NW	5	4	1	86	107	428	99	4
17	2400	NW	6	4	2	63	95	378	99	4
18	2100	NW	8	6	2	59	79	475	99	4
28	2200	SE	6	3	3	71	143	428	2	3
30	4300	NE	9	5	4	48	86	428	13	3
31	4400	N	8	3	5	54	143	428	13	3
32	4400	E	9	5	4	42	76	378	13	3
33	4500	R	5	5	0	33	33	163	13	3
35	4550	S	4	3	1	29	38	114	13	3
36	4300	NE	7	4	3	61	107	428	13	3
37	4300	N	5	4	2	86	107	428	13	3
41	2900	R	4	4	0	107	107	428	9	5
45	4900	SW	3	3	0	54	54	163	13	3
46	2800	SW	7	3	4	61	143	428	9	3
47	2800	SW	7	5	2	61	86	428	11	3
48	2800	SW	3	2	1	126	189	378	11	3
49	2500	SW	7	5	2	68	95	475	11	3
50	2550	NW	2	1	1	214	428	428	7	5
51	2500	NW	1	1	0	428	428	428	6	5

SITE	ELEV	ASP	#F	#A	#U	FI1	FI2	REC	HABT	UN
52	2800	NW	4	4	0	119	119	475	9	5
53	2100	N	5	2	3	86	214	428	7	5
54	3300	NE	2	2	0	214	214	428	9	5
55	4300	N	2	2	0	97	97	193	13	5
56	2400	NW	1	1	0	378	378	378	5	5
57	1900	N	2	2	0	238	238	475	7	5
58	1850	B	1	1	0	428	428	428	6	5
59	2350	SE	3	3	0	115	115	344	5	3
60	1900	S	6	4	2	60	90	359	2	4
61	1950	NW	2	2	0	214	214	428	5	5
62	1900	NW	2	1	1	214	428	428	5	5
63	1950	NW	4	4	0	95	95	378	4	5
64	1700	NW	4	3	1	107	143	428	5	5
65	2000	NW	1	1	0	428	428	428	99	4
66	1900	NW	6	2	4	79	238	475	99	4
67	4500	NW	2	2	0	51	51	101	16	5
68	4100	NW	3	2	1	32	49	97	14	5
69	3900	N	6	2	4	79	238	475	16	5
70	2700	W	2	1	1	214	428	428	5	5
71	4200	R	3	3	1	51	51	153	16	5
72	3800	N	3	3	0	143	143	428	9	5
73	3850	E	2	1	1	214	428	428	17	5
74	3900	N	4	3	1	119	158	475	16	5
75	3900	NW	3	2	1	143	214	428	16	5
76	3900	N	1	1	0	428	428	428	9	5
77	3600	N	2	1	1	214	428	428	9	5
78	2900	N	1	1	0	428	428	428	9	5
79	2900	N	1	1	0	428	428	428	9	5
80	2600	N	7	3	4	61	143	428	4	5
81	2700	NW	1	1	0	428	428	428	5	5
82	2800	NW	6	3	3	71	143	428	3	5
83	2800	NW	1	1	0	71	71	71	99	4
84	3000	NW	2	1	1	37	74	74	99	4
85	3300	SE	2	2	0	77	77	153	10	3
86	3200	R	6	4	2	71	107	428	99	4
87	3200	R	3	1	2	126	378	378	99	4
88	2700	W	9	4	5	53	119	475	99	4
89	2750	R	12	2	10	36	214	428	99	4
90	2600	SE	5	2	3	95	238	475	9	3
91	2700	E	5	3	2	86	143	428	9	3
93	3100	S	9	4	6	48	107	428	10	3
94	2900	S	5	4	1	76	95	378	11	3
95	2700	SE	4	3	1	107	143	428	5	3
96	2300	SE	2	2	0	172	172	344	4	3
97	2850	NW	1	1	0	428	428	428	99	4
98	4600	S	5	4	2	44	55	218	13	3
99	4900	R	1	1	0	61	61	61	13	3
100	2700	S	5	5	0	86	86	428	9	3

SITE	ELEV	ASP	#F	#A	#U	FI1	FI2	REC	HABT	UN
101	4200	R	4	2	2	62	124	247	13	3
102	3750	S	10	6	5	43	71	428	10	3
103	4000	S	5	4	1	86	107	428	11	3
104	3700	SW	2	1	1	214	428	428	11	3
105	4000	S	6	3	3	71	143	428	11	3
106	3950	SE	9	3	6	48	143	428	16	3
107	3050	W	8	3	5	54	143	428	13	3
108	4000	W	6	2	4	57	172	344	17	3
109	3650	B	5	2	3	86	214	428	15	5
110	3950	W	6	2	4	71	214	428	10	3
111	4650	NE	2	2	0	97	97	193	13	5
112	4750	R	6	4	2	32	48	193	13	3
113	3800	SW	5	2	3	76	189	378	16	3
114	3800	S	6	3	3	63	126	378	17	3
115	3750	S	5	3	2	86	143	428	10	3
116	3650	SW	5	4	2	72	90	359	10	3
117	2400	W	2	2	0	214	214	428	11	3
118	3200	NW	3	3	0	158	158	475	9	5
119	3950	W	8	4	4	59	119	475	10	3
121	2350	SW	7	6	1	68	79	475	99	4
123	4150	S	8	3	5	59	158	475	13	3
124	4500	SE	2	2	0	189	189	378	13	3
125	4450	R	4	2	2	62	124	247	12	3
126	2300	NW	5	3	3	86	143	428	5	5
127	3850	NW	5	2	3	86	214	428	9	3
128	4050	W	4	4	0	107	107	428	9	3
129	4500	N	7	4	3	61	107	428	16	3
130	3950	NW	4	2	2	107	214	428	9	3
131	2850	R	2	2	1	189	189	378	99	4
132	3150	W	7	2	5	54	189	378	99	4
133	2850	W	3	2	1	25	37	74	99	4
134	2700	W	4	2	3	107	214	428	99	4
135	3800	E	2	1	2	77	153	153	99	2
136	3650	R	7	4	4	61	107	428	99	2
137	3650	R	3	2	2	64	97	193	99	2
138	2950	S	3	2	1	49	73	146	99	2
139	2850	E	2	2	1	73	73	146	99	2
140	2350	B	5	2	3	31	77	153	99	2
141	2300	B	2	1	1	77	153	153	99	2
142	3000	N	3	2	1	64	97	193	99	2
143	2600	B	2	2	0	97	97	193	99	2
144	2600	W	4	4	1	23	23	90	99	4
145	2250	NW	1	1	1	74	74	74	99	4
146	2800	W	8	4	4	47	95	378	99	4
147	2700	W	7	2	5	68	238	475	99	4
148	2600	W	4	3	1	107	143	428	99	4
149	2450	NW	4	1	3	107	428	428	99	4
150	2600	W	6	5	2	71	86	428	99	4

SITE	ELEV	ASP	#F	#A	#U	FI1	FI2	REC	HABT	UN
151	3000	W	3	2	1	143	214	428	99	4
152	3200	R	5	2	3	18	45	90	10	3
153	3600	R	3	3	0	25	25	74	10	3
154	3100	S	7	5	2	68	95	475	9	3
155	3000	SW	5	3	3	76	126	378	11	3
156	3000	S	4	2	2	95	189	378	11	3
157	2800	SW	5	4	1	86	107	428	11	3
158	2850	S	4	2	2	95	189	378	11	3
159	2800	W	6	3	4	79	158	475	11	3
160	2850	NW	2	1	1	214	428	428	99	4
161	2750	W	4	1	3	107	428	428	99	4
162	3100	NW	8	6	2	54	71	428	99	4
163	3250	NW	4	4	0	107	107	428	99	4
164	2800	NW	1	2	0	17	9	17	99	4
165	3100	W	5	4	1	86	107	428	99	4
166	3650	NW	6	6	1	71	71	428	99	4
167	3550	N	4	2	3	107	214	428	99	4
168	3700	N	4	1	3	95	378	378	99	4
169	3350	B	4	1	3	107	428	428	99	4
170	3450	NW	2	1	1	214	428	428	99	4
171	3650	N	5	3	2	86	143	428	99	4
172	3350	B	3	1	2	143	428	428	99	4
173	3550	N	6	2	4	71	214	428	99	4
174	3650	N	1	1	0	9	9	9	99	4
175	3750	NE	3	2	1	143	214	428	99	2
176	3750	E	8	2	6	54	214	428	99	2
177	3950	SE	3	2	1	51	77	153	99	2
178	4000	S	10	5	6	48	95	475	99	2
179	3700	N	3	3	0	126	126	378	99	4
180	4400	R	12	6	6	36	71	428	13	3
181	4050	SW	5	3	2	69	115	344	16	3
182	3650	NE	1	1	0	32	32	32	99	2
183	4050	E	3	2	1	54	82	163	99	2
184	3950	SE	1	1	0	130	130	130	99	2
185	3850	E	2	1	1	65	130	130	99	2
186	4150	NE	7	4	4	61	107	428	99	2
187	3350	E	7	4	3	51	90	359	99	2
188	3850	N	5	3	2	14	24	71	99	2
189	3950	R	2	1	1	36	71	71	99	2
190	3650	N	10	3	7	43	143	428	99	2
191	3850	NE	3	2	1	20	31	61	99	2
192	3750	NE	14	4	10	31	107	428	99	2
193	3400	NE	14	4	11	31	107	428	99	2
194	3400	E	6	4	3	26	38	153	99	2
195	3400	N	1	1	1	61	61	61	99	2
196	3000	N	5	3	2	19	32	97	99	2
197	3400	NE	11	3	9	39	143	428	99	2

SITE	ELEV	ASP	#F	#A	#U	FI1	FI2	REC	HABT	UN
207	4350	NW	7	3	4	61	143	428	13	3
208	4400	R	8	2	6	24	97	193	13	3
209	4400	W	15	6	9	29	71	428	13	3
210	4500	W	4	2	2	41	82	163	13	3
211	5050	R	1	1	0	163	163	163	12	3
212	4400	NE	3	2	1	158	238	475	99	2
213	3100	E	1	1	0	344	344	344	99	2
214	3400	N	3	3	0	158	158	475	99	2
215	2950	E	1	1	0	71	71	71	99	2
216	3200	SE	1	1	0	74	74	74	99	2
217	3250	B	2	1	1	51	101	101	99	2
218	3250	E	6	1	5	63	378	378	99	2
219	3150	E	1	1	0	247	247	247	99	2
220	2400	E	1	1	0	344	344	344	5	3
221	2500	B	1	1	0	428	428	428	6	5
222	2950	N	3	3	0	143	143	428	4	5
223	2800	S	5	4	1	86	107	428	11	3
224	2300	W	1	1	0	90	90	90	99	4
225	1800	B	1	1	0	53	53	53	8	5
226	3000	NE	7	4	4	61	107	428	9	5
227	2650	E	4	3	1	107	143	428	9	5
228	2050	B	6	1	5	71	428	428	6	5
229	2500	W	4	1	3	107	428	428	6	5
230	5050	R	2	2	0	77	77	153	12	3
231	5050	R	3	2	1	27	40	80	18	3
232	4100	E	1	1	1	61	61	61	99	2
233	4150	N	6	5	1	71	86	428	99	2
234	4600	E	3	3	0	158	158	475	99	2
236	3250	R	1	1	0	80	80	80	10	3
237	4700	R	2	2	1	57	57	114	12	2
238	4800	W	2	2	0	97	97	193	16	3
239	4650	W	3	3	0	51	51	153	18	3
240	4250	N	2	1	1	77	153	153	99	2
241	3900	NE	4	3	1	86	115	344	99	2
246	2800	N	2	2	1	214	214	428	99	2
247	3250	NE	2	2	0	31	31	61	99	2
384	3000	E	1	1	0	378	378	378	99	2
412	4550	E	2	2	0	65	65	130	99	2
413	4450	SW	6	6	0	71	71	428	99	2
416	4450	SE	3	3	0	115	115	344	99	2
417	3500	SE	1	1	0	153	153	153	99	2
418	3350	NE	1	1	0	114	114	114	99	2
420	1900	B	1	1	0	247	247	247	99	2
423	4350	E	4	5	0	24	19	97	13	5
424	4300	E	1	1	0	42	42	42	16	5
425	4450	R	3	3	0	32	32	97	16	5
426	4300	SW	1	1	0	80	80	80	14	5
427	3950	N	8	5	3	59	95	475	14	5

SITE	ELEV	ASP	#F	#A	#U	FI1	FI2	REC	HABT	UN
428	4100	N	5	1	4	86	428	428	16	5
429	3400	N	1	1	0	428	428	428	9	5
430	3400	NE	4	3	1	107	143	428	9	5
431	3400	NE	1	1	0	428	428	428	16	5
432	3400	NE	2	1	1	214	428	428	16	5
434	4400	R	3	2	1	36	55	109	13	5
435	4450	R	2	2	0	45	45	90	13	5
436	4350	R	1	1	0	90	90	90	13	5
437	4400	R	7	2	6	61	214	428	13	5
438	4500	R	3	3	0	54	54	163	13	5
439	3500	R	1	1	0	90	90	90	13	5
440	3300	R	2	1	1	214	428	428	9	5
441	3350	R	2	1	2	36	71	71	9	5
442	3250	SW	3	2	1	143	214	428	9	3
443	2850	SW	1	1	1	53	53	53	9	3
444	2400	SE	1	1	0	378	378	378	5	3
445	2400	SW	6	4	2	71	107	428	4	3
446	2450	SW	6	2	4	79	238	475	5	3
447	2350	SE	4	2	2	107	214	428	5	3
448	2250	SE	5	3	2	95	158	475	2	3
449	1900	NW	4	2	2	95	189	378	99	4
450	2400	R	6	4	2	71	107	428	1	3
451	2400	W	1	1	0	378	378	378	99	4
452	2450	SE	3	2	1	143	214	428	4	3
453	2300	NW	4	4	0	95	95	378	99	4
454	2650	R	2	2	0	180	180	359	99	4
455	2750	R	4	2	2	95	189	378	5	4
456	2500	SW	5	4	1	95	119	475	99	4
457	1800	W	2	2	0	36	36	71	99	4
458	1600	NW	5	2	3	95	238	475	99	4
459	2100	NW	7	3	4	61	143	428	99	4
460	1550	W	1	1	0	428	428	428	99	4
481	3400	B	4	2	2	107	214	428	99	4
482	3300	NE	1	1	0	344	344	344	99	2
483	3200	NE	2	2	0	172	172	344	99	2
491	2550	B	4	2	2	95	189	378	99	2
497	2000	B	1	1	1	193	193	193	99	2
499	2800	E	2	2	0	51	51	101	99	2
500	3350	E	4	2	2	107	214	428	99	2
503	2800	SE	4	3	1	107	143	428	99	2
504	3300	SE	1	1	0	97	97	97	99	2
505	3400	SE	3	2	1	120	180	359	99	2
506	3400	NE	1	1	0	53	53	53	99	2
507	3600	NE	1	1	0	359	359	359	99	2
508	3800	E	4	2	2	119	238	475	99	2
509	3800	E	2	2	0	49	49	97	99	2
510	3950	E	4	3	1	80	106	319	99	2

SITE	ELEV	ASP	#F	#A	#U	FI1	FI2	REC	HABT	UN
513	4600	E	1	1	0	114	114	114	99	2
514	4400	NE	5	2	3	86	214	428	99	2
515	4200	R	3	2	1	126	189	378	99	2
516	4100	NE	2	2	0	124	124	247	99	2
517	4400	SW	1	1	0	163	163	163	13	2
518	4450	R	2	2	0	160	160	319	13	2
519	4600	R	7	3	4	46	106	319	13	2
521	4100	SE	4	3	1	62	82	247	99	2
523	4050	SE	4	4	0	119	119	475	99	2
525	3900	E	2	2	0	82	82	163	99	2
527	3800	NE	1	1	1	25	25	25	99	2
528	3800	N	2	1	1	214	428	428	99	4
529	3600	NW	1	1	0	428	428	428	99	4
530	2900	SE	2	2	0	189	189	378	99	2
531	3350	E	2	2	0	31	31	61	99	2
532	3450	SE	5	4	1	86	107	428	99	2
534	3400	NW	2	2	0	238	238	475	99	4
535	3100	NW	2	1	1	214	428	428	99	4
536	3000	NW	4	3	1	119	158	475	99	4
537	2750	NW	1	1	0	9	9	9	99	4
538	2700	NW	4	3	1	62	82	247	99	4
539	2250	W	3	1	2	143	428	428	99	4
540	2350	W	2	2	0	214	214	428	99	4
541	2450	W	6	3	3	79	158	475	99	4
542	2700	W	2	1	2	51	101	101	99	4
543	2750	NW	3	3	0	30	30	90	99	4
544	2800	W	1	1	0	97	97	97	99	4
545	2950	W	7	3	4	68	158	475	99	4
546	2600	W	2	2	0	45	45	90	99	4
547	2800	NW	7	2	5	61	214	428	99	4
548	2600	B	2	2	0	189	189	378	11	3
549	2659	B	3	3	0	158	158	475	6	3
550	2700	B	2	2	0	82	82	163	6	3
551	3100	W	3	3	0	143	143	428	11	3
552	2850	S	1	1	0	90	90	90	11	3
553	2950	SW	1	1	1	25	25	25	11	3
555	3000	SW	1	1	0	90	90	90	11	3
556	3000	SW	4	1	3	107	428	428	11	3
557	3000	SW	4	1	3	107	428	428	9	3
558	3300	SE	1	1	0	61	61	61	9	3
559	3250	S	2	3	0	37	25	74	10	3
560	3400	R	1	1	0	74	74	74	10	3
561	3900	R	6	3	3	71	143	428	10	3
562	4100	R	3	1	2	64	193	193	13	3
563	4150	SW	1	1	0	17	17	17	13	3
564	4000	SW	1	1	1	61	61	61	11	3
565	4000	SW	1	1	0	378	378	378	11	3
566	4100	S	2	1	2	31	61	61	11	3

SITE	ELEV	ASP	#F	#A	#U	FI1	FI2	REC	HABT	UN
567	3950	S	1	1	0	359	359	359	17	3
568	4050	SW	1	1	0	378	378	378	16	3
571	3650	W	3	2	1	143	214	428	9	3
572	3800	W	2	1	1	37	74	74	9	3
573	3800	NW	2	1	1	214	428	428	9	3
574	3700	R	1	1	1	74	74	74	9	3
575	3750	S	3	2	1	143	214	428	9	3

*) where:
ELEV = elevation;
ASP = general aspect
N = north, NE = northeast, E = east,
SE = southeast, S = south,
SW = southwest, W = west,
NW = northwest, R = ridgetop, and
B = valley bottom;
#F = number of fires recorded;
#A = number of age-classes;
#U = number of recorded underburns;
FI1 = composite mean fire return interval;
FI2 = stand (or partial stand) replacement mean fire return interval;
REC = length of fire record;
HABT = habitat type, following syntax of Dyrness, Franklin, and Moir (1974) and Zobel et al. (1976), as follows:

number	habitat type	zone
1	PSME/HODI	DOUGLAS-FIR ZONE
2	PSME-TSHE/COCOCA	TRANSITION ZONE
3	TSHE/CACH	
4	TSHE/RHMA-GASH	
5	TSHE/RHMA-BENE	WESTERN HEMLOCK ZONE
6	TSHE/ACCI	
7	TSHE/POMU	
8	TSHE/POMU-OXOR	
9	TSHE-ABAM/RHMA-BENE	
10	TSHE-ABAM/ACCI-BENE	TRANSITION ZONE
11	TSHE-ABAM/LIBO	
12	ABAM/TSME-XETE	
13	ABAM/VAMA-XETE	
14	ABAM/RHMA-XETE	SILVER FIR ZONE
15	ABAM/VAAL-COCA	
16	ABAM/ACTR	
17	ABAM/TIUN	

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