#2324 Swanson

HISTORICAL FIRE REGIMES OF FOUR SITES IN THE BLUE MOUNTAINS, OREGON AND WASHINGTON

FINAL REPORT
December 1996

Emily K. Heyerdahl
James K. Agee

University of Washington
College of Forest Resources
Box 352100
Seattle, WA 98195-2100
(206) 685-2671
heyerdah@u.washington.edu
jagee@u.washington.edu

Ecosystem Science and Conservation Division

College of Forest Resources ◆ University of Washington ◆ Campus Box 352100 ◆ Seattle, Washington 98195-2100

(206) 685-2671 ◆ (206) 543-3254 (fax) ◆ heyerdah@u.washington.edu

January 10, 1997

Fred Swanson
USDA Forest Service
PNW Research Station
3200 SW Jefferson Way
Corvallis, OR 97331

Dear Fred

Here's the fire history report I prepared for the Blue Mountains National Forests. Linda Brubaker and I are currently working it into a form suitable for publication in "Ecoscience" and the article, along with the appendices, will form the first chapter of my dissertation. Any comments you have would be appreciated.

You'll notice that there's no spatially explicit analysis in this report. I decided that was beyond the scope of my dissertation but Dave Wallin has agreed to co-author a paper with me (after I finish my degree) on the spatial aspects of my data. Working with Dave will allow me to learn more about landscape analysis and it will be useful for Dave to become more familiar with fire history in the Blues if we get our USDA NRICGP proposal funded. Did Dave send you a copy of the proposal? If so, what did you think of it?

Thanks again and best wishes,

Emily

Emily K. Heyerdahl

enclosures: "Fire history of ..."

Historical Fire Regimes of Four Sites in the Blue Mountains, Oregon and Washington

Final Report
December 1996

Emily K. Heyerdahl
James K. Agee

University of Washington
College of Forest Resources
Box 352100
Seattle, WA 98195-2100
(206) 685-2671
heyerdah@u.washington.edu
jagee@u.washington.edu

ABSTRACT

We present here tree-ring reconstructions of fire regimes in the Blue Mountains. Four sites were sampled on roughly regular grids. Both dry and mesic forests were sampled at all but one site which had only dry forests. Establishment dates of age classes were used to identify fires in mesic forests and scar dates were used to identify fires in dry forests. Cores or fire-scarred sections were removed from 1,500 trees at 300 plots distributed over 47,000 acres. From the fire-scarred sections, over 4,000 scars were dated. In dry forests, 32 to 65 separate fire years, from 1687 to 1994, were identified at each site. In mesic forests, 4 fire years, from 1750 to 1994, were identified at two sites but fire years could not be distinguished using age classes at the third site. Although dry forests experienced a broad range of annual fire extents (50 to 20,000 acres), most extents were small relative to the size of the sampling site (during half the fire years, less than 24% of sampling area was burned) but large relative to modern classifications of fire size (during half the fire years, at least 1000 acres burned). Although there were no major changes in cumulative fire extent early in the record, dry forests at all four sites experienced a dramatic decrease beginning in the late 1800's. Historical fire regimes at the northern two sites were similar but differed from those of the southern two sites. In dry forests, fire occurred half as frequently at the northern sites as at the southern sites, regardless of dry forest zone. At the northern sites, fire occurred one-fourth as frequently in mesic forests as in dry forests. We found no relationship between topography and fire intervals except at one site where fire was less frequent at higher elevations. Based on the position of scars within annual rings, most historical fires occurred in the late summer or fall although five fires at the southern sites appear to have occurred earlier in the year. Sampling at a landscape scale while retaining within-site variability yields a robust picture of the historical fire regimes in the watersheds we sampled. We did not find a single historical fire regime for the Blue Mountains but rather found differences between fire regimes in dry and mesic forests and between similar dry forest zones at different sites. We speculate that the differences in fire regimes between sites are due to climate and landscape position.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Introduction

Concern over declining forest health in the Blue Mountains, partly due to fire suppression, was one factor prompting the USDA Forest Service to institute a nation-wide policy of ecosystem management (Everett et al. 1994). Designing implementation plans for this policy requires a broad range of social and scientific inputs (Bormann et al. 1994), one critical element of which is quantitative estimates of the range of historical variability of disturbance regimes (Everett et al. 1994, Swanson et al. 1993). Before the turn of this century, the dominant disturbance type in the forests of the Blue Mountains was fire (Smith 1983, Agee 1996). Archival records of fire are not sufficient for estimating the range of historical variability because complete records exist only for the last century (USDA 1990a, b) - a period of great change in fire regimes. Fortunately, tree rings record a multicentury record of fire that can be reconstructed in the Blue Mountains.

Tree rings record several facets of fire regimes: severity, occurrence, extent and, for dry forests, seasonality. Fire severity, the impact of fire on the forest overstory, dictates the record of fire that will be left. A low-severity fire burning near a tree can kill a portion of the cambium without killing the tree itself. This creates a callus within which new vascular cambium forms, leaving a scar that can be dated to the correct calendar year of the fire's occurrence (McBride 1983). In contrast, moderate- and high-severity fires kill patches of trees. This opens growing space for early seral, shade-intolerant species (Oliver and Larson 1990). The establishment date of patches of these early seral trees can be used to estimate the year of fire occurrence (Barrett and Arno 1988, Arno et al. 1993). Dry forests in the Blue Mountains historically experienced frequent low-severity fires, while mesic forests experienced moderate- to high-severity fires. The difference in historical fire severity between the two forest types is clearly evident in the forests of the Blue Mountains. Dry forests contain multiply-scarred trees while those in mesic forests rarely do. In addition, mesic forests are often composed of one to several obvious size classes of early seral species. Annual fire extent can also be reconstructed from tree rings by mapping the locations of sampled trees that have evidence of fire in a given year. Fire extent boundaries are then estimated using the mapped evidence of fire and simple rules based on topography. Finally, the location of a scar within an annual ring indicates fire seasonality (Weaver 1951, Ahlstrand 1982, Barrett 1981, Dieterich and Swetnam 1984). Seasonality can only be estimated for low-severity fires since high-severity fires kill trees.

Beyond archival records, little information on past fire regimes existed for the Blue Mountains prior to this study, particularly information about the areal extent of fire (Agee 1996, Everett et al. 1994, Heyerdahl et al. 1995). Three previous tree-ring reconstructions of fire history were all limited to one or two forest zones and none reconstructed fire extent (Hall 1976, Bork 1984, Maruoka 1994). Our study was designed to reconstruct a multicentury history of fire regimes at a landscape scale, across a range of forest zones in the Blue Mountains using standard methods of dendrochronology. We sampled both dry and mesic forests on a roughly regular grid in four watersheds in order to reconstruct fire extent across a range fire severities. Sampling at this scale yields robust reconstructions of the range of historical variability in fire regimes but also retains within-site variability. We did not reconstruct all facets of fire regimes nor did we reconstruct fire history in all forest types of the Blue Mountains. For example, moderate- and high-severity fires probably occurred in dry forests, however, we did not reconstruct these events. We did not reconstruct the landscape dynamics of forest structure and composition caused by fire. Nor did we explore the influence of climate, other disturbances and land use change on the fire regimes. These will be the subjects of future analyses.

In this paper we present reconstructions of the range of historical variability in fire severity, recurrence, extent, and, for dry forests, seasonality at four sites in the Blue Mountains. We examined within-site variability in these facets of fire regimes and compared them between sites. We also explored the influence of forest zone and topography on fire recurrence, and the influence of geographic location and landscape position on fire regimes.

STUDY AREA

The study area encompasses forests in the eastern portion of the Blue Mountains of northeastern Oregon and southeastern Washington (Figure 1). The Blue Mountains include numerous small mountain ranges and canyons. Elevations range from near sea level to 10,000 feet but most of the Blue Mountains lie between 2000 and 6000 feet. Summers are generally warm and dry and convective lightning storms are common. Average annual precipitation varies from 15 to 30 inches and falls primarily as snow in winter (Johnson and Simon 1987, Johnson and Clausnitzer 1992). The forests of the Blue Mountains have been classified into five potential vegetation zones (from warm/dry to cool/moist): western juniper (*Juniperus occidentalis*), ponderosa pine (*Pinus ponderosa*), Douglas-fir (*Pseudotsuga menziesii*), grand fir (*Abies grandis*) and subalpine fir (*Abies lasiocarpa*; Johnson and Simon 1987, Johnson and Clausnitzer 1992). In the Blue Mountains, dry forests (ponderosa pine, Douglas-fir and dry forests within the grand fir zone) historically experienced low-severity fire regimes while mesic forests (subalpine fir, lodgepole pine and mesic forests within the grand fir zone) historically experienced moderate- to high-severity fire regimes.

The Blue Mountains were inhabited for many centuries by numerous tribes, bands and families of nomadic Native Americans whose economies were based on hunting and gathering (Schwantes 1989, Langston 1995). Their populations declined dramatically after the 1780s due to disease (Schwantes 1989). Euroamericans settled the Blue Mountains beginning in the late 1800s. Although some of the emigrants traveling the Oregon Trail between 1840 and 1860 settled in the Blue Mountains, the population in this area did not increase dramatically until the completion of the transcontinental railroad 1884 (Schwantes 1989, Evans 1990, Robbins and Wolf 1994, Langston 1995). There was a concomitant rise in the numbers of grazing animals with an eight- to ten-fold increase from the 1870s to the 1880s (Irwin et al. 1994). Intensive timber harvesting began in the Blue Mountains in the late 1800s (Robbins and Wolf 1994, Langston 1995).

Four sampling sites were selected with the assistance of the Malheur, Umatilla and Wallowa-Whitman National Forests (Figure 1). All sites include a range of forest zones with minimal tree harvesting. The sites are not replicates of each other with respect to topography or vegetation. The northernmost site straddles the Tucannon River (Umatilla National Forest, Washington; detailed site maps in Appendix A) which flows west-northwest through a canyon with steep, dissected slopes. This site includes both northeast and southwest aspects of the canyon and is the most mesic of the four sites. The dry forests north of the river historically experienced low-severity fires while the more mesic forests south of the river experienced high severity fires. The second site straddles the eastward flowing Imnaha River (Hells Canyon National Recreation Area, Oregon), northeast of Baker City. This site includes relatively undissected slopes to the north and south of the river. As at Tucannon, the dry forests north of the river historically experienced low severity fires while the mesic forests south of the river experienced high severity fires. The third site lies within the watershed for Baker City (Wallowa-Whitman National Forest, Oregon). The sampling site at this location is on the northeastern face of the Elkhorn Mountains. It spans the largest range in elevation of the four sites and the modern vegetation is the most varied and least spatially homogeneous of all the sites. The dry forests on lower elevation, south slopes historically experienced low severity fires while the mesic forests on northern slopes and at higher elevations experienced high severity fires. The southernmost site includes Dugout Creek (Malheur National Forest, Oregon) and covers a west aspect of gentle topography. The entire site lies in dry forest, which historically experienced low severity fires.

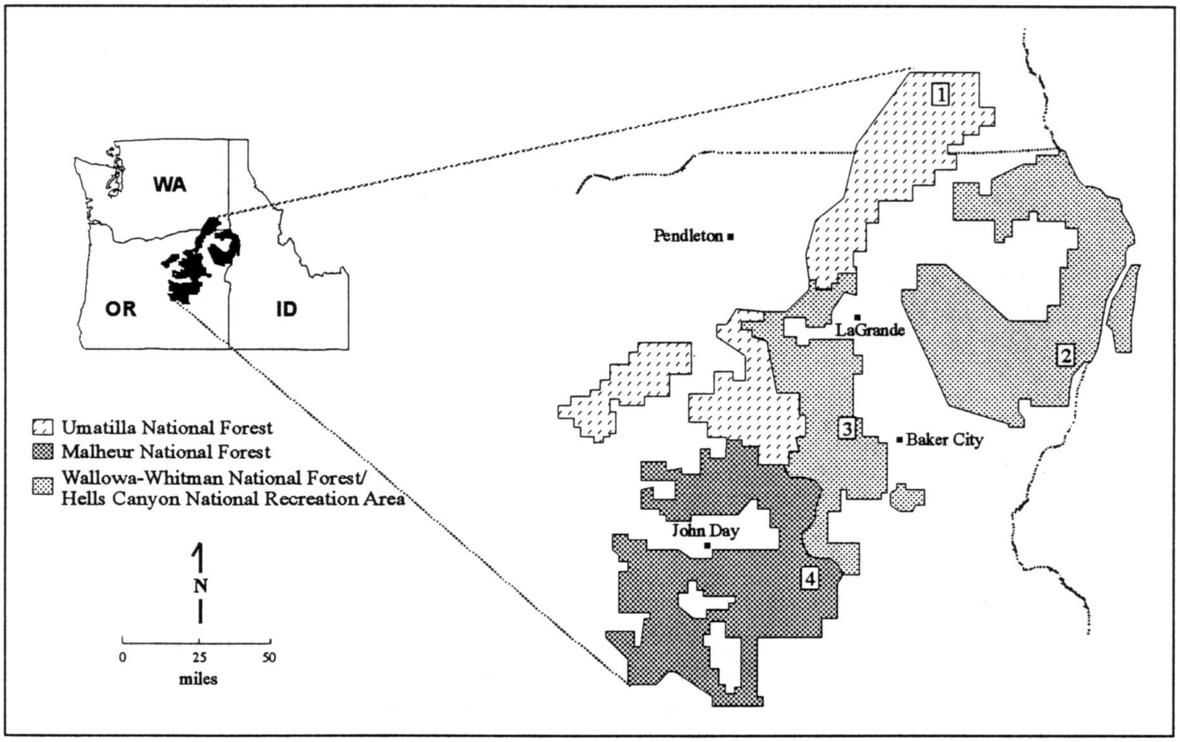


Figure 1. The Blue Mountains of Oregon and Washington, showing the location of the four fire history sampling sites. Site 1 straddles the Tucannon River; 2 straddles the Imnaha River; 3 is within the Baker City Watershed; and 4 includes the Dugout Creek Proposed Research Natural Area.

METHODS

Sampling scheme

Prior to this study, almost no information existed on the historical extent of fires in the Blue Mountains, especially in dry forests. In the absence of such information, we used a two-stage adaptive sampling scheme so that the sampling density could be adjusted during the second stage if our assumptions about historical fire size during the first stage proved incorrect. In the first stage, at each of the four sites, a 4,000 acre area was sampled on a roughly regular grid with one sampling plot (one to two acres) in each 60 acre grid cell (Figure 2). This sampling design allowed detection of fires less than 4,000 acres in extent. Many of the fires reconstructed from the first stage of sampling intersected the boundary of the 4,000 acre areas. Therefore, for the second stage of sampling, we located an additional 10 to 19 plots at a lower density to reconstruct the extent of large fires. The second stage of sampling was conducted only in dry forests.

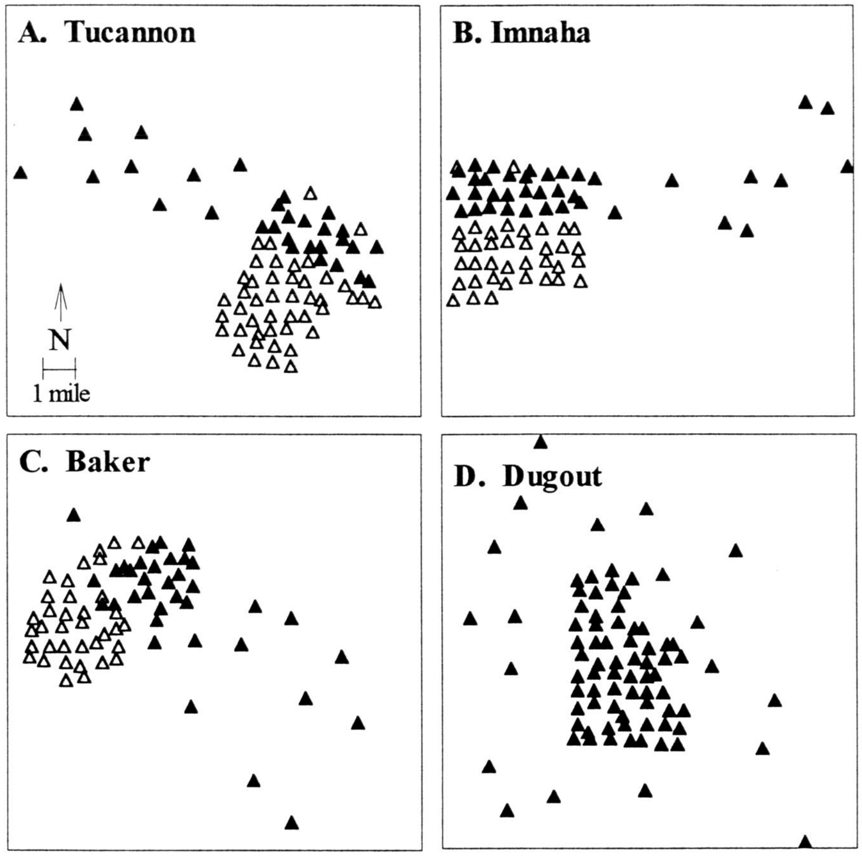


Figure 2. Schematic maps of the four fire history sampling sites showing the location of sampling plots in the 4000 acre densely sampled areas and the additional plots that were placed in dry forests at a lower density to reconstruct the extent of larger fires. Plots sampled in dry (solid triangles) and mesic (hollow triangles) forests are indicated. Detailed site maps are in Appendix A.

Vegetation and topography

At each plot, in addition to evidence of fire (discussed below for dry and mesic forests), we determined vegetation composition and structure using reconnaissance methods (Agee et al. 1990). Each plot was assigned to a plant association, an indication of potential vegetation, according to Johnson and Simon (1987) or Johnson and Clausnitzer (1992) and the dominant overstory tree species at each plot was used as an indicator of current vegetation. The topographic and geographic characteristics of each plot were recorded (slope, aspect, elevation, latitude and longitude) and two photographs were taken.

To evaluate the degree to which the sampled plots represent current vegetation in the Blue Mountains, we compared the distribution of current vegetation at the sampled plots with satellite-derived forest classes in the Blue Mountains (Burgan et al. 1996). We grouped the satellite-derived vegetation into eight categories: ponderosa pine, grand fir, Douglas-fir, lodgepole pine, juniper, spruce/subalpine fir, aspen and whitebark pine. The grand fir category includes both dry and mesic forest types.

To evaluate the degree to which the sampled plots represent the topography of the Blue Mountains, we used elevation, aspect and slope. The topographic characteristics of the Blue Mountains were derived from a digital elevation model (DEM) with approximately 300-foot resolution. Because only forests were sampled for this study and the DEM includes both forested and non-forested areas, we eliminated the land area lying below 2000 feet and above 8000 feet (7% of total land area) since these areas are likely to be non-forested (Johnson and Simon 1987). Aspect was classified into four categories of 90 degrees each (N=0°-45° plus 316°-360°; E=46°-135°; S=136°-225°; and W=226°-315°) and slope was classified into three categories of 33% each.

Collecting and dating evidence of fire

Dry forests

At each plot in dry forests, a chainsaw was used to cut fire-scarred sections from 1 to 8 trees with an average of 3 per plot. The purpose was to obtain the longest, most complete inventory of fires possible. The most complete inventory of fires was obtained by combining the scar record from all the trees sampled at each plot. Low-severity fires are rarely uniform in severity nor are trees uniformly susceptible to scarring (Dieterich 1982). Furthermore, scars may be consumed in subsequent fires or eroded from a tree by weathering. Consequently, a scarred tree may be adjacent to an unscarred tree that experienced the same fire (Agee 1993). Combining the record of fires from several trees within a small area will therefore yield a more complete record of fire. Logs, stumps and snags were sampled when present and well preserved. Live trees were also sampled. Because scars may have eroded from some portions of the bole due to weathering, rot or a subsequent fire, we removed more than one section from 35% of the dead trees sampled. Although all species were examined for fire-scars, most samples were taken from ponderosa pine because, of the species commonly present, ponderosa pine scars most readily and is the least susceptible to rot.

In the laboratory, the fire-scarred sections were sanded until the cell structure was clearly visible. They were then crossdated visually using a binocular microscope and existing master tree-ring width chronologies (Fritts 1976, Cook and Kairiukstis 1990, Yamaguchi 1991, Swetnam et al. 1985, Swetnam 1993a), augmented by statistical crossdating in many cases (Holmes 1983). Samples that did not crossdate were excluded from further analysis. After the rings were crossdated, fire dates were determined by noting the year of the ring in which a fire scar was located (Arno and Sneck 1977, Madany et al. 1982, McBride 1983, Dieterich and Swetnam 1984, Agee 1993).

In addition to scars, we noted other evidence of fire. Radial growth after fire depends in part on the extent to which the fire damaged the tree and how it affected the tree's environment. Several studies of ponderosa pine, conducted mostly in the Pacific Northwest, found that radial growth can increase or decrease after low-severity fire (Morris and Mowat 1958, Van Sickle and Hickman 1959, Weaver 1967, Landsberg et al. 1984, Sutherland et al. 1991). These studies contend that fire may kill competing trees or release nutrients, resulting in the increased radial growth observed for the survivors. Conversely, damage to roots or other portions of the tree was speculated to result in decreased radial growth. Therefore, the beginning year of sharp increases or decreases in ring width was recorded as potential evidence of fire. This evidence was used to reconstruct fire if it was spatially and temporally consistent with fire locations and dates derived from scars.

Trees with a portion of their bole not covered by bark, due to an existing fire scar, are more likely to record subsequent fires because the bark at the edge of the previous scar is thin (Gill 1974, Romme 1982). To identify the periods when trees are more susceptible to scarring, we define *recorder* years as those years after first scarring and *null* years as those before first scarring (Grissino-Mayer 1995).

Mesic forests

For plots in mesic forests, we identified *age* classes by visually determining the *size* classes of early seral species (western larch (*Larix occidentalis*) and lodgepole pine (*Pinus contorta*)). Within each size class, increment cores were removed from the largest diameter trees for a total of 5 to 10 trees at each plot. We targeted the largest trees within each size class for several reasons. First, these trees may have established sooner after disturbance than smaller trees. Second, these trees may have had greater early height growth and therefore fewer rings are missed by coring above the root collar. Cores were taken as close to the ground as possible and the coring height recorded (average height: 9 inches). Trees were cored throughout each plot to avoid reconstructing small scale gap-forming events. We sampled only in continuous forest.

The increment cores were mounted on wooden holders and sanded until the cell structure was clearly visible (Stokes and Smiley 1968). The cores were crossdated visually using a binocular microscope, augmented by statistical crossdating for some samples (Holmes 1983, Yamaguchi 1991). For cores that did not intersect the pith (60% of all cores), the establishment date was corrected by an estimated number of rings to the pith (Applequist 1958, Earle 1993). An additional correction was made for the number of years necessary for the tree to reach coring height. Based on previous work in the Blue Mountains (Maruoka 1994), we subtracted one year for every two inches between the base of the tree and the coring height.

Although scars yield *exact* calendar dates for fires, establishment dates are only *estimates* for fire dates. In part, this is because trees establish in fire-created openings over a period of years so age classes include trees with a range of ages (Oliver and Larson 1990). To accommodate the range in ages of trees that established after a fire, we used a two-stage statistical process to identify age classes (Duncan and Stewart 1991) for each site that had mesic forests (Baker, Imnaha and Tucannon). The first stage used spatial autocorrelation to test for the potential presence of similarly-aged patches of trees at each site (Legendre and Fortin 1989). When the results of spatial autocorrelation indicated the presence of similarly-aged patches, we performed the second stage of the analysis: identifying the geographical location and extent of the patches. This was done using hierarchical agglomerative clustering (MathSoft 1995). For clustering, we used a matrix of dissimilarity indices that incorporates both distance between trees and difference between tree ages. A more detailed discussion of this analysis is given in Appendix B. The earliest establishment date was assigned as the fire date for each of the age classes identified through the two-stage statistical process. However, when the age class was coincident with a large low-severity fire in an adjacent area of dry forest, the date of the low-severity fire was assigned as the fire date in the mesic forest.

Fire extent

Annual fire extent is the area burned by all reconstructed fires during a given year. We determined annual fire extent by mapping plot locations and evidence of fire on topographic maps and using simple rules to subjectively draw fire boundaries for every year in which there was evidence of fire. Although we used these *subjectively* determined fire extents in all subsequent analyses, we also determined fire extent *objectively* for comparison.

Subjective determination of fire extent

A geographic information system (GIS) was used to determine the extent of annual area burned. For every year with evidence of fire (fire scars or age classes), all sample plots were mapped. Fire boundaries were placed approximately halfway between plots with and without evidence of fire for a given year. If a major stream was between a plot with evidence of fire and the fire boundary, the fire boundary was adjusted to lie along the major stream. Because low-severity fires are often patchy in severity, areas that did not burn or that burned with very low severity can be surrounded by forest that did burn. Therefore, plots lacking evidence of fire were included within fire boundaries if they were surrounded by plots that did have evidence of fire in that year (e.g., Dugout fire year 1794). Plots with no recording trees for that year were treated as not sampled. Fire boundaries were not extended beyond the edges of the sampling sites. If plots with evidence of fire were separated by many plots without evidence of fire, multiple fire boundaries were drawn. Fire is not the only agent that scars trees; mammals, insects, and physical impacts can also cause basal scars (Molnar and McMinn 1960; Lawrence et al. 1961, Swetnam 1984, Gara et al. 1986, Thomas and Agee 1986), however, it is the only agent which is likely to repeatedly scar many trees simultaneously. Therefore, to exclude scars that may not have been caused by fire, we only mapped years in which two or more trees were scarred. Annual area burned at each site, was computed by the GIS as the area within the fire boundary (or boundaries) for each fire year.

Objective determination of fire extent

For comparison with the subjective determination, fire extent was also determined objectively by computing Voronoi (Thiessen) polygons and convex hulls. The location of sampled plots and evidence of fire was used to determine fire extent for every fire year at each site by the program SPANFIRE (Swetnam and Holmes 1994). To compute fire extent with Voronoi polygons, each site was divided into polygons, each of which contains only one of the sampling plots. These polygons completely cover the site and do not overlap spatially (Mark 1987). The sides of each polygon lie halfway between the sampling plot and each of its nearest neighbor plots. Fire extent was determined for every fire year by summing the area of all polygons that contain evidence of fire in that year. Plots lacking trees with recorder years for a given fire year were considered unsampled for that year. Polygon boundaries were re-determined to account for changing sample size through time. Convex hulls determine fire extent using a single polygon rather than dividing the entire site into multiple polygons. Fire extent for a given year is the area of the smallest convex polygon containing all the sampling plots that have evidence of fire in that year (Sedgewick 1988). Although Voronoi polygons can be identified for any number of plots, identification of a convex hull requires at least three plots with evidence of fire so the extent of the smallest fires could not be determined using convex hulls. The pixel size for both methods, a measure of the spatial resolution used by SPANFIRE, was approximately 25 acres.

Cumulative fire extent

To investigate potential changes in fire extent through time, we computed cumulative fire extent and fit a linear regression model using ordinary least squares. Cumulative fire extent was the dependent variable and year was the independent variable. A straight line will fit the data well if annual area burned has been constant through time.

Fire rotation

We computed fire rotation to compare fire regimes between sites and between dry and mesic forests. Fire rotation is the length of time necessary for an area equal in size to that of the sampling site to burn (Heinselman 1973, Romme 1982). Although fire rotation has generally been computed only for high-severity fires in mesic forests, it has recently been calculated for low-severity fires in dry forests (Agee et al. 1990, Agee 1991, Wright 1996). Fire rotation is comparable between sites because it incorporates sampling area size. For this study, we computed the fire rotation separately for dry and mesic forests at each site for the period common to both forest types and before major changes in low-severity fire regimes (1750-1900):

$$\text{fire rotation (years)} = \frac{\text{total time period (years)}}{\text{proportion of area burned during the time period}}$$

Although fire rotation has the advantage of being comparable between sites of different sizes, it does not preserve spatial variability in fire intervals across a sampling site. Some parts of the sampling site may have burned numerous times during the period of interest while other parts may not have burned at all.

Fire recurrence

Fire recurrence, the aperiodic repeated occurrence of fires, was characterized in two ways: fire intervals and number of fires. A fire interval is the period, in years, between two successive fires. We computed fire intervals for dry forests but were unable to compute fire intervals for many mesic forest plots because these plots experienced only a single fire. Therefore, to compare mesic and dry forests, we also computed the number of fires that occurred during a time period that was common to the sites and forest types being compared.

Fire intervals in dry forests

Fire interval is dependent on the size of the area under consideration (Romme 1982). Therefore, we computed fire intervals for individual plots so that the area for each fire interval calculation was the same (one to two acres). Computing fire intervals for individual plots also preserves variability in fire intervals across a sampling site that may result from differences in topography or vegetation. A plot was considered to have experienced a fire if there was evidence of that fire (scars and/or changes in ring width) but not if it was within a fire boundary but did not have evidence of fire. The fire intervals were sorted by site. We tested for differences in fire intervals among the four sites using a nonparametric analysis of variance by ranks (Kruskal-Wallis test; Zar 1984). The null hypothesis, no difference in fire intervals among the sites, was rejected if the test statistic (H) was significant ($p<0.01$). Following the Kruskal-Wallis test, we performed nonparametric multiple comparisons by ranks (Dunn test, Zar 1984) to identify homogeneous groups of sites, those that have no difference in fire intervals. The Dunn test accommodates unequal numbers of plots among the four sites.

Influence of topography on fire intervals in dry forests

If there is a relationship between fire recurrence and topography, the results of this study could be extrapolated to other sites with similar topography in the Blue Mountains. We assessed the influence of topography on fire intervals in dry forests using nonparametric (Spearman rank) correlation of the median fire interval at each plot with the slope, aspect and elevation of that plot. We classified aspect into eight categories of 45 degrees each, beginning at 23° (NE, E, SE, S, SW, W, NW, N). Elevation and slope were included as continuous variables. Because the sample distribution of intervals is skewed (Appendix H), we used *median* fire interval as a better measure of central tendency than *mean* fire interval.

Number of fires in mesic and dry forests

Fires in mesic forests were reconstructed at Tucannon and Imnaha from 1750 to the present. Therefore, we computed the number of fires at individual sampling plots for the period 1750 to 1900. All the plots from both sampling sites were sorted into one of five forest zones based on plant association. We used two dry forest zones (dry grand fir and Douglas-fir plus ponderosa pine) and three mesic forest zones (subalpine fir, lodgepole pine and mesic grand fir). We combined Douglas-fir and ponderosa pine to ensure an adequate sample size. To test for differences in the number of fires between forest zones, we used nonparametric analysis of variance followed by nonparametric multiple comparisons, as described above.

Fires in dry forests were reconstructed at all four sampling sites so we performed a similar analysis for dry forest zones only, over the same time period. The number of fires at individual sampling plots was computed and the plots from each site were assigned to one of two dry forest zones (dry grand fir or Douglas-fir plus ponderosa pine). We tested for differences in the number of fires in forest zones and sites using nonparametric analysis of variance followed by nonparametric multiple comparisons, as described above.

Fire seasonality

The position of a fire scar within an annual ring provides an indication of the time of year during which a low-severity fire burned (Weaver 1951, Ahlstrand 1982, Barrett 1981, Dieterich and Swetnam 1984). For this study, scars were assigned to one of five categories: early, middle and late earlywood; latewood; and dormant (i.e., on the boundary between two rings). Scars in the earlywood portion of a ring were caused by fires that burned early in the radial growth season, while dormant scars were caused by fires that burned sometime after the cessation of radial growth during the year prior to the scar but before the onset of radial growth during the year following the scar. This dormant period spans two calendar years: radial growth ceases in the summer or early fall and resumes again in the late spring of the following calendar year in the Pacific Northwest (Wright 1996). For this study, dormant scars were assigned to the *preceding* calendar year because most modern fires in the Pacific Northwest occur in the summer or fall (Agee 1993) and there is no paleoclimatic evidence for changes in the seasonal timing of precipitation over the last few hundred years (Graumlich 1985). However, several fires had numerous earlywood scars, indicating that the fire occurred early in the radial growing season. For these fires, the dormant scars were assigned to the same year, i.e., the *following* calendar year, assuming that the fire occurred at the beginning of the fire season. The placement of scars is not always visible because ring widths are often narrow, especially in the vicinity of fire scars, and scars can be obscured by insect galleries.

Assigning calendar months to the position of scars within annual rings requires documentation of the annual timing of radial growth, including the spatially and temporally variable influence of climate. No such information currently exists for the Blue Mountains. However, in the eastern Cascades of Washington, scars in the earlywood probably burned in the spring or early summer while scars on the boundary between two rings probably burned during the late summer or fall (Wright 1996). We have no record of the seasonality of fire in mesic forests because they historically experienced moderate to high-severity fires that killed trees.

RESULTS

Vegetation and topography

At each of the four sites, we sampled a range of forest zones (potential vegetation; Figure 3). Within these forest zones, we sampled 30 different plant associations, 14 in dry forest types and 16 in mesic forest types (Johnson and Simon 1987; Johnson and Clausnizer 1992; Appendix A). As expected, the topographic characteristics of the sites are reflected in the vegetation types that were sampled. Most of the Dugout site is a low elevation, western slope, covered by dry forests (ponderosa pine and Douglas-fir). The other three sites all have more complex topography and also have a greater range in forest zones. Baker has the greatest range of elevation of the four sites and the greatest percentage of plots in subalpine forest types (subalpine fir and lodgepole pine).

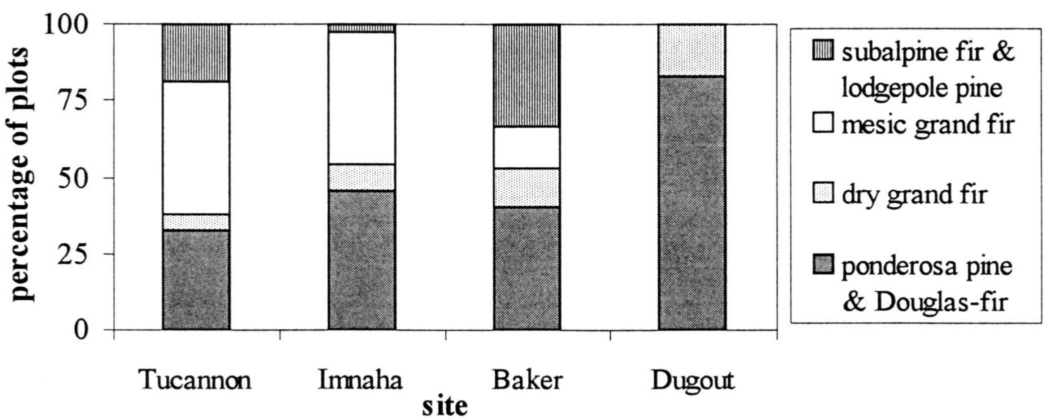


Figure 3. Distribution of sampling plots by forest zones (potential vegetation) and site. The subalpine fir, lodgepole pine and mesic grand fir zones are found in mesic forests. The dry grand fir, ponderosa pine and Douglas-fir zones are found in dry forests.

With several exceptions, the distribution of the vegetation and topography of the sampling plots is representative of Blue Mountains forests (Figure 4). We oversampled ponderosa pine, grand fir and subalpine forests and undersampled Douglas-fir and juniper. We also oversampled mid-elevations (4000-6000 feet), north and south aspects, and moderate slopes (33-66%).

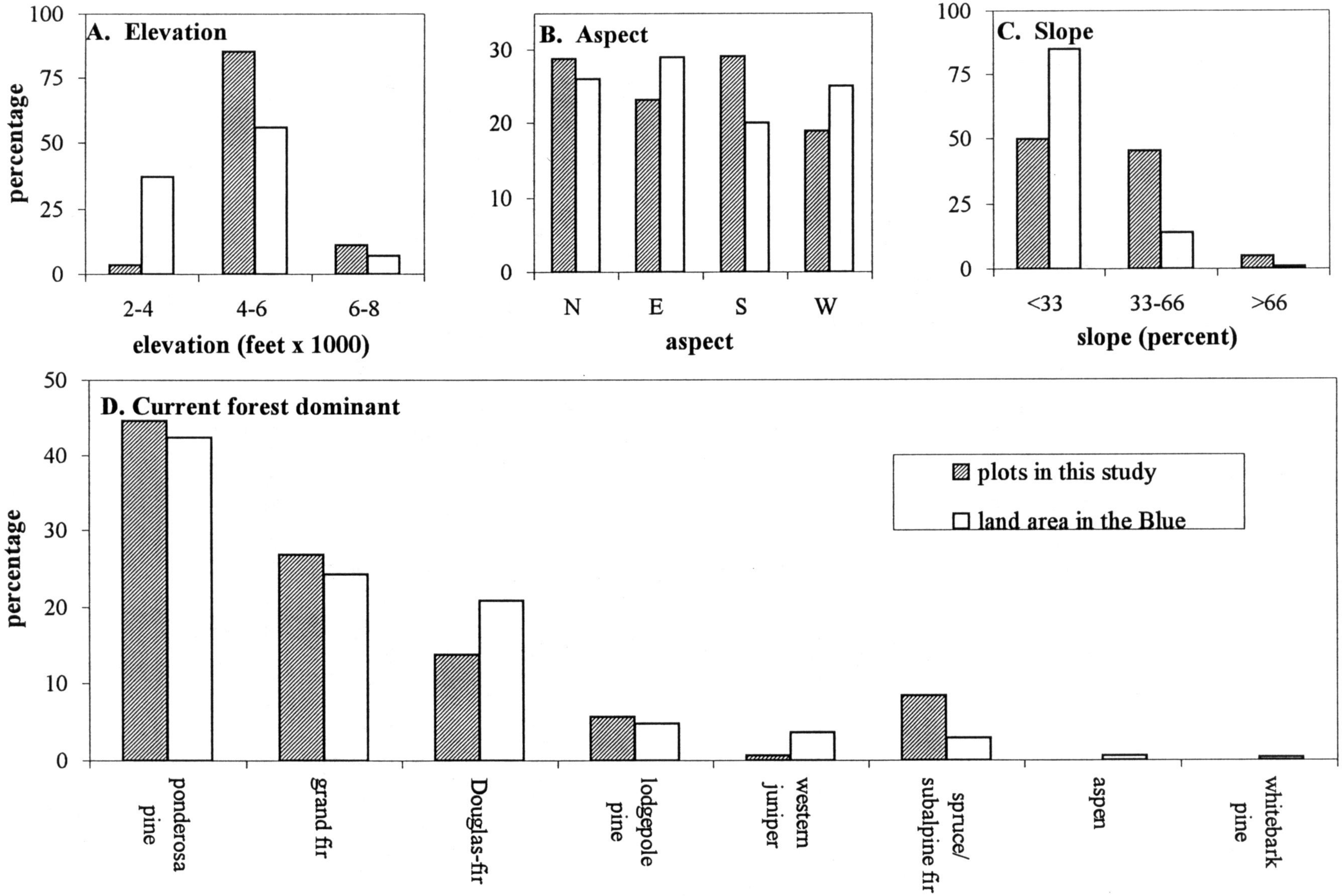


Figure 4. Distribution of topography and vegetation for sampling plots and for the Blue Mountains. Percentage land area in the Blue Mountains was derived from a 300 foot resolution digital elevation model. For aspect, N is 0°-45° plus 316°-360°; E is 46°-135°; S is 136°-225°; and W is 226°-315°. Current forest dominant for the Blue Mountains was derived from satellite data with approximately 0.5 mile resolution.

Evidence of fire

Across four study sites covering nearly 47,000 acres, we sampled just over three hundred plots (Table 1). The dense sampling area at each site covers approximately 4,000 acres and is split between mesic and dry forests for all sites except Dugout, which has only dry forest. We augmented the size of the sampling areas in dry forests at all sites by sampling an additional 10 to 19 plots. This increased the size of each site to between roughly 7,000 and 20,000 acres. The difference in historical fire severity between dry and mesic forests was clearly evident in the field. Plots in dry forests contained multiply-scarred trees while those in mesic forests rarely did. In addition, plots in mesic forests were composed of one to several obvious age classes of early seral species. Only 2% of the plots we sampled had both fire-scarred trees and trees of early seral species in obvious age classes.

Table 1. Size of sampling areas and number of plots sampled.

	Area (ac)			Number of plots sampled		
Site	Mesic forests	Dry forests	Total	Mesic forests	Dry forests	Total
Tucannon	2,254	4,946	7,200	46	28	74
Imnaha	2,124	5,176	7,300	40	34	74
Baker	1,577	9,419	10,996	37	36	73
Dugout	0	21,213	21,213	0	82	82
Total	5,955	40,754	46,709	123	180	303

Nearly 1,500 trees were sampled at the four sites, two-thirds of which were cored to identify age classes in mesic forests and one-third from which fire-scarred sections were removed in dry forests (Table 2). All trees cored for age were alive; of these, cores from 49 trees did not crossdate and were excluded from further analysis. Of the trees from which fire-scarred sections were removed, 55% were dead when sampled (i.e., stumps, logs, or short snags). From the fire-scarred sections, we dated over 4,000 scars plus several hundred sharp increases and decreases in ring width that were potentially caused by fire. The fire-scarred sections from 21 trees did not crossdate and were excluded from further analysis. In addition to the samples collected for this study, we crossdated four fire-scarred sections collected for a previous study in the Blue Mountains (Maruoka 1994). All four sections were sampled within a 60 ac area at the Imnaha site. These data are included in our analysis as Imnaha plot number 9.

Table 2. Amount of evidence collected to reconstruct fire history.

	Mesic forests	Dry forests		
Site	Cored trees	Fire-scarred trees	Fire scars	Potential evidence
Tucannon	334	86	382	21
Imnaha	282	109	517	48
Baker	286	114	1,258	88
Dugout	0	215	2,156	124
Total	902	524	4,313	281

Period of record and period of reliability (1687-1994)

Trees provide a limited temporal window through which we can observe historical fire regimes. Because fire regimes can change through time (e.g., Swetnam 1993b), it is important to identify the temporal window available by noting how the number of trees changes through time. In dry forests, the number of trees changes through time for several reasons. First, sample size decreases with increasing age of trees because they have limited life spans. Second, sample size for dry forests decreases with decreasing tree age because we sampled dead trees.

At all four sites, we found some scars in the 1500s. Although we have a tree-ring record that is over 500 years long in the dry forests at every site (Table 3, Figure 5), only a small number of trees were alive during the earliest years of this record. Because we cannot obtain a clear picture of historical fire regimes from only a few trees, we selected a period during which at least 30% of the plots were recording (i.e., had trees that had been previously scarred) as the period for which we could reliably reconstruct fire regimes. This yielded periods of reliability greater than 300 years at each site (Table 3). The period of reliability for fire regimes that is common to dry forests at all four sites is 1687 to 1994. For mesic forests, the period of reliability during which we can reconstruct fire regimes is shorter than that for dry forests. We found only a small number of trees in mesic forests that established before 1700 (Figure 5). We reconstructed fires from the mid-1700's to the present. Other trees that may have established before this time, were probably killed by moderate to high severity fires over the last several hundred years.

For all subsequent analyses in mesic forests, we used the period 1750 to 1900. For dry forests, the period 1687 to 1900 was generally used, except for comparison of dry forests to mesic forests, in which case the common period of 1750 to 1900 was used.

Table 3. Period of reliability for dry forests by site. Begin and end years are dates of first and last rings found at each site and the period of reliability is the span of time during which at least 30% of dry forest plots were recording.

	Begin	End	Period of reliability		
Site	Year	Year	Begin	End	Length (yr)
Tucannon	1487	1994	1639	1994	355
Imnaha	1480	1994	1687	1994	307
Baker	1403	1994	1646	1994	348
Dugout	1346	1994	1629	1994	365

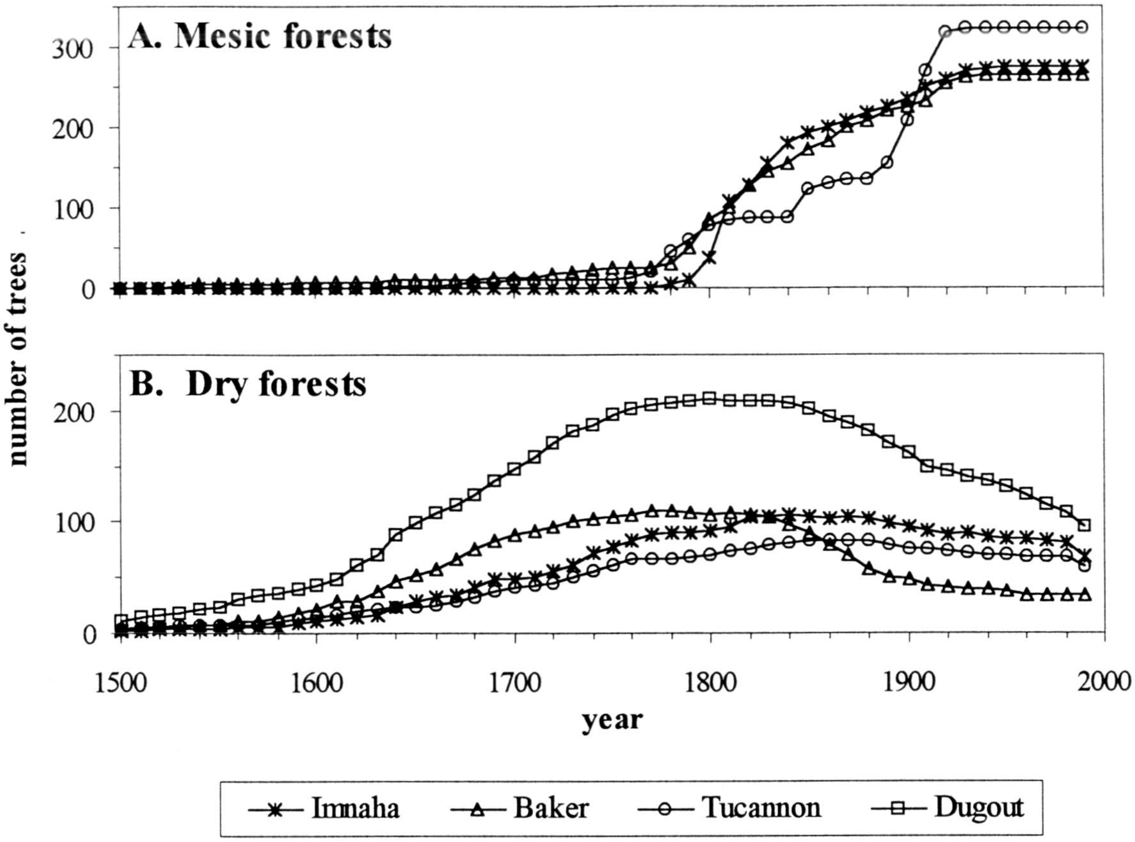


Figure 5. Sample size for mesic and dry forests, by year. Sample size is the number of trees with rings for a given year.

Fire dates

Dry forests

During the 307 year period of reliability, we reconstructed 121 years in which low severity fires burned in dry forests at one or more of the four sampling sites. Between 32 and 65 separate fire years were identified at each of the four sites (Appendix C). Almost all scars were assigned to a fire (98%). Fire charts, which display the composite record of scars and potential evidence of fire at each plot through time, simultaneously show many spatial and temporal features of the fire regimes that were reconstructed. These charts include both scars that were used to reconstruct fires and those few scars that were not used. Fire occurred less frequently at the northern sites, Tucannon and Imnaha (Figure 6), than at the southern sites (Figure 7), Baker and Dugout. The southern sites, which have a higher fire frequency, also have a longer record for most plots. All four sites had a dramatic decrease in fire occurrence after the late 1800's. A few scars occurred after this time (1% of total scars), particularly at Tucannon, but no large fires occurred at any of the sites. All sites also show a range in the number of plots that were scarred in the same year, indicating a range in annual fire extent. Years with large fire extents have many plots with evidence of fire (e.g., Dugout fire year 1829) while years with small fire extents have only a few plots with evidence (e.g., Dugout fire year 1812).

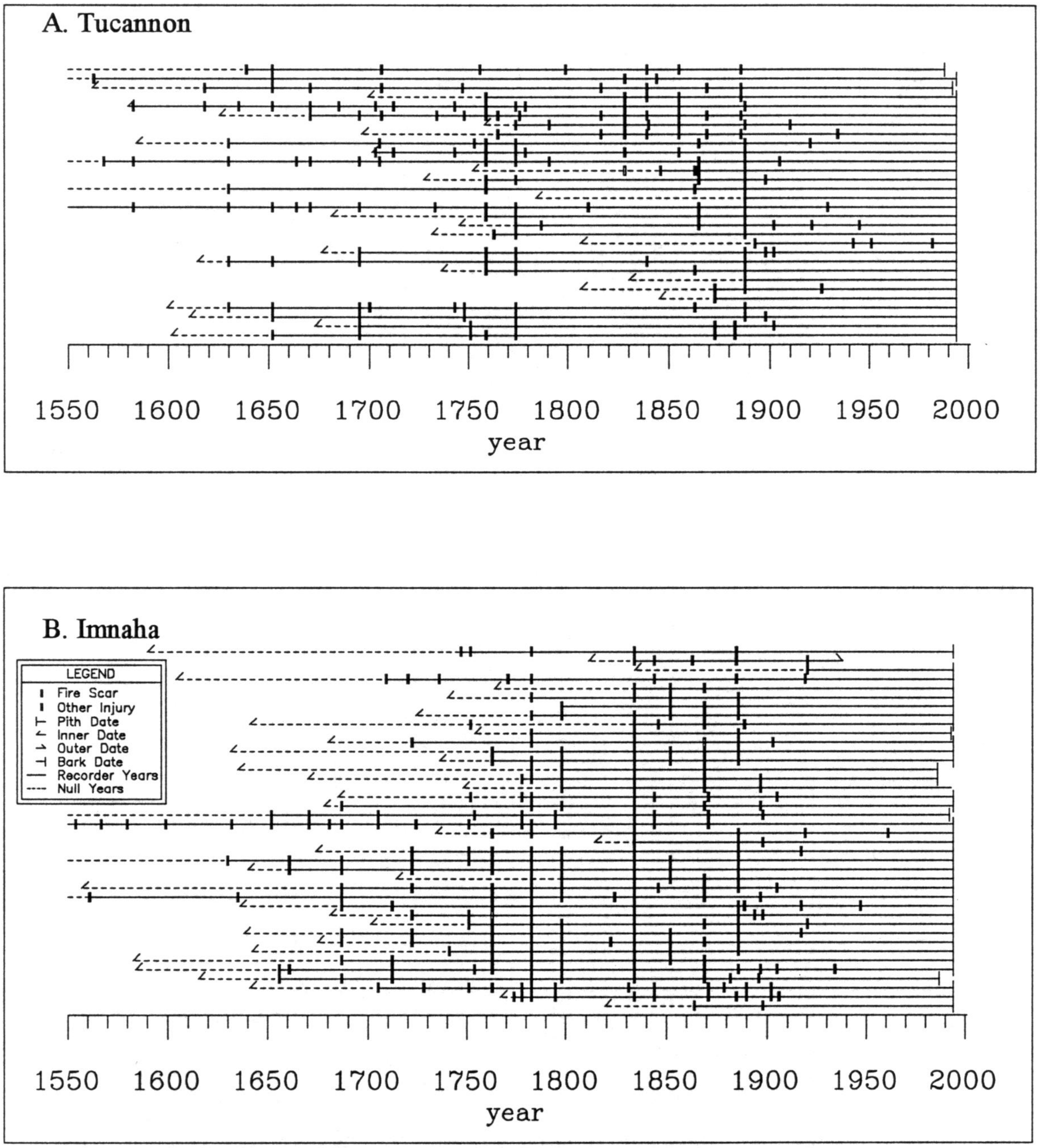


Figure 6. Fire chart for dry forests at Tucannon and Imnaha (the northern sites). Each horizontal line shows the composite fire record at a single sampling plot through time. The lines are arranged roughly north (top) to south (bottom). A fire may have scarred more than one tree per plot. "Other injury" indicates potential evidence of fire (sharp increases or decreases in ring width). All dated scars are shown, whether or not they were mapped as part of a fire. The period of reliability is from 1687 to 1994. Changing sample size through time is evident.

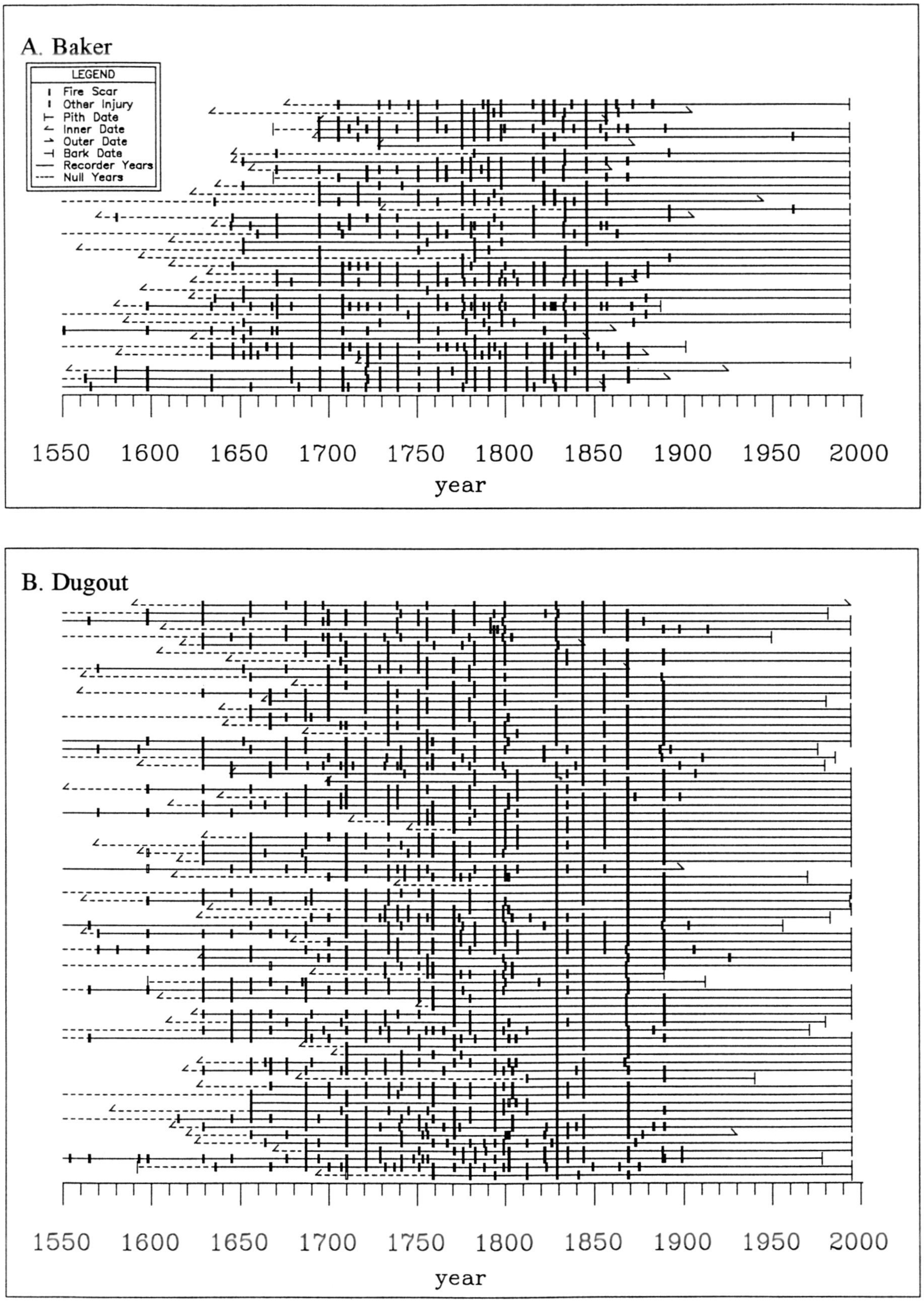


Figure 7. Fire chart for dry forests at Baker and Dugout (the southern sites; see Figure 6 for explanation).

Mesic forests

At Tucannon and Imnaha, spatial autocorrelation revealed that the distribution of tree ages had a statistically significant spatial structure, consistent with patches of similarly-aged trees (Appendix B). However, tree ages at Baker did not have a statistically significant spatial structure. Consequently we were unable to identify individual age classes at this site. Cluster analysis at Tucannon and Imnaha identified four age classes at each site (Figure 8 and Appendix C). The distribution of age classes at these sites shows the advantage of including tree locations in the identification of age classes (Figure 8). The age classes that established after the 1754 and 1774 fires at Tucannon and all of the age classes at Imnaha are not distinguishable based on establishment dates alone. Two of the fires at Tucannon and three of the fires at Imnaha were coincident with low severity fires that burned in adjacent dry forest.

The range of tree ages within an age class varied from 14 to 36 years at Tucannon and 18 to 42 years at Imnaha, with an average range of 30 years at both sites. There was no temporal overlap in the ages of trees assigned to different age classes at either site. The majority of trees at both sites were assigned to an age class; 95% of the trees were assigned to one of the four age classes at Tucannon, and 82% at Imnaha. We identified between 1 and 3 age classes per plot at both sites, indicating that both experienced high- and moderate-severity fires. Sixty-seven percent of the plots at Tucannon and 48% of the plots at Imnaha had 1 age class.

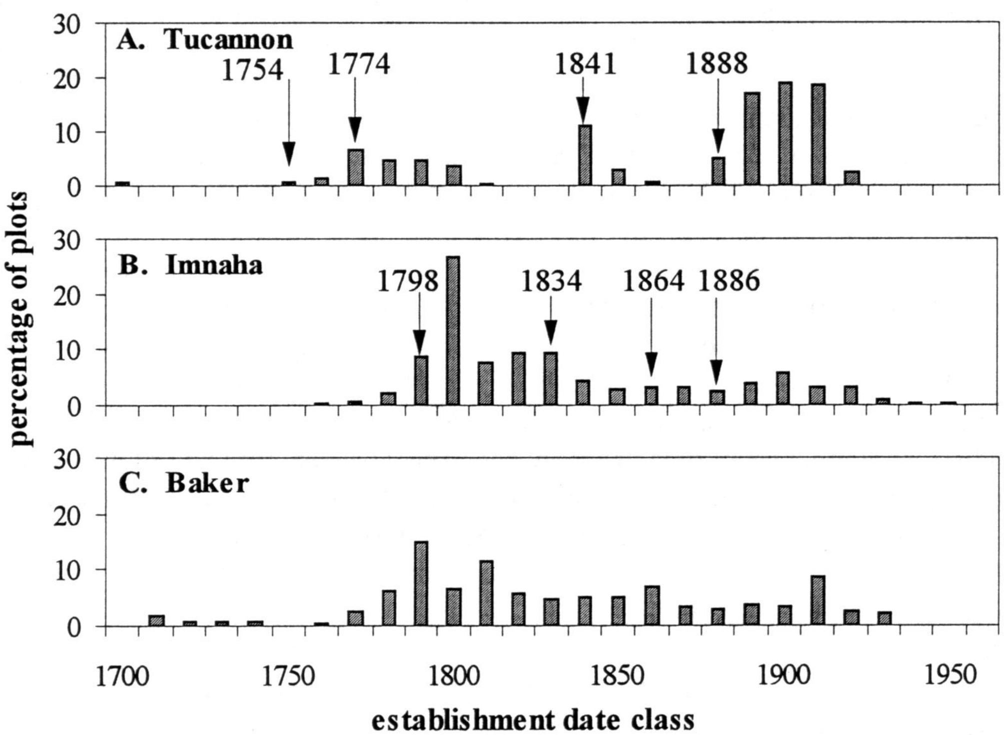


Figure 8. Distribution of plots by establishment date classes for mesic forests. The fire dates reconstructed from age classes of early seral trees are indicated by arrows for Tucannon (A) and Imnaha (B). Spatial information was included in the identification of age classes. Individual age classes could not be identified at Baker (C).

Fire extent

Fire boundaries were determined subjectively using mapped locations of fire evidence and a few simple rules. Maps of fire evidence and fire boundaries in both dry and mesic forests for all four sites are presented in Appendices D through G.

Dry forests

The fire extents we reconstructed in dry forests estimate actual fire extents conservatively. In part, this is because the reconstructed fire boundaries and the sampling area boundary intersect for the majority of fire years (82%) at all sites during the period of reliability. Although the sampling site boundaries were located along potential natural fire breaks where possible, the fires we detected at the edge of the sampling sites undoubtedly extended beyond the site boundary during many fire years. Therefore, to avoid overemphasizing artificially small fire extents in the following analysis, we excluded fire years with fewer than four plots having evidence of fire, if those plots were at the edge of the sampling site. For example, Dugout fire year 1926 was included but Dugout fire year 1899 was not. This eliminated approximately 15 to 30% of the fire years at each site.

Although all four sites experienced a range of annual fire extents, most extents were small relative to the size of the sampling site (Figure 9). Fire extent was 20 to 24% of sampling area for half the fire years at every site. In actual area, this means that half the fire years at Tucannon and Imnaha had extents less than 1,300 acres, at Baker less than 2,300 acres and at Dugout less than 4,300 acres. All sites except Tucannon had at least one year during which fires covered almost the entire sampling area. In contrast, the maximum extent at Tucannon was only 70% of the sampling area.

Although fire extent was small relative to the size of the sampling area for most fire years, it was large relative to modern classification of fire sizes (Figure 10). The USDA Forest Service classifies modern fires into one of seven fire extent categories (USDA 1990a,b. A: <0.25 ac; B: 0.26-9 ac; C:10-99 ac; D:100-299 ac; E:300-999 ac; F:1000-4999 ac; G:≥5000 ac). Our study could detect fires in the larger classes (C and above). Although some fires in small classes were detected (B and C), additional small fires probably occurred between sampling plots and were not detected. The majority of fire years at all sites had extents in classes E and above. At the northern sites, the sampling area was not large enough to detect fires in class G. During a 213 year period (1687-1900) every site experienced 13 or more class F fires and the southern sites both experienced 12 or more class G fires.

During some years, fire extent appears to be limited by the extent of a very recent previous fire. For example, during 1780, much of the eastern portion of Dugout burned (Appendix G). Three years later (1783), much of the western portion of this site burned but there was no evidence of fire in the area that burned in 1780. However, 11 years later (1794) both the eastern and the western portion of the site burned.

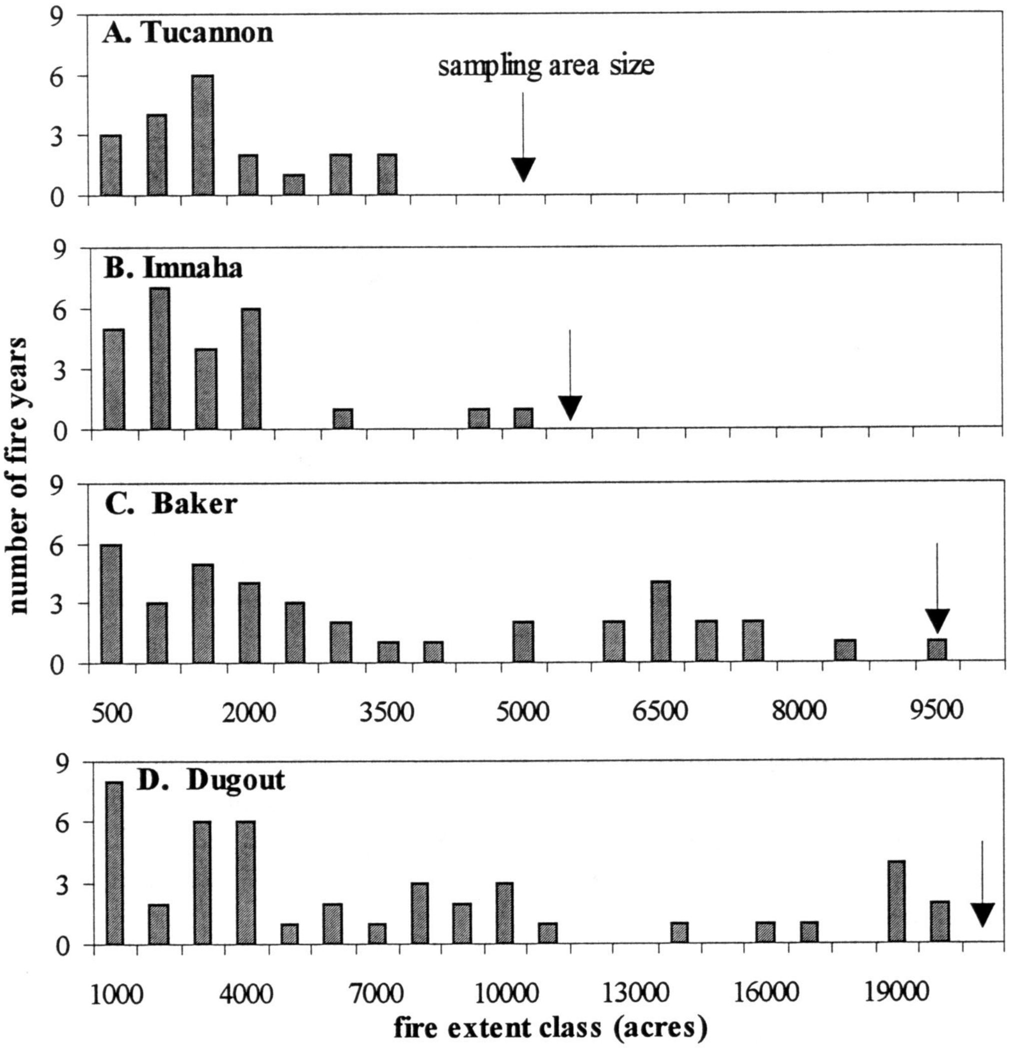


Figure 9. Distribution of fire years by fire extent classes in dry forests (1687-1900). Extent classes for Dugout are twice as large as the classes for the other three sites. The size of the dry forest sampling area for each site is indicated by an arrow. Fire years with evidence of fire at fewer than four plots on the edge of the sampling area are not included in this figure.

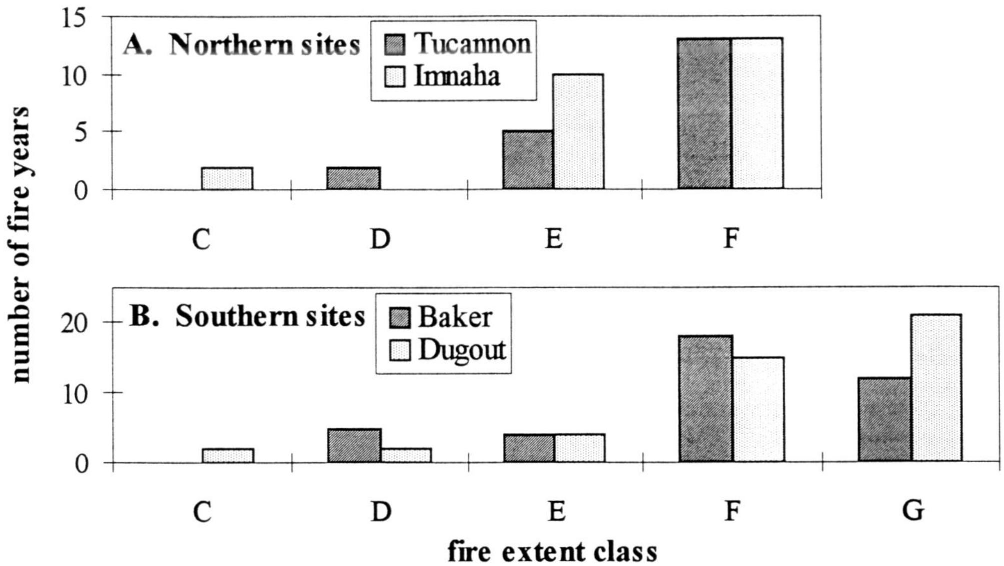


Figure 10. Distribution of fire years by the fire extent classes that are used to classify modern fires. C:10-99 ac; D:100-299 ac; E:300-999 ac; F:1000-4999 ac; G:≥5000 ac. The sampling area at both northern sites was not large enough to detect fires in class G.

Mesic forests

Because only four fires were reconstructed in mesic forests at the Tucannon and Imnaha sites, all of which intersected the boundary of the study area, we can only draw limited conclusions about the annual extent of fire in these forests. Each site experienced years of both large and small fire extent, relative to the sampling area size (Figure 11). Most of these fires are in class E (300-999 ac) but some are in class F (1000-4999 ac).

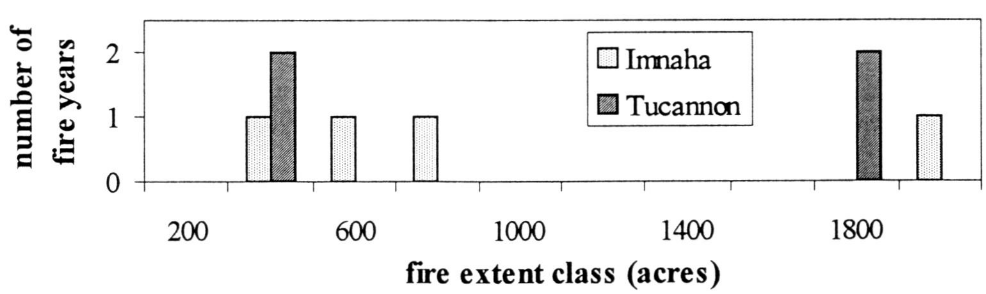


Figure 11. Distribution of fire years by fire extent classes, in mesic forest. Sampling area size is just over 2000 acres at both sites.

Subjective vs. objective determination of fire extent

The subjective and objective determinations of fire extent are significantly and highly correlated (Figure 12, Table 4). All fire years during the period of reliability were included in this analysis. At each site, over the entire sampling area as well as over the dense sampling area only, we correlated the two objective methods with the subjective method. In addition, the two objective methods were correlated with each other. Although all the comparisons are significantly and highly correlated, there are some outliers in the comparison between subjective and objective methods for the entire sampling area (Figure 12).

At Tucannon and Imnaha, the greatest differences occur between fire extents determined subjectively and using Voronoi polygons. The difference between the two methods is due to the complex shape of the sampling area perimeter at both Tucannon and Imnaha (Figure 2 and Appendix A). The years with the greatest difference in fire extent calculated by the two methods all have large fire extents (Tucannon 1774, Imnaha 1763, 1783, 1798). In determining fire boundaries subjectively, we did not extrapolate to the unsampled areas south of the dry forest sampling areas at either site but the Voronoi method did. The difference between the methods is reduced when the sampling area perimeter has a simple shape. The correlation between subjectively and objectively determined fire extent improves dramatically for Imnaha and slightly for Tucannon when only fires from the dense sampling area are included (Table 4). At Baker and Dugout the greatest differences occur for annual fire extents determined using convex hulls. The years for which fire extent differs the most when calculated by the two methods all have isolated points that were subjectively mapped with multiple fire boundaries but were included within a single convex hull (Dugout 1700, 1741, 1802, Baker 1776, 1816, 1828, 1869).

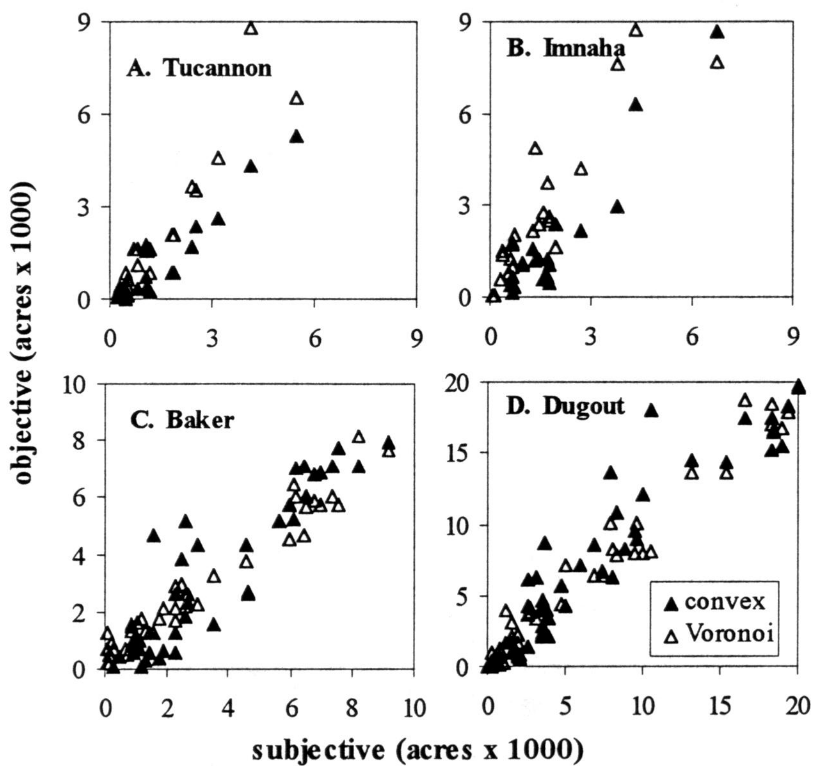


Figure 12. Scatter plots of subjectively- versus objectively-determined annual fire extent for the entire sampling area, by site. Two objective methods were used: convex hull and Voronoi polygons. Both mesic and dry forests were included.

Table 4. Correlation of subjectively and objectively determined fire extents. The nonparametric (Spearman rank) correlation coefficient (r) of annual fire extent is given. Convex hull and Voronoi polygon are the objective methods. Both mesic and dry forests were included. All correlations are significant ($p< 0.01$). The number of fire years correlated is given in parentheses.

	Entire sampling site			Dense sampling area		
	Subjective with:		Voronoi with:	Subjective with:		Voronoi with:
	convex hull	Voronoi	convex hull	convex hull	Voronoi	convex hull
Tucannon	0.89 (19)	0.92 (24)	0.94 (19)	0.90 (8)	0.97 (13)	0.95 (8)
Imnaha	0.74 (20)	0.87 (26)	0.65 (20)	0.93 (14)	0.97 (18)	0.98 (14)
Baker	0.90 (36)	0.96 (44)	0.87 (36)	0.91 (27)	0.90 (33)	0.85 (27)
Dugout	0.95 (43)	0.96 (46)	0.94 (43)	0.97 (34)	0.96 (40)	0.95 (34)

Cumulative fire extent

To identify possible changes in the fire regime through time, we used simple linear regression to fit a line to cumulative fire extent at each site (Figure 13). All fire years from 1687 to 1900 were included. At all four sites, most of the variance ($r^2 = 0.97$ to 0.99) is explained by the regression model. This indicates that there have been no major changes in fire regime in spite of small deviations from the regression line. Therefore, summarizing fire regimes at the four sites over the period 1687 to 1900 does not mask changes in fire regimes through time. There has been a change in the fire regimes at all site since the late 1800's. These features of the fire regimes at the four sites can also be seen in the fire charts (Figure 6 and Figure 7). Cumulative fire extent also shows the differences in fire regimes between the sites. The slopes of the lines for Tucannon and Imnaha are shallow and almost identical, that for Dugout is steep and Baker is intermediate.

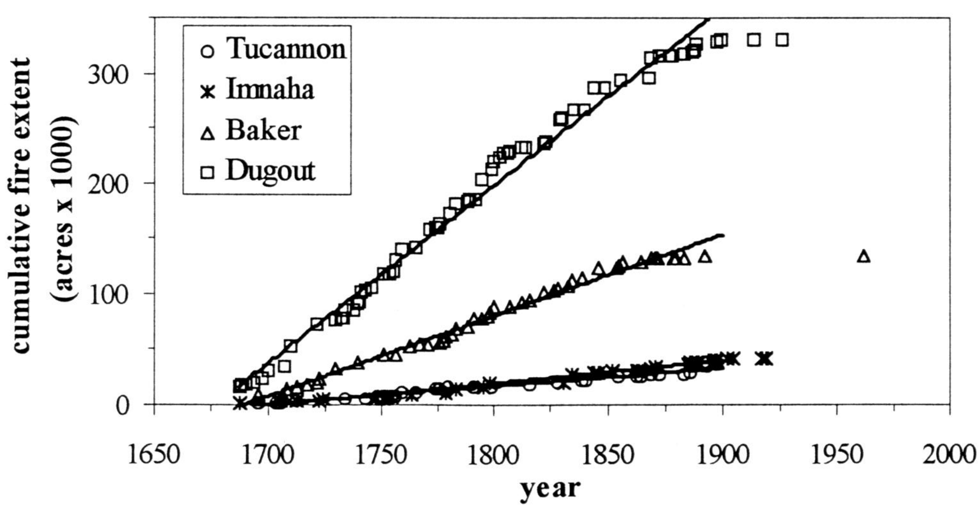


Figure 13. Cumulative fire extent by site for fires occurring since 1687. Regression lines were determined using ordinary least squares from 1687 to 1900.

Fire rotation

We computed fire rotation as the proportion of the study area burned over the period 1687 to 1900 (Figure 14). All fire years from 1750 to 1900 were included in this analysis. Two features of fire rotation are noteworthy. First, for dry forests, fire rotation was twice as long at the northern sites than at the southern sites. Historically, an area equivalent to the sampling area burned about every 25 to 30 years at Imnaha and Tucannon but about every 15 years at Baker and Dugout. Second, at the northern sites, fire rotation in the mesic forests was more than two and a half times longer than in dry forests at the same site. Historically, an area equivalent to the sampling area burned every 85 to 90 years in mesic forests but every 25 to 30 years in dry forests.

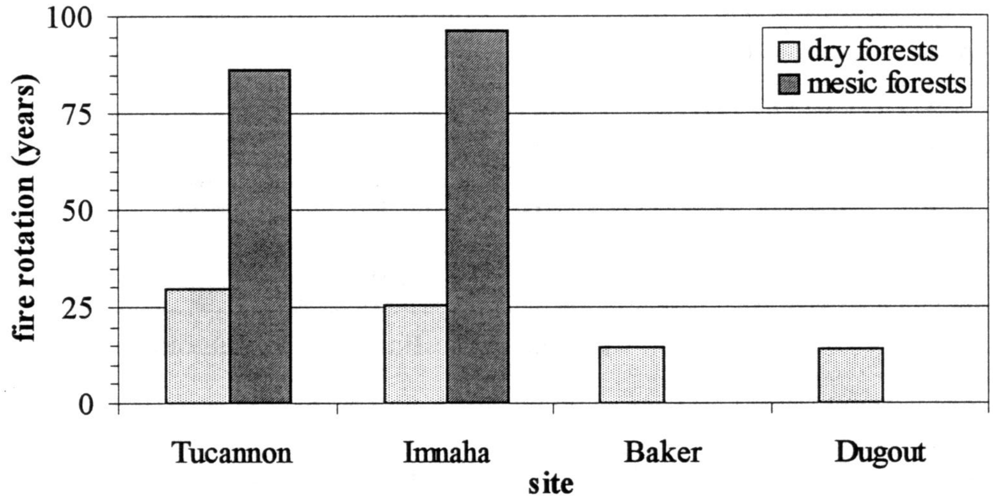


Figure 14. Fire rotation for dry and mesic forests, by site. All fires from 1750-1900 were included. Mesic forests were sampled at Baker but individual fires could not be identified using age-classes. Dugout has only dry forests.

Fire recurrence

Fire intervals in dry forests

Fire intervals were calculated from individual plots during the period 1687 to 1900 and sorted by site (Figure 15). The total number of intervals ranged from 107 to 922 (Table 5). All sites overlap in their range of fire intervals and share a common minimum interval of 1 to 2 years. In spite of these common features, analysis of variance (Kruskal-Wallis test) revealed that the fire intervals are not the same across the four sites ($p<0.01$). Following the analysis of variance, multiple comparisons (Table 5) revealed that fire intervals between the northern sites (Tucannon and Imnaha) do not differ, nor do the fire intervals between the southern sites (Baker and Dugout). However, fire intervals are different between these two groups, with longer fire intervals at the northern sites and shorter intervals at the southern sites. At the southern sites, *most* of the intervals (90%) are less than 25 years. In contrast, at the northern sites, only *half* of the fire intervals are less than 25 years. The maximum interval decreases from north to south. Tucannon has the largest range of fire intervals and Dugout the smallest.

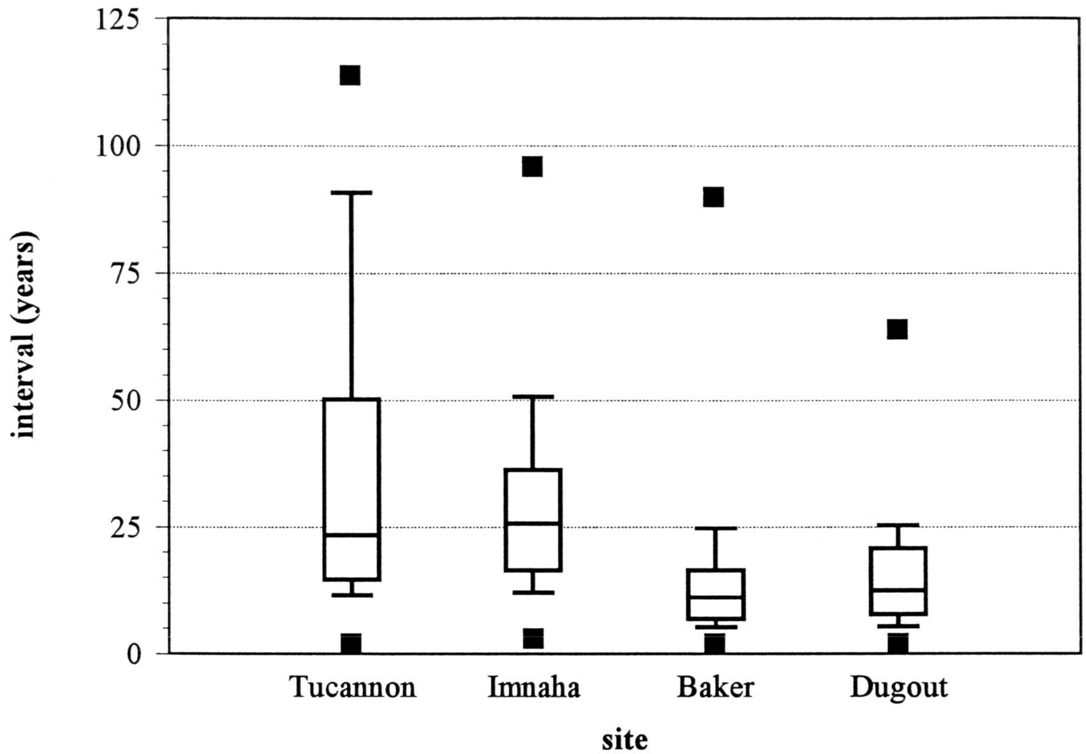


Figure 15. Fire intervals, by site, for the period 1687 to 1900. The boxes enclose the 25th to 75th percentiles of the reconstructed fire intervals so that half of the fire intervals lie within the boxes. The line across the box shows the 50th percentile (median fire interval). The whiskers mark the 10th and 90th percentiles. The maximum and minimum intervals are also shown. A table of these percentiles is provided in Appendix H.

Table 5. Fire intervals, by site, during the period 1687-1900. Sites with indistinguishable fire intervals (Dunn test, $p<0.01$) have x's in the same column.

Site	Number of intervals	Median fire interval	Homogenous groups of sites	
Tucannon	107	23	x	
Imnaha	200	25	x	
Baker	393	11		x
Dugout	922	12		x

Influence of topography on fire intervals in dry forests

We investigated the influence of topography on fire intervals by correlating elevation, aspect class and slope with median fire interval from individual plots sorted by site, for the period 1687 to 1900. We found no significant relationship for aspect or slope at any site, nor for elevation except at Baker (Table 6). The median fire interval increases with increasing elevation at this site. Six plots at this site have longer fire intervals than other plots at similar elevations (Figure 16). These are the six longest fire intervals. The relationship between median fire interval and elevation is strengthened (r=0.79) when these six sites are removed from the analysis.

*Table 6. Nonparametric (Spearman rank) correlation between median fire intervals and topographic characteristics of sampling plots in dry forests for the period 1687 to 1900. Correlation coefficients (r) that are significant (p<0.01) are indicated by *.*

	Tucannon	Imnaha	Baker	Dugout
Elevation	0.23	0.26	0.68*	0.20
Aspect class	0.20	0.06	0.06	0.24
Slope	-0.16	-0.12	0.28	-0.15
Number of plots	25	37	36	64

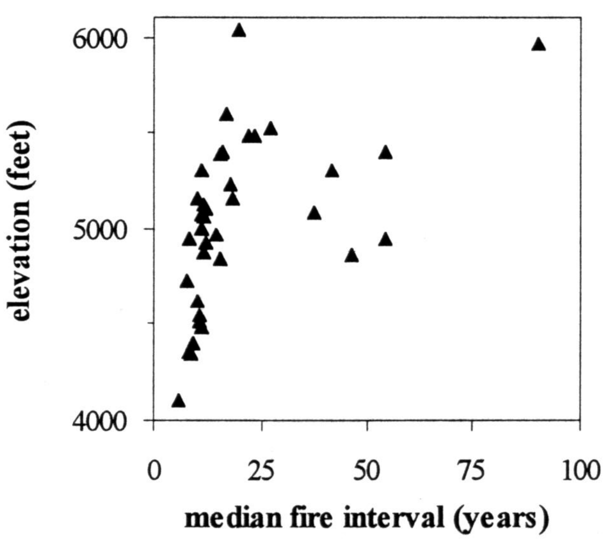


Figure 16. Scatter plot of median fire interval (1687-1900) and elevation in dry forest at Baker.

Number of fires in mesic and dry forests

We examined the differences in fire recurrence between dry and mesic forest zones by computing fire intervals at individual plots at Tucannon and Imnaha and sorting plots by forest zones, for the period 1750 to 1900. There is little overlap in the range of number of fires among forest zones even though all zones share a common minimum number of fires (Figure 17). Analysis of variance (Kruskal-Wallis test) revealed that the number of fires is *not* the same across the five forest zones ($p<0.01$). Following the analysis of variance, multiple comparisons identified two groups within which the number of fires cannot be distinguished (Table 7). The mesic forest zones plus dry grand fir were grouped and the dry forest zones were grouped. The number of fires from 1750 to 1900 is greater for dry forest zones than for the group including the mesic forest zones. For the dry forest zones, less than 10% of the plots experienced 2 or fewer fires. In contrast, for the mesic forest zones, 90% of the plots experienced 2 or fewer fires. The combined Douglas-fir and ponderosa pine zones have the greatest median number of fires as well as the largest range.

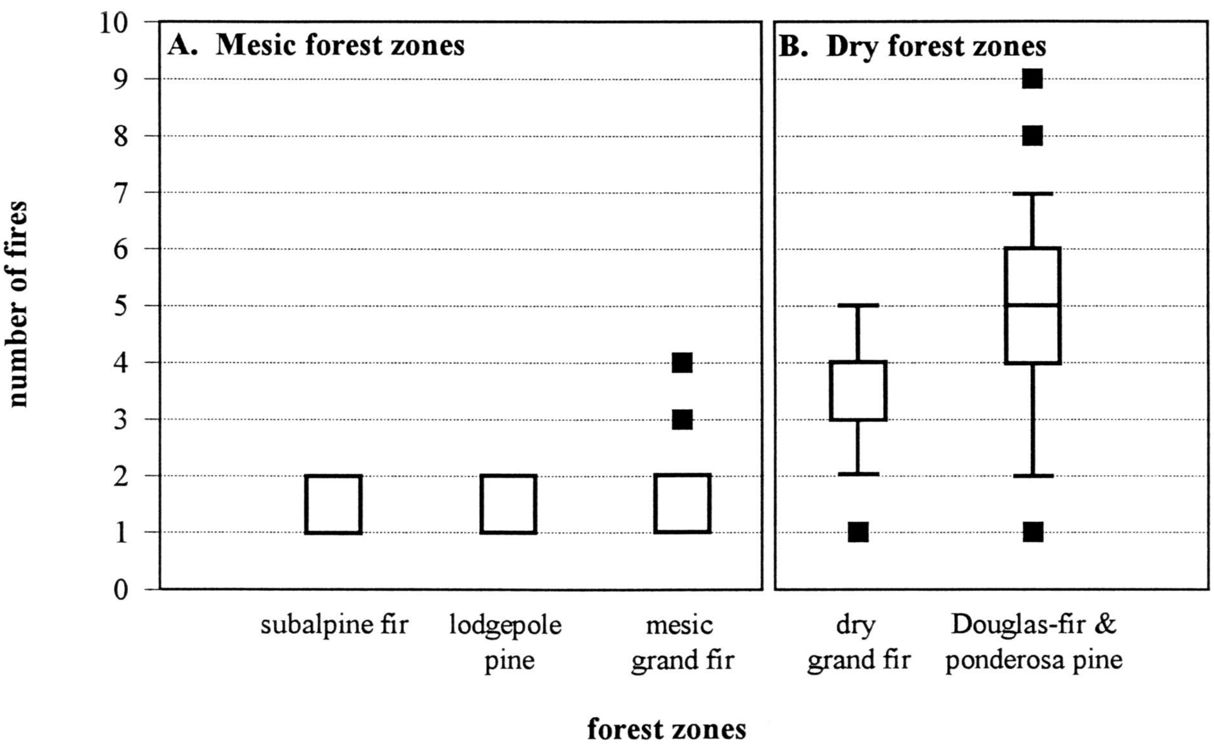


Figure 17. Number of fires at individual plots, sorted by forest zone during the period 1750 to 1900. Plots from Tucannon and Imnaha were combined. The boxes enclose the 25th to 75th percentiles so that half the plots lie within the box. The line across the box shows the 50th percentile (median). The whiskers mark the 10th and 90th percentiles. Forest zones lacking whiskers and lines had a limited range in number of fires, e.g., the subalpine fir plots had only one or two fires each. All plots that fall outside the 10th through the 90th percentiles are shown as filled squares.

Table 7. Number of fires, by mesic and dry forest zones, during the period 1750-1900 at Tucannon plus Imnaha. Sites with indistinguishable numbers of fires (Dunn test, p<0.01) have x's in the same column.

Forest zone	Number of plots	Median number of fires	Homogeneous forest zones	
Subalpine fir	9	1	x	
Lodgepole pine	7	1	x	
Mesic grand fir	56	1	x	
Dry grand fir	17	3	x	x
Douglas-fir & ponderosa pine	59	5		x

We examined the differences in fire recurrence in dry forest zones by computing fire intervals at individual plots and sorting plots by forest zone and site (Figure 18). Analysis of variance (Kruskal-Wallis test) revealed that the number of fires is *not* the same among forest zones and sites (p<0.01). Following the analysis of variance, multiple comparisons identified three groups with homogeneous numbers of fires (Table 8). The first group includes both forest zones at Tucannon and Imnaha plus dry grand fir at Baker. The second group includes both forest zones at Baker and Dugout. The third group is intermediate, spanning portions of groups one and two. The plots in the first group experienced the lowest number of fires (median from 2 to 6 fires) and the second group experienced the highest number (median from 10 to 12).

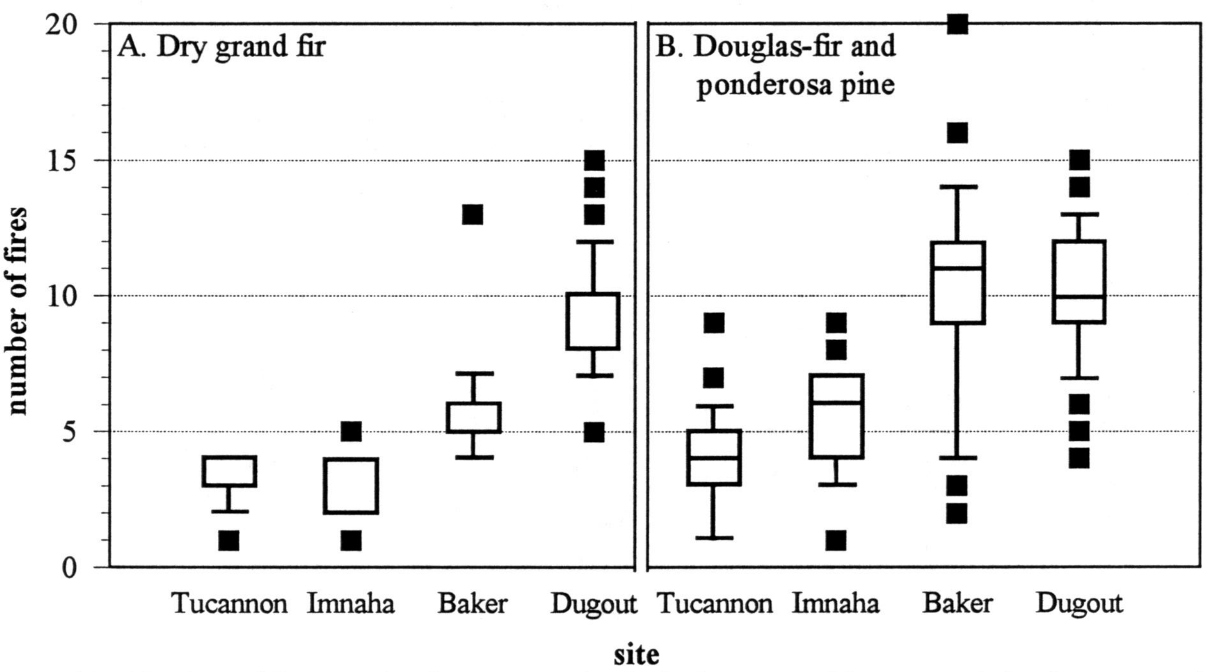


Figure 18. Number of fires in dry forests at individual plots, sorted by site and dry forest zone (dry grand fir (A) and Douglas-fir plus ponderosa pine (B)), for the period 1750 to 1900. The boxes enclose the 25^{th}-75^{th} percentiles so that half the plots lie within the box. The line across the box is the 50^{th} percentile (median). Whiskers mark the 10^{th} and 90^{th} percentiles. All plots that fall outside the 10^{th} through the 90^{th} percentiles are shown as filled squares. Sites lacking whiskers and lines had limited ranges in number of fires.

Table 8. Number of fires, by site and dry forest zone, during the period 1750-1900. Sites and forest zones with indistinguishable numbers of fires (Dunn test, p<0.01) have x's in the same column.

Site	Forest zone	Number of plots	Median number of fires	Homogeneous sites and zones		
Imnaha	dry grand fir	11	2	x		
Tucannon	dry grand fir	4	4	x		
Tucannon	Douglas-fir & ponderosa pine	24	4	x		
Imnaha	Douglas-fir & ponderosa pine	35	6	x	x	
Baker	dry grand fir	9	6	x	x	x
Dugout	dry grand fir	14	10		x	x
Baker	Douglas-fir & ponderosa pine	27	12			x
Dugout	Douglas-fir & ponderosa pine	58	12			x

Fire seasonality

The position of a fire scar within an annual ring indicates the season during which the fire that caused it burned. The intra-annular position was visible for nearly 70% of the scars at the four sites (Figure 19). The position of scars was not always visible because ring widths are often narrow, especially in the vicinity of fire scars, and scars can be obscured by rot or insect galleries. Of the scars for which the season could be determined, the majority at all sites were in the latewood or dormant position (91%). However, all four sites have a small percentage of scars in the earlywood (9%). Although many fire years had *some* earlywood scars, only a few fire years had *most* scars in the earlywood. Four fire years at Dugout (1656, 1729, 1788, 1794) and one at Baker (1833) had between 60 and 80% of scars with a detectable position, in the earlywood. No fire years at either Tucannon or Imnaha were dominated by earlywood scars.

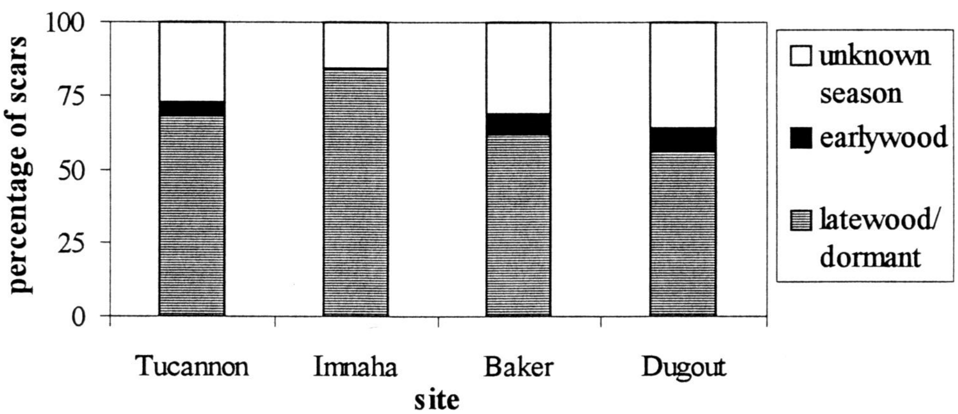


Figure 19. Intra-annular position of scars by site. Although the majority of scars are dormant period scars (i.e., they lie on the boundary between two rings), a small percentage of scars at each site were in the earlywood.

Discussion

Our landscape-scale approach yielded a robust reconstruction of the fire regimes in dry forests at four sites and in mesic forests at two northern sites. The greatest differences we found were between mesic and dry forests at the northern sites and between dry forests at the northern and southern sites.

Fire extent

Our estimates of fire extent in both dry and mesic forests are conservative because most fires intersected the boundaries of the sampling sites. Although most fire years in dry forests had extents that were small relative to sampling area size, relatively large extents in these forests were not uncommon (Figure 9). Also, fire extent for most years was large relative to modern classifications of fire size (Figure 10). The fire extents we detected were probably influenced by our choice of site location within the sampled watersheds. In dry forests at Tucannon, for example, 44% of fire boundaries during the period of reliability intersected the western edge of the sampling area while only 19% intersected the eastern edge. Fires may have spread into the sampling site from the west so that had a similarly-sized area been sampled west of the existing site, fire extents may have been greater. In addition, we located the boundaries of our sampling sites along potential fire breaks but did not determine how often they actually were fire breaks. For example, Imnaha fire year 1798 burned to the ridge forming the southern boundary of the sampling area and may have burned south of this ridge but we did not sample there.

We reconstructed four fires in mesic forests at Tucannon and Imnaha (Figure 8). All eight fires intersected the boundaries of the study sites so that our estimates of extent are again conservative. Annual fire extent ranged from about 250 to 2000 acres. Although we were unable to reconstruct individual fires in mesic forests at Baker using age classes, we speculate that fire extent was smaller at this site than at Tucannon and Imnaha. Because portions of all the fires we reconstructed were only *partially* stand replacing, many of the sampled plots have multiple age classes. As a consequence, the effect on forest structure of each fire is superimposed on the effects of previous fires. Therefore, the fire extents we reconstructed in mesic forests do not necessarily correspond to the size of patches with similar structure.

Fire recurrence

Dry forests

Fire was half as frequent at the northern sites compared to the southern sites, regardless of forest zone. The median fire interval at Tucannon and Imnaha was approximately 24 years, while it was approximately 12 years at Baker and Dugout (Table 5). Fire was also less frequent in mesic forests than dry forests at the northern sites. At Tucannon and Imnaha, the mean number of fires from 1750 to 1900 was 1 in mesic forests but 3 to 5 in dry forests. We have probably under-estimated fire recurrence in dry forests at all sites for several reasons. First, very low severity fires may not scar any trees. Second, we may not have detected some small fires, especially in the low density sampling areas. Third, because we sampled only an average of 3 trees per plot, we may have missed some evidence of fire.

Fire recurrence was not correlated with topography at any of the sites, with the exception of Baker where fire intervals increased with increasing elevation. The long fire intervals at Baker could be due to incomplete scar records or fires that were of low enough severity that they didn't scar any trees. On the other hand, fires could occur more frequently at lower elevations at Baker for several reasons. On the northeast slopes of the Elkhorn range, where Baker is located, winter snows melt earliest at lower elevations. Although high-severity fires can burn when snow is on the ground (Huff 1988), low-severity fires cannot. Therefore, persistent winter snow may shorten the fire season at higher elevations relative to lower elevations. Fire may also have been more frequent at lower elevations because fires that ignited in the grasslands of the Grande Ronde valley may have spread into the lower elevations of the Elkhorn range but failed to spread to the higher elevations.

Fire recurrence declined abruptly after the late 1800s at all four sites (Figure 6 and Figure 7). This decline was concurrent with a dramatic increase in the number of sheep and cattle grazing the Blue Mountains (Irwin et al. 1994). Modern studies and tree-ring reconstructions in conifer forests in the western United States have shown that grazing has impacted fire regimes by reducing fine fuels (Madany and West 1983; Rummell 1951; Savage and Swetnam 1990; Touchan et al. 1993). This may have happened at the four sites we sampled in Blue Mountains. We are currently investigating the abrupt change in fire regime that occurred at all four sites by examining climate, insect outbreaks, land-use (including grazing) and other factors.

The dry forests of the Blue Mountains survived many low-severity fires as evidenced by the ubiquity of old multiply-scarred trees. However, these forests also experienced moderate- and high-severity fires. In dry forests elsewhere in the west, age-class patches created by moderate- to high-severity fires are less than one acre (Cooper 1960, 1961; West 1969; Morrow 1985; Arno et al. 1995). We assume that fire-created patches in the dry forests of the Blue Mountains would be comparable in size. Although our sampling scheme did not include reconstruction of age classes in dry forests and we did not always sample the pith of scarred-trees, it appears that there are more plots with old trees at the southern sites than at the northern sites (Figure 6 and Figure 7). This may imply that small, moderate- and high-severity fires were more frequent in dry forests at the northern sites than at the southern sites. This would be consistent with the increased fuel buildup we would expect during the longer fire intervals at the northern sites.

Mesic forests

We reconstructed four fire years in mesic forests at each of the two northern sites using age classes but were unable to identify individual fire years in mesic forests at Baker. Our inability to identify individual fire years at Baker does not imply that these forests did not experience fire. On the contrary, we sampled trees of early seral species at 37 plots. We speculate that we were unable to identify individual fire years from these trees because fires were frequent and small in extent. The age classes that establish after fire contain trees with a range of ages so that when fires occur frequently the age ranges of classes overlap and cannot be distinguished unless they occur at different locations. Fire is not the only agent that opens growing space for new age classes of early seral trees to establish. Baker may have experienced many small-scale non-fire disturbances, such as insect outbreaks or windthrow. The age classes established as a consequence of these disturbances would overlay or be interspersed with age classes resulting from fire and further thwart our attempts to identify individual fire years.

The relative landscape position of dry and mesic forests may have contributed to the frequency of fire in mesic forests at Baker. The frequent low-severity fires reconstructed in low elevation dry forests at this site may have spread or spotted upslope into the mesic forests where they failed to attain large size. In contrast, the Tucannon and Imnaha Rivers appear to have served as natural fire breaks since many fires that burned in the dry forests on one side of these rivers did not spread into the mesic forests on the other side.

Why is there a difference between the fire regimes of the northern and southern sites?

Even though we sampled a similar range of dry forest zones at all four sites (Figure 3), the northern sites experienced less than half the number of fires as the southern sites (Table 8). In mesic forests, fire frequency may also have been lower at the northern sites than at Baker, to the south. We speculate that these differences in fire regime are primarily due to differences in the climate among the sites but could also be influenced by the landscape position of the sites.

Two aspects of climate may have influenced the historical fire regimes of the Blue Mountains: precipitation and lightning. The modern importance of precipitation in controlling fire is well-documented on local scales (e.g. Schroeder et al. 1966; Deeming et al. 1977; reviewed by Chandler et al. 1983). Models using modern data reveal that annual precipitation is higher at the northern than the southern sites (Daly et al. 1994). Also, during the summer an airmass boundary lies over the Blue Mountains, separating cooler, moister Pacific air to the northwest from warmer, drier interior air to the southeast (Mitchell 1976). Tucannon lies north of this airmass boundary while Baker and Dugout lie south of it. Although Imnaha is south of the boundary, in the area of dry interior air, the Wallowa Mountains to the west of this site increase precipitation orographically.

The northern Blue Mountains also appear to have a lower incidence of lightning. A seven-year study (1925-1931) of lightning storms and lightning-ignited fires in Oregon and Washington, show both to be less common at Tucannon and Imnaha than at Baker and Dugout (Morris 1934). These results are consistent with a modern summary of automatically-detected lightning strikes in the Pacific Northwest (Krider et al. 1980; data from 1986-1990 summarized by M. Peterson and S. Ferguson, USDA Forest Service, PNW Research Station). Furthermore, lightning may be accompanied by precipitation more often at Tucannon and Imnaha than at Baker and Dugout (Ferguson, pers. comm.), leading to fewer lightning-ignited fires at the northern sites.

Landscape position may also have contributed to the differences we found in fire regimes, as it has elsewhere in the west (Swanson et al. 1988). Both northern sites are in valleys where steep topography may have been a barrier to fire spread. In contrast, Dugout is in an area of gentle topography with no steep topographic breaks and Baker is at the edge of a broad, flat valley. As a consequence, fires ignited at a distance may have spread into the southern sites more often than distant fires spread into the northern sites. This is consistent with the smaller fire extents we reconstructed at the northern sites as compared to the southern sites.

These results imply that historical fire regimes cannot be predicted solely on the basis of forest zone (Table 8). Local climate and landscape position must also be considered.

Comparison to other reconstructions of fire history

Because the fire regimes of the northern sites are so different from those of the southern sites, we would expect similar conclusions from other fire history reconstructions in the Blue Mountains. However, the most extensive previous study found no relationship between latitude and mean fire return interval (Maruoka 1994). This lack of consistency is due to the different sampling scales of the two studies. The previous study reconstructed fire history at small plots separated by many miles. The sampling sites were selected to fall within a narrow range of plant associations. Our study reconstructed fire history at a landscape scale by sampling many small plots separated by fractions of a mile at each of our four sites. This sampling method revealed that fire regimes were quite variable within a sampling site. For example, in the 40 dry forest plots at Imnaha, median fire intervals ranged from 15 to 88 years. For the same period, a sampling site from the previous study, located within our Imnaha sampling site, had a median fire interval of 12 years. It is not surprising, then, to find a lack of consistency between these two studies. We would expect future studies conducted at a landscape scale to be consistent with our findings.

Similar to this study, other reconstructions of fire seasonality in western North America have found results that are generally consistent with modern regional climate (Figure 20). All of the studies reviewed here were conducted in dry forests of ponderosa and other pine, various species of oak, Douglas-fir, true fir or mixed conifer with the exception of the study in northern coastal California which was conducted in coast redwood (*Sequoia sempervirens*). Although there is little data on cambial phenology for any of these studies, most assume that scars found in earlywood were created by fires that burned in the spring or early summer while scars found in latewood or on the boundary between two rings (radial growth dormant period) were created by fires that burned in the late summer or early fall. For the three northern studies, over 90% of fire scars were found in the latewood or on the boundary between two rings. In contrast, for the three southern studies, less than 50% of fire scars were found in the latewood or on the boundary between two rings. These scar positions are consistent with regional climate. The northern three studies were all conducted in areas that experience relatively dry summers and a winter precipitation maximum (Mock 1996, Karl and Koscielny 1982). In contrast, the southern three studies were conducted in areas which have relatively dry winters and a summer precipitation maximum (Mock 1996, Karl and Koscielny 1982, O'Hara and Metcalfe 1995). As a consequence, fires occurred primarily in late summer or fall at the northern sites but commonly in the spring or early summer at the southern sites.

Recommendations for future research

Although this study is the most complete reconstruction of fire history in the Blue Mountains to date, there are still many aspects of historical fire regimes that we do not yet know. We present here several suggestions for future research, some of which are currently under way.

(1) Although all four sites included riparian areas, these areas were not targeted for sampling. Historical fire regimes in riparian areas could be reconstructed by specifically targeting these areas in future fire history studies. The riparian areas should be stratified, by stream order for example, to account for the variable influence of water flow in streams of different sizes.

(2) We still know very little about the fire history of non-forested areas in the Blue Mountains. Although there is no tree-ring record of fire in non-forested areas, these areas sometimes contain or are surrounded by trees. For example, much of the southern quarter of Dugout is covered with young ponderosa pine (< 100 year old) so we assume that before *circa* 1900, this area was not forested. However, old, multiply-scarred trees are present in riparian areas along several intermittent streams within the young forest (e.g. plot 16, Dugout site map in Appendix A). Some but not all fire dates at these sites matched those of the dense sampling area north of the

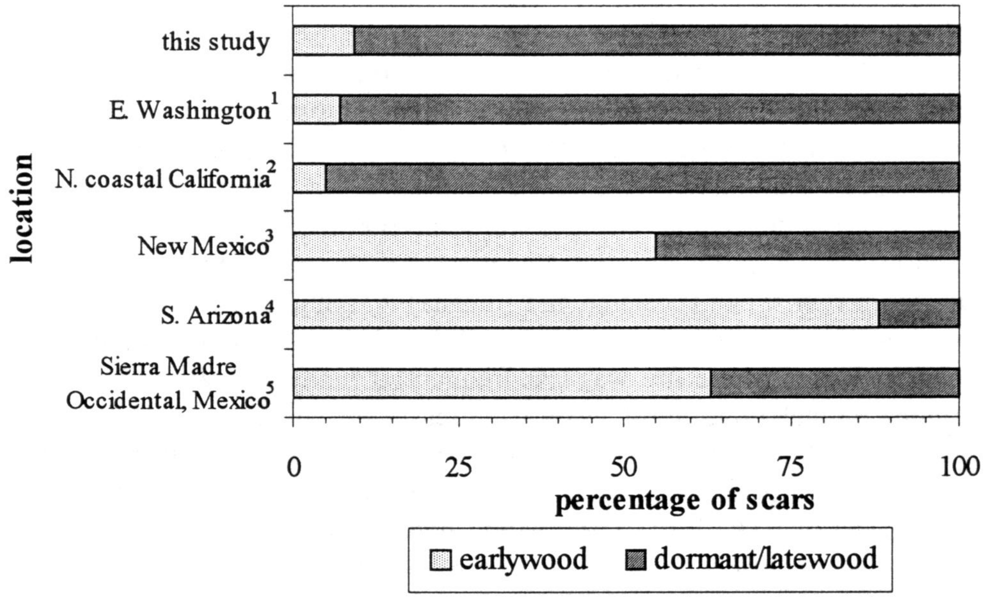


Figure 20. Seasonality of historical fire regimes of selected sites in western North America. Sites are ordered from north (top) to south (bottom). (1) 1319 scars, Wright 1996; (2) 56 scars, Brown and Swetnam 1994; (3) 1623 scars, Grissino-Mayer 1995; (4) > 900 scars, Baisan and Swetnam 1990; (5) 1384 scars, Heyerdahl et al., unpublished data.

young forest. From this, we could infer the fire history of the non-forested area. During years with evidence of fire both at sites within this area and in the dense sampling area, fire probably also burned in the non-forested area as well. More complete sampling of these areas would permit us to estimate the fire regimes of non-forested areas.

(3) We presented evidence that the differences we found in fire regimes between the northern and the southern sites is due to differences in climate but we also speculate that landscape position is a contributing factor. Additional tree-ring reconstructions of fire regimes at southern sites with topographic fire breaks and at northern sites without topographic fire breaks would help determine the relative importance of these two factors in controlling historical fire regimes.

(4) To fully understand fire regimes in mesic forests, we need to reconstruct fire history in larger areas. We reconstructed high-severity fires in mesic forests at two sites. However, the sampling areas at both sites were too small to reconstruct the full extent of any of the fires we detected. Also, we should reconstruct the history of moderate- and high-severity fires in dry forest types.

(5) Although land managers would like to know the historical range of variability in fire regimes, they should also know what drove that variability, especially in the face of a potential change in climate. Such an understanding could come from a time-series analysis of historical fire regimes and the factors that influence it. This work is currently under way and will include tree-ring reconstructions of climate and insect outbreaks (Swetnam et al. 1995) and archival records of land use including fire suppression, mining, grazing, forest harvesting and settlement.

Conclusions

Standard dendrochronological methods, applied at a landscape scale, yielded robust multicentury reconstructions of historical fire regimes at four sites in the Blue Mountains. Although dry forests experienced a range of annual fire extents, most extents were small relative to the size of the sampling site but large relative to modern classifications of fire size. Dry forests at all four sites experienced a dramatic decrease in cumulative fire extent beginning in the late 1800's, although there were no major changes early in the record. The fire extents we reconstructed are conservative because most extents intersected the sampling area boundary. Fire recurrence at the northern two sites (Tucannon and Imnaha) was similar but was lower than that of the southern two sites (Baker and Dugout). We found no relationship between topography and fire recurrence except at Baker where fire was less frequent at higher elevations. Based on the position of scars within annual rings, most historical fires occurred in the late summer or fall although five fires at the southern sites appear to have occurred earlier in the year. We speculate that the differences in fire regimes at the northern vs. the southern sites is due to a combination of climate and landscape position. The lack of correlation between fire recurrence and topography or forest zone implies that historical fire regimes cannot be inferred from either of these two features alone. Rather, our reconstructions of fire regimes revealed the importance of landscape position and local climate in inferring historical fire regimes.

Acknowledgments

The authors extend heartfelt thanks to the many people who helped make this work possible. The USDA Forest Service funded this project and provided logistical support: the Pacific Northwest Research Station and the Malheur, Wallowa-Whitman and Umatilla National Forests. Many people helped out in the field, most notably Grady Steere but also Bob Allbee, Erick Bishop, Ray Borgen, Linda Brubaker, Bill Clausen, Bruce Countryman, Jon Datillo, Sam Feider, Ralph Foster, Ed Guzman, Rose Guzman, Janet Hall, Charlie Johnson, Travis Kern, Tracy Kissire, Bill Mitchell, Heather Naughton, Melinda Shelton, Rachael Shultz, John Szymoniak and Ryan Taie. We thank Linda Brubaker for her many insightful contributions to this research. Steve McKay, Linda Wilkinson and Clint Wright provided many helpful reviews of this research. Steve McKay kindly wrote the S-plus program used for the spatial statistical analysis and helped to interpret the results. Ernesto Alvarado and Carlos Avalos provided summaries of the entire Blue Mountains DEM and satellite vegetation information. Kat Maruoka provided the Blue Mountains map used in Figure 1.

Literature Cited

Agee, J.K. 1991. Fire history along an elevational gradient in the Siskiyou Mountains, Oregon. Northwest Science. 65:188-199.

Agee, J.K. 1993. Fire ecology of Pacific Northwest forests. Washington, DC: Island Press. 493 p.

Agee, J.K. 1996. Blue Mountains fire: a history, ecology and research agenda. In: Jaindl, R.G., T.M. Quigley (eds.). Search for a solution: sustaining the land, people, and economy. Washington, D.C.: American Forests in cooperation with the Blue Mountains Natural Resources Institute. pp. 119-145.

Agee, J.K., M. Finney, R. deGouvenain. 1990. Forest fire history of Desolation Peak, Washington. Canadian Journal of Forest Research. 20:350-356.

Ahlstrand, G.M. 1982. Fire history of a mixed-conifer forest in Guadalupe Mountains National Park. In: Proceedings of the Fire History Workshop, 20-24 Oct. 1980, Tucson. Technical coordinators: M.A. Stokes, J.H. Dieterich (eds.). USDA Forest Service, Rocky Mountain Forest and Range Experiment Station. General Technical Report RM-81. pp. 4-7.

Applequist, M.B. 1958. A simple pith locator for use with off-center increment cores. Journal of Forestry. 56:141.

Arno, S.F., K.M. Sneck. 1977. A method for determining fire history in coniferous forests of the mountain west. GTR-INT-42. Ogden, UT: United States Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station. 28 p.

Arno, S.F., E.D. Reinhardt, J.H. Scott. 1993. Forest structure and landscape patterns in the subalpine lodgepole pine type: a procedure for quantifying past and present conditions. General Technical Report INT-294. Ogden, UT: United States Department of Agriculture, Forest Service, Intermountain Research Station. 25 p.

Arno, S.F., J.H. Scott, M.G. Hartwell. 1995. Age-class structure of old growth ponderosa pine/Douglas-fir stands and its relationship to fire history. Research Paper INT-RP-481. Ogden, UT: USDA Forest Service, Intermountain Research Station. 25 p.

Baisan, C.H., T.W. Swetnam. 1990. Fire history on a desert mountain range: Rincon Mountains Wilderness, Arizona, U.S.A. Canadian Journal of Forest Research. 20:1559-1569.

Barrett, S.W. 1981. Relationship of Indian caused fires to the ecology of western Montana forests. M.S. thesis. Missoula: University of Montana.

Barrett, S.W., S.F. Arno. 1988. Increment-borer methods for determining fire history in coniferous forests. General Technical Report INT-244. Ogden, UT: United States Department of Agriculture, Forest Service, Intermountain Research Station. 17 p.

Bork, J. 1984. (unpublished data) compiled for R.J. Mangan. Elkhorn fire management action plan. United States Department of Agriculture, Forest Service, Wallowa-Whitman National Forest. 48 p.

Bormann, B.T., M.H. Brookes, E.D. Ford, et al. 1994. Volume V: A framework for sustainable-ecosystem management. General Technical Report PNW-GTR-331. Portland, OR: United States Department of Agriculture, Forest Service, Pacific Northwest Research Station. (Everett, R.L., assessment team leader; Eastside forest ecosystem health assessment). 61 p.

Brown, P.M., T.W. Swetnam. 1994. A cross-dated fire history from coast redwood near Redwood National Park, California. Canadian Journal of Forest Research. 24:21-31.

BURGAN, R.E., C.C. HARDY, D.H. OLHEN, G. FOSNIGHT, R. TREDER. 1996. Ground truth data for the national Land Cover Characteristics database. Unpublished report.

CHANDLER, C., P. CHENEY, P. THOMAS. 1983. Fire in forestry. Volume 1: Forest fire behavior and effects. New York: John Wiley and Sons. 450 p.

COOK, E.R., L.A. KAIRIUKSTIS. 1990. Methods of dendrochronology: applications in the environmental sciences. Boston: Kluwer Academic Publishers. 394 p.

COOPER, C.F. 1960. Changes in vegetation, structure, and growth of southwestern pine forests since white settlement. Ecological Monographs. 30:129-164.

COOPER, C.F. 1961. Pattern in ponderosa pine forests. Ecology. 42:493-499.

DALY, C., R.P. NEILSON, D.L. PHILLIPS. 1994. A statistical-topographic model for mapping climatological precipitation over mountainous terrain. Journal of Applied Meteorology 33: 140-158.

DEEMING, J.E., R.E. BURGAN, J.D. COHEN. 1977. The National Fire Danger Rating System - 1978. General Technical Report INT-39. Ogden, UT: United States Department of Agriculture, Forest Service, Intermountain Research Station. 63 p.

DIETERICH, J.H. 1982. The composite fire interval: a tool for more accurate interpretation of fire history. In: Proceedings of the Fire History Workshop, 20-24 Oct. 1980, Tucson. Technical coordinators: M.A. Stokes, J.H. Dieterich (eds.). USDA Forest Service, Rocky Mountain Forest and Range Experiment Station. General Technical Report RM-81. pp. 8-14.

DIETERICH, J.H., T.W. SWETNAM. 1984. Dendrochronology of a fire-scarred ponderosa pine. Forest Science. 30:238-247.

DUNCAN, R.P., G.H. STEWART. 1991. The temporal and spatial analysis of tree age distributions. Canadian Journal of Forest Research. 21:1703-1710.

EARLE, C.J. 1993. Forest dynamics in a forest-tundra ecotone, Medicine Bow Mountains, Wyoming. Ph.D. dissertation. Seattle: University of Washington. 141 p.

EVANS, J.W. 1990. Powerful Rockey: The Blue Mountains and the Oregon Trail, 1811-1883. La Grande, OR: Eastern Oregon State College. 374 p.

EVERETT, R., P. HESSBURG, M. JENSEN, B. BORMANN. 1994. Volume I: executive summary. General Technical Report PNW-GTR-317. Portland, OR: United States Department of Agriculture, Forest Service, Pacific Northwest Research Station. (Everett, R.L., assessment team leader, Eastside forest ecosystem health assessment). 61 p.

FORTIN, M.J., P. DRAPEAU, P. LEGENDRE. 1989. Spatial autocorrelation and sampling design in plant ecology. Vegetatio. 83:209-222.

FRITTS, H.C. 1976. Tree rings and climate. New York: Academic Press. 567 p.

GARA, R.I., J.K. AGEE, W.R. LITTKE, D.R. GEISZLER. 1986. Fire wounds and beetle scars: distinguishing between the two can help reconstruct past disturbances. Journal of Forestry. 84:47-50.

GILL, M. 1974. Toward an understanding of fire-scar formation: field observation and laboratory simulation. Forest Science. 20:198-205.

GRAUMLICH,L. 1985. Long-term records of temperature and precipitation in the Pacific Northwest derived from tree rings. Ph.D. dissertation. Seattle:University of Washington. 196 p.

GRISSINO-MAYER, H.D. 1995. Tree-ring reconstructions of climate and fire history at El Malpais National Monument, New Mexico. Ph.D. dissertation. Tucson: University of Arizona. 407 p.

HALL, F.C. 1976. Fire and vegetation in the Blue Mountains - implications for land managers. In: Proceedings of the Annual Tall Timbers Fire Ecology Conference, October 16-17, 1974, Portland, OR. 15:155-170.

HEINSELMAN, M.L. 1973. Fire in the virgin forests of the Boundary Waters Canoe Area, Minnesota. Quaternary Research. 3:329-82.

HEYERDAHL, E.K., D. BERRY, J.K. AGEE. 1995. Fire history database of the western United States. EPA/600/R-96/081. Washington, D.C.:United States Environmental Protection Agency. 81 p.

HOLMES, R.L. 1983. Computer-assisted quality control in tree-ring dating and measurement. Tree-Ring Bulletin. 43:69-78.

HUFF, M. 1988. Mount Rainier: Fire and Ice. Park Science. 8(3):22-23.

IRWIN, L.L., J.G. COOK, R.A. RIGGS, J.M. SKOVLIN. 1994. Effects of long-term grazing by big game and livestock in the Blue Mountains forest ecosystems. Gen. Tech. Rep. PNW-GTR-325. Portland, OR: USDA Forest Service, Pacific Northwest Research Station. 49 p.

JOHNSON, C.G. JR., R.R. CLAUSNITZER. 1992. Plant associations of the Blue and Ochoco Mountains. R6-ERW-T-036-92. Portland, OR: United States Department of Agriculture, Forest Service, Pacific Northwest Region. 164 p.

JOHNSON, C.G. JR., S.A. SIMON. 1987. Plant associations of the Wallowa-Snake Province. Wallowa-Whitman National Forest. R6-ECOL-TP-255A-86. Portland, OR: United States Department of Agriculture, Forest Service, Pacific Northwest Region, Wallowa-Whitman National Forest. 400 p.

KARL, T.R., A.J. KOSCIELNY. 1982. Drought in the United States: 1895-1981. Journal of Climate. 2:313-329.

KENNEDY-SUTHERLAND, E., W.W. COVINGTON, S. ANDARIESE. 1991. A model of ponderosa pine growth response to prescribed burning. Forest Ecology and Management. 44:161-173.

KRIDER, E.P., R.C. NOGGLE, A.E. PIFER, D.L. VANCE. 1980. Lightning direction-finding systems for forest fire detection. Bulletin American Meteorological Society. 61:980-986.

LANDSBERG, J.D., P.H. COCHRAN, M.M. FINCK, R.E. MARTIN. 1984. Foliar nitrogen content and tree growth after prescribed fire in ponderosa pine. Research Note PNW-412. Portland: USDA Forest Service, Pacific Northwest Forest and Range Experiment Station. 15 p.

LANGSTON, N. 1995. Forest dreams, forest nightmares: the paradox of old growth in the inland west. Seattle: University of Washington. 368 p.

LAWRENCE, W.H., N.B. KVERNO, H.D. HARTWELL. 1961 (reprinted in 1996). Guide to wildlife feeding injuries on conifers in the Pacific Northwest. Technical Report 9624-2834-MTDC. Missoula: USDA Forest Service, Missoula Technology and Development Center. 44 p.

LEGENDRE, P., M.-J. FORTIN. 1989. Spatial pattern and ecological analysis. Vegetatio. 80:107-138.

MADANY, M.H., T.W. SWETNAM, N.E. WEST. 1982. Comparison of two approaches for determining fire dates from tree scars. Forest Science. 28:856-861.

MADANY, M.H., N.E. WEST. 1983. Livestock grazing-fire regime interactions within montane forests of Zion National Park, Utah. Ecology. 64:661-667.

MARK, D.M. 1987. Recursive algorithm for determination of proximal (Thiessen) polygons in any metric space. Geographical Analysis. 19:264-272.

MARUOKA, K.R. 1994. Fire history of *Pseudotsuga menziesii* and *Abies grandis* stands in the Blue Mountains of Oregon and Washington. M.S. thesis. Seattle: University of Washington. 73 p.

MATHSOFT, INC. 1995. S-Plus Version 3.3 for Windows. Seattle, WA.

MCBRIDE, J.M. 1983. Analysis of tree rings and fire scars to establish fire history. Tree-Ring Bulletin. 43:51-67.

MITCHELL, V.L. 1976. The regionalization of climate in the western United States. Journal of Applied Meteorology. 15:920-927.

MOCK, C.J. 1996. Climatic controls and spatial variations of precipitation in the western United States. Journal of Climate. 9:1111-1125.

MOLNAR, A.C., R.G. MCMINN. 1960. The origin of basal scars in the British Columbia interior white pine type. Forestry Chronicle. 36:50-61.

MORRIS, W.G. 1934. Lightning storms and fires on the National Forests of Oregon and Washington. Portland, OR: USDA Forest Service, Pacific Northwest Forest and Range Experiment Station. 27 p.

MORRIS, W.G., E.L. MOWAT. 1958. Some effects of thinning a ponderosa pine thicket with a prescribed fire. Journal of Forestry. 56:203-209.

MORROW, R.J. 1985. Age structure and spatial pattern of old-growth ponderosa pine in Pringle Falls Experimental Forest, Central Oregon. M.S. thesis. Corvallis, OR: Oregon State University. 80 p.

O'HARA, S.L., S.E. METCALFE. 1995. Reconstructing the climate of Mexico from historical records. The Holocene. 5:485-490.

OLIVER, C.D., B.C. LARSON. 1990. Forest stand dynamics. New York: McGraw-Hill Inc. 467 p.

ROBBINS, W.G., D.W. WOLF. 1994. Landscape and the intermontane northwest: an environmental history. General Technical Report PNW-GTR-319. Portland, OR: United States Department of Agriculture, Forest Service, Pacific Northwest Research Station. 32 p. (Everett, R.L., assessment team leader; Eastside forest ecosystem health assessment; Hessburg, P.F., science team leader and technical editor, Volume III: assessment).

ROMME, W. 1982. Fire history terminology: report of the ad hoc committee. In: Proceedings of the Fire History Workshop, 20-24 Oct. 1980, Tucson. Technical coordinators: M.A. Stokes, J.H. Dieterich. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station. General Technical Report RM-81. pp. 135-137.

RUMMELL, R.S. 1951. Some effects of livestock grazing on ponderosa pine forest and range in central Washington. Ecology. 32:594-607.

SAVAGE, M., T.W. SWETNAM. 1990. Early 19th-century fire decline following sheep pasturing in a Navajo ponderosa pine forest. Ecology. 71:2374-2378.

SCHROEDER, M.J., M. GLOVINSK, V.F. HENDRICKS, ET AL. 1966. Synoptic weather types associated with critical fire weather. Springfield, VA: Weather Bureau, United States Department of Commerce and United States Department of Agriculture, Forest Service for Office of Civil Defense. 280 p.

SCHWANTES, C. 1989. The Pacific Northwest: an interpretive history. Lincoln: University of Nebraska Press. 427 p.

SEDGEWICK, R. 1988. Algorithms, second edition. Reading, MA: Addison-Wesley. 657 p.

SMITH, C.S. 1983. A 4300 year history of vegetation, climate, and fire from Blue Lake, Nez Perce County, Idaho. M.S. thesis. Pullman, WA: Washington State University. 86 p.

STOKES, M.A., T.L. SMILEY. 1968. An introduction to tree-ring dating. Chicago: University of Chicago Press. 73 p.

SWANSON, F.J., T.K. KRATZ, N. CAINE, R.G. WOODMANSEE. 1988. Landform effects on ecosystem patterns and processes. BioScience. 38:92-98.

SWANSON, F.J., J.A. JONES, D.O. WALLIN, J. CISSEL. 1993. Natural variability: implications for ecosystem management. In: Jensen, M.E. Bourgeron, P.S. (eds.) Eastside forest ecosystem health assessment--Volume II: Ecosystem management: principles and applications. Portland, OR: U.S. Dept. of Agriculture, Forest Service, Pacific Northwest Research Station, pp. 89-103.

SWETNAM, T.W. 1984. Peeled ponderosa pine trees: a record of inner bark utilization by Native Americans. Journal of Ethnobiology. 4:177-190.

SWETNAM, T.W. 1993a. Tree-ring data from CO, NM, OR. Contribution number 93-025 to the International Tree-Ring Databank. National Geophysical Data Center, World Data Center -A for Paleoclimatology.

SWETNAM, T.W. 1993b. Fire history and climate change in giant Sequoia groves. Science. 262:885-889.

SWETNAM, T.W., M.A. THOMPSON, E. KENNEDY-SUTHERLAND. 1985. Using dendrochronology to measure radial growth of defoliated trees. Agriculture Handbook No. 639. USDA Forest Service, Cooperative State Research Service. 39 p.

SWETNAM, T.W. , R.L. HOLMES. 1994. Spatial analysis of fire events: description of computer program SPANFIRE. Unpublished report, Laboratory of Tree-Ring Research, University of Arizona, Tucson.

SWETNAM, T.W., B.E. WICKMAN, H.G. PAUL, C.H. BAISAN. 1995. Historical patterns of western spruce budworm and Douglas-fir tussock moth outbreaks in the northern Blue Mountains, Oregon, since A.D. 1700. Research Paper PNW-RP-484. Portland: USDA Forest Service, Pacific Northwest Research Station. 27 p.

THOMAS, T.L., J.K. AGEE. 1986. Prescribed fire effects on mixed conifer forest structure at Crater Lake, Oregon. Canadian Journal of Forest Research. 16:1082-1087.

TOUCHAN, R., T.W. SWETNAM, H.D. GRISSINO-MAYER. 1993. Effects of livestock grazing on pre-settlement fire regimes in New Mexico. Symposium on Fire in Wilderness and Park Management: Past Lessons and Future Opportunities. Missoula, MT, March 30-April 1, 1993.

USDA FOREST SERVICE. 1990a. Wildfire statistics, 1968-1990 (was: Forest fire statistics 1916-1967). Washington, DC: USDA Forest Service.

USDA FOREST SERVICE. 1990b. National forest fire report, 1938-1959 and 1977-1986 (was: Annual fire report for the national forests 1960-1968, National forests fire report 1969-1976). Washington, DC: USDA Forest Service.

VAN SICKLE, F.S., R.D. HICKMAN. 1959. The effect of understory competition on the growth rate of ponderosa pine in north central Oregon. Journal of Forestry. 57:852-853.

WEAVER, H. 1951. Fire as an ecological factor in southwestern ponderosa pine forests. Journal Forestry. 49:93-98.

WEAVER, H.A. 1967. Fire and its relationship to ponderosa pine. Proceedings of the Tall Timbers Fire Ecology Conference. 7:127-149.

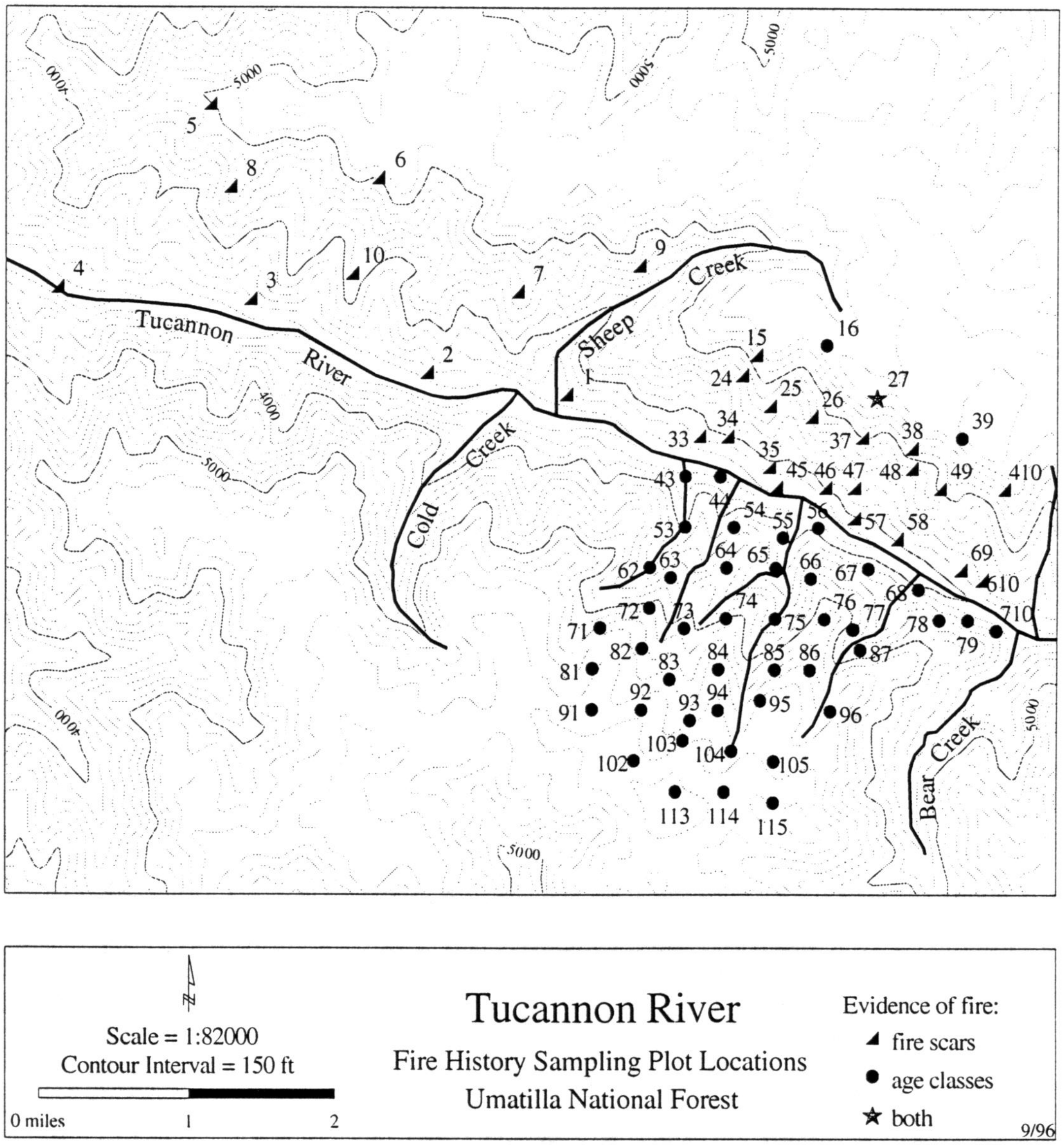
WEST, N.E. 1969. Tree patterns in central Oregon ponderosa pine forests. American Midland Naturalist. 81:265-271.

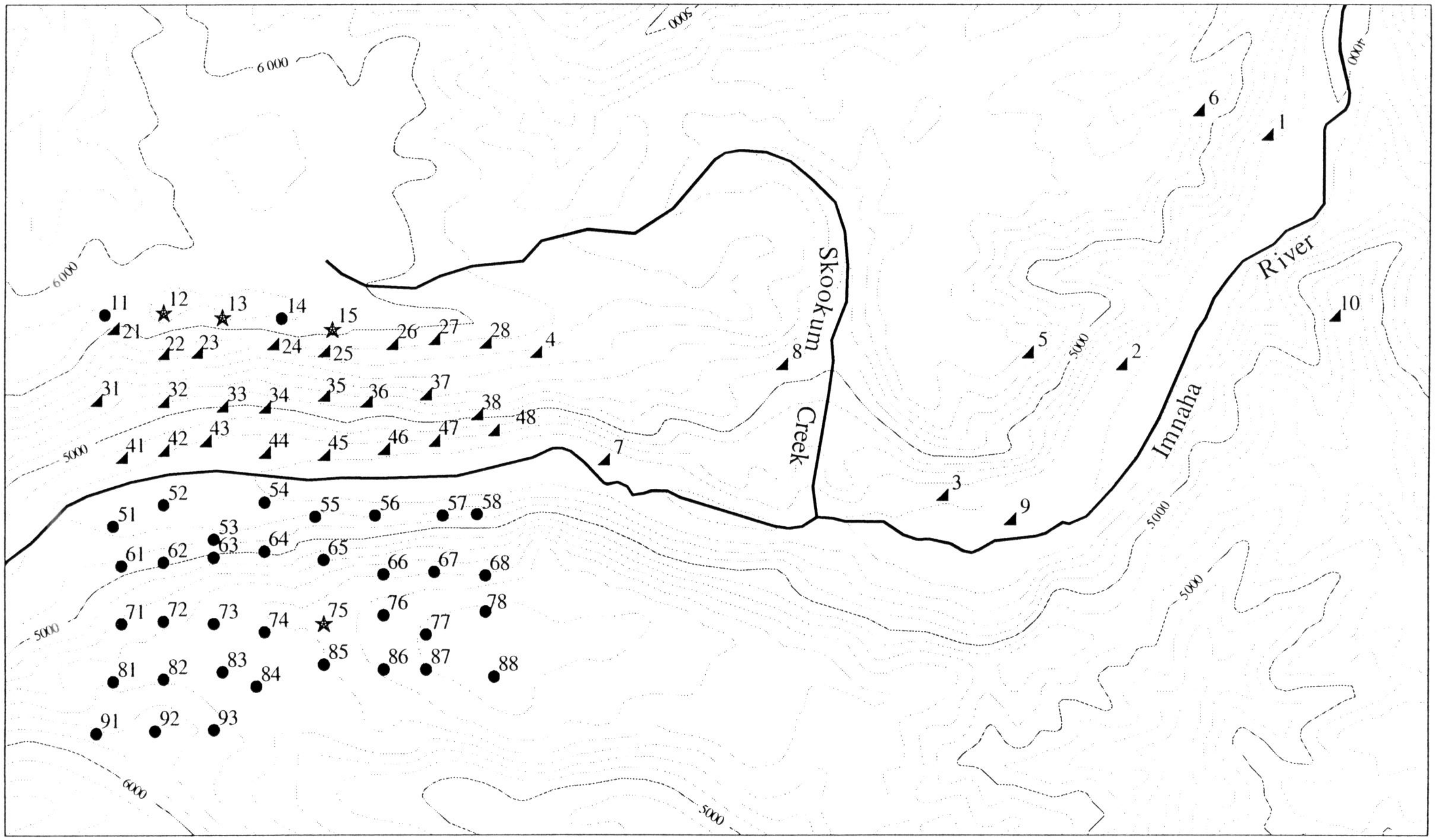
WRIGHT, C.S. 1996. Fire history of the Teanaway River drainage, Washington. M.S. thesis. Seattle: University of Washington. 190 p.

YAMAGUCHI, D.K. 1991. A simple method for cross-dating increment cores from living trees. Canadian Journal of Forest Research. 21:414-416.

ZAR, J.H. 1984. Biostatistical analysis, second edition. Englewood Cliffs, NJ: Prentice Hall. 718 p.

APPENDIX A: SITE INFORMATION: SITE MAPS AND SAMPLING PLOT DESCRIPTIONS





Imnaha River

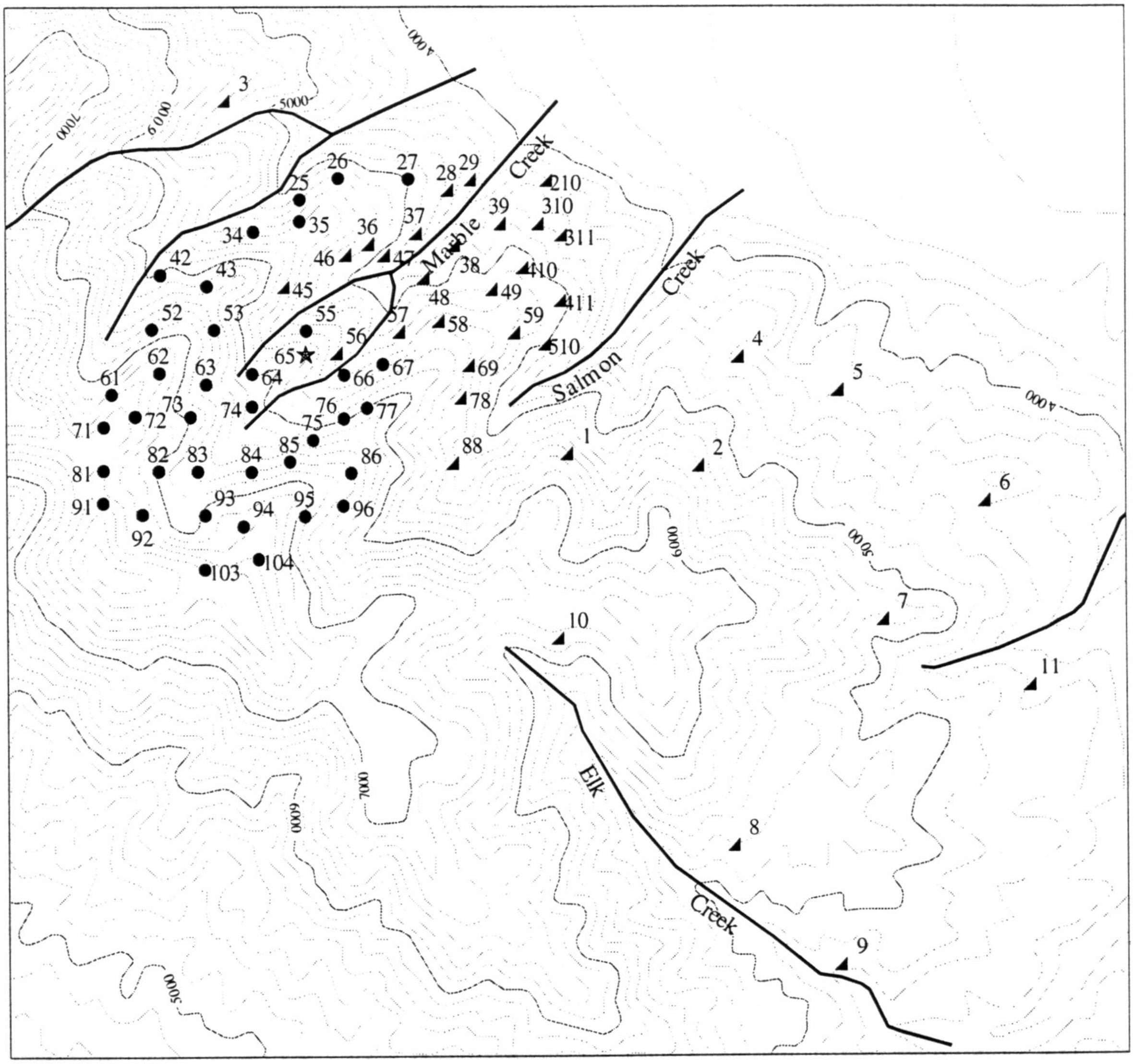
Fire History Sampling Plot Locations
Wallowa-Whitman National Forest

Scale=1:65000, Contour Interval=150 ft

0 miles 1 2

Evidence of fire:
- fire scars
- age classes
- both

9/96



Baker City Watershed

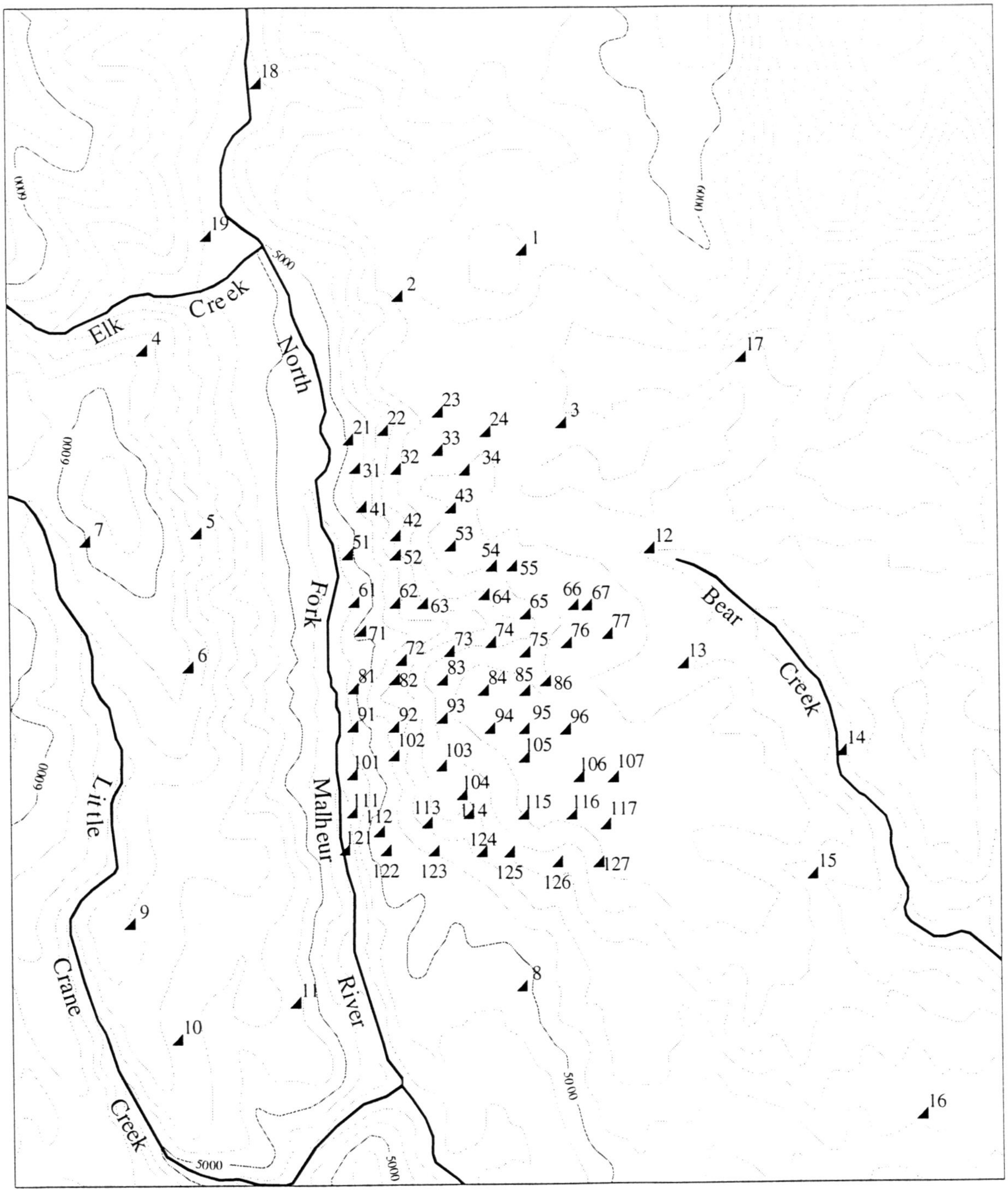
Fire History Sampling Plot Locations
Wallowa-Whitman National Forest

Scale = 1:75000
Contour Interval = 150 ft

0 miles 1 2

Evidence of fire:
- fire scars
- age classes
- both

9/96



Scale=1:75000
Contour Interval=150 ft

0 miles 1 2

Dugout Creek

Fire History Sampling Plot Locations

Malheur National Forest

Evidence of fire:
- ◢ fire scars
- ● age classes
- ☆ both

9/96

Table A1. Sampling plot characteristics for ***Tucannon****. The abbreviations for plant association follow Johnson and Clausnitzer (1992).*

Plot ID	Elevation (ft)	Aspect (deg.)	Slope (%)	Longitude (deg.)	Latitude (deg.)	Albers-x (m)	Albers-y (m)	Plant Association
1.5	5280	221	62	-117.596	46.195	654,034	577,396	PSME/CARU
1.6	5560	--	0	-117.586	46.196	654,806	577,502	PICO(ABLA2)/VAME
2.4	4710	185	58	-117.598	46.193	653,878	577,175	PSME/CARU
2.5	4650	70	66	-117.594	46.190	654,184	576,839	PSME/CARU
2.6	4920	273	37	-117.588	46.189	654,646	576,724	PSME/CARU
2.7	5550	--	0	-117.579	46.191	655,342	576,942	PICO(ABLA2)/VAME
3.3	3900	216	48	-117.604	46.187	653,411	576,511	ABGR/CARU
3.4	3900	165	62	-117.600	46.187	653,719	576,509	PSME/CARU
3.5	4280	165	33	-117.594	46.184	654,179	576,171	PSME/CARU
3.7	5970	230	49	-117.581	46.187	655,184	576,498	PSME/CARU
3.8	4960	225	64	-117.574	46.186	655,724	576,383	PSME/CARU
3.9	5680	--	0	-117.567	46.187	656,264	576,490	PICO(ABLA2)/CAGE
4.3	3900	340	35	-117.606	46.183	653,253	576,067	ABGR/TABR/LIBO2
4.4	3700	60	85	-117.601	46.183	653,639	576,064	ABGR/TABR/LIBO2
4.5	3810	305	62	-117.593	46.182	654,255	575,948	ABGR/CARU
4.6	4180	127	51	-117.586	46.182	654,795	575,944	PSME/CARU
4.7	4340	246	64	-117.582	46.182	655,103	575,942	PSME/CARU
4.8	4750	142	59	-117.574	46.184	655,722	576,160	PSME/CARU
4.9	5160	205	51	-117.570	46.182	656,029	575,936	PSME/CARU
4.10	5500	215	58	-117.561	46.182	656,724	575,931	PSME/CARU
5.3	4200	290	70	-117.606	46.178	653,248	575,511	ABGR/SPBE
5.4	4560	355	75	-117.599	46.178	653,789	575,507	ABGR/BRVU
5.5	4140	355	60	-117.592	46.177	654,328	575,391	ABGR/LIBO2
5.6	3920	20	40	-117.587	46.178	654,715	575,500	ABGR/TABR/CLUN
5.7	3870	144	55	-117.582	46.179	655,101	575,609	ABGR/CARU
5.8	4200	190	42	-117.576	46.177	655,563	575,383	PSME/CARU
6.2	4480	337	60	-117.611	46.174	652,860	575,069	ABGR/CLUN
6.3	4600	168	60	-117.608	46.173	653,090	574,956	ABGR/CARU
6.4	4780	350	50	-117.600	46.174	653,708	575,062	ABGR/VAME
6.5	4360	70	50	-117.593	46.174	654,248	575,058	ABGR/LIBO2
6.6	4700	20	70	-117.588	46.173	654,633	574,944	ABGR/SPBE
6.7	4240	80	40	-117.580	46.174	655,251	575,051	ABGR/SPBE
6.8	4080	50	60	-117.573	46.172	655,790	574,825	ABGR/TABR/CLUN
6.9	4380	235	38	-117.567	46.174	656,254	575,044	PSME/CARU
6.10	4500	0	35	-117.564	46.173	656,485	574,931	ABGR/LIBO2

Table A1. (cont). Sampling plot characteristics for **Tucannon**. *The abbreviations for plant association follow Johnson and Clausnitzer (1992).*

Plot ID	Elevation (ft)	Aspect (deg.)	Slope (%)	Longitude (deg.)	Latitude (deg.)	Albers-x (m)	Albers-y (m)	Plant Association
7.1	5180	350	65	-117.618	46.168	652,315	574,405	ABGR/BRVU
7.2	5180	320	53	-117.611	46.170	652,856	574,624	ABGR/VAME
7.3	5080	310	63	-117.606	46.168	653,240	574,398	ABGR/VAME
7.4	5080	355	50	-117.600	46.169	653,704	574,506	ABGR/VAME
7.5	4660	335	65	-117.593	46.169	654,244	574,502	ABGR/CLUN
7.6	5220	5	40	-117.586	46.169	654,784	574,498	PICO(ABGR)/VAME
7.7	4680	155	65	-117.582	46.168	655,092	574,385	ABGR/SPBE
7.8	4420	45	55	-117.570	46.169	656,019	574,489	ABGR/SPBE
7.9	4300	70	60	-117.566	46.169	656,327	574,487	ABGR/LIBO2
7.10	4060	70	57	-117.562	46.168	656,636	574,374	ABGR/TABR/LIBO2
8.1	5580	320	7	-117.619	46.164	652,234	573,961	ABLA2/VAME
8.2	5420	90	45	-117.612	46.166	652,776	574,180	ABGR/VAME
8.3	5300	50	30	-117.608	46.163	653,082	573,843	ABGR/VAME
8.4	5280	50	70	-117.601	46.164	653,623	573,951	ABGR/VAME
8.5	5340	290	65	-117.593	46.164	654,240	573,946	ABGR/VAME
8.6	5180	80	58	-117.588	46.164	654,626	573,943	ABGR/VAME
8.7	4880	55	60	-117.581	46.166	655,168	574,162	ABGR/GYDR
9.1	5560	117	27	-117.619	46.160	652,230	573,516	ABGR/VAME
9.2	5640	348	25	-117.612	46.160	652,771	573,512	ABLA2/VAME
9.3	5420	290	25	-117.605	46.159	653,310	573,397	PICO(ABLA2)/VAME
9.4	5360	80	50	-117.601	46.160	653,620	573,506	ABGR/VAME
9.5	5700	315	40	-117.595	46.161	654,083	573,613	ABGR/VAME
9.6	4800	300	53	-117.585	46.160	654,854	573,496	ABGR/VAME
10.2	5560	70	25	-117.613	46.155	652,689	572,956	PICO(ABLA2)/VAME
10.3	5600	355	38	-117.606	46.157	653,231	573,175	ABLA2/VAME
10.4	5600	320	30	-117.599	46.156	653,771	573,059	ABLA2/MEFE
10.5	5640	70	15	-117.593	46.155	654,233	572,945	ABLA2/MEFE
11.3	5820	0	18	-117.607	46.152	653,150	572,619	ABLA2/VAME
11.4	5700	320	15	-117.600	46.152	653,690	572,615	ABLA2/MEFE
11.5	5780	30	25	-117.593	46.151	654,229	572,500	ABLA2/VAME
1	3810	203	37	-117.623	46.191	651,948	576,967	PIPO/CARU
2	3760	150	55	-117.643	46.193	650,408	577,202	PSME/CARU
3	3530	267	47	-117.668	46.200	648,486	577,996	PSME/CARU
4	3200	200	44	-117.695	46.201	646,405	578,125	PSME/CAGE
5	5090	214	28	-117.674	46.219	648,041	580,114	PSME/CARU
6	5090	230	47	-117.650	46.212	649,885	579,320	PSME/CAGE
7	4540	248	54	-117.630	46.201	651,417	578,084	PIPO/CAGE
8	4720	225	50	-117.671	46.211	648,265	579,222	PSME/CAGE
9	4540	137	47	-117.613	46.204	652,741	578,370	--
10	4360	314	57	-117.654	46.203	649,605	578,279	PSME/CARU

Table A2. Sampling plot characteristics for ***Imnaha****. The abbreviations for plant association follow Johnson and Simon (1987).*

Plot ID	Elevation (ft)	Aspect (deg.)	Slope (%)	Longitude (deg.)	Latitude (deg.)	Albers-x (m)	Albers-y (m)	Plant Association
1.1	6050	190	37	-117.023	45.126	698,192	458,314	ABGR/CARU
1.2	6100	--	0	-117.016	45.126	698,742	458,347	ABGR/CARU
1.3	6140	--	0	-117.009	45.126	699,292	458,302	ABGR/CAGE
1.4	6190	210	27	-117.002	45.126	699,843	458,280	ABGR/CARU
1.5	6220	175	37	-116.996	45.125	700,314	458,191	PSME/CARU
2.1	5900	199	34	-117.022	45.125	698,270	458,191	ABGR/CAGE
2.2	5700	171	28	-117.016	45.123	698,742	457,957	PSME/CARU
2.3	5700	177	28	-117.012	45.123	699,057	457,969	PSME/CARU
2.4	5850	147	62	-117.003	45.124	699,764	458,046	PSME/CARU
2.5	5830	168	38	-116.997	45.123	700,236	457,980	PSME/CARU
2.6	5860	171	36	-116.989	45.124	700,865	458,046	PSME/CARU
2.7	5810	171	45	-116.984	45.124	701,258	458,091	PSME/CARU
2.8	5820	186	37	-116.978	45.124	701,730	458,058	PSME/CARU
3.1	5440	112	57	-117.024	45.119	698,113	457,524	PSME/CARU
3.2	5160	167	27	-117.016	45.119	698,742	457,513	PSME/CARU
3.3	5040	157	42	-117.009	45.118	699,292	457,468	PSME/CARU
3.4	5040	150	47	-117.004	45.118	699,686	457,457	PSME/CARU
3.5	5120	175	28	-116.997	45.119	700,236	457,568	PSME/CARU
3.6	5100	169	49	-116.992	45.119	700,629	457,513	PSME/CARU
3.7	5400	170	37	-116.985	45.119	701,179	457,579	PSME/CARU
3.8	5120	155	49	-116.979	45.118	701,651	457,391	PSME/CARU
4.1	4780	115	12	-117.021	45.114	698,349	456,990	PSME/CARU
4.2	4730	168	13	-117.016	45.115	698,742	457,057	PSME/CARU
4.3	4740	175	20	-117.011	45.116	699,135	457,146	PSME/CARU
4.4	4635	170	7	-117.004	45.115	699,686	457,034	PSME/CARU
4.5	4560	186	28	-116.997	45.114	700,236	457,012	PSME/CARU
4.6	4610	149	47	-116.990	45.115	700,786	457,068	PSME/CARU
4.7	4520	180	45	-116.984	45.116	701,258	457,146	PSME/CARU
4.8	4640	189	46	-116.977	45.117	701,808	457,246	PSME/CARU
5.1	5670	71	6	-117.022	45.108	698,270	456,345	ABGR/CARU
5.2	4700	--	0	-117.016	45.110	698,742	456,545	ABGR/CLUN
5.3	4590	20	32	-117.010	45.107	699,214	456,222	ABGR/VAME
5.4	4600	356	18	-117.004	45.110	699,686	456,567	ABGR/VAME
5.5	4800	342	15	-116.998	45.109	700,157	456,434	PSME/CARU
5.6	4780	337	48	-116.991	45.109	700,708	456,445	ABGR/VAME
5.7	4630	321	53	-116.983	45.109	701,337	456,445	ABGR/ACGL
5.8	4810	12	23	-116.979	45.109	701,651	456,456	PSME/VAME

Table A2 (cont.) Sampling plot characteristics for **Imnaha**. *The abbreviations for plant association follow Johnson and Simon (1987).*

Plot ID	Elevation (ft)	Aspect (deg.)	Slope (%)	Longitude (deg.)	Latitude (deg.)	Albers-x (m)	Albers-y (m)	Plant Association
6.1	5920	351	11	-117.021	45.105	698,348	455,978	ABGR/VAME
6.2	4970	355	19	-117.016	45.105	698,742	456,011	ABGR/VAME
6.3	4975	357	57	-117.010	45.106	699,214	456,055	ABGR/VAME
6.4	5020	357	63	-117.004	45.106	699,686	456,111	ABGR/VAME
6.5	5280	342	57	-116.997	45.106	700,236	456,033	ABGR/CARU
6.6	5520	5	25	-116.990	45.104	700,787	455,900	ABGR/CLUN
6.7	5520	0	60	-116.984	45.105	701,258	455,922	ABGR/VAME
6.8	5440	348	18	-116.978	45.104	701,730	455,889	ABGR/VAME
7.1	5240	335	27	-117.021	45.100	698,348	455,444	ABGR/VAME
7.2	5400	50	5	-117.016	45.100	698,742	455,466	ABGR/CARU
7.3	5560	340	8	-117.010	45.100	699,213	455,444	ABGR/VAME
7.4	5620	190	12	-117.004	45.100	699,686	455,366	ABGR/VAME
7.5	5740	335	25	-116.997	45.100	700,236	455,455	ABGR/VAME
7.6	5800	345	6	-116.990	45.101	700,787	455,522	PICO(ABGR)/VAME
7.7	5920	15	4	-116.985	45.099	701,180	455,344	ABGR/CARU
7.8	5860	70	10	-116.978	45.101	701,730	455,555	ABLA2/VAME
8.1	5400	25	20	-117.022	45.096	698,270	454,910	ABGR/VAME
8.2	5440	0	35	-117.016	45.096	698,742	454,932	ABGR/VAME
8.3	5560	0	30	-117.009	45.096	699,292	454,998	ABGR/VAME
8.4	5480	280	15	-117.005	45.095	699,607	454,865	ABGR/VAME
8.5	5420	180	10	-116.997	45.097	700,236	455,065	ABGR/VAME
8.6	5720	159	10	-116.990	45.097	700,787	455,021	ABGR/CARU
8.7	5850	170	12	-116.985	45.097	701,180	455,021	ABGR/CARU
8.8	5780	130	10	-116.977	45.096	701,809	454,955	ABGR/VAME
9.1	5640	15	32	-117.024	45.091	698,112	454,432	ABGR/VAME
9.2	5640	--	0	-117.017	45.091	698,663	454,454	ABGR/VAME
9.3	5600	60	18	-117.010	45.091	699,213	454,465	ABGR/VAME
1	4440	155	52	-116.886	45.141	708,958	459,977	PIPO/CARU
2	4200	--	0	-116.903	45.122	707,625	457,862	PIPO/CARU
3	4410	173	38	-116.924	45.111	705,975	456,637	PSME/CARU
4	5690	173	28	-116.972	45.123	702,201	457,969	PSME/CARU
5	5430	101	37	-116.914	45.123	706,760	457,972	PSME/CARU
6	5150	171	48	-116.894	45.143	708,330	460,199	PSME/CARU
7	4470	209	58	-116.964	45.114	702,831	456,968	PSME/CAGE
8	4980	150	25	-116.943	45.122	704,481	457,859	PSME/CARU
9	4199	164	2	-116.916	45.109	706,605	456,415	ABGR/VAME
10	5300	226	19	-116.878	45.126	709,590	458,310	PSME/CARU

Table A3. Sampling plot characteristics for ***Baker****. The abbreviations for plant association follow Johnson and Clausnitzer (1992).*

Plot ID	Elevation (ft)	Aspect (deg.)	Slope (%)	Longitude (deg.)	Latitude (deg.)	Albers-x (m)	Albers-y (m)	Plant Association
2.5	5300	330	45	-118.016	44.801	619,684	422,660	ABGR/BRVU
2.6	5360	355	38	-118.011	44.803	620,082	422,878	PICO(ABGR)/CARU
2.7	5140	70	40	-118.002	44.803	620,794	422,869	ABGR/VAME
2.8	4720	135	55	-117.997	44.802	621,187	422,752	PSME/CARU
2.9	4480	135	20	-117.994	44.803	621,426	422,861	PSME/CARU
2.10	4360	85	43	-117.984	44.803	622,216	422,851	PSME/CARU
3.4	5360	350	55	-118.022	44.798	619,205	422,333	ABGR/VAME
3.5	5520	330	55	-118.016	44.799	619,681	422,438	ABGR/VAME
3.6	5300	135	35	-118.007	44.797	620,390	422,206	PSME/CARU
3.7	4860	136	49	-118.001	44.798	620,866	422,312	PSME/CARU
3.8	4940	0	50	-117.996	44.797	621,259	422,196	PSME/CARU
3.9	4870	5	38	-117.990	44.799	621,737	422,412	PSME/CARU
3.10	4620	109	48	-117.985	44.799	622,132	422,407	PSME/CARU
3.11	4970	100	49	-117.982	44.798	622,367	422,293	PSME/CARU
4.2	6180	321	37	-118.034	44.794	618,251	421,900	ABGR/VAME
4.3	6200	330	39	-118.028	44.793	618,724	421,782	ABGR/VAME
4.5	5480	170	51	-118.018	44.793	619,515	421,772	PSME/CARU
4.6	5150	170	45	-118.010	44.796	620,151	422,098	PSME/CARU
4.7	5000	180	44	-118.005	44.796	620,547	422,093	PSME/CARU
4.8	4840	13	67	-118.000	44.794	620,939	421,866	ABGR/LIBO2
4.9	5230	306	35	-117.991	44.793	621,649	421,746	ABGR/LIBO2
4.10	5070	103	37	-117.987	44.795	621,968	421,964	PSME/CARU
4.11	5060	57	12	-117.982	44.792	622,359	421,626	PSME/CARU
5.2	6780	331	36	-118.035	44.789	618,165	421,345	ABLA2/VASC
5.3	6380	80	63	-118.027	44.789	618,797	421,337	ABLA2/ARCO
5.5	5360	10	45	-118.015	44.789	619,746	421,325	ABGR/LIBO2
5.6	5520	125	40	-118.011	44.787	620,060	421,098	PSME/CARU
5.7	5080	330	35	-118.003	44.789	620,695	421,313	ABGR/LIBO2
5.8	5400	310	45	-117.998	44.790	621,092	421,419	ABGR/VAME
5.9	5160	160	25	-117.988	44.789	621,881	421,298	PSME/CELE/CAGE
5.10	4920	135	45	-117.984	44.788	622,196	421,183	PSME/CARU
6.1	7180	293	72	-118.040	44.783	617,761	420,683	ABLA2-PIAL/POPU
6.2	7060	120	50	-118.034	44.785	618,239	420,899	ABLA2/VASC
6.3	6580	140	37	-118.028	44.784	618,711	420,782	ABGR/ARCO
6.4	6160	340	47	-118.022	44.785	619,187	420,887	PICO(ABLA2)/VASC
6.5	5960	130	18	-118.015	44.787	619,743	421,102	PSME/CARU
6.6	5460	290	45	-118.010	44.785	620,136	420,875	ABGR/BRVU
6.9	5600	160	50	-117.994	44.786	621,402	420,970	PSME/CARU

Table A3 (cont.). Sampling plot characteristics for **Baker**. *The abbreviations for plant association follow Johnson and Clausnitzer (1992).*

Plot ID	Elevation (ft)	Aspect (deg.)	Slope (%)	Longitude (deg.)	Latitude (deg.)	Albers-x (m)	Albers-y (m)	Plant Association
7.1	7620	55	26	-118.041	44.780	617,678	420,350	PICO(ABLA2)/CAGE
7.2	6940	70	30	-118.037	44.781	617,995	420,457	PICO(ABLA2)/VASC
7.3	6800	4	37	-118.030	44.781	618,549	420,450	PICO(ABLA2)/VASC
7.4	6100	120	25	-118.022	44.782	619,183	420,553	ABLA2/VAME
7.5	6140	5	40	-118.014	44.779	619,811	420,211	ABLA2/VAME
7.6	6160	5	53	-118.010	44.781	620,130	420,430	ABLA2/VAME
7.7	6160	350	50	-118.007	44.782	620,369	420,538	PICO(ABGR)/VAME
7.8	5400	135	60	-117.995	44.783	621,319	420,638	PSME/CELE/CAGE
8.1	7380	110	35	-118.041	44.776	617,672	419,905	PICO(ABLA2)/CAGE
8.2	6830	122	24	-118.034	44.776	618,226	419,898	PICO(ABLA2)/CAGE
8.3	6600	80	20	-118.029	44.776	618,621	419,893	PICO(ABLA2)/VAME
8.4	6460	20	37	-118.022	44.776	619,174	419,886	PICO(ABLA2)/VASC
8.5	6620	10	50	-118.017	44.777	619,571	419,992	PICO(ABLA2)/VASC
8.6	5560	60	35	-118.009	44.776	620,202	419,873	ABGR/CARU
8.8	5300	45	54	-117.996	44.777	621,232	419,971	ABGR/CARU
9.1	7380	5	60	-118.041	44.773	617,667	419,571	ABLA2/VASC
9.2	7110	52	28	-118.036	44.772	618,061	419,455	PICO(ABLA2)/VASC
9.3	7070	355	28	-118.028	44.772	618,694	419,447	ABLA2/VASC
9.4	7150	310	18	-118.023	44.771	619,088	419,331	PICO(ABLA2)/VASC
9.5	6820	165	45	-118.015	44.772	619,722	419,434	PSME/CARU
9.6	6600	180	40	-118.010	44.773	620,119	419,540	PSME/CARU
10.3	7240	50	35	-118.028	44.767	618,687	418,891	PICO(ABLA2)/VASC
10.4	7320	320	5	-118.021	44.768	619,242	418,995	PICO(ABLA2)/CAGE
1	5480	59	54	-117.981	44.778	622,419	420,068	ABGR/CARU
2	5390	66	42	-117.964	44.777	623,763	419,940	ABGR/CARU
3	5120	132	54	-118.026	44.810	618,906	423,671	ABGR/CARU
4	4350	139	38	-117.959	44.787	624,171	421,048	PSME/CAGE
5	4100	24	21	-117.946	44.784	625,195	420,702	PSME/CARU
6	4400	189	31	-117.927	44.774	626,684	419,572	PIPO/FEID
7	4950	221	22	-117.940	44.763	625,642	418,361	PSME/CAGE
8	5100	130	22	-117.959	44.742	624,111	416,043	PSME/CAGE
9	4550	200	25	-117.945	44.731	625,205	414,807	PIPO/CAGE
10	6040	161	22	-117.982	44.761	622,317	418,178	ABGR/CAGE
11	4510	94	45	-117.921	44.757	627,138	417,676	PSME/CAGE

Table A4. Sampling plot characteristics for ***Dugout****. The abbreviations for plant association follow Johnson and Clausnitzer (1992).*

Plot ID	Elevation (ft)	Aspect (deg.)	Slope (%)	Longitude (deg.)	Latitude (deg.)	Albers-x (m)	Albers-y (m)	Plant Association
2.1	5240	280	22	-118.379	44.230	589,902	359,597	PSME/CARU
2.2	5440	290	35	-118.374	44.231	590,303	359,701	PSME/CARU
2.3	5640	150	0	-118.366	44.233	590,946	359,913	ABGR/CARU
2.4	5640	225	2	-118.359	44.231	591,500	359,681	PSME/CARU
3.1	5300	300	20	-118.378	44.227	589,976	359,262	ABGR/CAGE
3.2	5680	290	15	-118.372	44.227	590,455	359,254	PSME/CARU
3.3	5660	90	2	-118.366	44.229	590,938	359,468	PSME/CARU
3.4	5690	53	16	-118.362	44.227	591,253	359,240	PSME/CARU
4.1	5280	260	25	-118.377	44.223	590,048	358,816	PSME/CARU
4.2	5580	290	40	-118.372	44.220	590,442	358,476	PSME/CARU
4.3	5760	255	10	-118.364	44.223	591,086	358,798	PSME/CARU
5.1	5040	255	12	-118.379	44.218	589,879	358,263	PSME/CARU
5.2	5680	300	20	-118.372	44.218	590,438	358,253	PSME/CARU
5.3	5780	60	10	-118.364	44.219	591,079	358,354	PSME/CARU
5.4	5800	328	9	-118.358	44.217	591,554	358,123	PSME/CARU
5.5	5720	--	0	-118.355	44.217	591,793	358,119	PSME/CARU
6.1	5040	230	20	-118.378	44.213	589,949	357,706	PSME/CARU
6.2	5330	189	22	-118.372	44.213	590,428	357,697	PSME/CARU
6.3	5480	270	17	-118.368	44.213	590,748	357,692	PSME/CARU
6.4	5580	280	23	-118.359	44.214	591,468	357,791	PSME/CAGE
6.5	5700	185	22	-118.353	44.212	591,944	357,561	PSME/CARU
6.6	5800	170	12	-118.346	44.213	592,505	357,662	PSME/CARU
6.7	5860	234	10	-118.344	44.213	592,664	357,660	PSME/CARU
7.1	5280	--	6	-118.377	44.210	590,024	357,370	PSME/CARU
7.2	5340	340	20	-118.371	44.207	590,497	357,029	PSME/CARU
7.3	5460	342	16	-118.364	44.208	591,058	357,131	ABGR/CARU
7.4	5560	14	14	-118.358	44.209	591,539	357,234	ABGR/CARU
7.5	5560	278	32	-118.353	44.208	591,937	357,116	ABGR/CARU
7.6	5760	315	15	-118.347	44.209	592,417	357,219	PSME/CARU
7.7	5860	305	6	-118.341	44.210	592,898	357,322	PSME/CARU
8.1	5320	300	32	-118.378	44.204	589,932	356,705	PSME/CARU
8.2	5480	270	30	-118.372	44.205	590,413	356,808	PSME/CARU
8.3	5680	0	10	-118.365	44.205	590,973	356,799	PSME/CAGE
8.4	5780	332	3	-118.359	44.204	591,450	356,679	PSME/CARU
8.5	5880	60	15	-118.353	44.204	591,929	356,671	ABGR/CAGE
8.6	5760	253	13	-118.350	44.205	592,170	356,778	PSME/CAGE
9.1	5040	242	35	-118.378	44.200	589,925	356,260	PSME/CARU
9.2	5300	324	20	-118.372	44.200	590,404	356,252	PSME/CARU
9.3	5740	173	7	-118.365	44.201	590,965	356,354	PSME/CAGE
9.4	5700	--	0	-118.358	44.200	591,522	356,233	PSME/CARU
9.5	5880	345	8	-118.353	44.200	591,922	356,226	PSME/CAGE

Table A4 (cont.). Sampling plot characteristics for **Dugout**. *The abbreviations for plant association follow Johnson and Clausnitzer (1992).*

Plot ID	Elevation (ft)	Aspect (deg.)	Slope (%)	Longitude (deg.)	Latitude (deg.)	Albers-x (m)	Albers-y (m)	Plant Association
9.6	5820	--	0	-118.347	44.200	592,401	356,218	PSME/CARU
10.1	4900	228	18	-118.378	44.195	589,915	355,704	PSME/CARU
10.2	5250	307	28	-118.372	44.197	590,398	355,918	PSME/CARU
10.3	5540	--	0	-118.365	44.196	590,956	355,798	PSME/CAGE
10.4	5480	220	15	-118.362	44.193	591,189	355,460	PSME/CAGE
10.5	5820	165	11	-118.353	44.197	591,916	355,893	PSME/CAGE
10.6	5840	--	0	-118.345	44.195	592,551	355,660	PSME/CARU
10.7	5840	258	6	-118.340	44.195	592,951	355,653	PSME/CAGE
11.1	4900	340	20	-118.378	44.191	589,908	355,260	PSME/CARU
11.2	5000	--	0	-118.374	44.189	590,223	355,032	PSME/CARU
11.3	5480	220	8	-118.367	44.190	590,784	355,133	PIPO/AGSP
11.4	5400	220	15	-118.361	44.191	591,265	355,237	PSME/CAGE
11.5	5840	--	0	-118.353	44.191	591,905	355,226	PSME/CARU
11.6	5840	355	8	-118.346	44.191	592,464	355,217	PSME/CARU
11.7	5820	--	0	-118.341	44.190	592,861	355,098	PSME/CARU
12.1	4620	280	50	-118.379	44.187	589,820	354,816	PSME/CAGE
12.2	5080	230	12	-118.373	44.187	590,299	354,808	PSME/CARU
12.3	5150	245	12	-118.366	44.187	590,859	354,799	PSME/CARU
12.4	5360	260	50	-118.359	44.187	591,418	354,789	PSME/CARU
12.5	5620	255	14	-118.355	44.187	591,737	354,784	PIPO/CARU
12.6	5560	100	20	-118.348	44.186	592,295	354,663	PIPO/CARU
12.7	5760	268	12	-118.342	44.186	592,774	354,655	PIPO/CARU
1	5760	10	8	-118.354	44.250	591,935	361,786	ABGR/CARU
2	5640	222	12	-118.372	44.245	590,489	361,255	PIPO/CARU
3	5520	350	20	-118.348	44.232	592,380	359,777	ABGR/CARU
4	5670	69	12	-118.409	44.239	587,525	360,639	ABGR/CARU
5	5580	40	27	-118.401	44.220	588,126	358,516	ABGR/CARU
6	5680	107	22	-118.402	44.206	588,019	356,960	ABGR/CARU
7	5960	190	18	-118.417	44.219	586,847	358,427	ABGR/CARU
8	4860	299	33	-118.353	44.173	591,871	353,225	PIPO/CARU
9	5340	--	0	-118.410	44.179	587,327	353,970	PSME/CARU
10	5130	65	18	-118.403	44.167	587,864	352,626	PSME/CARU
11	4950	103	38	-118.386	44.171	589,230	353,047	PSME/CARU
12	5300	190	17	-118.335	44.219	593,394	358,315	PIPO/CAGE
13	5260	150	33	-118.330	44.207	593,771	356,974	PIPO/CARU
14	5100	261	46	-118.307	44.198	595,592	355,943	PIPO/CARU
15	5200	150	35	-118.311	44.185	595,249	354,503	PIPO/CARU
16	4830	200	12	-118.295	44.160	596,483	351,703	PIPO/CARU
17	5550	323	18	-118.322	44.239	594,469	360,521	ABGR/CARU
18	5140	210	25	-118.393	44.267	588,856	363,729	PIPO/CAGE
19	5030	65	6	-118.400	44.251	588,266	361,960	ABGR/CAGE

APPENDIX B: IDENTIFYING AGE-CLASSES USING SPATIAL STATISTICS

Because age classes of trees resulting from fire typically have a range of ages and can overlap spatially in forests that experience partial stand-replacement fires, we identified them statistically (Duncan and Stewart 1991) for each site with mesic forests (Baker, Imnaha and Tucannon). First, we tested for the presence of similarly-aged patches of trees using Moran's I as a measure of spatial autocorrelation (Legendre and Fortin 1989). An all-directional correlogram of Moran's I was constructed for 9 to 11 distance classes (0.3 miles each) and tested for global significance using the Bonferroni correction for multiple tests (Figure B1). Significant *positive* autocorrelation in the short distance classes implies that trees that are near each other are similar in age while significant *negative* autocorrelation in long distance classes implies differences in age between distant trees. The Bonferroni method determines global significance by checking the correlogram for at least one value that is significant at the corrected level which is calculated as:

$$\alpha' = \alpha/\upsilon = 0.01/10 = 0.001$$

where: α' = corrected significance level for a each distance class,
α = global significance level,
υ = number of distance classes being tested.

At Tucannon, 8 out of 11 distance classes were significantly autocorrelated and at Imnaha 3 out of 10 distance classes were significantly autocorrelated. However, at Baker, no distance classes were significantly autocorrelated. This indicates that Tucannon and Imnaha have spatial structures consistent that are statistically consistent with similarly-aged patches but Baker does not.

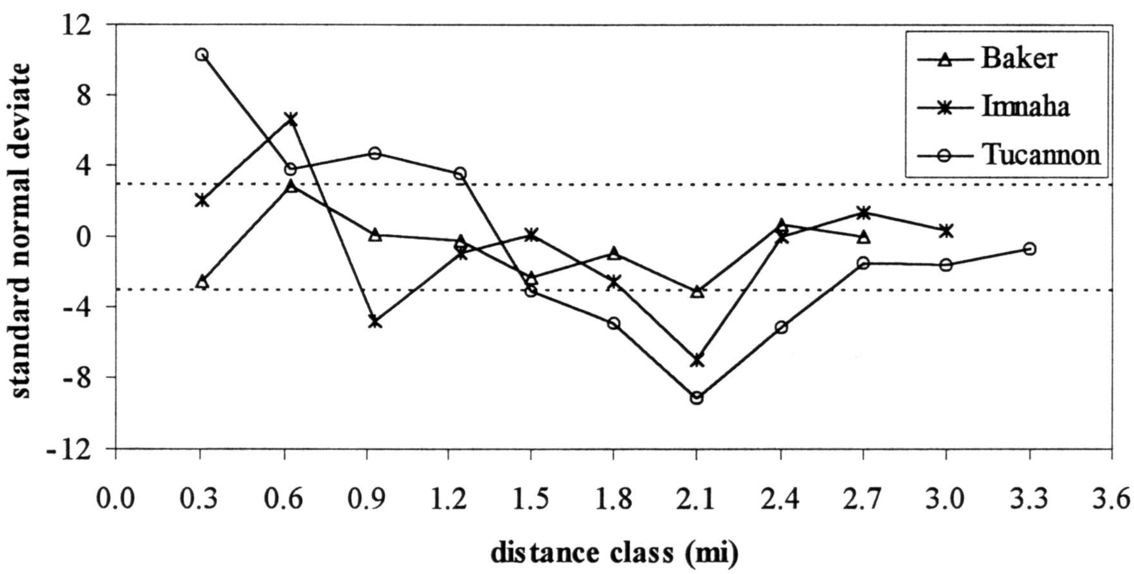


Figure B1. Spatial correlogram of tree ages by site for mesic forests. Standard normal deviate of Moran's I is plotted. Values falling outside the envelope of the dotted lines are significant at the Bonferroni corrected level (0.001).

Next, at Tucannon and Imnaha, we performed hierarchical agglomerative clustering (MathSoft 1995) with a matrix of dissimilarity indices that incorporates both distance between trees and difference between tree ages:

$$c_{ij} = \lambda \frac{d_{ij}}{d_{max}} + (1-\lambda)\frac{a_{ij}}{a_{max}}$$

where: c_{ij} = measure of dissimilarity,
a_{ij} = difference in age between trees i and j,
a_{max} = greatest age difference between a pair of trees at the site,
d_{ij} = difference in distance between trees i and j,
d_{max} = greatest distance between a pair of trees at the site,
λ = weighting assigned to age versus distance, a constant ($0 \le \lambda \le 1$).

We gave age and distance equal weighting ($\lambda = 0.5$). Even-aged classes of trees identified by clustering were recognized as fire-created patches of trees if they were spatially discrete. The earliest establishment date in each even-aged class was selected as the fire date except when the class was coincident with a large low severity fire in an adjacent dry forest. In this case, the date of the low severity fire was assigned as the establishment date of the age class. At all sites, we sampled more than the 30 localities recommended for analysis with spatial statistics (Fortin et al. 1989).

APPENDIX C: SUMMARY STATISTICS FOR FIRE YEARS, BY SITE

Table C1. Summary statistics for fire years at ***Tucannon.***

	Fire year	Extent: Total (ac)	Extent: Dry forests (ac)	Extent: Mesic forests (ac)	No. of plots: Dry	No. of plots: Mesic	No. of trees: Dry	No. of trees: Mesic
1	1583	901	901	--	3	--	5	--
2	1618	954	954	--	2	--	3	--
3	1630	973	973	--	6	--	9	--
4	1635	354	354	--	1	--	2	--
5	1652	1,937	1,937	--	9	--	12	--
6	1664	544	544	--	2	--	3	--
7	1671	1,930	1,930	--	5	--	9	--
8	1685	398	398	--	1	--	2	--
9	1695	1,050	1,050	--	9	--	15	--
10	1703	1,185	1,185	--	2	--	5	--
11	1705	318	318	--	2	--	4	--
12	1706	1,206	1,206	--	3	--	5	--
13	1712	707	707	--	2	--	2	--
14	1734	376	376	--	1	--	3	--
15	1743	1,056	1,056	--	3	--	8	--
16	1748	515	515	--	3	--	5	--
17	1751	75	75	--	2	--	3	--
18	1754	249	--	249	--	4	--	26
19	1756	250	250	--	1	--	4	--
20	1759	3,191	3,191	--	14	--	27	--
21	1765	670	670	--	2	--	2	--
22	1774	4,158	2,503	1,655	17	15	39	45
23	1776	295	295	--	1	--	3	--
24	1779	823	823	--	2	--	4	--
25	1791	425	425	--	2	--	2	--
26	1799	173	173	--	1	--	4	--
27	1816	1,131	1,131	--	3	--	7	--
28	1828	2,443	2,443	--	7	--	25	--
29	1839	1,817	1,817	--	5	--	13	--
30	1841	296	--	296	--	6	--	42
31	1855	2,543	2,543	--	7	--	24	--
32	1863	269	269	--	4	--	7	--
33	1865	857	857	--	7	--	18	--
34	1869	1,088	1,088	--	3	--	8	--
35	1873	507	507	--	4	--	7	--
36	1883	75	75	--	2	--	3	--
37	1886	1,868	1,868	--	5	--	15	--
38	1888	5,137	3,417	1,720	20	31	55	192
39	1893	47	47	--	1	--	2	--
40	1898	490	490	--	3	--	3	--

*Table C2. Summary statistics for fire years at **Imnaha**.*

	Fire year	Extent: Total (ac)	Extent: Dry forests (ac)	Extent: Mesic forests (ac)	No. of plots: Dry	No. of plots: Mesic	No. of trees: Dry	No. of trees: Mesic
1	1632	96	96	--	1	--	2	--
2	1652	96	96	--	1	--	3	--
3	1661	294	294	--	3	--	3	--
4	1671	678	678	--	2	--	3	--
5	1681	96	96	--	1	--	2	--
6	1687	1,434	1,434	--	11	--	16	--
7	1705	1,768	1,768	--	3	--	7	--
8	1712	644	644	--	4	--	6	--
9	1722	607	607	--	8	--	13	--
10	1724	301	301	--	1	--	2	--
11	1747	200	200	--	1	--	3	--
12	1751	1,251	1,251	--	6	--	8	--
13	1752	606	606	--	2	--	6	--
14	1754	390	390	--	2	--	2	--
15	1763	1,347	1,347	--	17	--	27	--
16	1778	1,731	1,731	--	6	--	13	--
17	1783	4,289	4,289	--	30	--	51	--
18	1795	1,583	1,583	--	4	--	9	--
19	1798	3,783	1,847	1,936	20	33	49	117
20	1831	316	316	--	1	--	4	--
21	1834	5,449	4,824	625	35	13	84	45
22	1844	2,671	2,671	--	7	--	18	--
23	1846	63	63	--	1	--	2	--
24	1852	697	697	--	12	--	20	--
25	1863	329	329	--	1	--	4	--
26	1864	346	--	346	--	6	2	16
27	1869	1,764	1,764	--	18	--	33	--
28	1871	1,682	1,682	--	5	--	17	--
29	1885	971	971	--	4	--	13	--
30	1886	1,732	1,329	403	20	11	42	45
31	1889	98	98	--	2	--	3	--
32	1890	544	544	--	2	--	3	--
33	1896	365	365	--	1	--	3	--
34	1897	757	757	--	6	--	11	--
35	1898	695	695	--	5	--	7	--
36	1902	600	600	--	2	--	4	--
37	1905	437	437	--	3	--	4	--
38	1917	99	99	--	2	--	2	--
39	1919	193	193	--	2	--	4	--

*Table C3. Summary statistics for fire years at **Baker.***

	Fire year	Extent: Total (ac)	Extent: Dry forests (ac)	Extent: Mesic forests (ac)	No. of plots: Dry	No. of plots: Mesic	No. of trees: Dry	No. of trees: Mesic
1	1634	3,726	3,726	--	6	--	10	--
2	1646	3,458	3,458	--	6	--	9	--
3	1652	2,933	2,933	--	9	--	12	--
4	1656	3,478	3,478	--	6	--	7	--
5	1668	988	988	--	2	--	3	--
6	1671	3,443	3,443	--	13	--	19	--
7	1679	3,419	3,419	--	6	--	11	--
8	1695	8,184	8,184	--	26	--	58	--
9	1706	1,121	1,121	--	7	--	9	--
10	1708	6,046	6,046	--	13	--	27	--
11	1712	1,048	1,048	--	6	--	10	--
12	1717	2,276	2,276	--	9	--	14	--
13	1721	1,154	1,154	--	2	--	4	--
14	1722	4,559	4,559	--	11	--	14	--
15	1729	7,485	7,485	--	21	--	45	--
16	1739	6,499	6,499	--	15	--	33	--
17	1751	6,923	6,923	--	22	--	52	--
18	1756	122	122	--	2	--	3	--
19	1762	6,375	6,375	--	19	--	55	--
20	1767	1,901	1,901	--	7	--	17	--
21	1770	550	550	--	1	--	4	--
22	1776	2,479	2,479	--	19	--	35	--
23	1777	1,154	1,154	--	3	--	11	--
24	1778	4,660	4,660	--	6	--	20	--
25	1781	909	909	--	7	--	14	--
26	1783	6,155	6,155	--	21	--	38	--
27	1788	842	842	--	3	--	8	--
28	1791	7,319	7,319	--	23	--	57	--
29	1794	877	877	--	4	--	5	--
30	1797	1,321	1,321	--	3	--	13	--
31	1798	2,585	2,585	--	15	--	31	--
32	1800	5,925	5,925	--	10	--	24	--
33	1807	283	283	--	1	--	3	--
34	1812	3,532	3,532	--	5	--	16	--
35	1816	2,626	2,626	--	16	--	35	--

Table C3 (cont.). Summary statistics for fire years at ***Baker.***

	Fire year	Extent: Total (ac)	Extent: Dry forests (ac)	Extent: Mesic forests (ac)	No. of plots: Dry	No. of plots: Mesic	No. of trees: Dry	No. of trees: Mesic
36	1822	6,736	6,736	--	20	--	45	--
37	1826	1,738	1,738	--	3	--	6	--
38	1828	1,579	1,579	--	7	--	15	--
39	1833	1,411	1,411	--	8	--	22	--
40	1834	5,592	5,592	--	19	--	36	--
41	1839	2,711	2,711	--	8	--	17	--
42	1846	9,140	9,140	--	31	--	64	--
43	1854	487	487	--	3	--	9	--
44	1855	2,266	2,266	--	3	--	7	--
45	1857	2,272	2,272	--	13	--	23	--
46	1865	723	723	--	1	--	3	--
47	1869	3,026	3,026	--	7	--	15	--
48	1871	647	647	--	1	--	3	--
49	1872	93	93	--	1	--	3	--
50	1879	190	190	--	2	--	5	--
51	1880	121	121	--	2	--	3	--
52	1883	82	82	--	1	--	4	--
53	1892	233	233	--	4	--	6	--
54	1962	93	93	--	2	--	3	--

Table C4. Summary statistics for fire years at ***Dugout.***

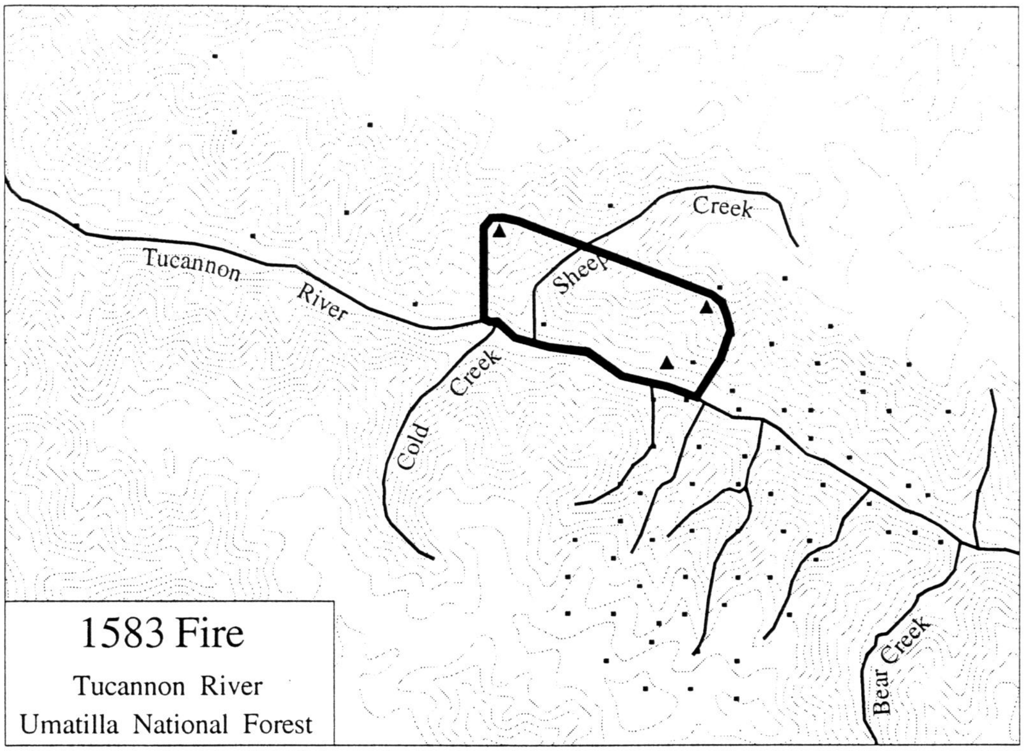
	Fire year	Extent: Total (ac)	Extent: Dry forests (ac)	Extent: Mesic forests (ac)	No. of plots: Dry	No. of plots: Mesic	No. of trees: Dry	No. of trees: Mesic
1	1529	784	784	--	3	--	3	--
2	1540	1,072	1,072	--	3	--	3	--
3	1547	121	121	--	2	--	2	--
4	1565	2,939	2,939	--	5	--	6	--
5	1570	1,735	1,735	--	5	--	5	--
6	1593	537	537	--	2	--	3	--
7	1598	3,108	3,108	--	12	--	12	--
8	1629	13,668	13,668	--	30	--	38	--
9	1645	6,627	6,627	--	16	--	17	--
10	1652	1,472	1,472	--	3	--	3	--
11	1656	12,319	12,319	--	34	--	48	--
12	1664	801	801	--	4	--	4	--
13	1667	2,935	2,935	--	17	--	24	--
14	1676	9,499	9,499	--	21	--	30	--
15	1685	93	93	--	2	--	3	--
16	1687	16,611	16,611	--	40	--	65	--
17	1688	848	848	--	1	--	3	--
18	1690	1,193	1,193	--	7	--	7	--
19	1694	1,613	1,613	--	3	--	3	--
20	1697	3,523	3,523	--	5	--	7	--
21	1700	7,909	7,909	--	26	--	30	--
22	1707	2,655	2,655	--	10	--	12	--
23	1710	18,318	18,318	--	47	--	76	--
24	1721	19,959	19,959	--	54	--	91	--
25	1729	3,102	3,102	--	6	--	7	--
26	1732	2,753	2,753	--	11	--	17	--
27	1733	323	323	--	1	--	2	--
28	1734	5,981	5,981	--	34	--	48	--
29	1737	914	914	--	1	--	2	--
30	1739	4,734	4,734	--	18	--	29	--
31	1740	1,345	1,345	--	1	--	3	--
32	1741	10,588	10,588	--	19	--	30	--
33	1743	250	250	--	3	--	3	--
34	1745	1,937	1,937	--	5	--	7	--
35	1751	13,149	13,149	--	47	--	83	--
36	1753	932	932	--	2	--	2	--
37	1755	1,677	1,677	--	2	--	3	--
38	1756	9,975	9,975	--	25	--	36	--
39	1759	9,548	9,548	--	31	--	50	--
40	1765	2,147	2,147	--	3	--	4	--

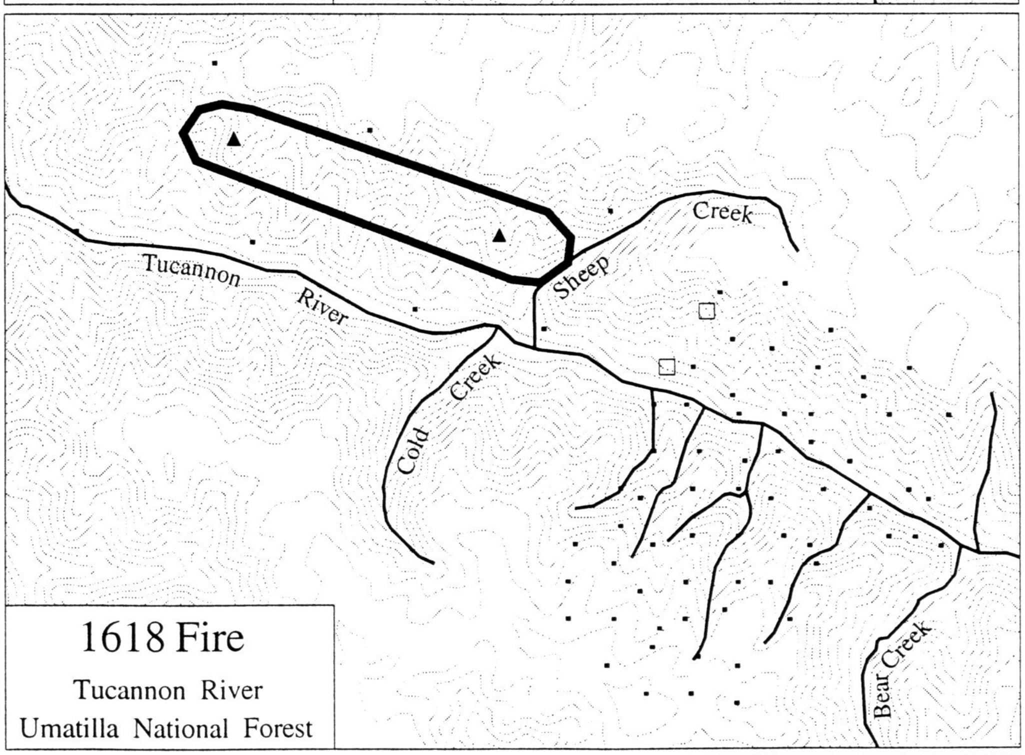
Table C4 (cont.). Summary statistics for fire years at ***Dugout.***

	Fire year	Extent: Total (ac)	Extent: Dry forests (ac)	Extent: Mesic forests (ac)	No. of plots: Dry	No. of plots: Mesic	No. of trees: Dry	No. of trees: Mesic
41	1771	15,426	15,426	--	51	--	94	--
42	1774	1,919	1,919	--	2	--	3	--
43	1775	390	390	--	6	--	7	--
44	1776	3,540	3,540	--	5	--	11	--
45	1780	9,509	9,509	--	31	--	48	--
46	1783	8,797	8,797	--	22	--	42	--
47	1788	1,881	1,881	--	2	--	7	--
48	1789	733	733	--	1	--	3	--
49	1792	1,427	1,427	--	2	--	4	--
50	1794	18,283	18,283	--	60	--	112	--
51	1799	8,251	8,251	--	17	--	20	--
52	1800	7,339	7,339	--	27	--	43	--
53	1802	3,633	3,633	--	14	--	18	--
54	1804	3,526	3,526	--	9	--	15	--
55	1806	259	259	--	3	--	4	--
56	1807	796	796	--	13	--	24	--
57	1812	3,876	3,876	--	7	--	17	--
58	1814	556	556	--	1	--	3	--
59	1822	3,886	3,886	--	6	--	16	--
60	1823	2,408	2,408	--	3	--	9	--
61	1829	19,292	19,292	--	66	--	151	--
62	1830	1,137	1,137	--	2	--	2	--
63	1835	6,856	6,856	--	23	--	34	--
64	1840	1,523	1,523	--	3	--	4	--
65	1844	18,437	18,437	--	64	--	132	--
66	1849	914	914	--	1	--	3	--
67	1856	7,964	7,964	--	29	--	56	--
68	1868	496	496	--	7	--	13	--
69	1869	18,910	18,910	--	57	--	125	--
70	1873	1,058	1,058	--	2	--	3	--
71	1877	590	590	--	1	--	3	--
72	1878	732	732	--	1	--	2	--
73	1883	1,539	1,539	--	2	--	4	--
74	1887	846	846	--	1	--	4	--
75	1888	2,570	2,570	--	4	--	20	--
76	1889	5,055	5,055	--	43	--	76	--
77	1898	2,003	2,003	--	3	--	4	--
78	1899	919	919	--	2	--	3	--
79	1914	635	635	--	1	--	2	--
80	1926	57	57	--	1	--	2	--

APPENDIX D: TUCANNON: FIRE MAPS

Evidence of fire was mapped at Tucannon for every year in dry forests which had at least two scars and for every fire event identified in mesic forests. The maps show whether the evidence of fire was age classes or scars. If the later, the intra-annular position of the scar is also indicated. Plots indicating as having probable evidence of fire are those for which the only evidence was an abrupt increase or decrease in ring width. Plots having no evidence of fire in a given year had recording trees for that year but did not have scars or an age class for that year. Plots indicated as having no record for a given year are plots that were sampled but had no trees recording during that year. Fire boundaries are shown as a heavy line.



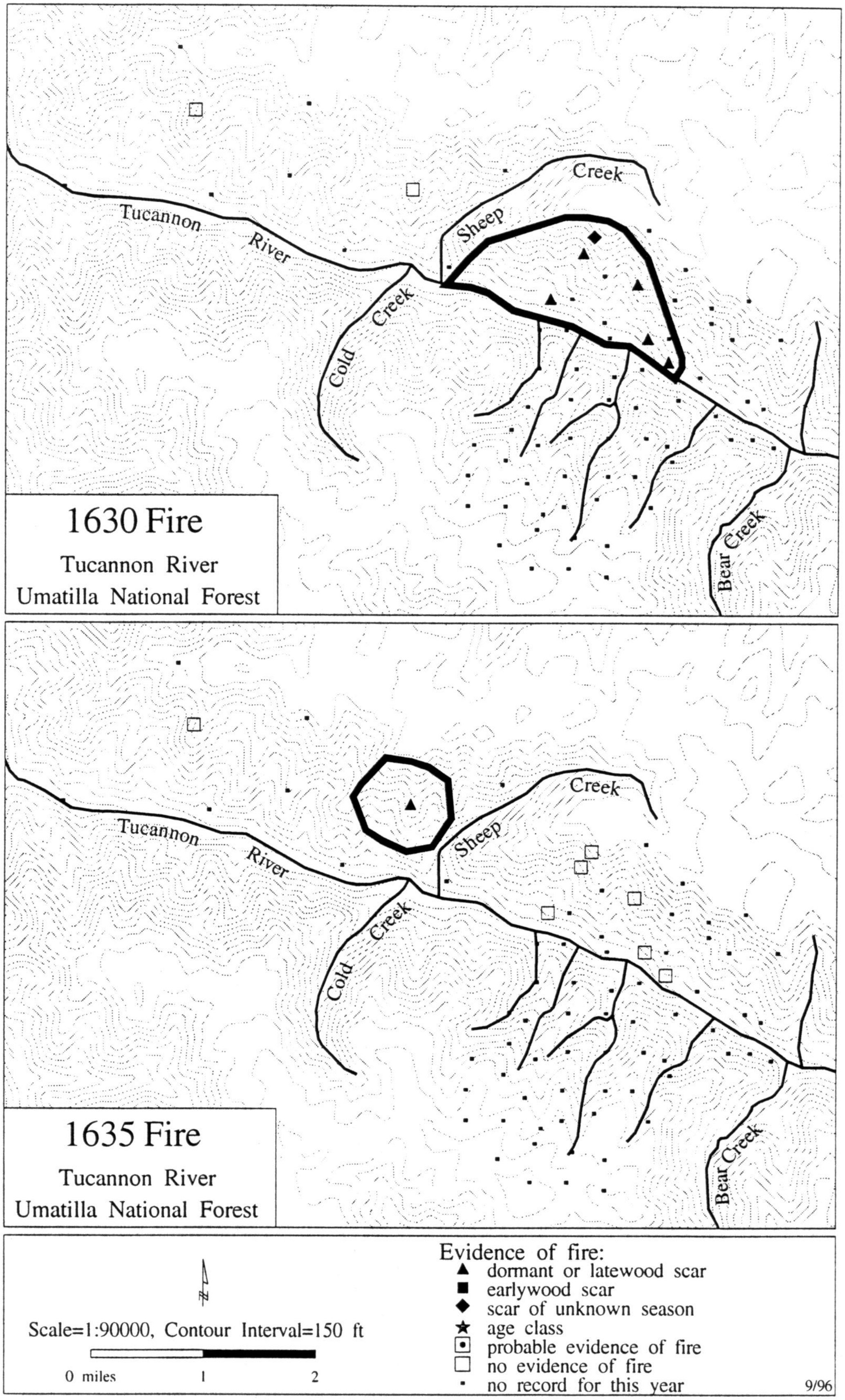


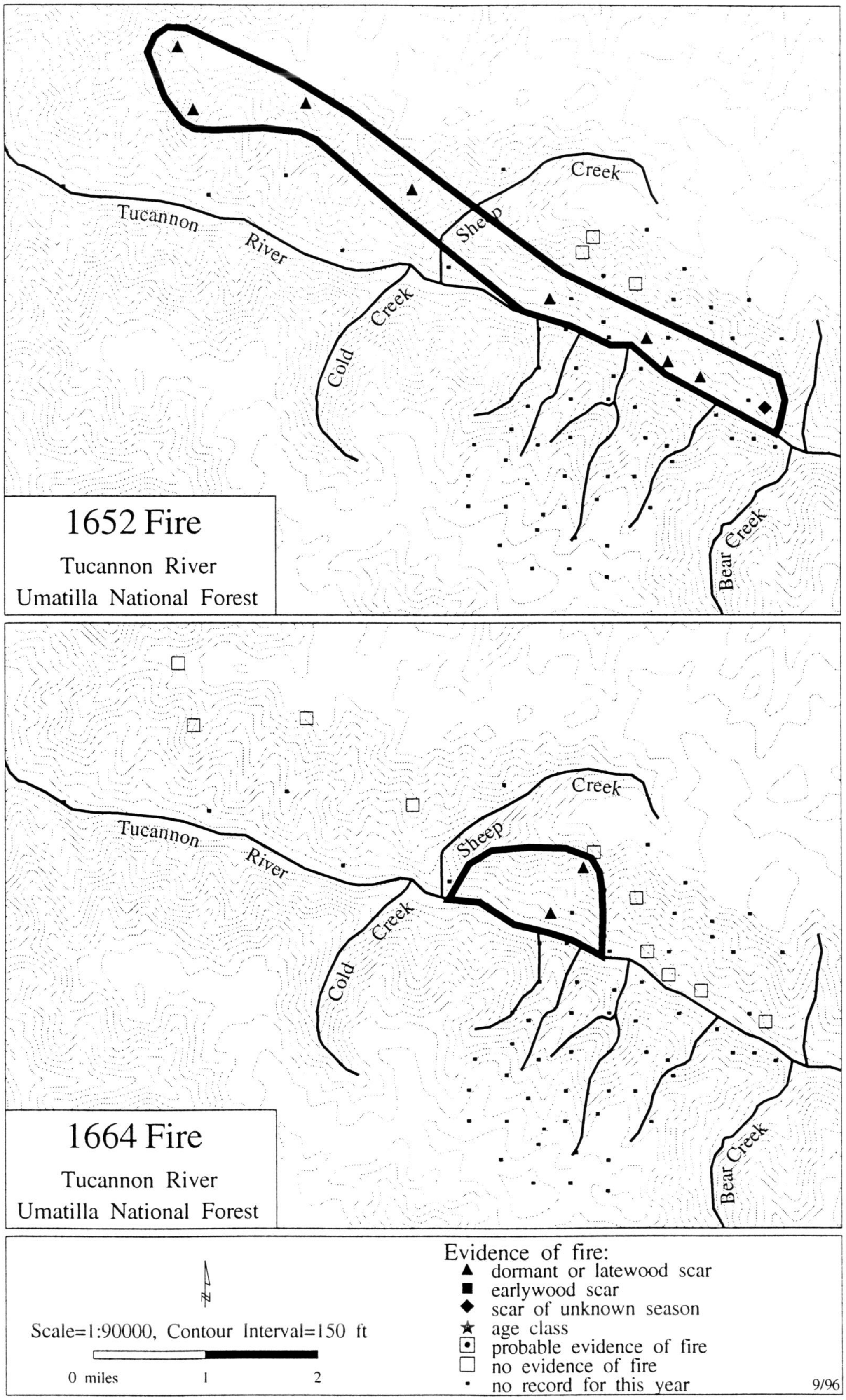
Scale=1:90000, Contour Interval=150 ft

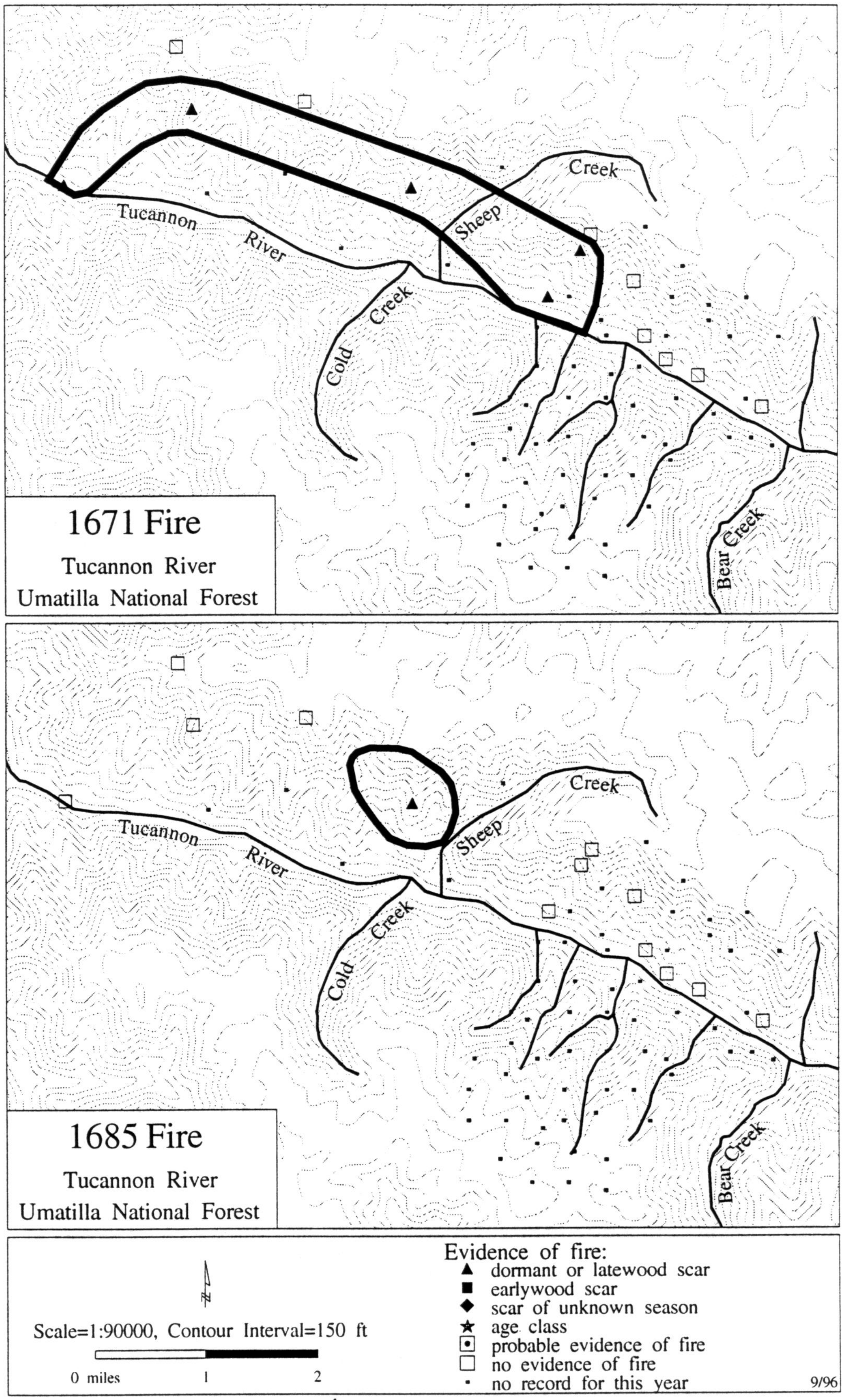
0 miles 1 2

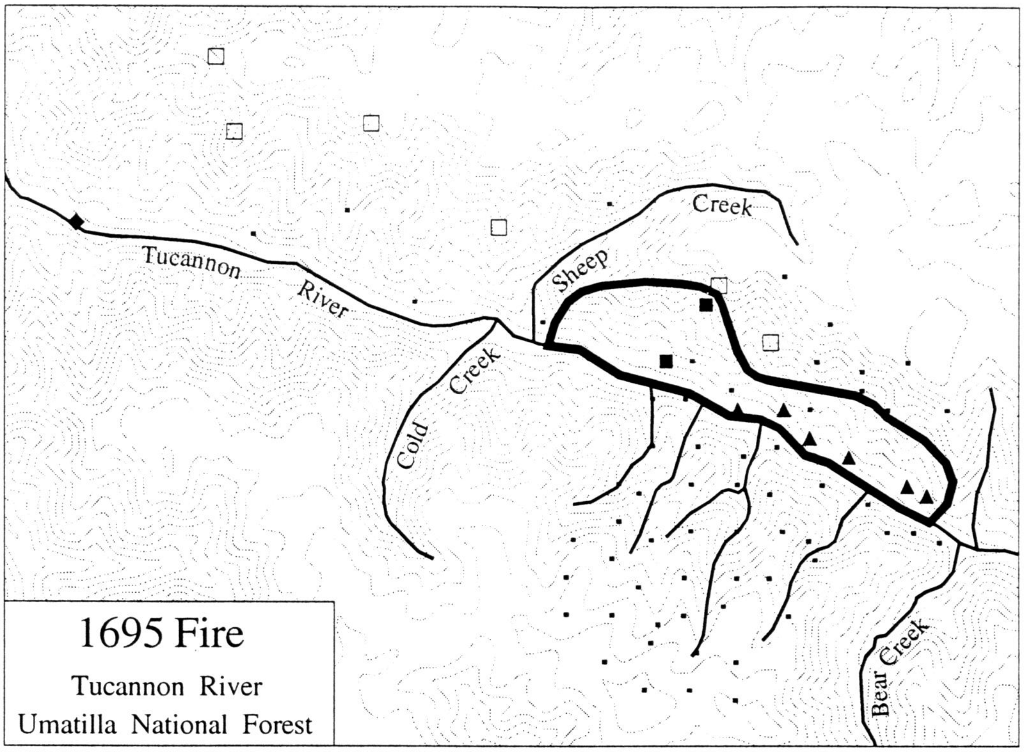
Evidence of fire:
- ▲ dormant or latewood scar
- ■ earlywood scar
- ◆ scar of unknown season
- ★ age class
- ⊡ probable evidence of fire
- □ no evidence of fire
- · no record for this year

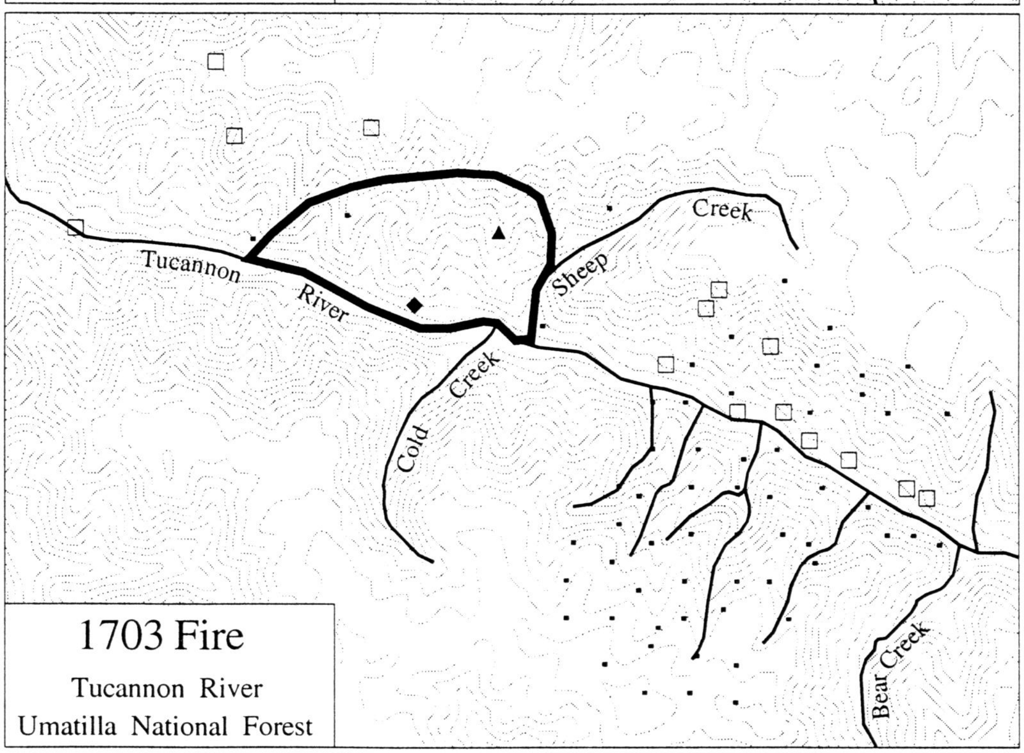
9/96


1630 Fire
Tucannon River
Umatilla National Forest
Tucannon River
Sheep Creek
Cold Creek
Bear Creek
1635 Fire
Tucannon River
Umatilla National Forest
Tucannon River
Sheep Creek
Cold Creek
Bear Creek
Scale=1:90000, Contour Interval=150 ft
0 miles
1
2
Evidence of fire:
▲ dormant or latewood scar
■ earlywood scar
◆ scar of unknown season
★ age class
probable evidence of fire
no evidence of fire
no record for this year
9/96


Creek
Sheep
Tucannon
River
Cold
Creek
Bear
Creek
1652 Fire
Tucannon River
Umatilla National Forest
Creek
Sheep
Tucannon
River
Cold
Creek
Bear
Creek
1664 Fire
Tucannon River
Umatilla National Forest
Scale=1:90000, Contour Interval=150 ft
0 miles
1
2
Evidence of fire:
▲ dormant or latewood scar
■ earlywood scar
◆ scar of unknown season
★ age class
probable evidence of fire
no evidence of fire
• no record for this year
9/96


1671 Fire
Tucannon River
Umatilla National Forest
Tucannon
River
Sheep
Creek
Cold
Creek
Bear Creek
1685 Fire
Tucannon River
Umatilla National Forest
Tucannon
River
Sheep
Creek
Cold
Creek
Bear Creek
Scale=1:90000, Contour Interval=150 ft
0 miles
1
2
Evidence of fire:
dormant or latewood scar
earlywood scar
scar of unknown season
age class
probable evidence of fire
no evidence of fire
no record for this year
9/96



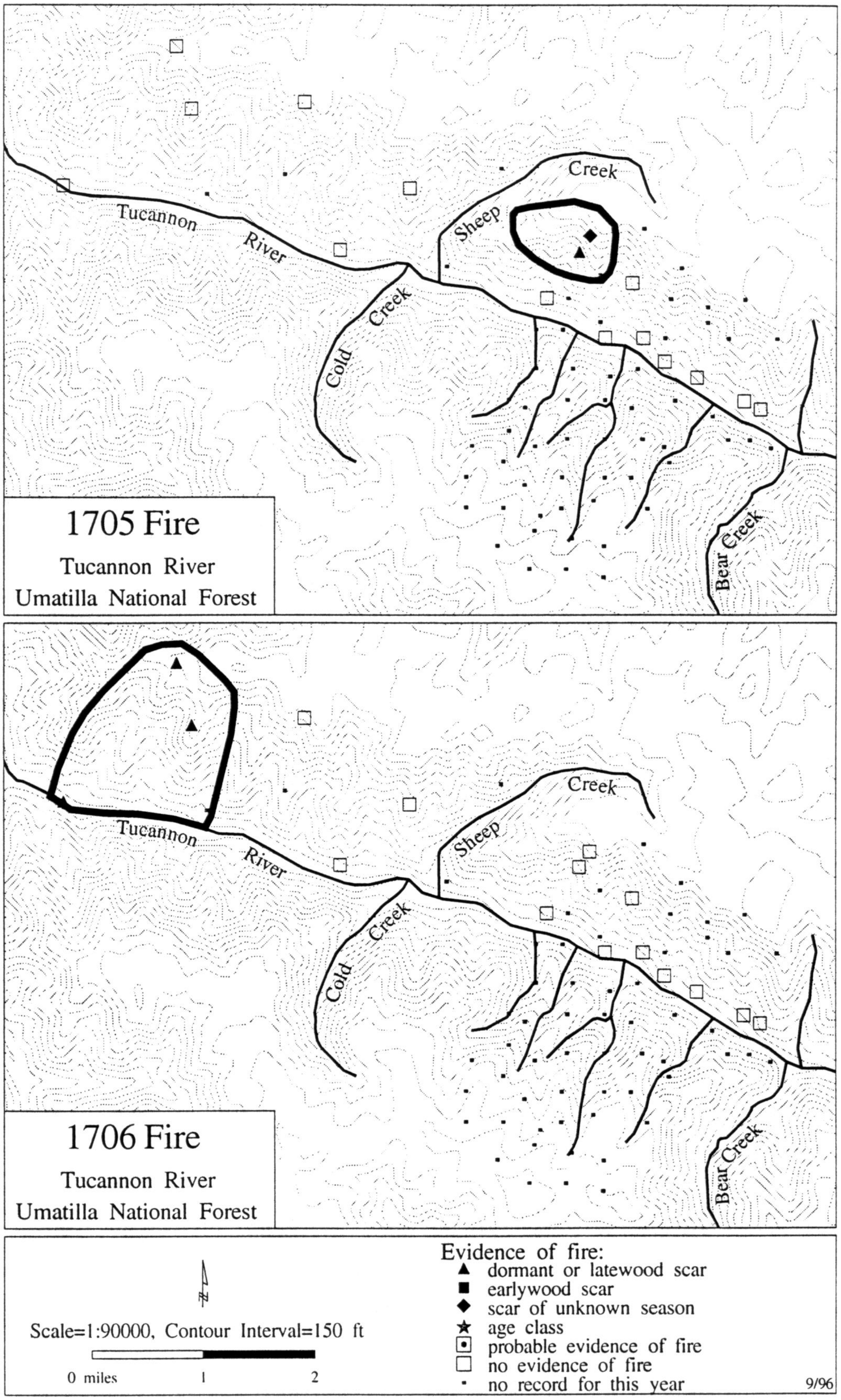


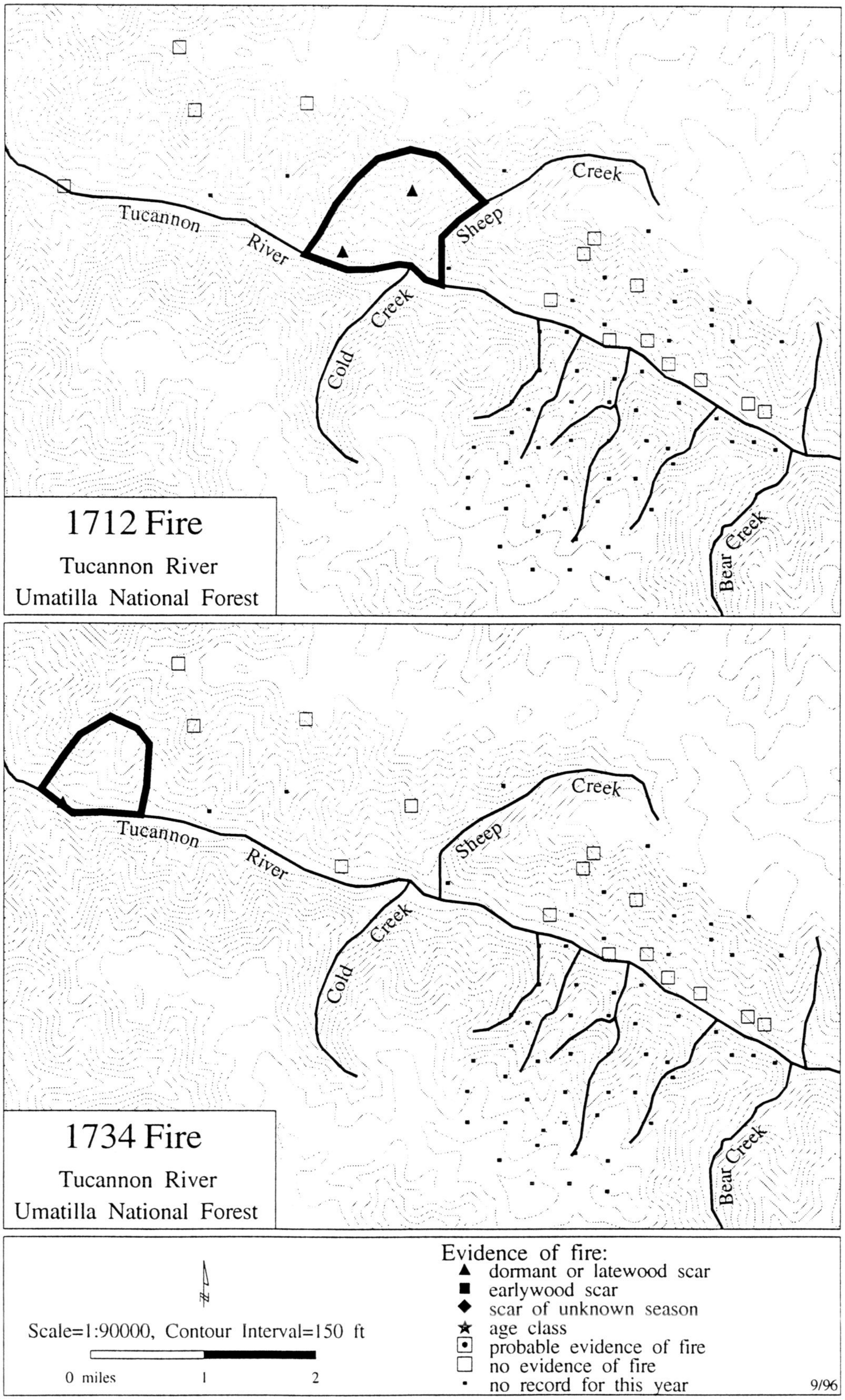
Scale=1:90000, Contour Interval=150 ft

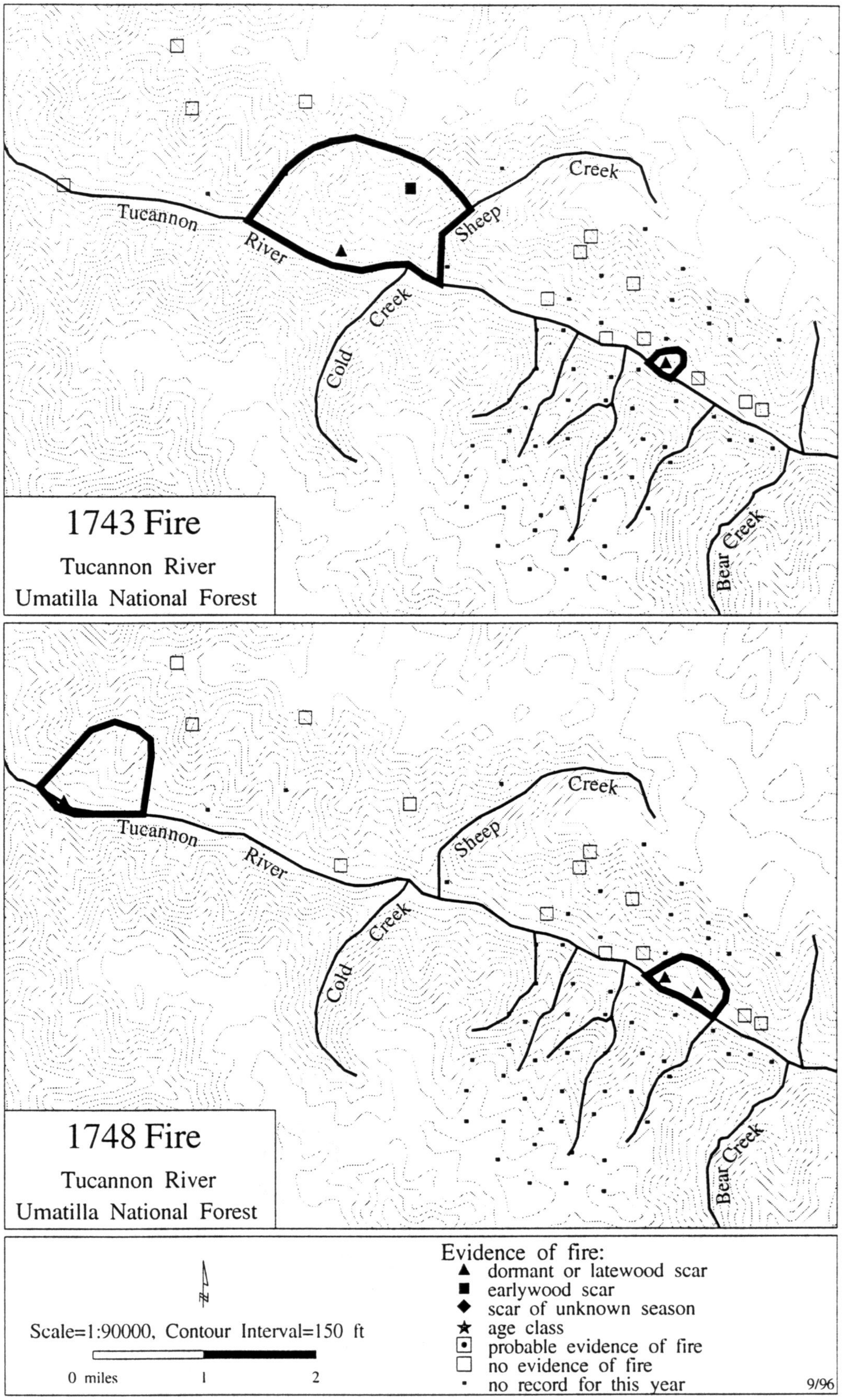
0 miles 1 2

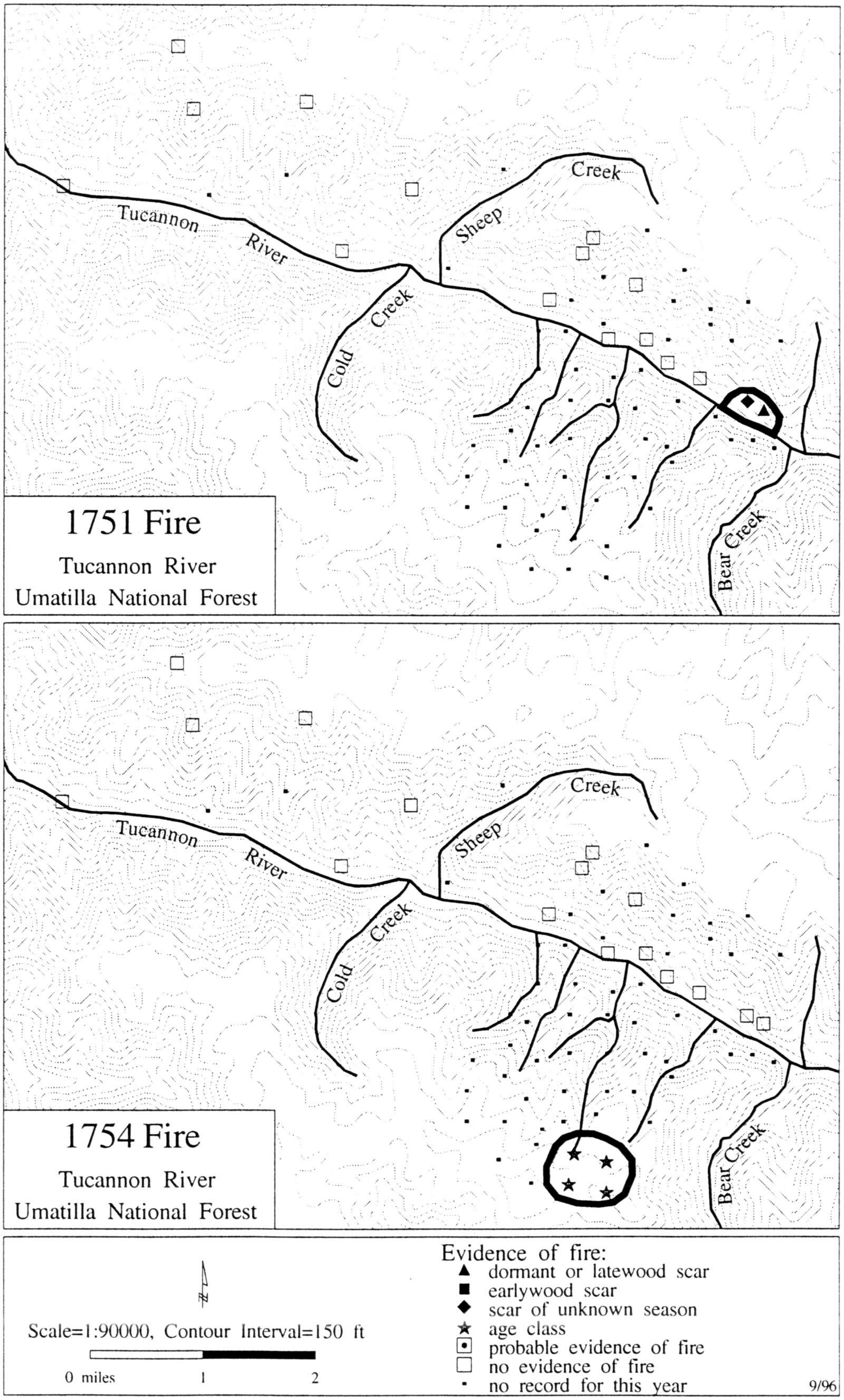
Evidence of fire:
- ▲ dormant or latewood scar
- ■ earlywood scar
- ◆ scar of unknown season
- ★ age class
- ⊡ probable evidence of fire
- □ no evidence of fire
- · no record for this year

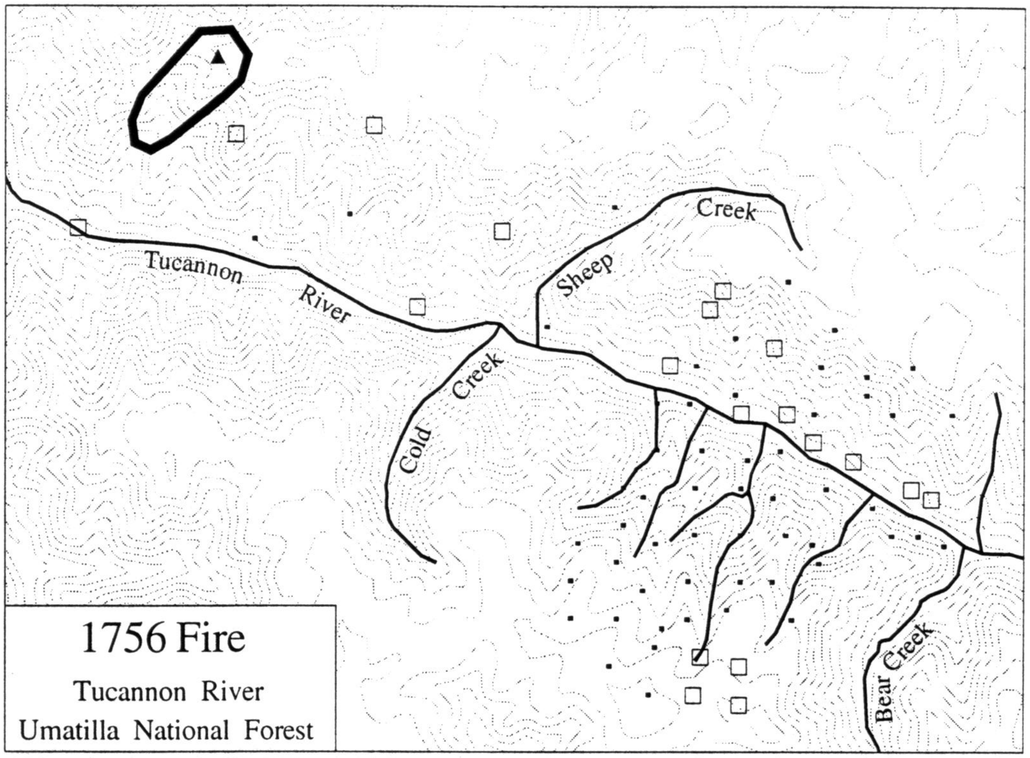
9/96

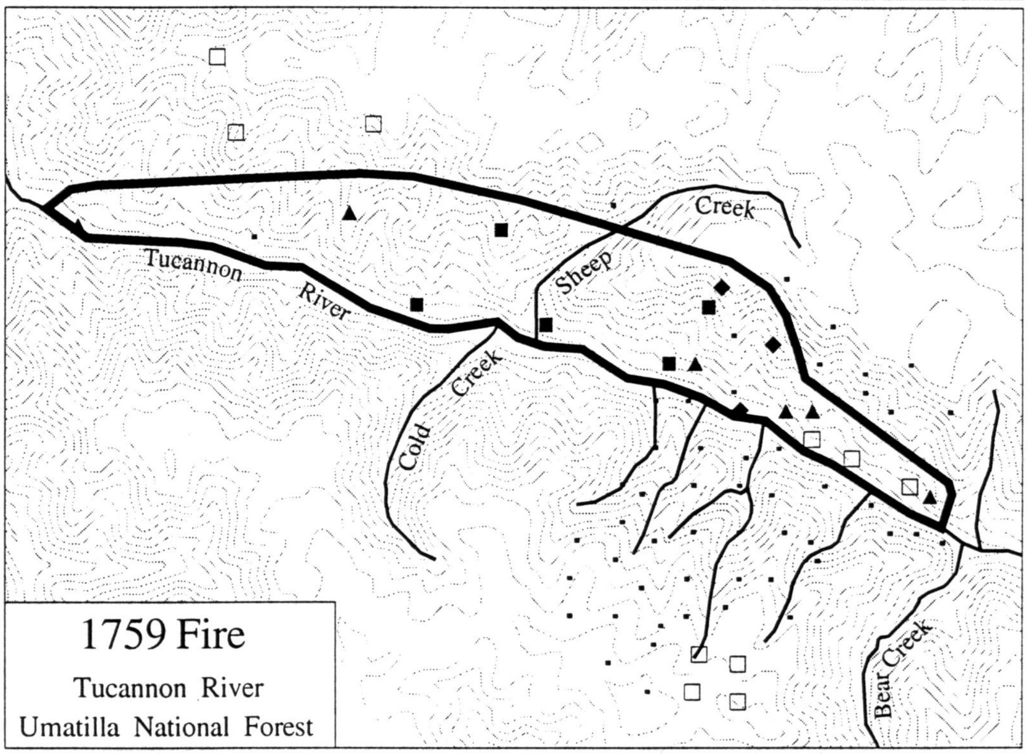

1705 Fire
Tucannon River
Umatilla National Forest
Tucannon River
Sheep Creek
Cold Creek
Bear Creek
1706 Fire
Tucannon River
Umatilla National Forest
Tucannon River
Sheep Creek
Cold Creek
Bear Creek
Scale=1:90000, Contour Interval=150 ft
0 miles 1 2
Evidence of fire:
▲ dormant or latewood scar
■ earlywood scar
◆ scar of unknown season
★ age class
probable evidence of fire
no evidence of fire
no record for this year
9/96


1712 Fire
Tucannon River
Umatilla National Forest
Tucannon
River
Sheep
Creek
Cold
Creek
Bear
Creek
1734 Fire
Tucannon River
Umatilla National Forest
Tucannon
River
Sheep
Creek
Cold
Creek
Bear
Creek
Scale=1:90000, Contour Interval=150 ft
0 miles
1
2
Evidence of fire:
▲ dormant or latewood scar
■ earlywood scar
◆ scar of unknown season
★ age class
probable evidence of fire
no evidence of fire
• no record for this year
9/96


Creek
Sheep
Tucannon
River
Cold
Creek
Bear Creek
1743 Fire
Tucannon River
Umatilla National Forest
Creek
Sheep
Tucannon
River
Cold
Creek
Bear Creek
1748 Fire
Tucannon River
Umatilla National Forest
Scale=1:90000, Contour Interval=150 ft
0 miles
1
2
Evidence of fire:
dormant or latewood scar
earlywood scar
scar of unknown season
age class
probable evidence of fire
no evidence of fire
no record for this year
9/96


1751 Fire
Tucannon River
Umatilla National Forest
Tucannon
River
Sheep
Creek
Cold
Creek
Bear
Creek
1754 Fire
Tucannon River
Umatilla National Forest
Tucannon
River
Sheep
Creek
Cold
Creek
Bear
Creek
Scale=1:90000, Contour Interval=150 ft
0 miles
1
2
Evidence of fire:
▲ dormant or latewood scar
■ earlywood scar
◆ scar of unknown season
★ age class
⊡ probable evidence of fire
□ no evidence of fire
· no record for this year
9/96



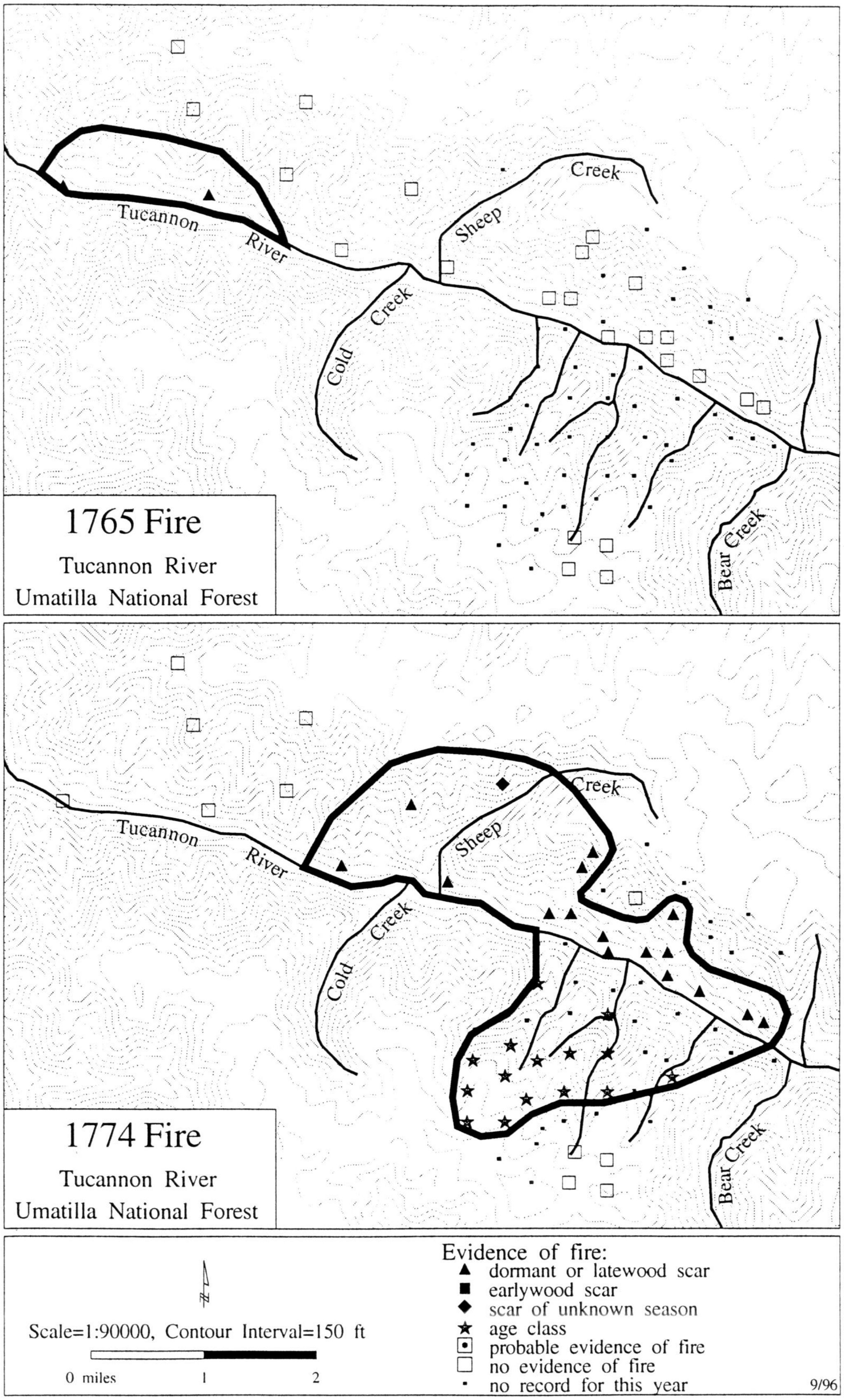


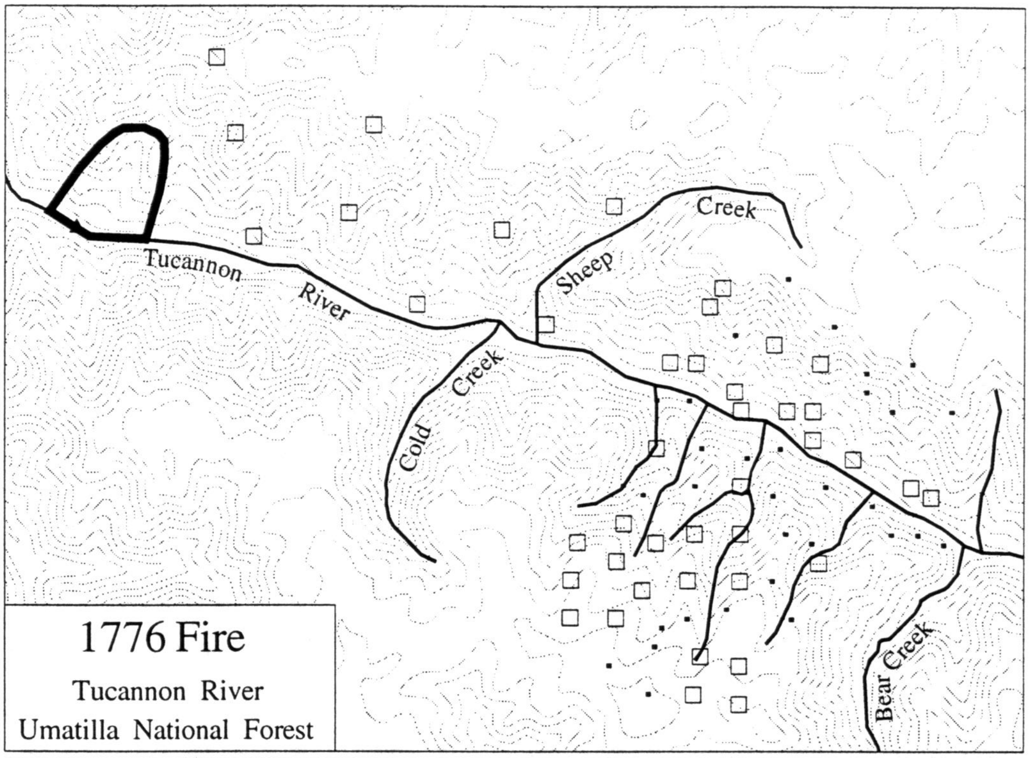
Scale=1:90000, Contour Interval=150 ft

0 miles 1 2

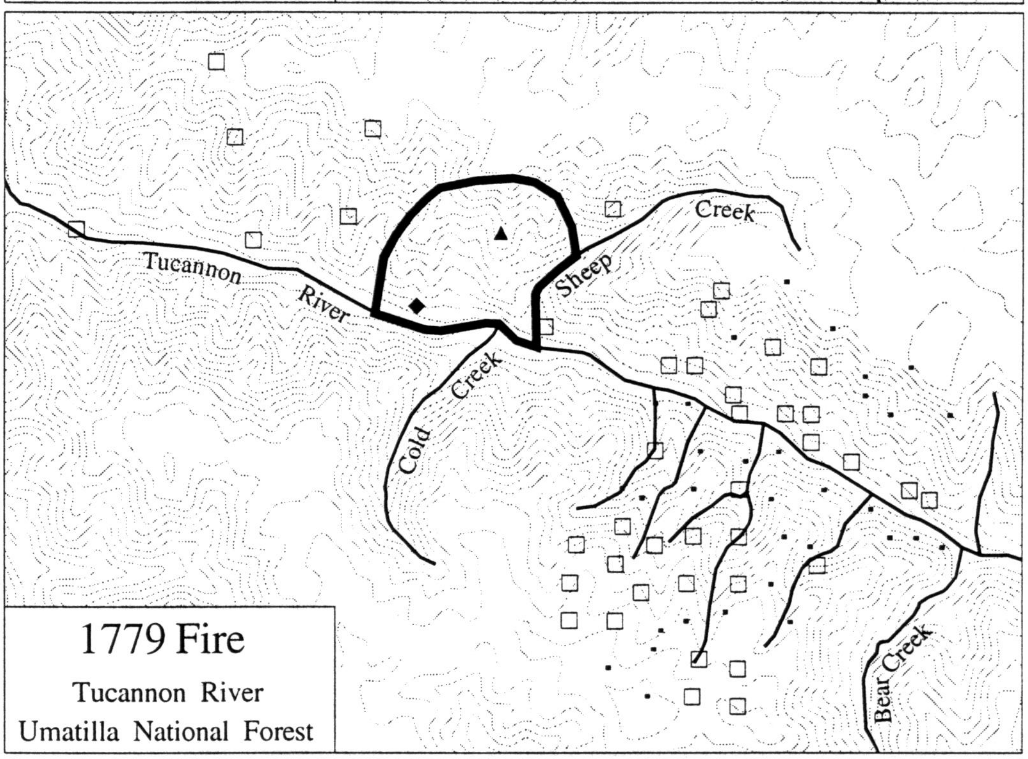
Evidence of fire:
- ▲ dormant or latewood scar
- ■ earlywood scar
- ◆ scar of unknown season
- ★ age class
- ⊡ probable evidence of fire
- □ no evidence of fire
- ▪ no record for this year

9/96

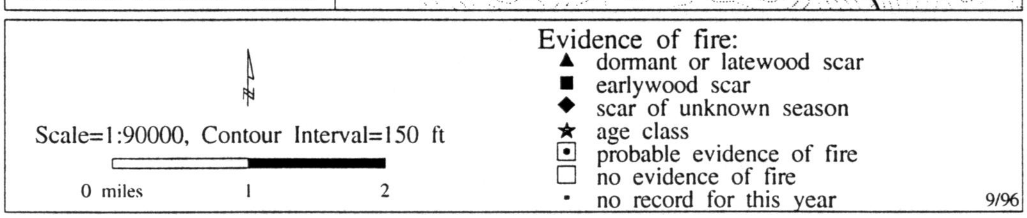

1765 Fire
Tucannon River
Umatilla National Forest
Tucannon River
Sheep Creek
Cold Creek
Bear Creek
1774 Fire
Tucannon River
Umatilla National Forest
Tucannon River
Sheep Creek
Cold Creek
Bear Creek
Scale=1:90000, Contour Interval=150 ft
0 miles
1
2
Evidence of fire:
▲ dormant or latewood scar
■ earlywood scar
◆ scar of unknown season
★ age class
probable evidence of fire
□ no evidence of fire
· no record for this year
9/96

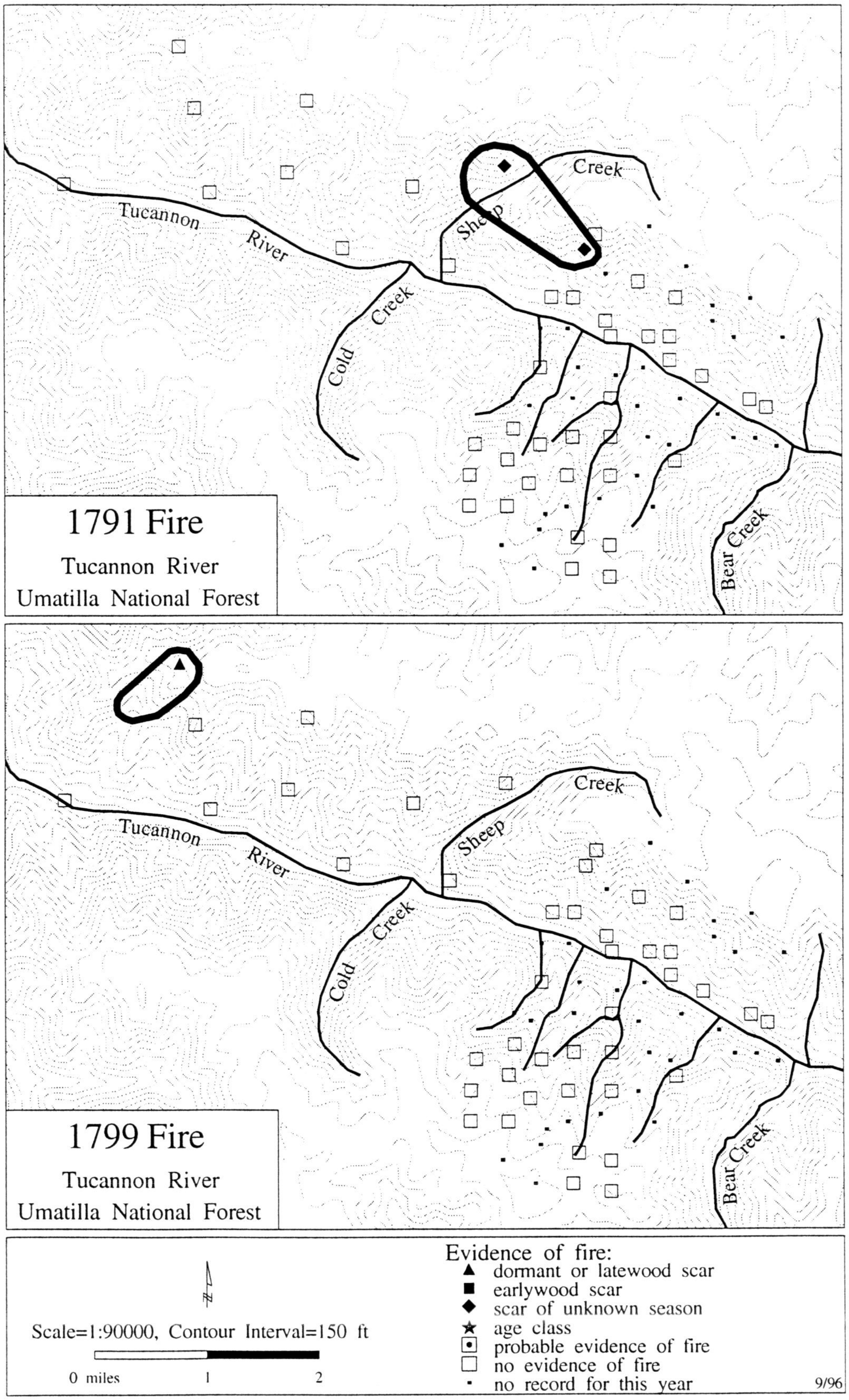


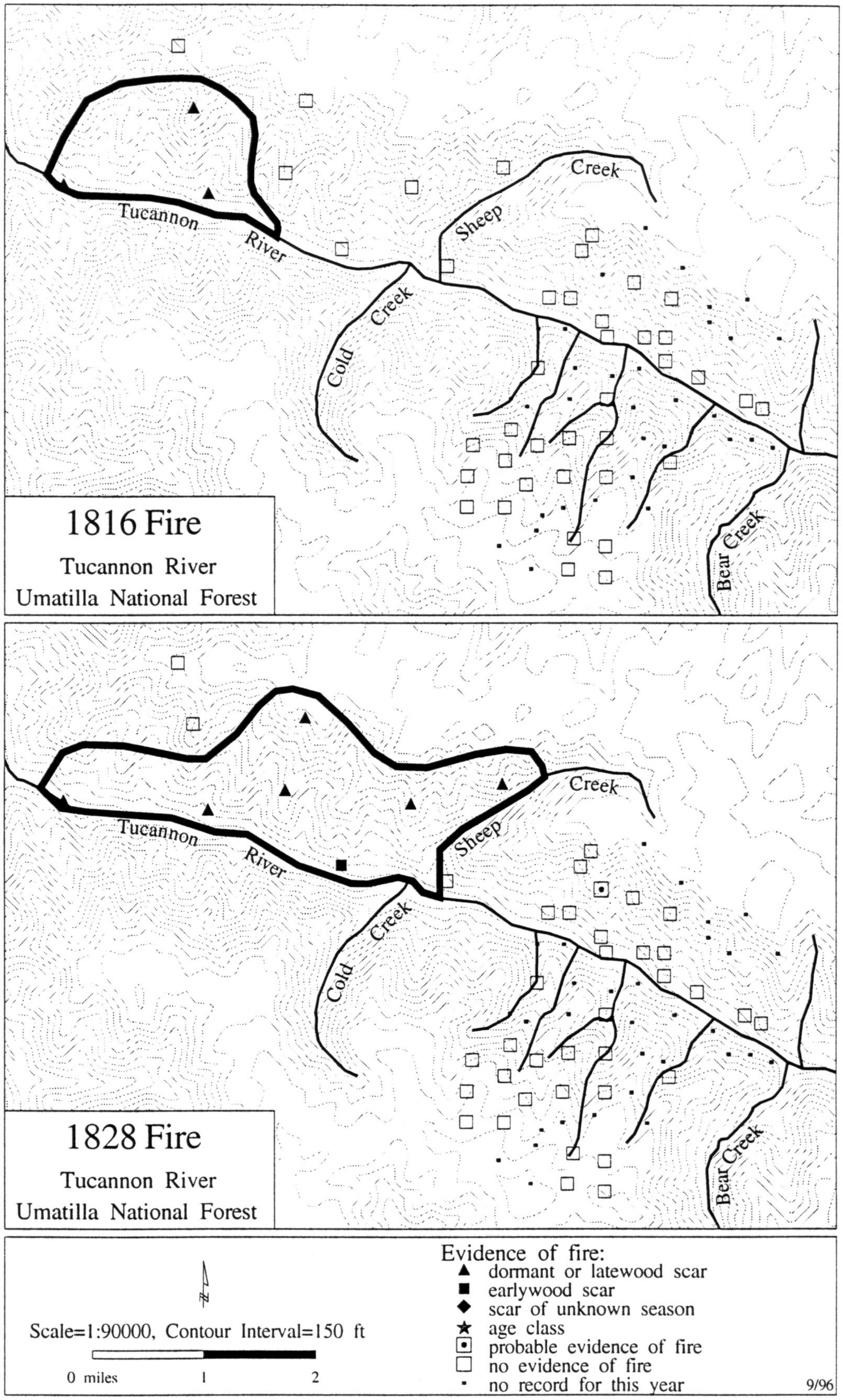
1776 Fire
Tucannon River
Umatilla National Forest

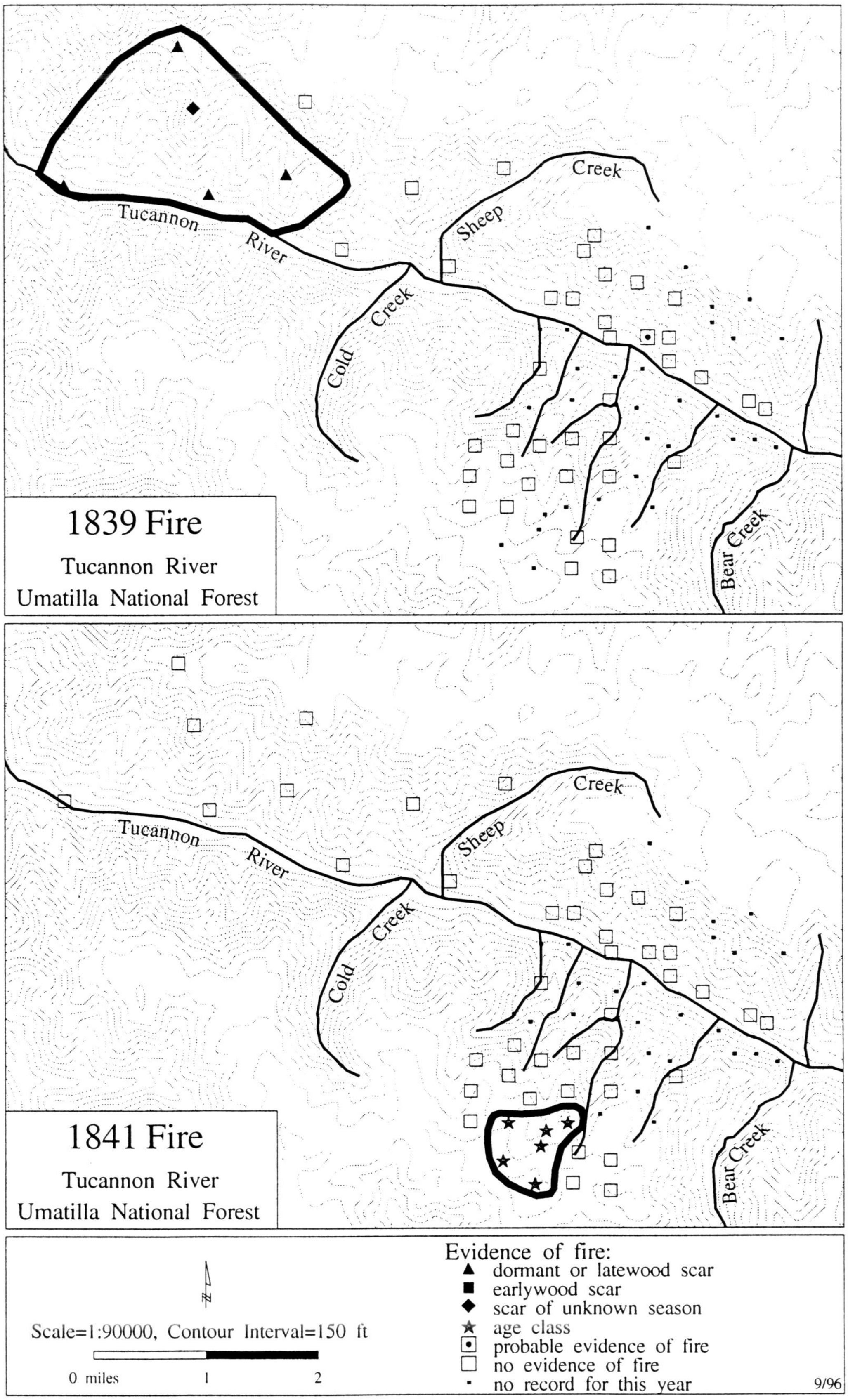


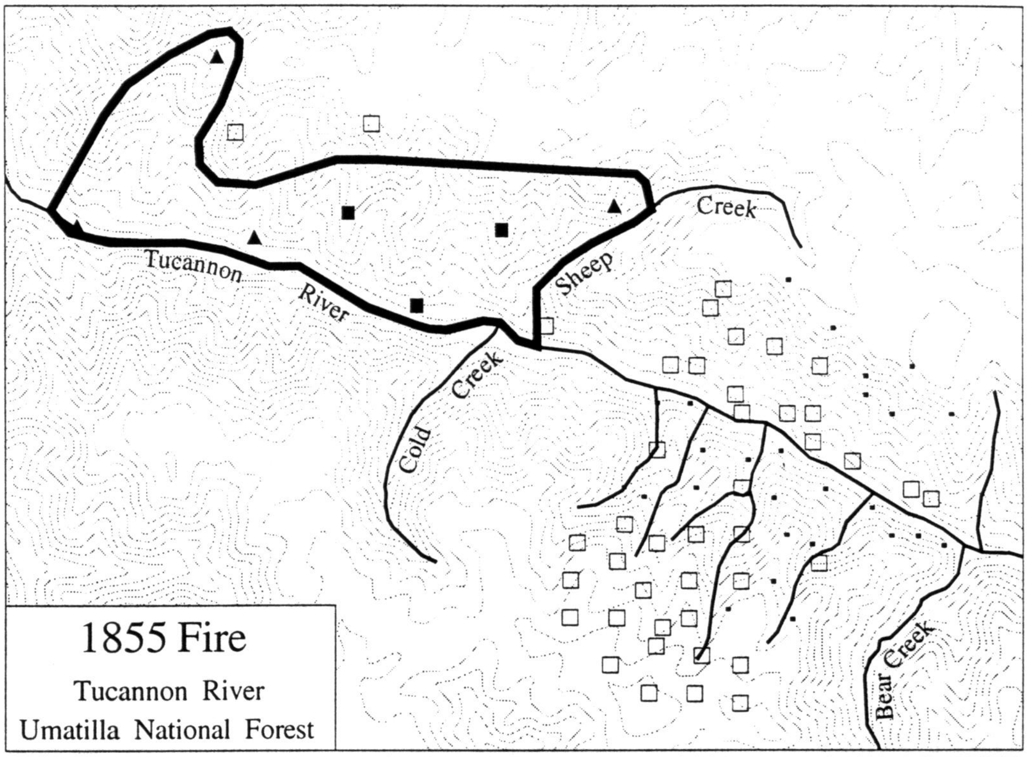
1779 Fire
Tucannon River
Umatilla National Forest

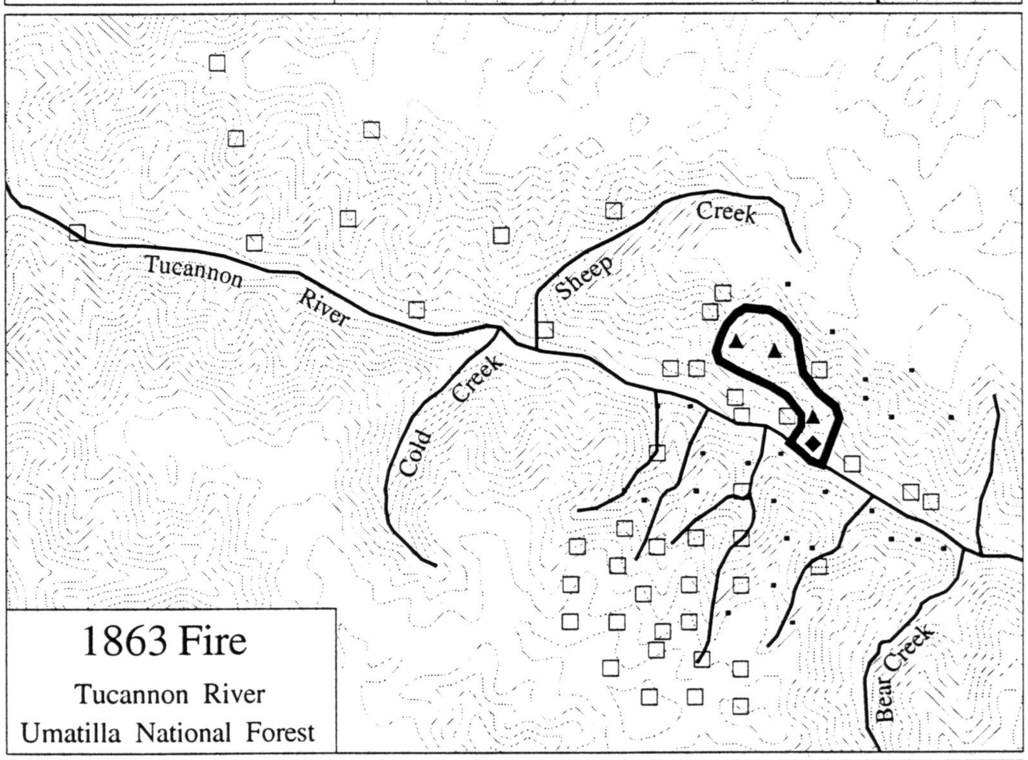


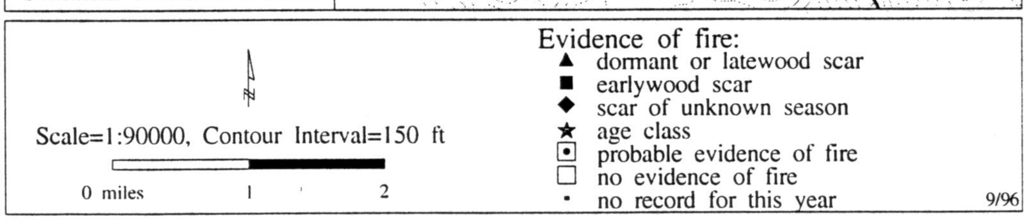

1791 Fire
Tucannon River
Umatilla National Forest
Tucannon
River
Sheep
Creek
Cold
Creek
Bear
Creek
1799 Fire
Tucannon River
Umatilla National Forest
Tucannon
River
Sheep
Creek
Cold
Creek
Bear
Creek
Scale=1:90000, Contour Interval=150 ft
0 miles
1
2
Evidence of fire:
dormant or latewood scar
earlywood scar
scar of unknown season
age class
probable evidence of fire
no evidence of fire
no record for this year
9/96

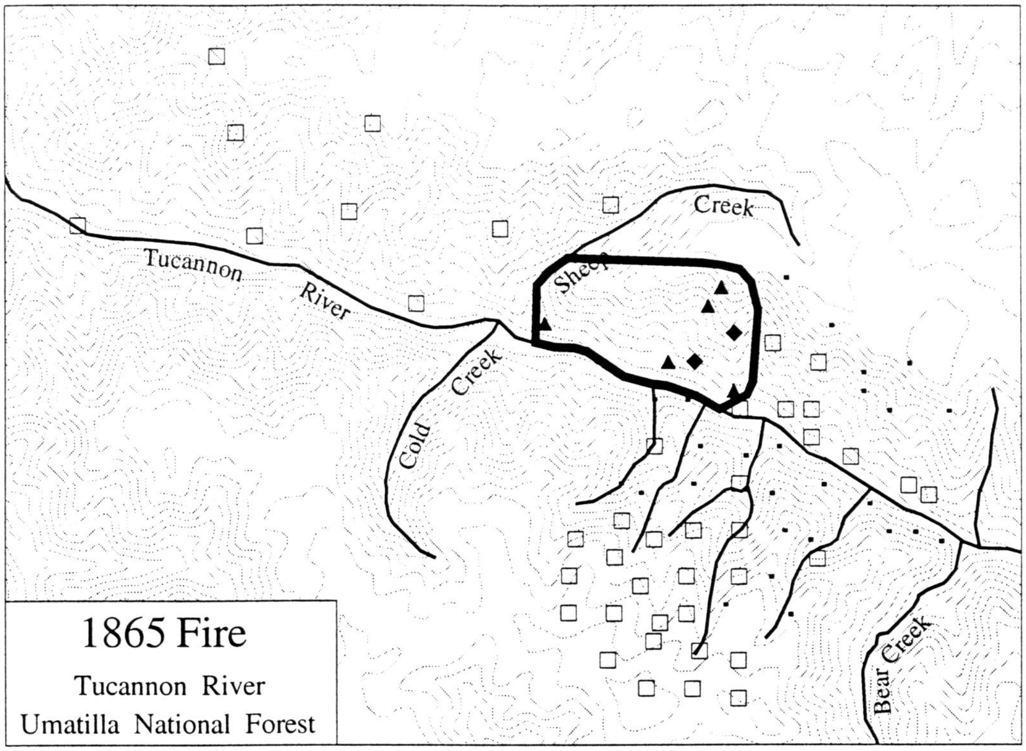

1816 Fire
Tucannon River
Umatilla National Forest
Tucannon
River
Sheep
Creek
Cold
Creek
Bear
Creek
1828 Fire
Tucannon River
Umatilla National Forest
Tucannon
River
Sheep
Creek
Cold
Creek
Bear
Creek
Scale=1:90000, Contour Interval=150 ft
0 miles
1
2
Evidence of fire:
dormant or latewood scar
earlywood scar
scar of unknown season
age class
probable evidence of fire
no evidence of fire
no record for this year
9/96

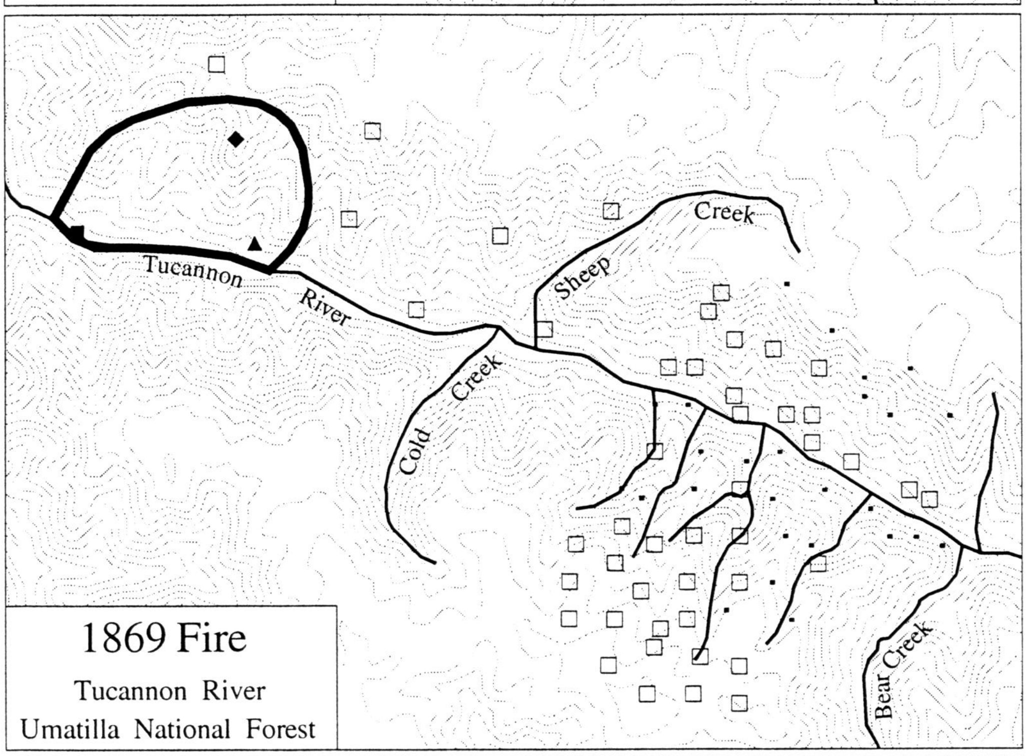

1839 Fire
Tucannon River
Umatilla National Forest
Tucannon
River
Sheep
Creek
Cold
Creek
Bear Creek
1841 Fire
Tucannon River
Umatilla National Forest
Evidence of fire:
dormant or latewood scar
earlywood scar
scar of unknown season
age class
probable evidence of fire
no evidence of fire
no record for this year
Scale=1:90000, Contour Interval=150 ft
0 miles
1
2
9/96

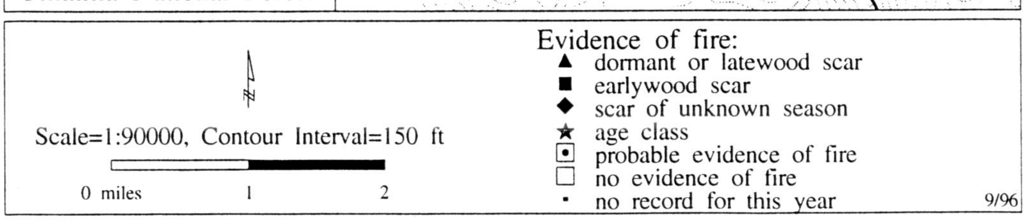

1855 Fire
Tucannon River
Umatilla National Forest
Tucannon
River
Sheep
Creek
Cold
Creek
Bear Creek

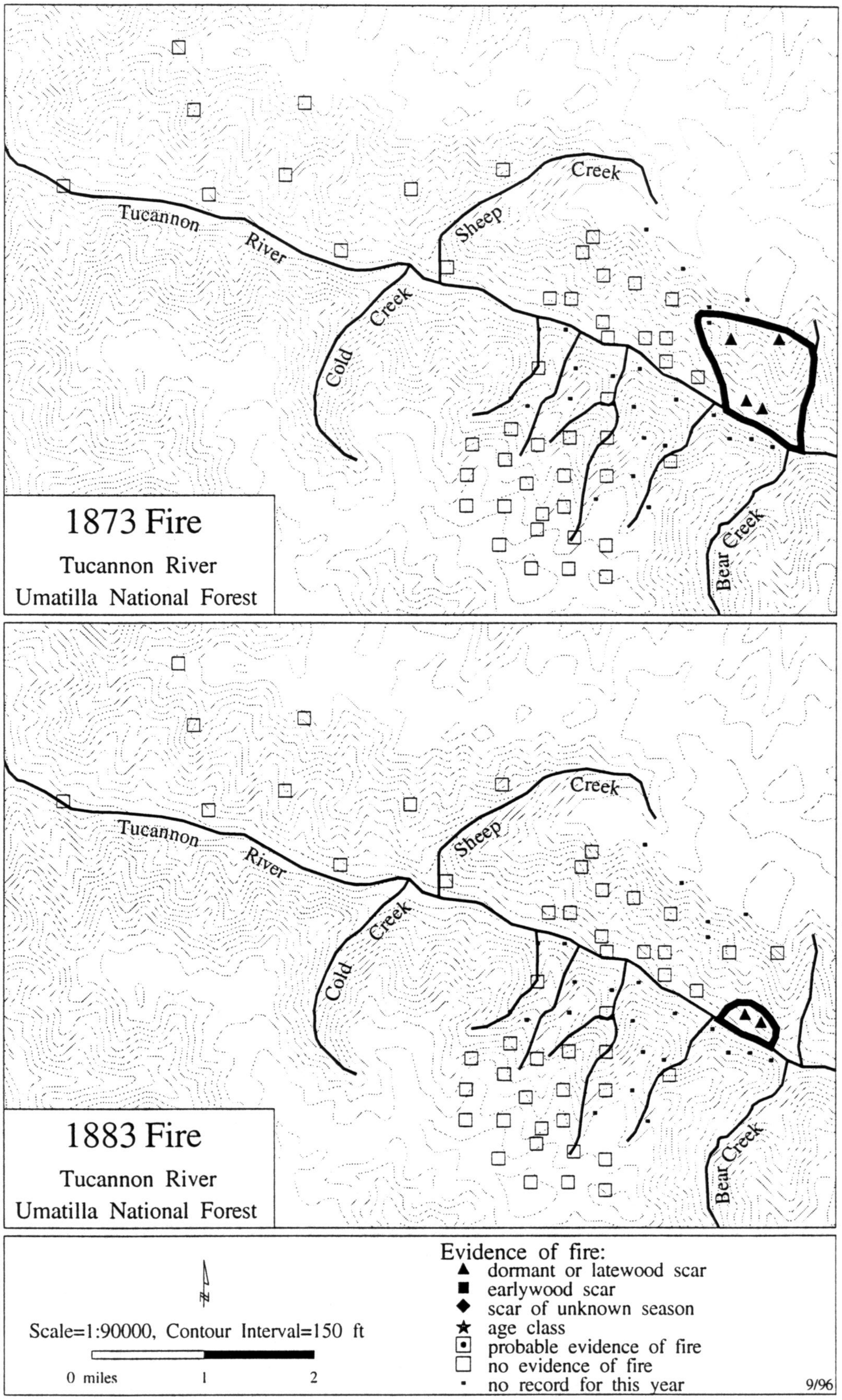

1863 Fire
Tucannon River
Umatilla National Forest
Tucannon
River
Sheep
Creek
Cold
Creek
Bear Creek

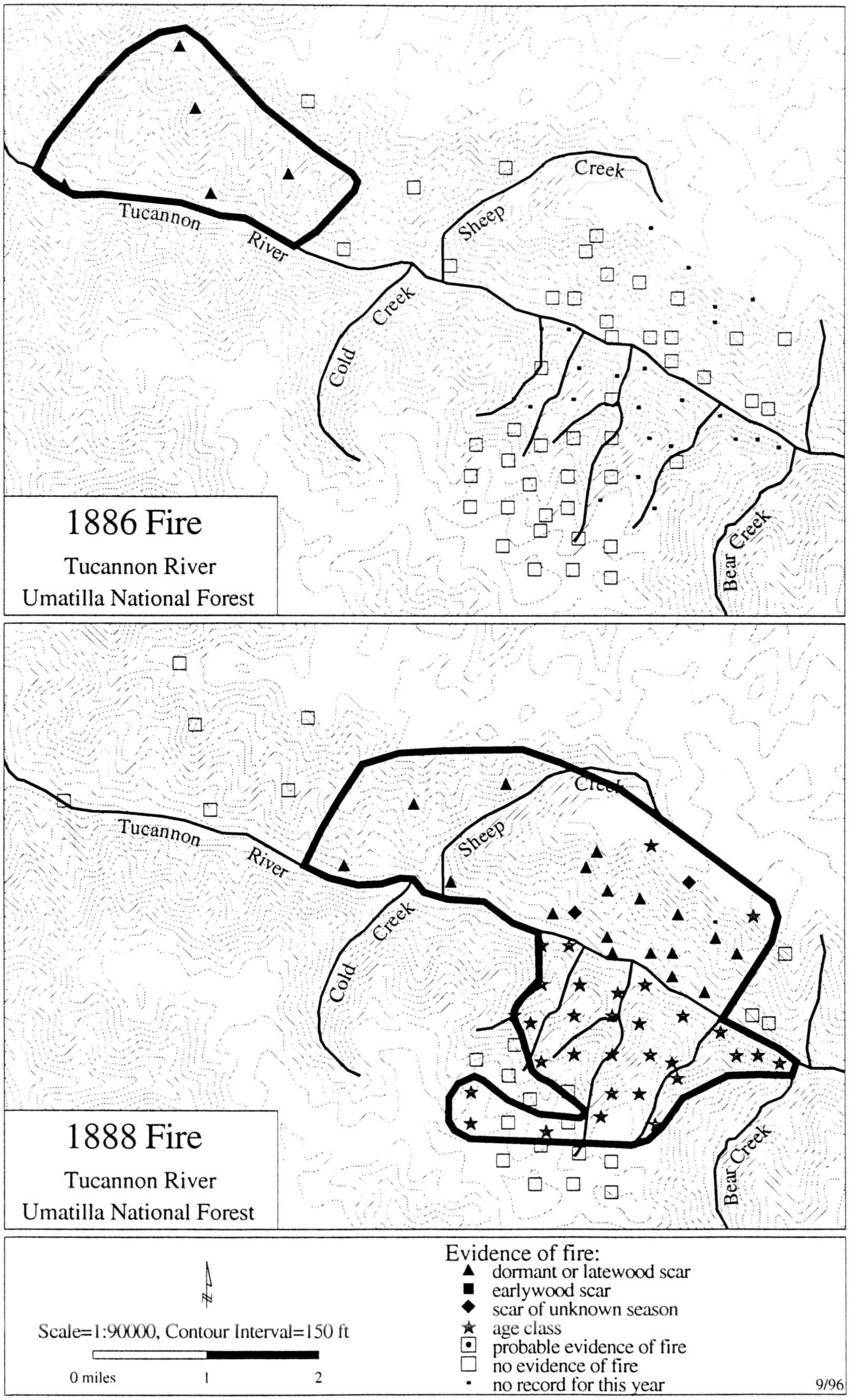

Scale=1:90000, Contour Interval=150 ft
0 miles
1
2
Evidence of fire:
▲ dormant or latewood scar
■ earlywood scar
◆ scar of unknown season
★ age class
⊡ probable evidence of fire
□ no evidence of fire
· no record for this year
9/96

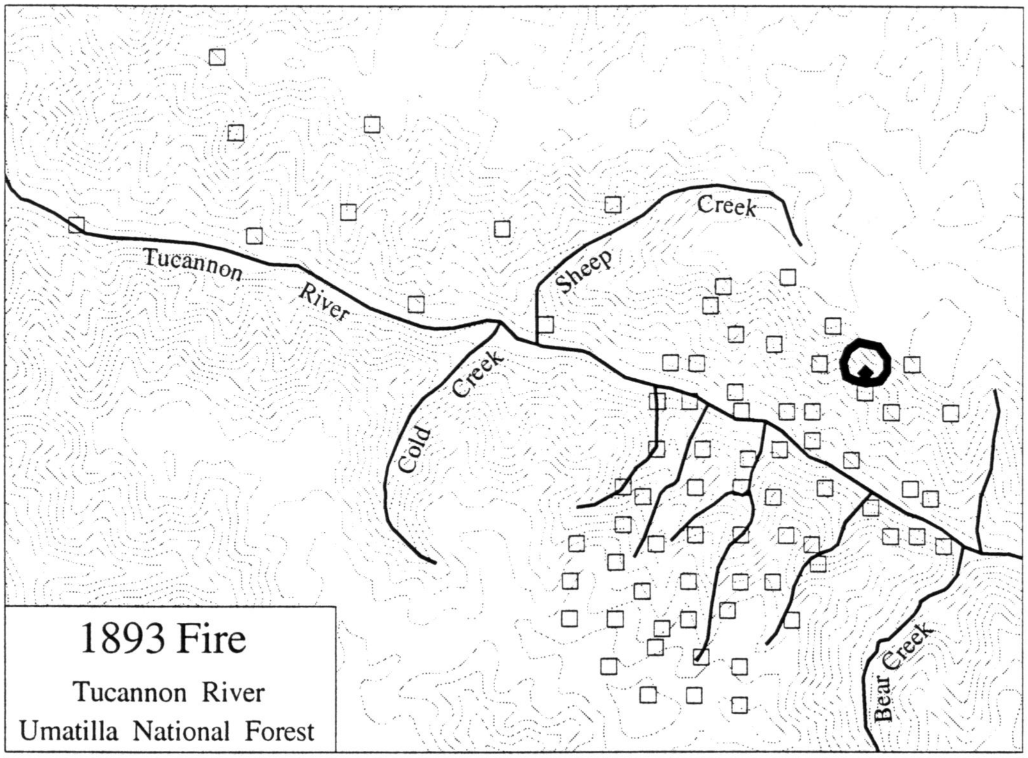

1865 Fire
Tucannon River
Umatilla National Forest
Tucannon
River
Creek
Sheep
Cold
Creek
Bear
Creek

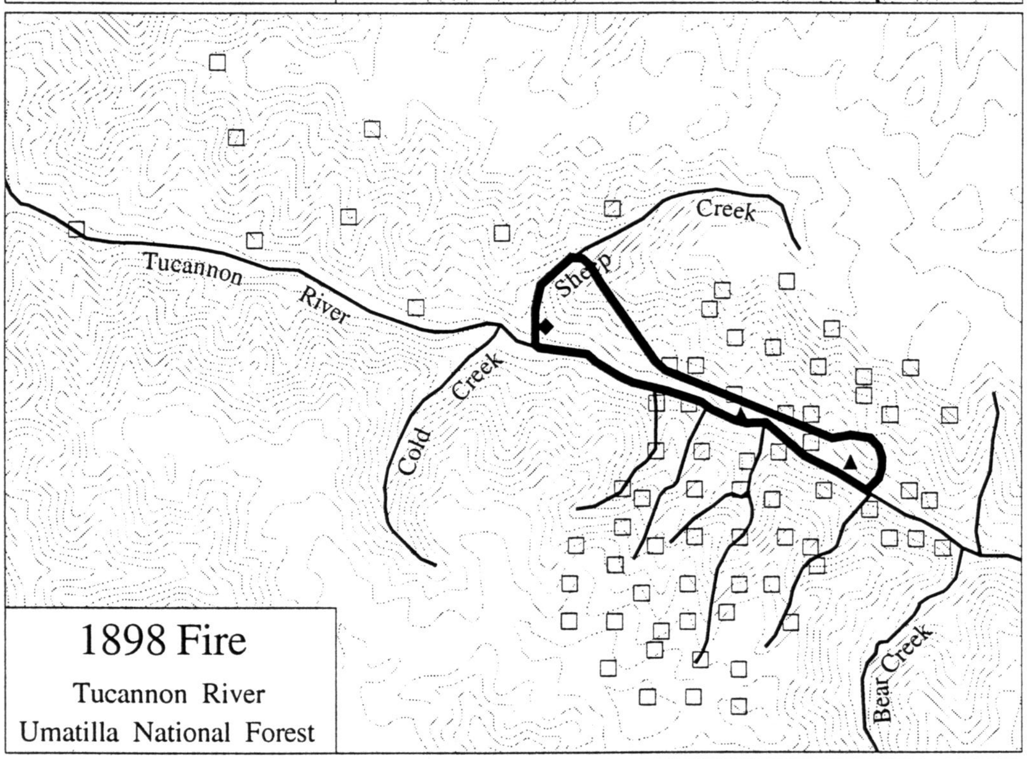

1869 Fire
Tucannon River
Umatilla National Forest
Tucannon
River
Creek
Sheep
Cold
Creek
Bear
Creek

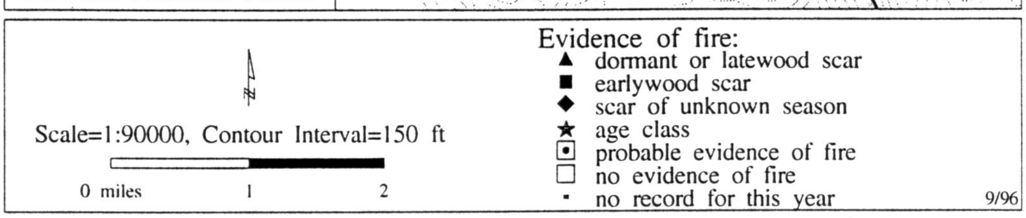

Scale=1:90000, Contour Interval=150 ft
0 miles
1
2
Evidence of fire:
▲ dormant or latewood scar
■ earlywood scar
◆ scar of unknown season
★ age class
probable evidence of fire
no evidence of fire
no record for this year
9/96


Creek
Sheep
Tucannon
River
Cold
Creek
Bear
Creek
1873 Fire
Tucannon River
Umatilla National Forest
Creek
Sheep
Tucannon
River
Cold
Creek
Bear
Creek
1883 Fire
Tucannon River
Umatilla National Forest
Scale=1:90000, Contour Interval=150 ft
0 miles
1
2
Evidence of fire:
dormant or latewood scar
earlywood scar
scar of unknown season
age class
probable evidence of fire
no evidence of fire
no record for this year
9/96


1886 Fire
Tucannon River
Umatilla National Forest
Tucannon River
Sheep Creek
Cold Creek
Bear Creek
1888 Fire
Tucannon River
Umatilla National Forest
Tucannon River
Sheep Creek
Cold Creek
Bear Creek
Scale=1:90000, Contour Interval=150 ft
0 miles
1
2
Evidence of fire:
dormant or latewood scar
earlywood scar
scar of unknown season
age class
probable evidence of fire
no evidence of fire
no record for this year
9/96

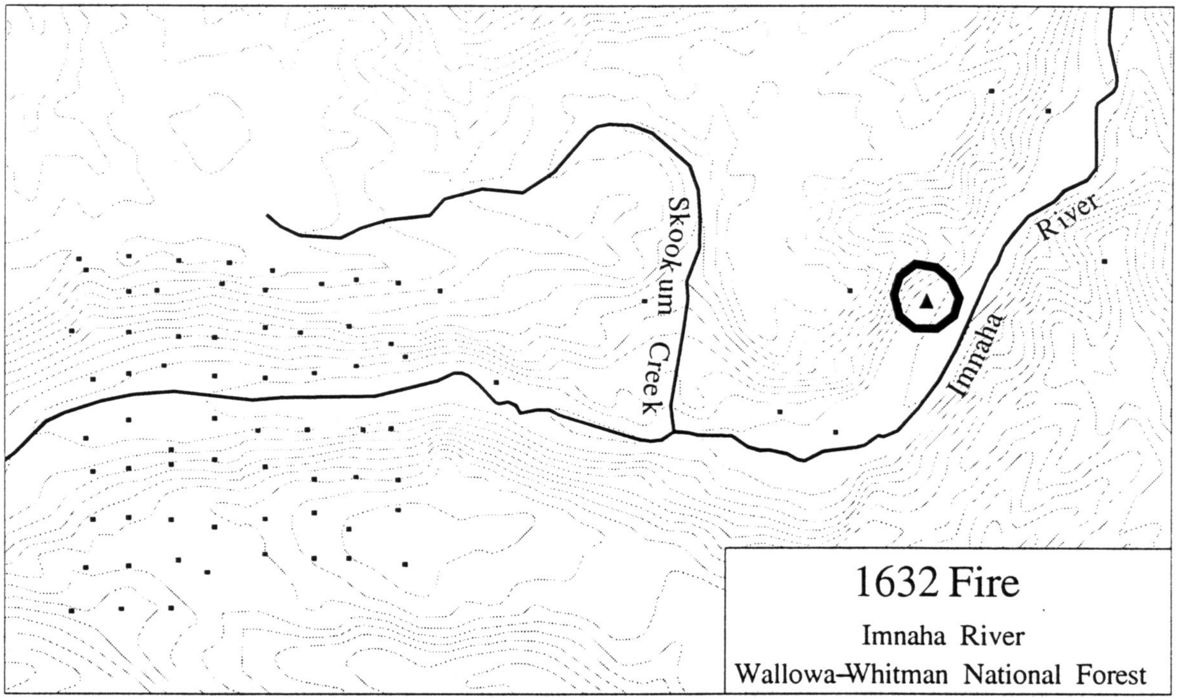

Creek
Sheep
Tucannon
River
Cold
Creek
Bear Creek
1893 Fire
Tucannon River
Umatilla National Forest

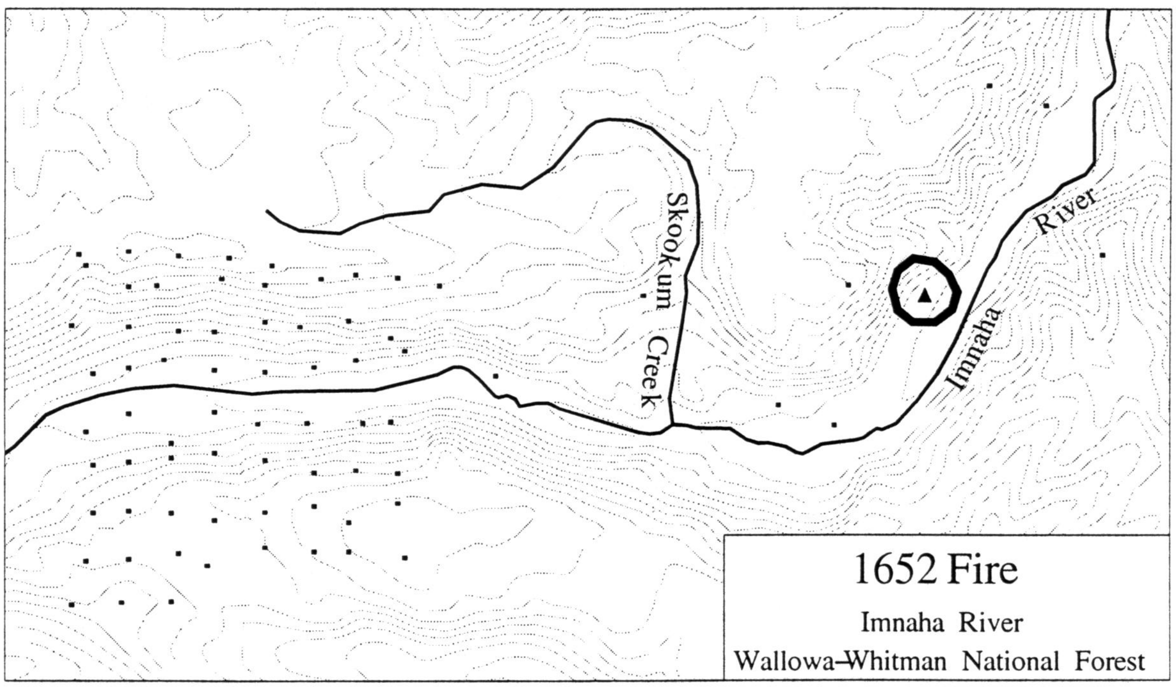

Creek
Sheep
Tucannon
River
Cold
Creek
Bear Creek
1898 Fire
Tucannon River
Umatilla National Forest

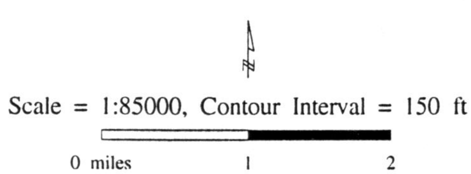

Scale=1:90000, Contour Interval=150 ft
0 miles
1
2
Evidence of fire:
dormant or latewood scar
earlywood scar
scar of unknown season
age class
probable evidence of fire
no evidence of fire
no record for this year
9/96

APPENDIX E: IMNAHA: FIRE MAPS

Evidence of ire was mapped at Imnaha for every year in dry forests which had at least two scars and for every fire event identified in mesic forests. The maps show whether the evidence of fire was age classes or scars. If the later, the intra-annular position of the scar is also indicated. Plots indicating as having probable evidence of fire are those for which the only evidence was an abrupt increase or decrease in ring width. Plots having no evidence of fire in a given year had recording trees for that year but did not have scars or an age class for that year. Plots indicated as having no record for a given year are plots that were sampled but had no trees recording during that year. Fire boundaries are shown as a heavy line.

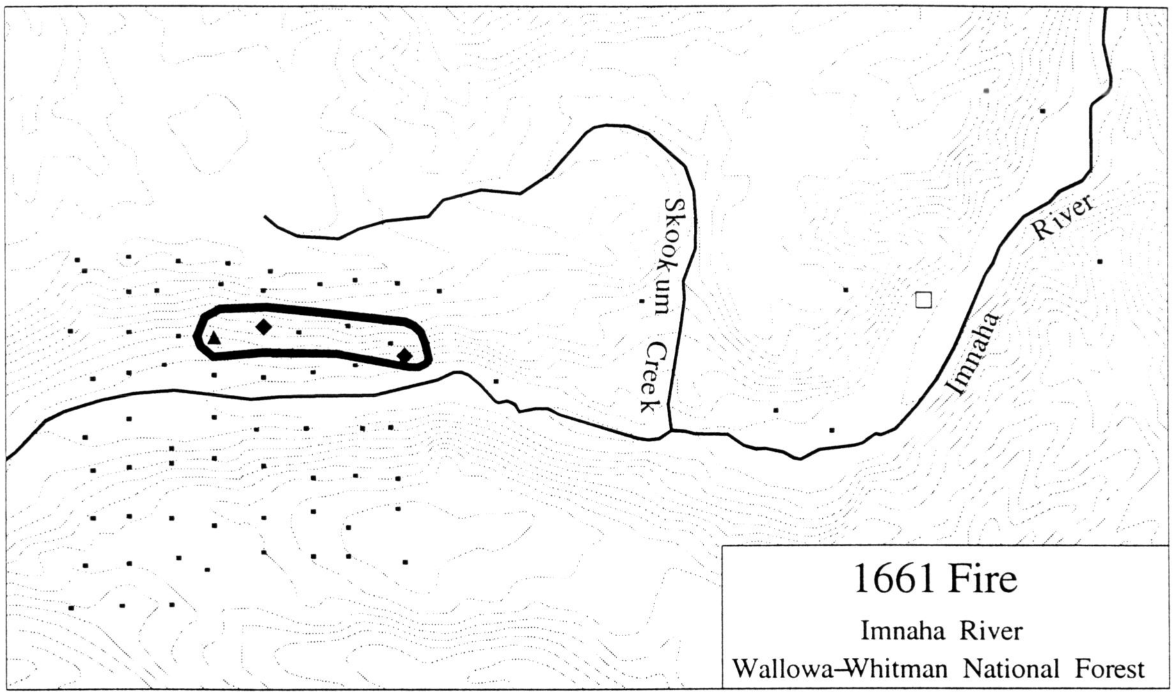


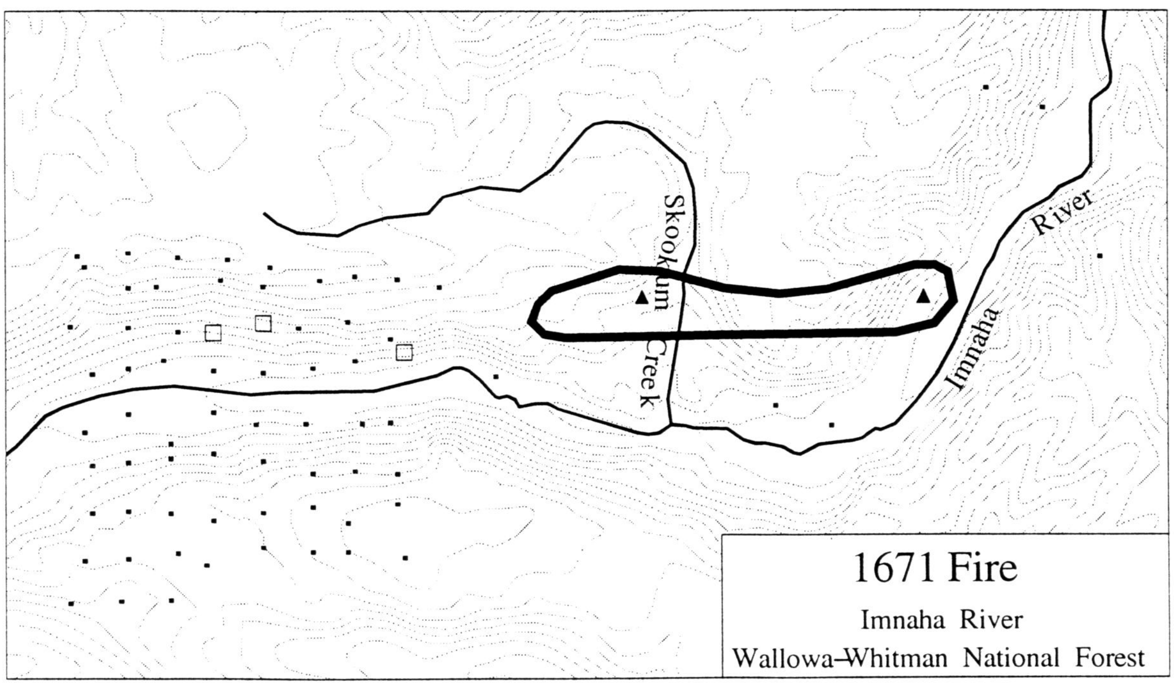


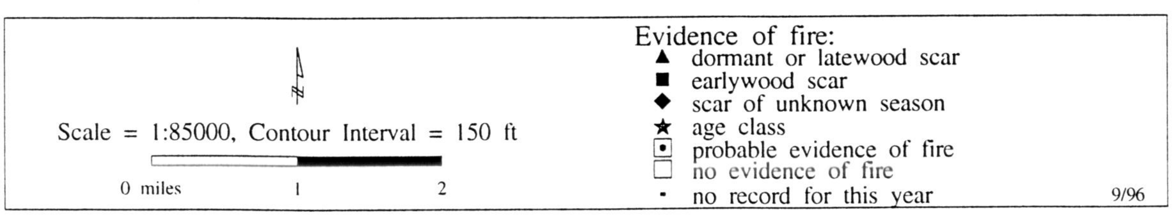


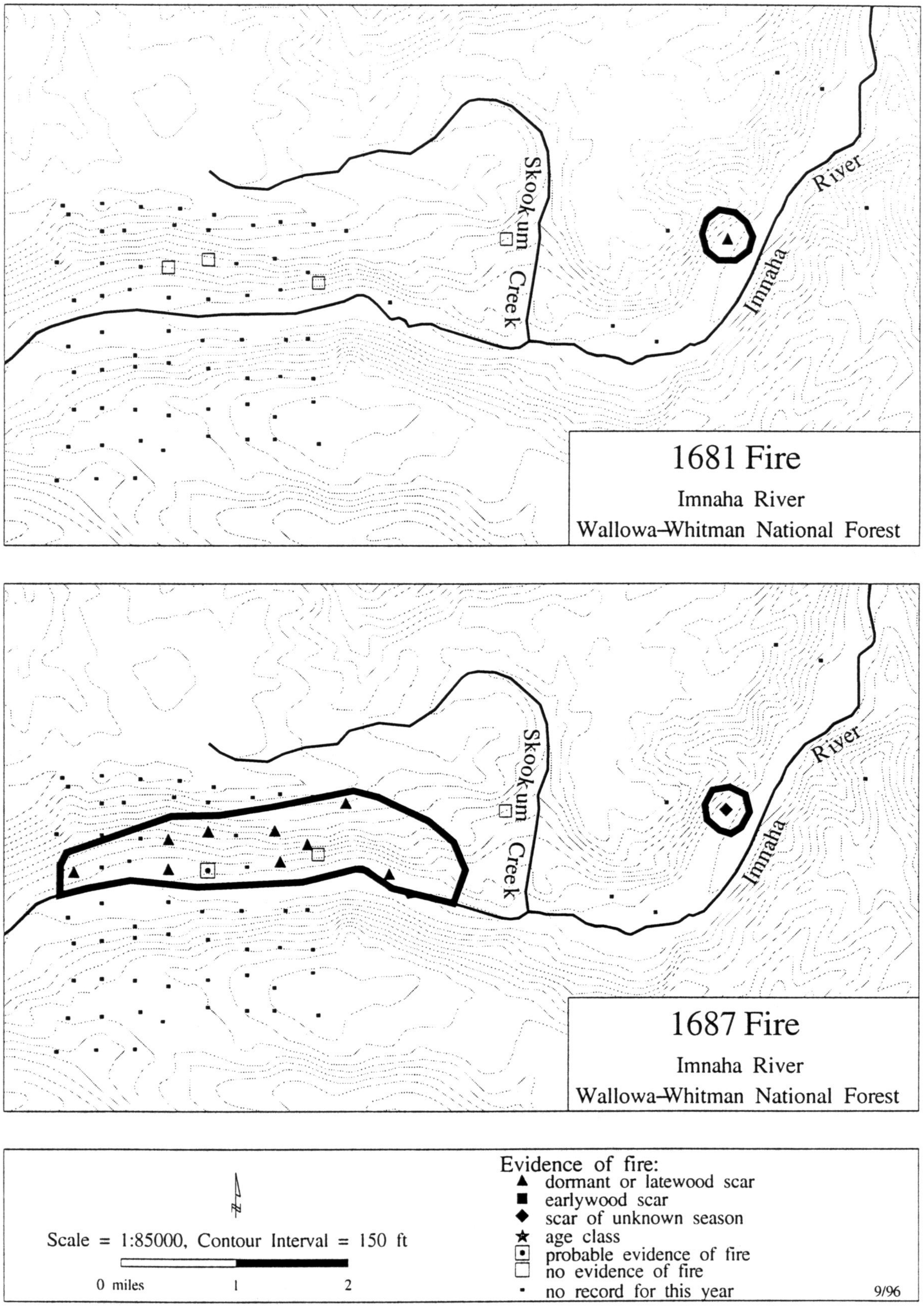
Evidence of fire:
▲ dormant or latewood scar
■ earlywood scar
◆ scar of unknown season
★ age class
⊡ probable evidence of fire
□ no evidence of fire
▪ no record for this year

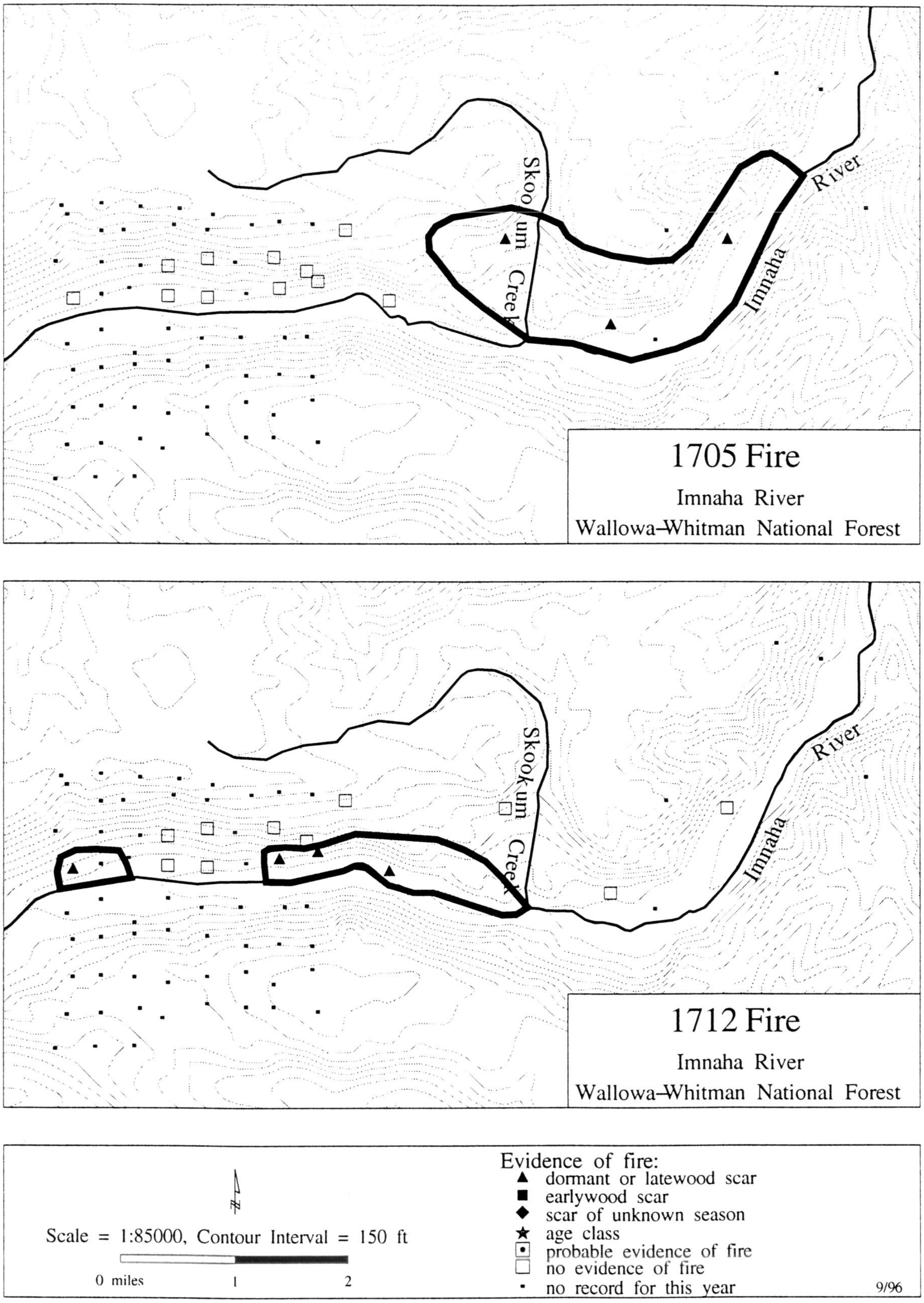
9/96

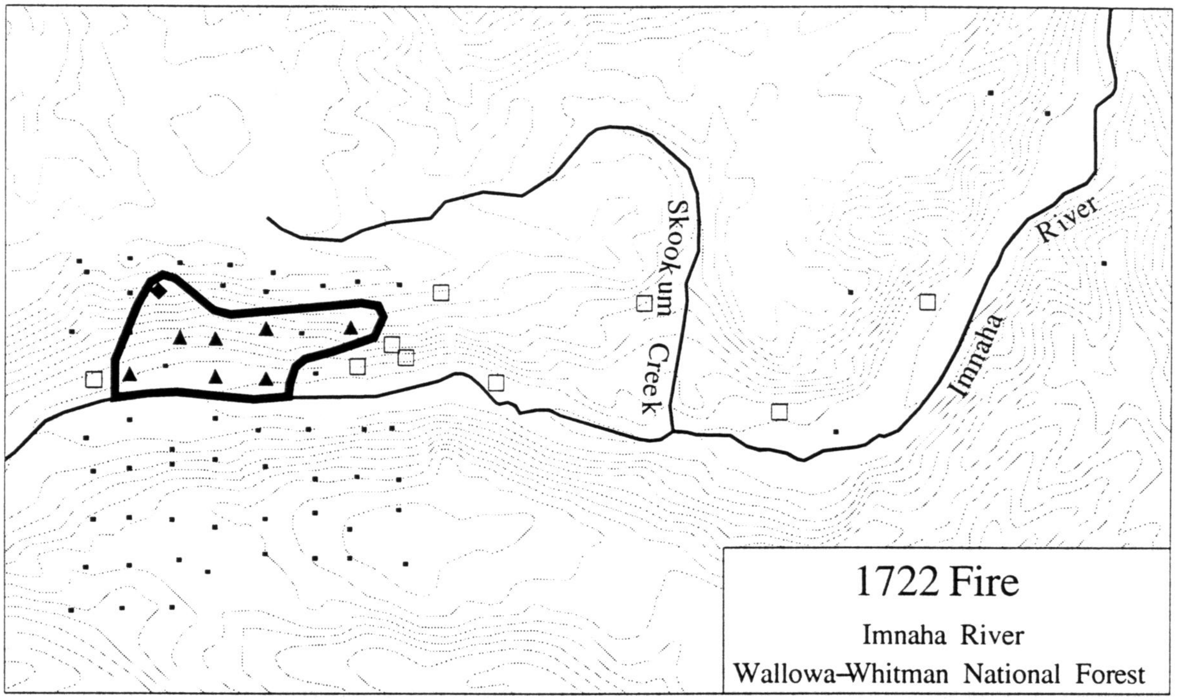

Skook um Creek
Imnaha
River
1661 Fire
Imnaha River
Wallowa–Whitman National Forest

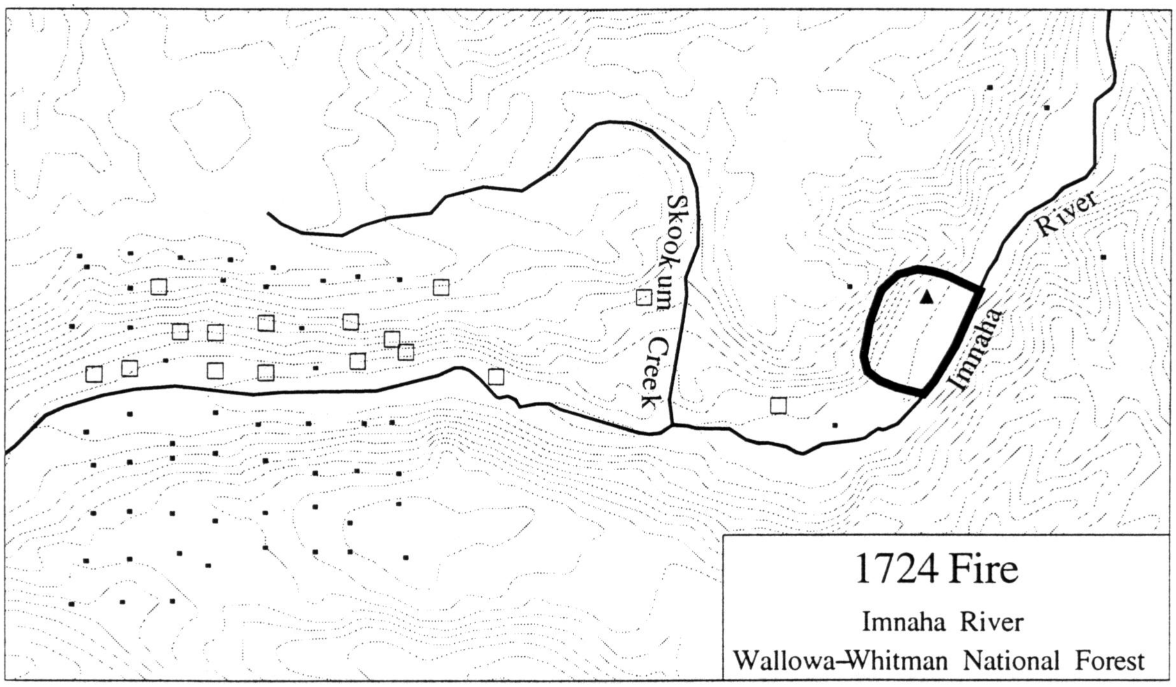

Skook um Creek
Imnaha
River
1671 Fire
Imnaha River
Wallowa–Whitman National Forest

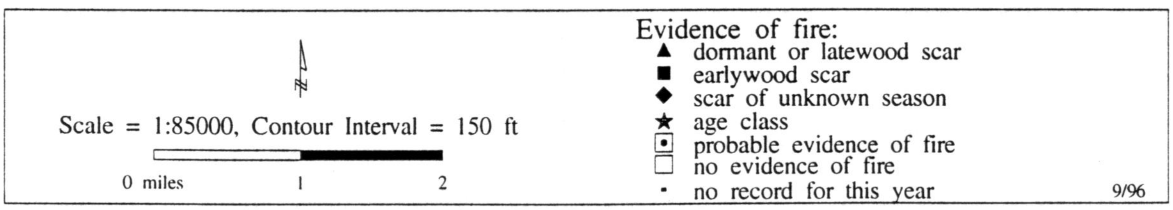

Scale = 1:85000, Contour Interval = 150 ft
0 miles
1
2
Evidence of fire:
dormant or latewood scar
earlywood scar
scar of unknown season
age class
probable evidence of fire
no evidence of fire
no record for this year
9/96

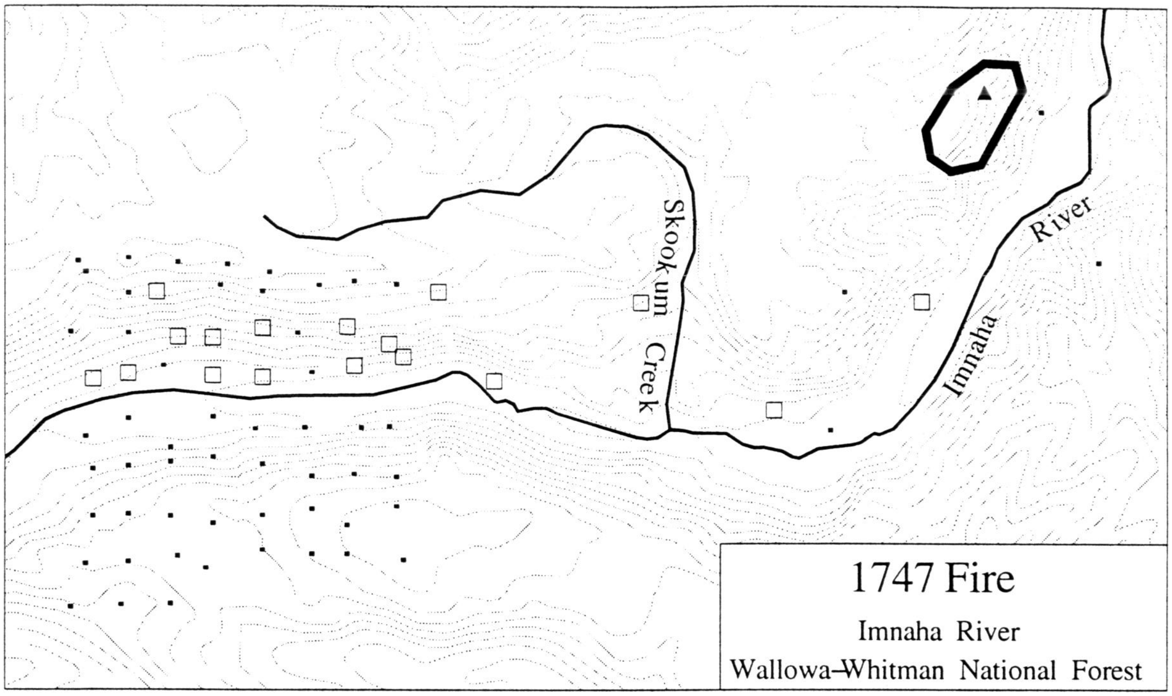

Skookum Creek
Imnaha River
1681 Fire
Imnaha River
Wallowa-Whitman National Forest
Skookum Creek
Imnaha River
1687 Fire
Imnaha River
Wallowa-Whitman National Forest
Scale = 1:85000, Contour Interval = 150 ft
0 miles 1 2
Evidence of fire:
▲ dormant or latewood scar
■ earlywood scar
◆ scar of unknown season
★ age class
probable evidence of fire
no evidence of fire
no record for this year
9/96

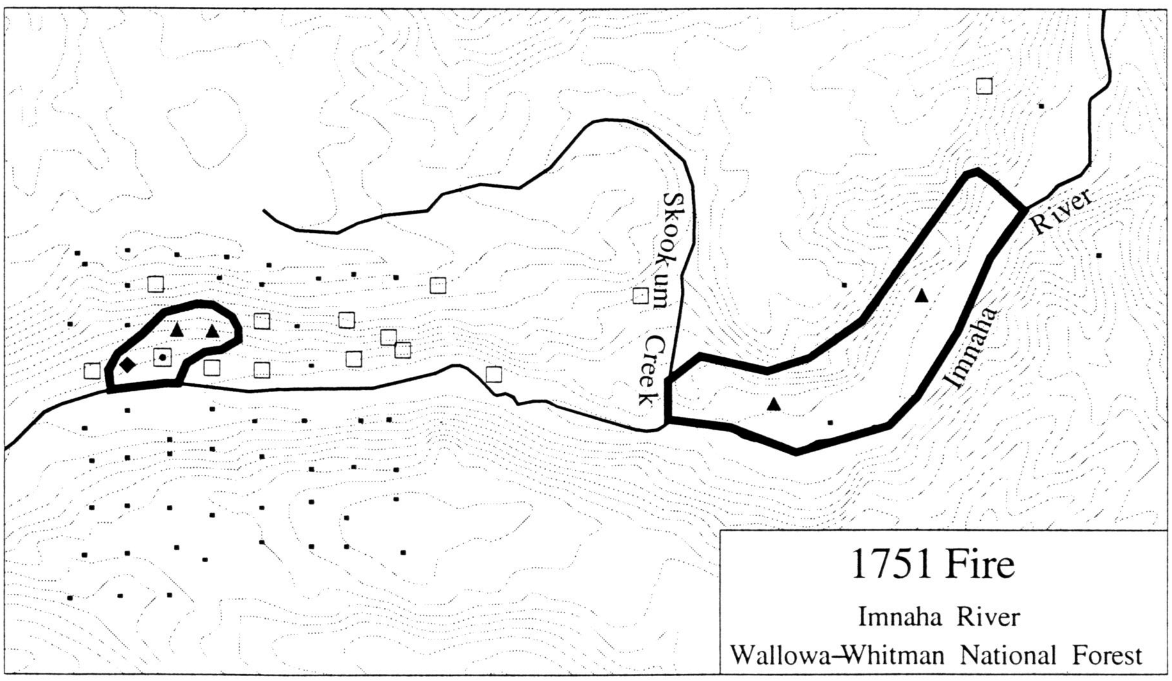

Skookum Creek
Imnaha River
1705 Fire
Imnaha River
Wallowa-Whitman National Forest
Skookum Creek
Imnaha River
1712 Fire
Imnaha River
Wallowa-Whitman National Forest
Scale = 1:85000, Contour Interval = 150 ft
0 miles
1
2
Evidence of fire:
▲ dormant or latewood scar
■ earlywood scar
◆ scar of unknown season
★ age class
probable evidence of fire
no evidence of fire
no record for this year
9/96

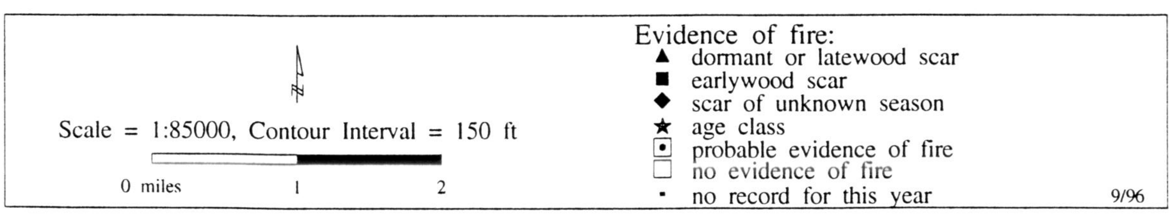

Skookum Creek
Imnaha River
1722 Fire
Imnaha River
Wallowa-Whitman National Forest

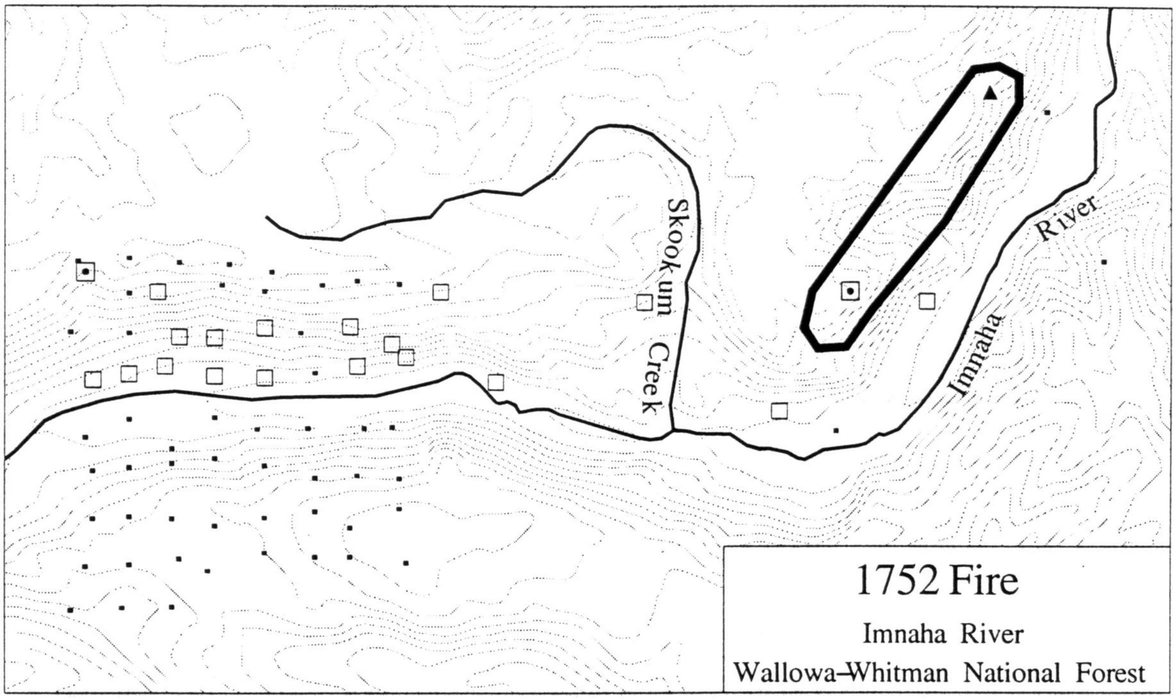

Skookum Creek
Imnaha River
1724 Fire
Imnaha River
Wallowa-Whitman National Forest

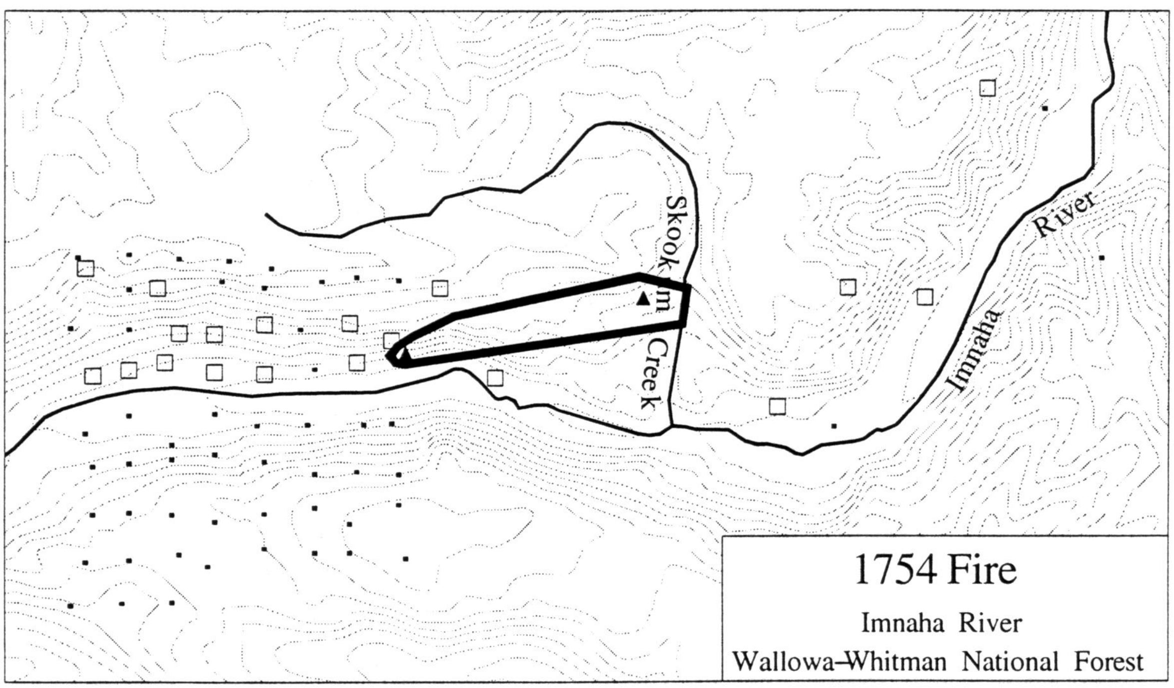

N
Scale = 1:85000, Contour Interval = 150 ft
0 miles
1
2
Evidence of fire:
dormant or latewood scar
earlywood scar
scar of unknown season
age class
probable evidence of fire
no evidence of fire
no record for this year
9/96

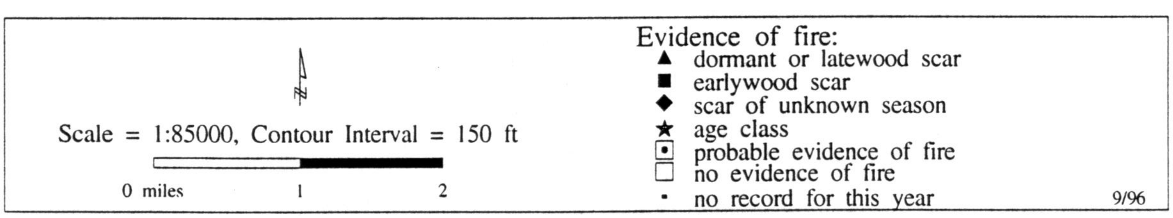

Skookum Creek
Imnaha River
1747 Fire
Imnaha River
Wallowa-Whitman National Forest

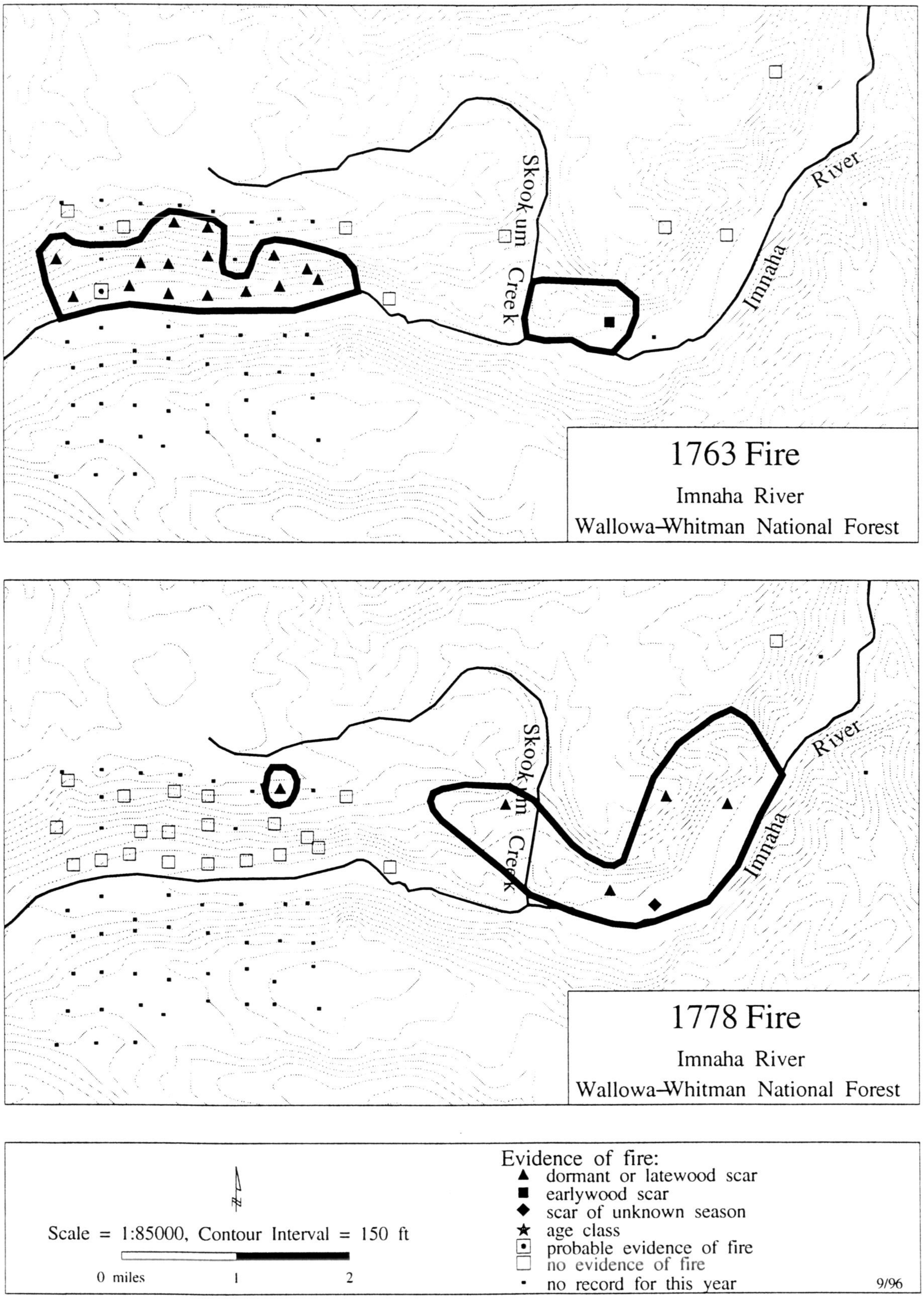

Skookum Creek
Imnaha River
1751 Fire
Imnaha River
Wallowa-Whitman National Forest

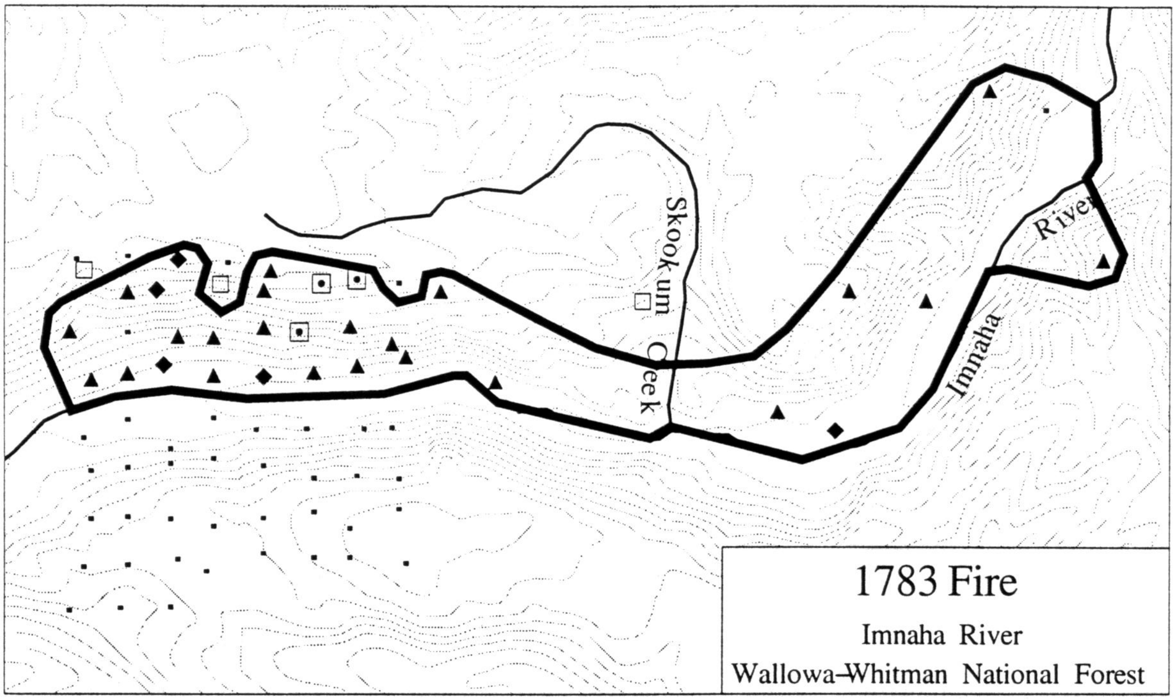

Scale = 1:85000, Contour Interval = 150 ft
0 miles
1
2
Evidence of fire:
▲ dormant or latewood scar
■ earlywood scar
◆ scar of unknown season
★ age class
probable evidence of fire
no evidence of fire
no record for this year
9/96

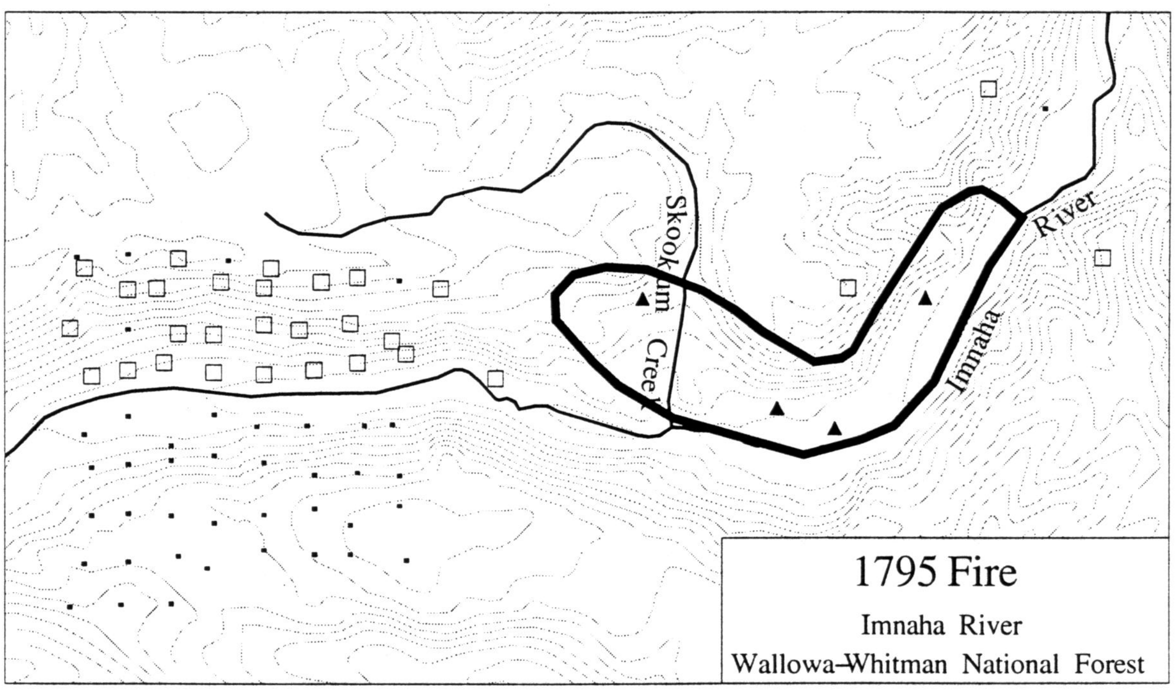

Skookum Creek
Imnaha River
1752 Fire
Imnaha River
Wallowa-Whitman National Forest

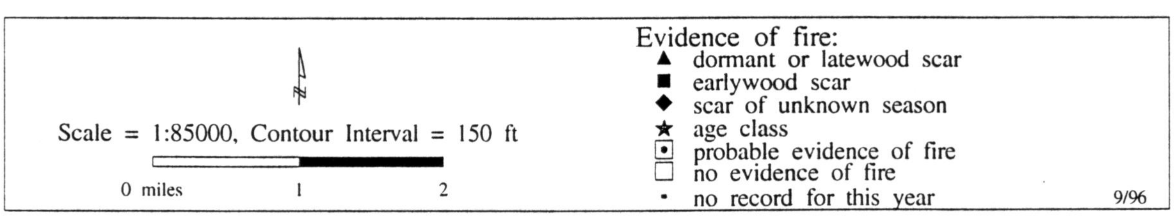

Skookum Creek
Imnaha River
1754 Fire
Imnaha River
Wallowa-Whitman National Forest

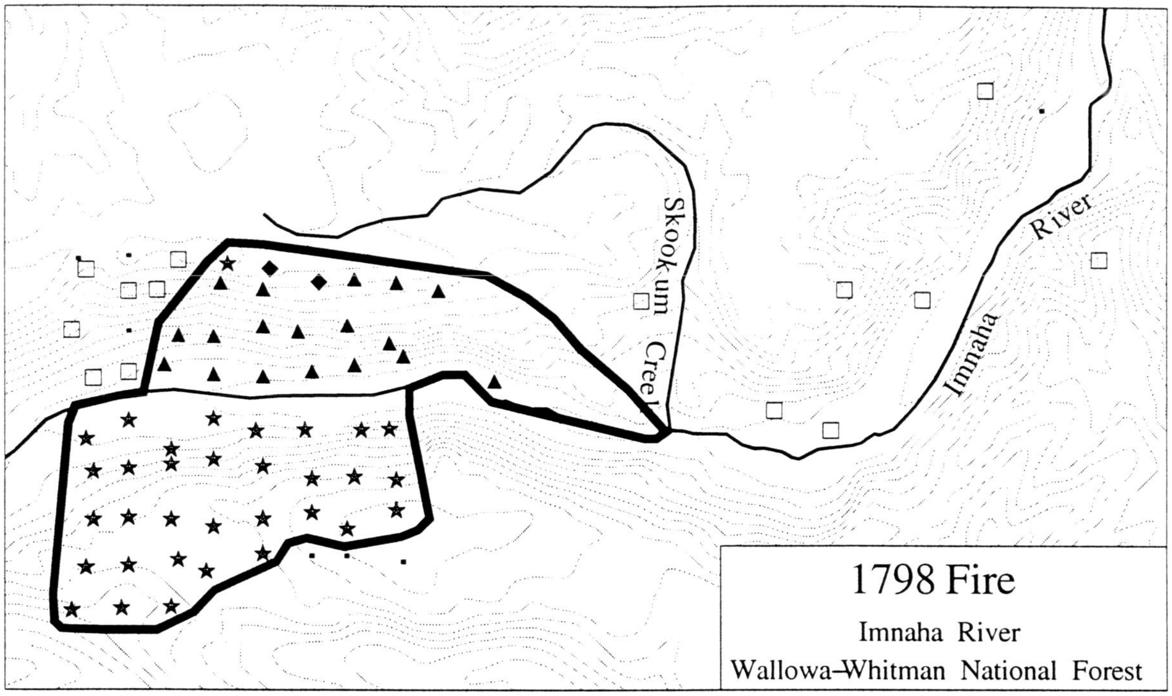

Scale = 1:85000, Contour Interval = 150 ft
0 miles
1
2
Evidence of fire:
dormant or latewood scar
earlywood scar
scar of unknown season
age class
probable evidence of fire
no evidence of fire
no record for this year
9/96

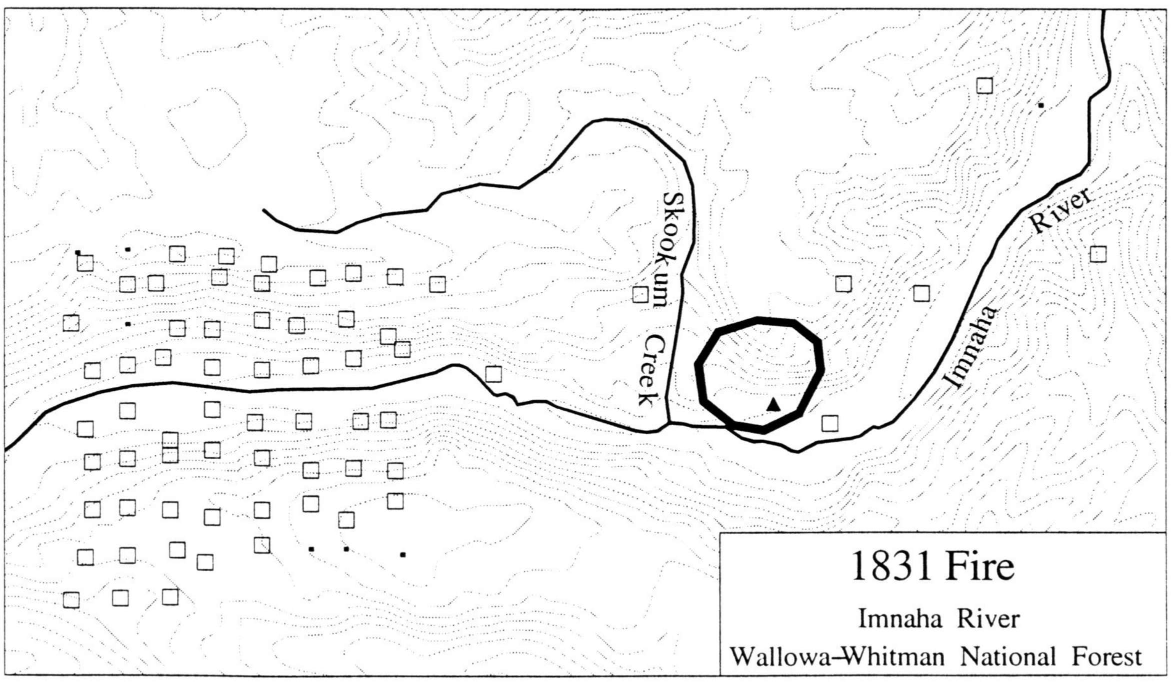

Skookum Creek
River
Imnaha
1763 Fire
Imnaha River
Wallowa-Whitman National Forest
Skookum Creek
River
Imnaha
1778 Fire
Imnaha River
Wallowa-Whitman National Forest
Scale = 1:85000, Contour Interval = 150 ft
0 miles
1
2
Evidence of fire:
dormant or latewood scar
earlywood scar
scar of unknown season
age class
probable evidence of fire
no evidence of fire
no record for this year
9/96

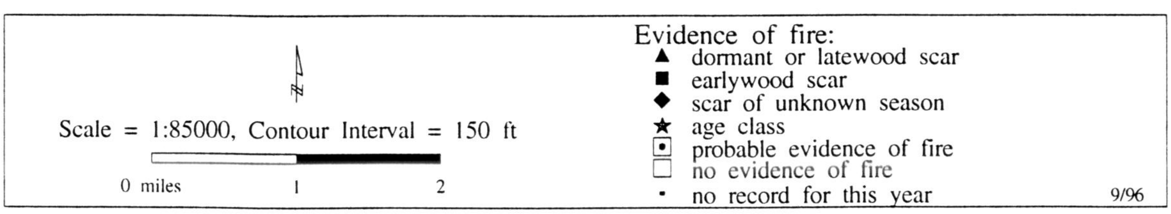

Skookum Creek
Imnaha River
1783 Fire
Imnaha River
Wallowa-Whitman National Forest

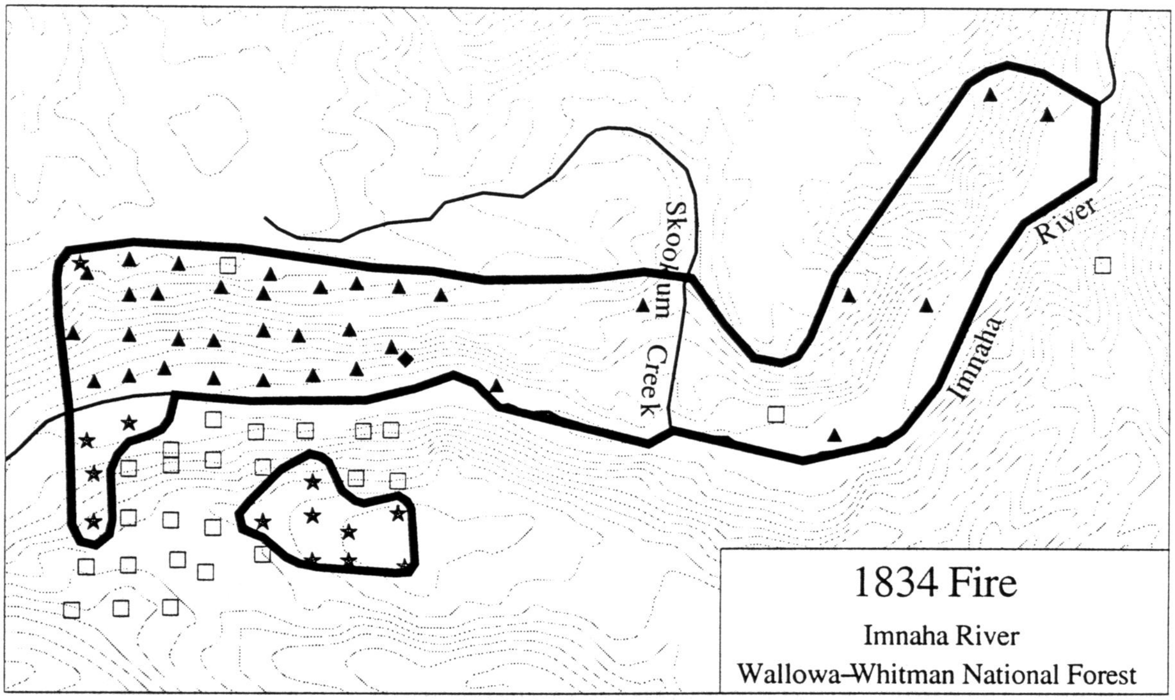

Skookum Creek
Imnaha River
1795 Fire
Imnaha River
Wallowa-Whitman National Forest

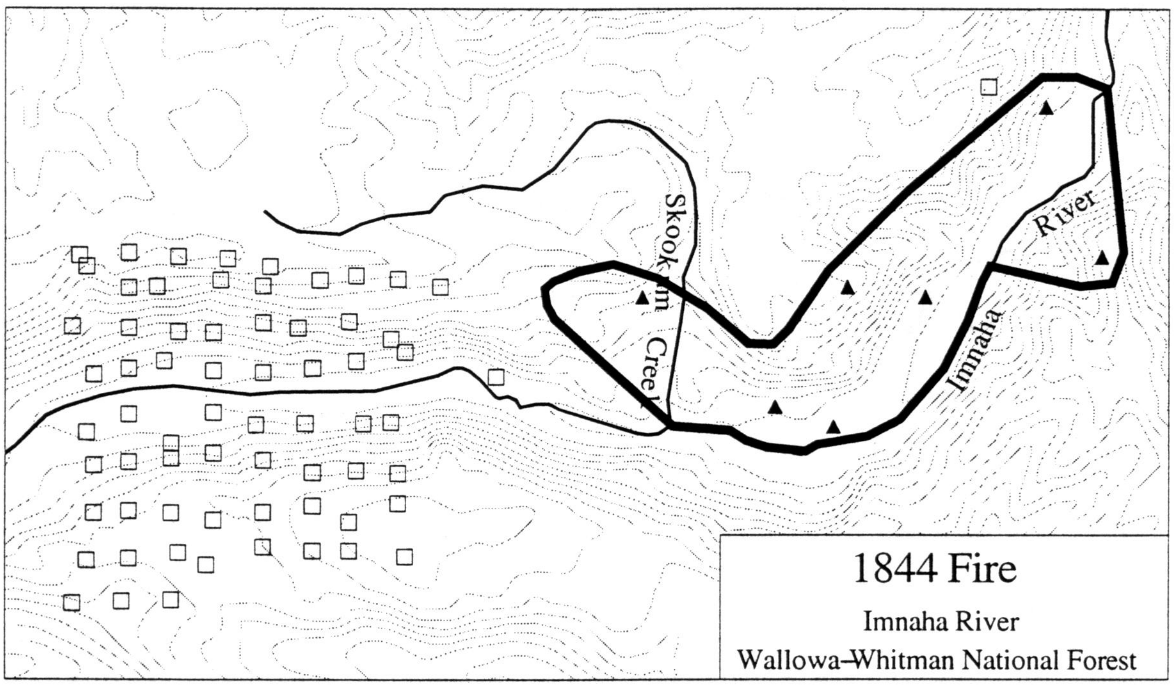

Scale = 1:85000, Contour Interval = 150 ft
0 miles
1
2
Evidence of fire:
dormant or latewood scar
earlywood scar
scar of unknown season
age class
probable evidence of fire
no evidence of fire
no record for this year
9/96

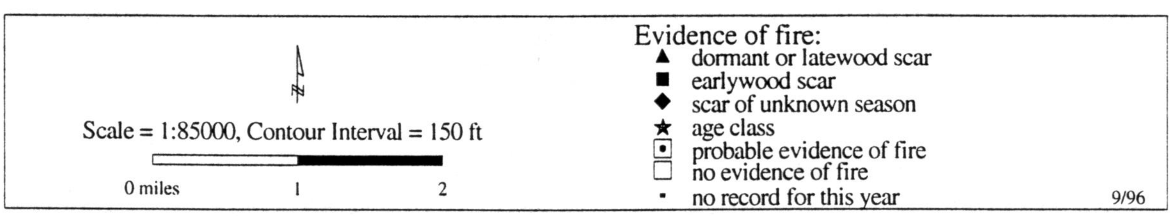

Skookum Creek
Imnaha River
1798 Fire
Imnaha River
Wallowa-Whitman National Forest

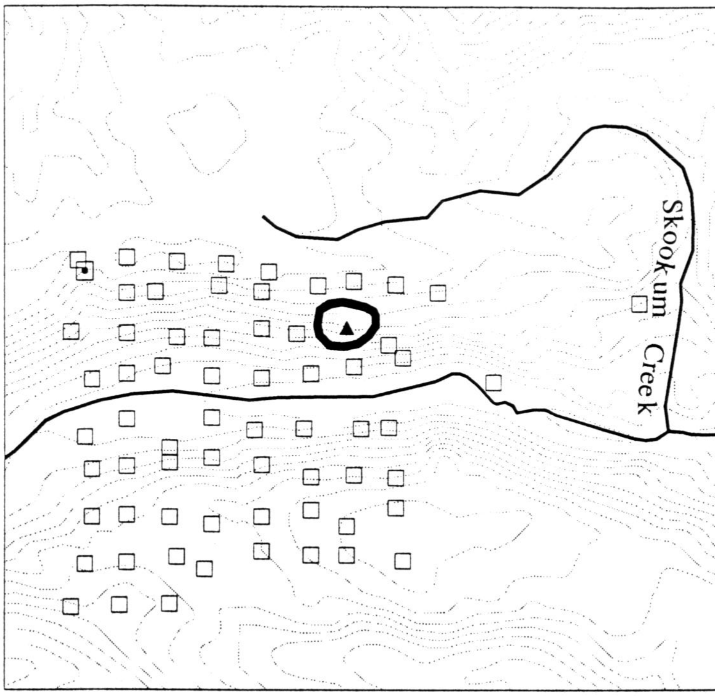

Skookum Creek
Imnaha River
1831 Fire
Imnaha River
Wallowa-Whitman National Forest


Scale = 1:85000, Contour Interval = 150 ft
0 miles
1
2
Evidence of fire:
▲ dormant or latewood scar
■ earlywood scar
◆ scar of unknown season
★ age class
probable evidence of fire
no evidence of fire
• no record for this year
9/96


Skookum Creek
Imnaha River
1834 Fire
Imnaha River
Wallowa-Whitman National Forest


Skookum Creek
Imnaha River
1844 Fire
Imnaha River
Wallowa-Whitman National Forest

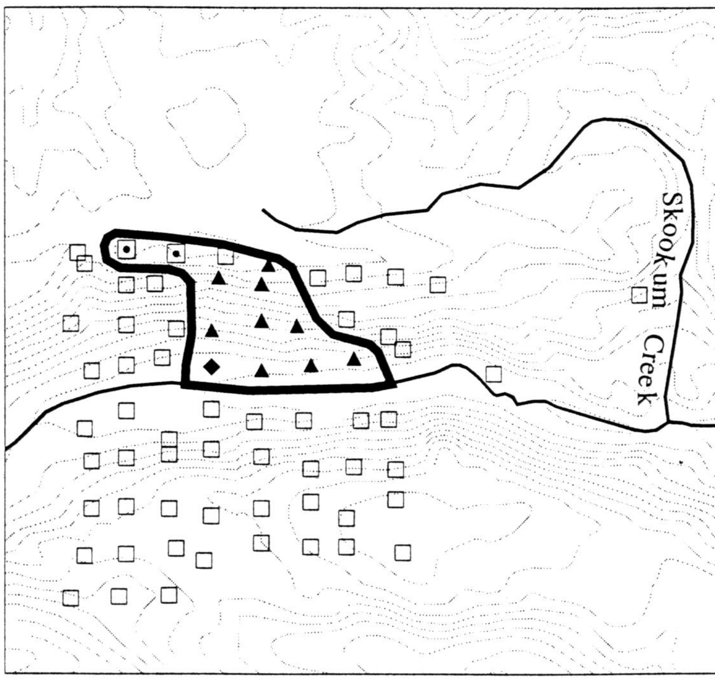

Scale = 1:85000, Contour Interval = 150 ft
0 miles
1
2
Evidence of fire:
dormant or latewood scar
earlywood scar
scar of unknown season
age class
probable evidence of fire
no evidence of fire
no record for this year
9/96



1846 Fire

Imnaha River

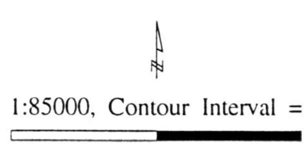
Wallowa-Whitman National Forest



1852 Fire

Imnaha River

Wallowa-Whitman National Forest

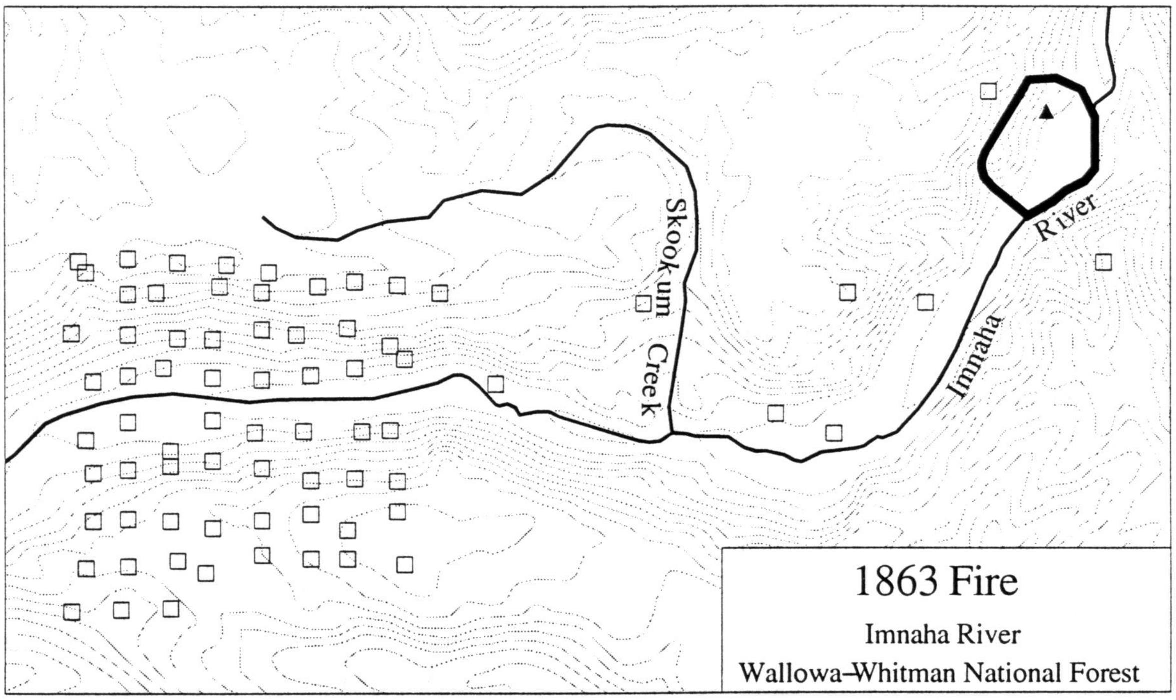


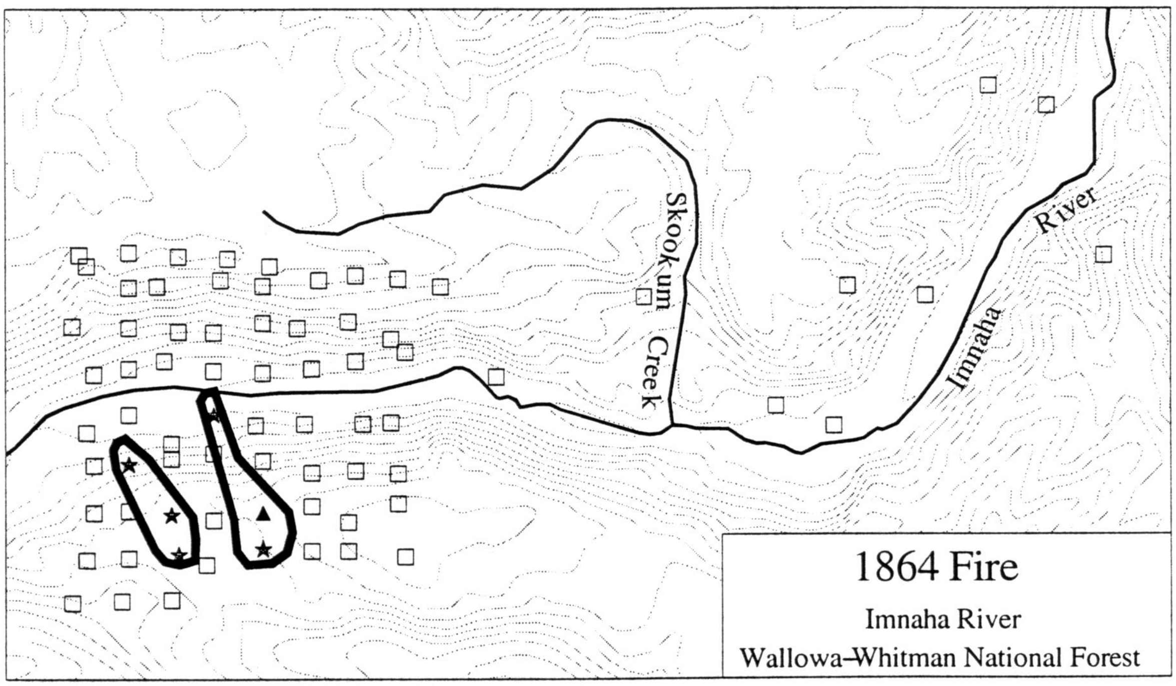
Scale = 1:85000, Contour Interval = 150 ft

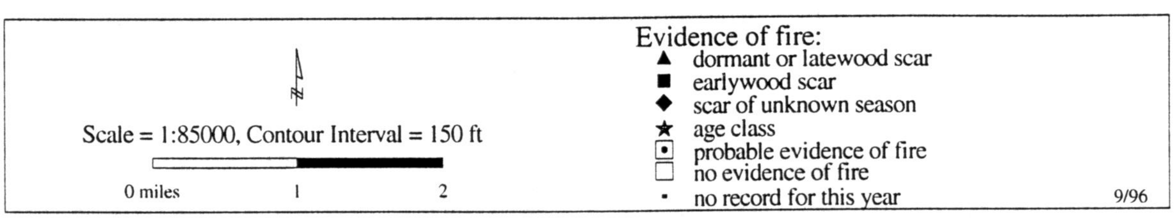
0 miles 1 2

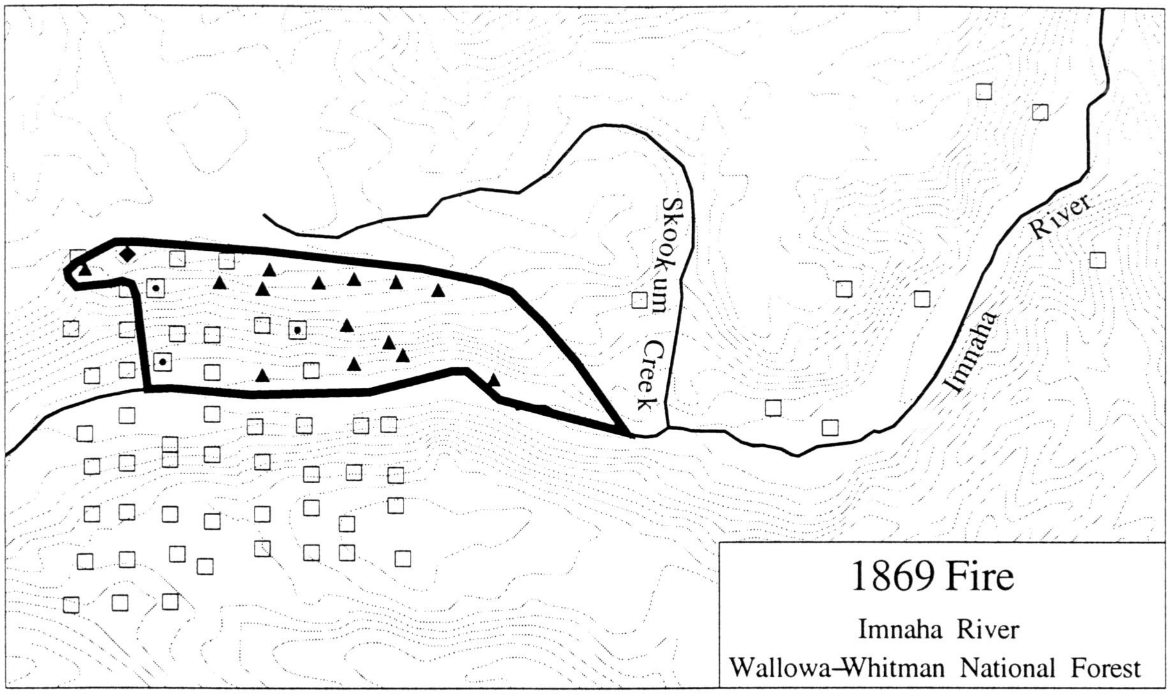
Evidence of fire:
- ▲ dormant or latewood scar
- ■ earlywood scar
- ◆ scar of unknown season
- ★ age class
- ⊡ probable evidence of fire
- □ no evidence of fire
- · no record for this year

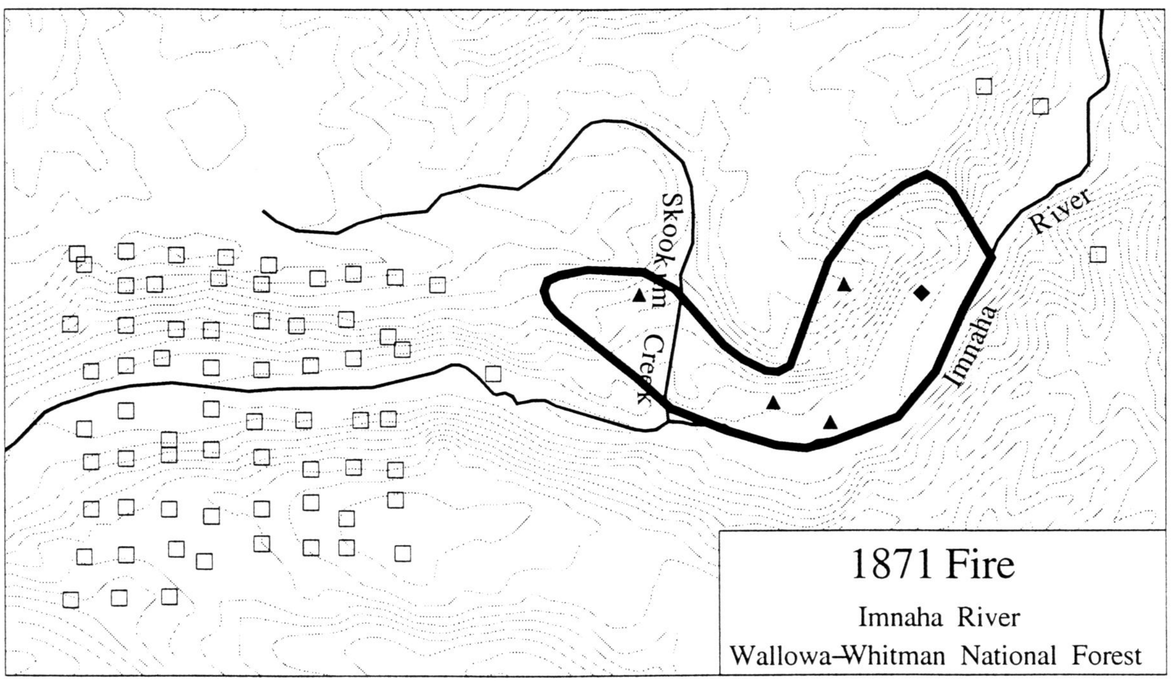
9/96

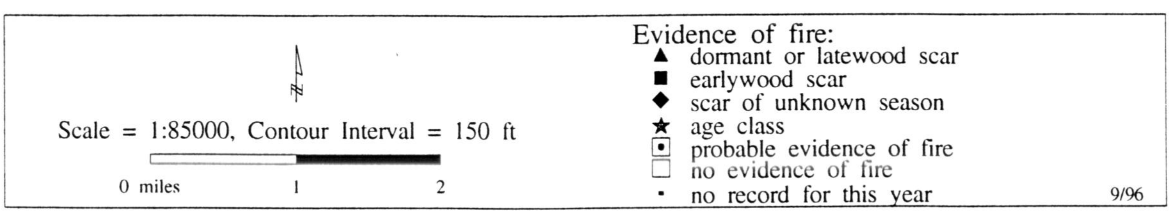

Skookum Creek
Imnaha
River
1863 Fire
Imnaha River
Wallowa-Whitman National Forest

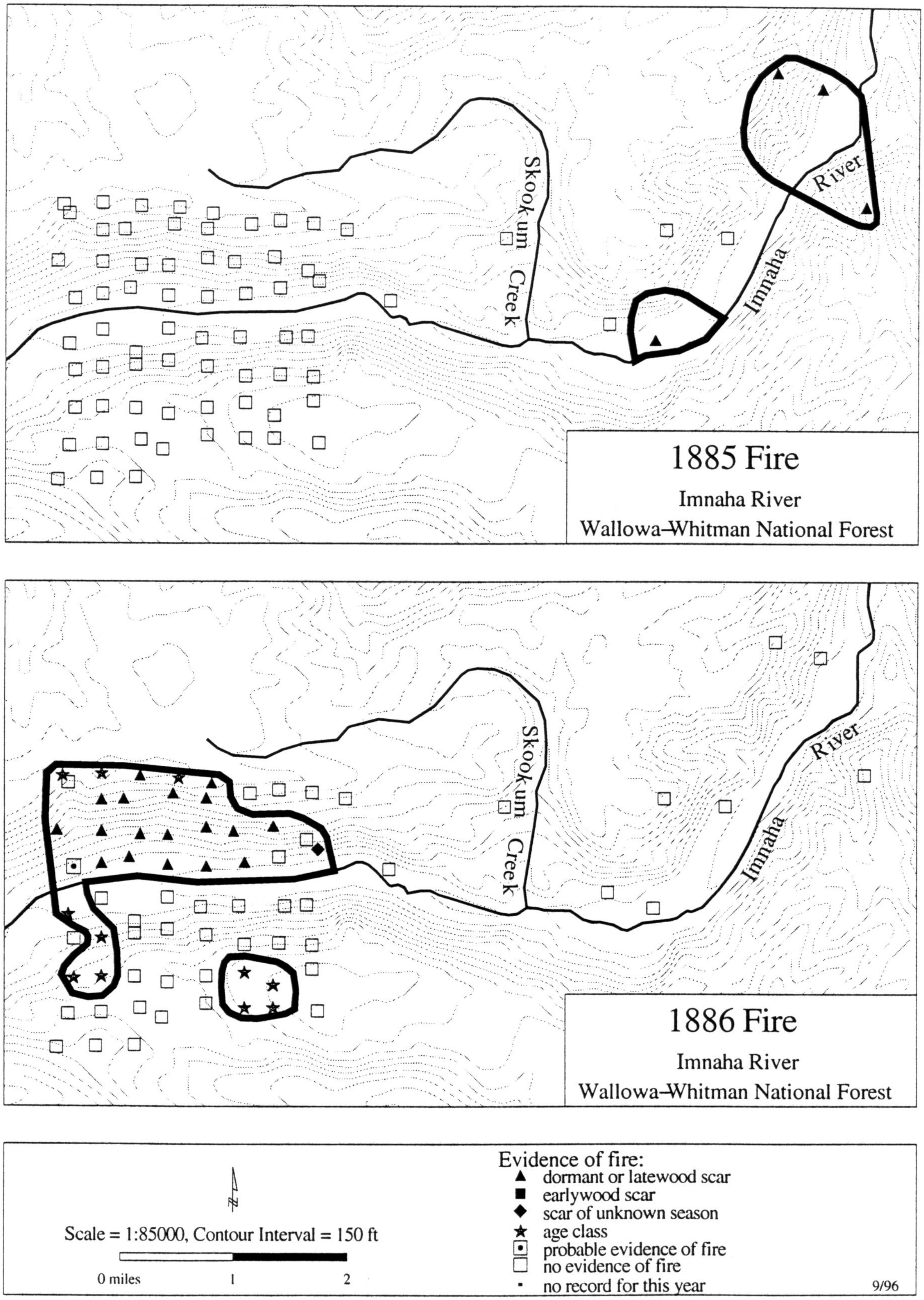

Skookum Creek
Imnaha
River
1864 Fire
Imnaha River
Wallowa-Whitman National Forest

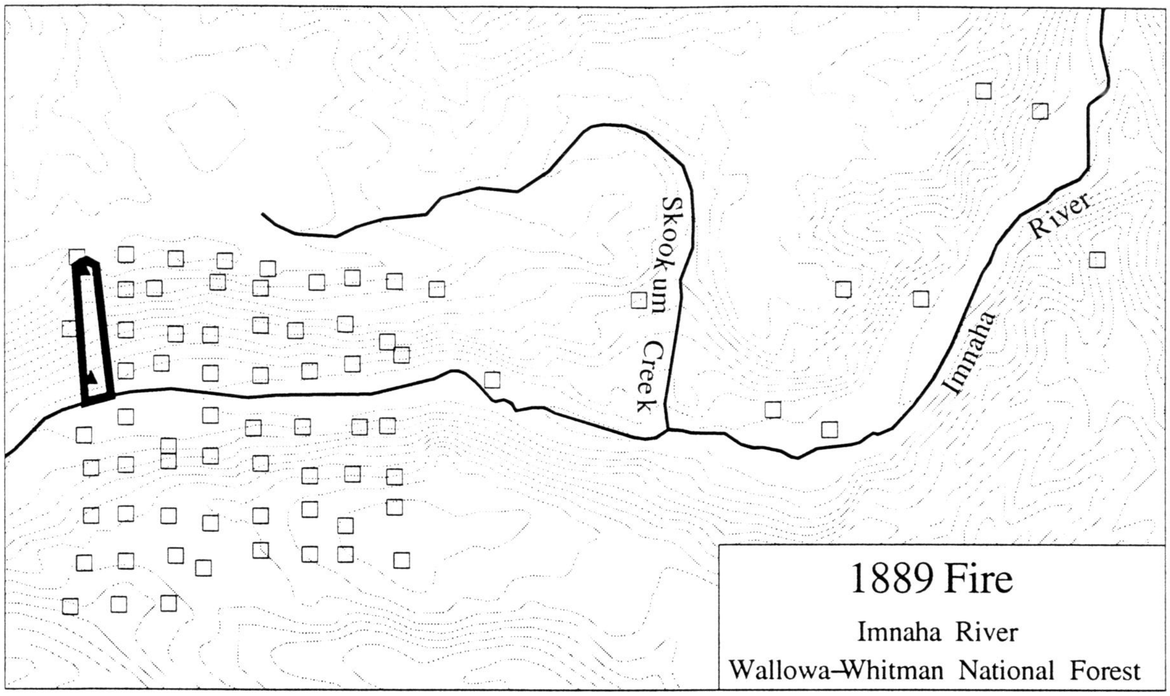

Scale = 1:85000, Contour Interval = 150 ft
0 miles
1
2
Evidence of fire:
▲ dormant or latewood scar
■ earlywood scar
◆ scar of unknown season
★ age class
⊡ probable evidence of fire
□ no evidence of fire
· no record for this year
9/96

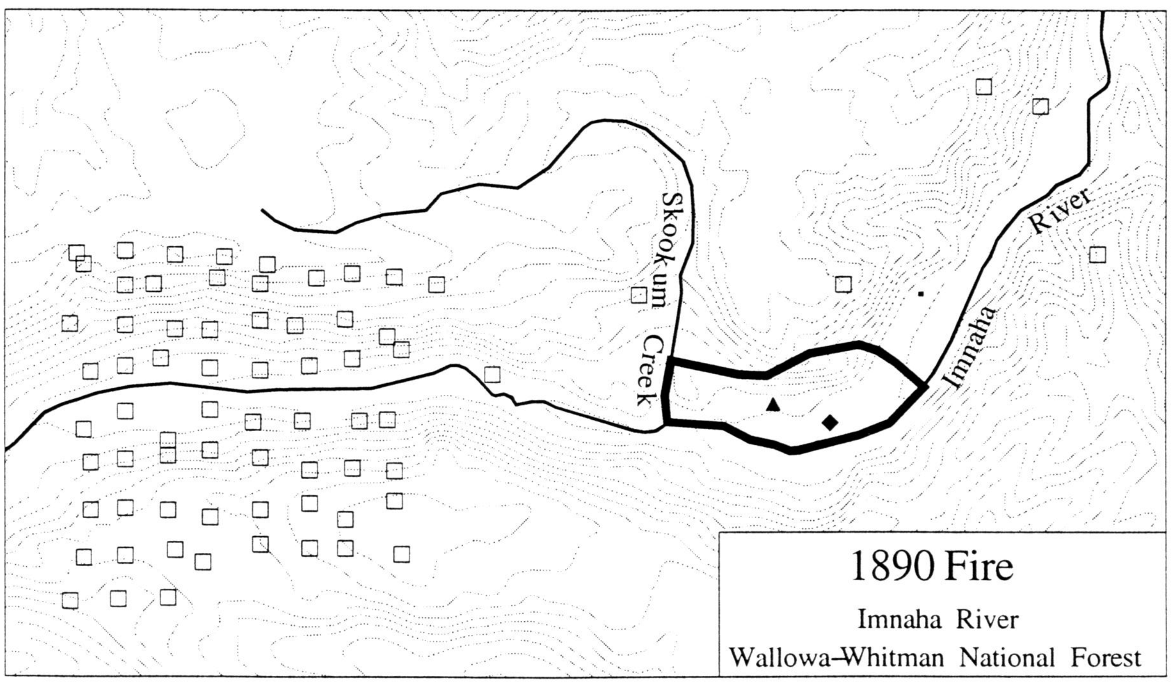

Skookum Creek
Imnaha River
1869 Fire
Imnaha River
Wallowa-Whitman National Forest


Skookum Creek
Imnaha River
1871 Fire
Imnaha River
Wallowa-Whitman National Forest


Scale = 1:85000, Contour Interval = 150 ft
0 miles
1
2
Evidence of fire:
dormant or latewood scar
earlywood scar
scar of unknown season
age class
probable evidence of fire
no evidence of fire
no record for this year
9/96


Skookum Creek
Imnaha River
1885 Fire
Imnaha River
Wallowa-Whitman National Forest
Skookum Creek
Imnaha River
1886 Fire
Imnaha River
Wallowa-Whitman National Forest
Scale = 1:85000, Contour Interval = 150 ft
0 miles
1
2
Evidence of fire:
▲ dormant or latewood scar
■ earlywood scar
◆ scar of unknown season
★ age class
⊡ probable evidence of fire
□ no evidence of fire
· no record for this year
9/96



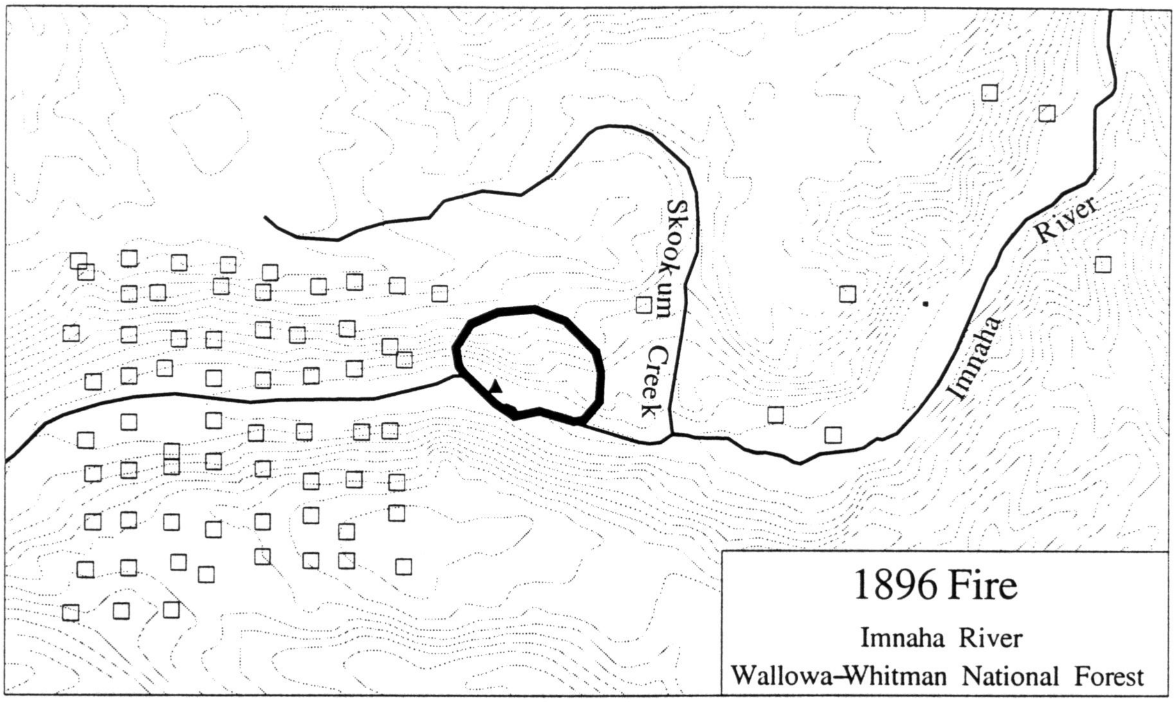


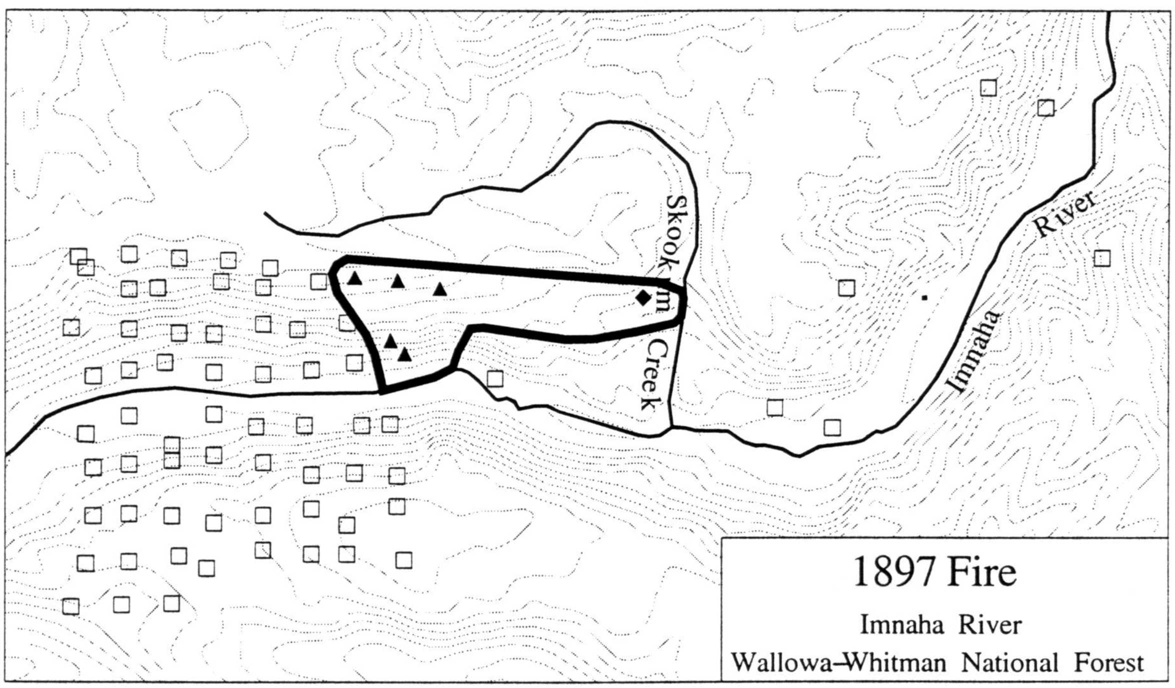
Scale = 1:85000, Contour Interval = 150 ft

0 miles 1 2

Evidence of fire:
- ▲ dormant or latewood scar
- ■ earlywood scar
- ◆ scar of unknown season
- ★ age class
- ⊡ probable evidence of fire
- □ no evidence of fire
- ▪ no record for this year

9/96



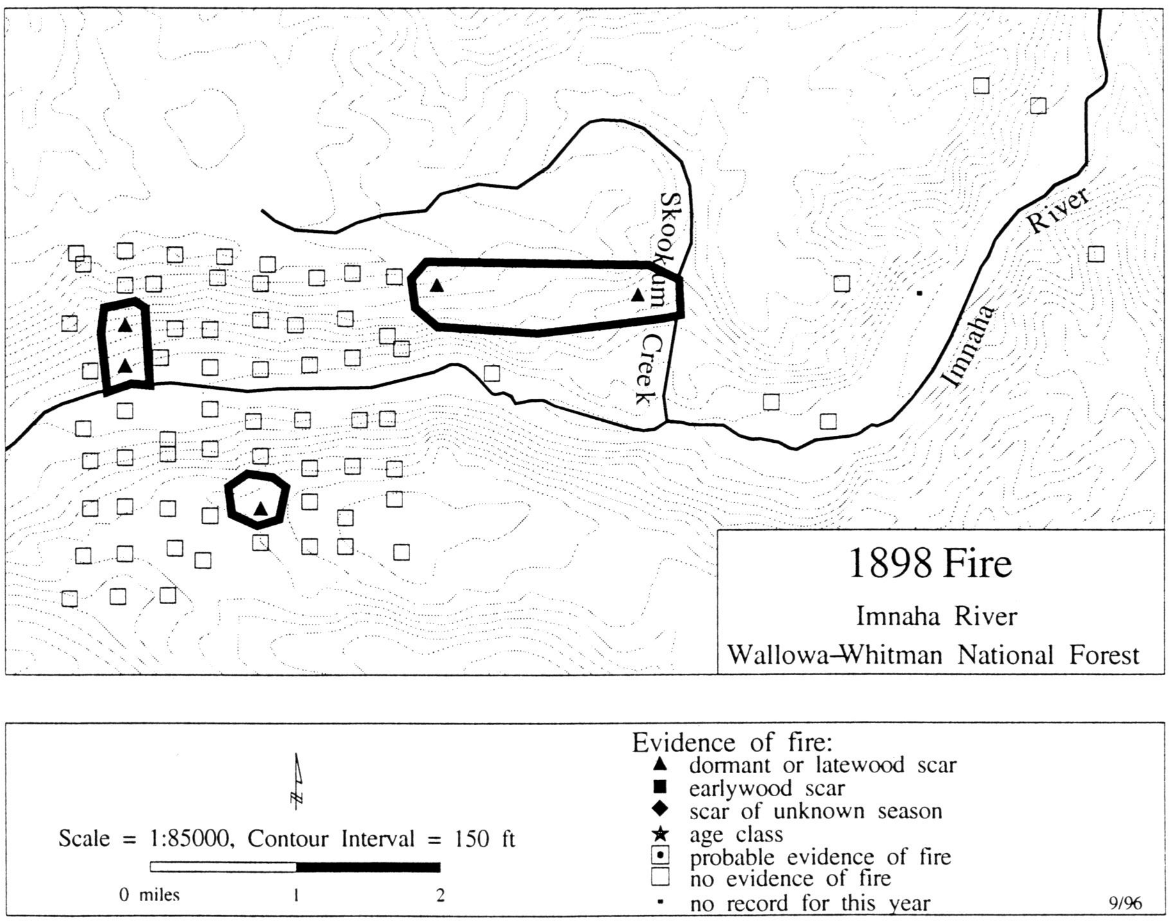


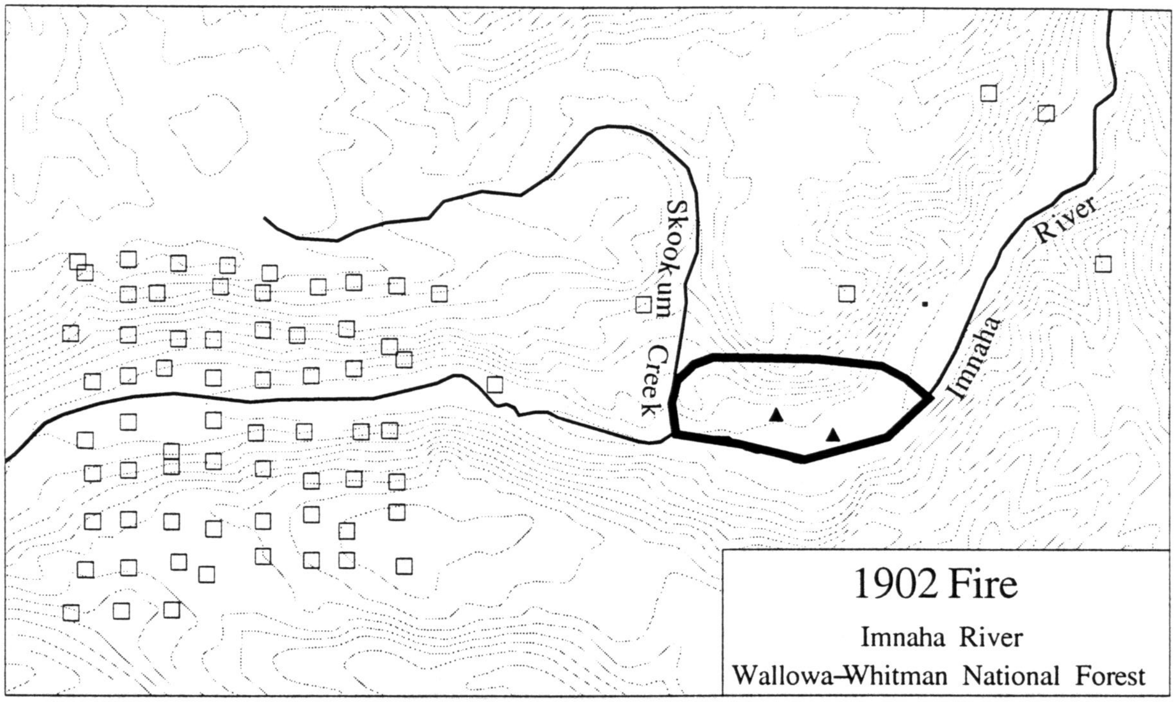
Scale = 1:85000, Contour Interval = 150 ft

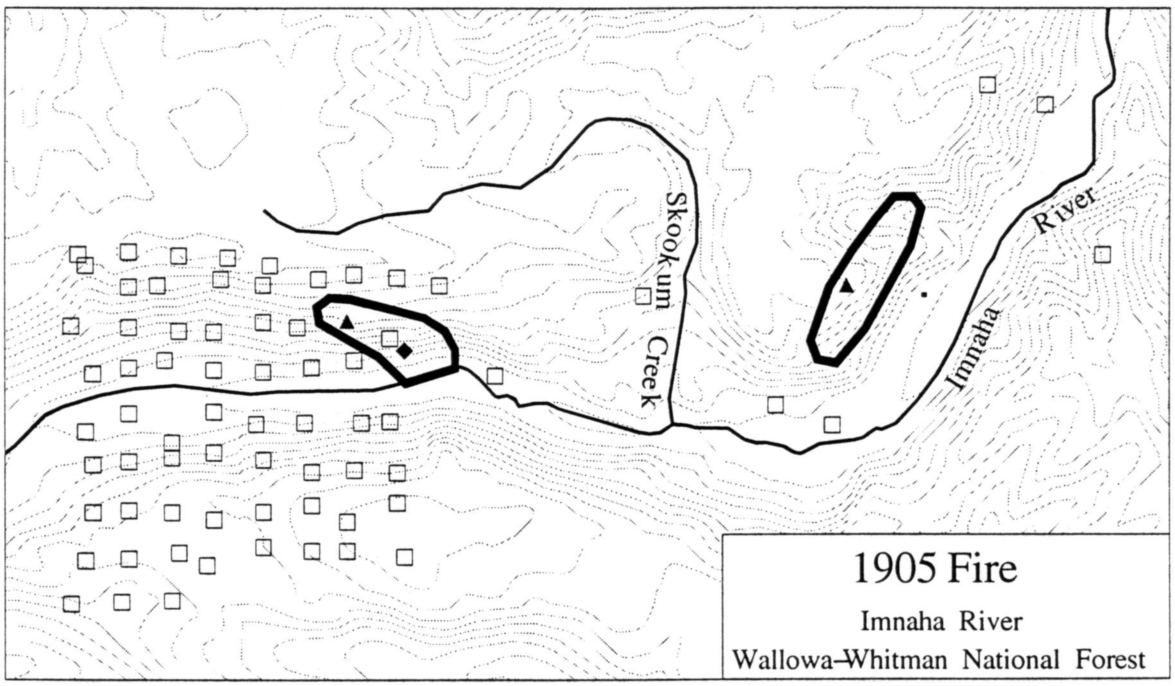
0 miles 1 2

Evidence of fire:
- dormant or latewood scar
- earlywood scar
- scar of unknown season
- age class
- probable evidence of fire
- no evidence of fire
- no record for this year

9/96


Skookum Creek
Imnaha River
1898 Fire
Imnaha River
Wallowa-Whitman National Forest
Scale = 1:85000, Contour Interval = 150 ft
0 miles
1
2
Evidence of fire:
dormant or latewood scar
earlywood scar
scar of unknown season
age class
probable evidence of fire
no evidence of fire
no record for this year
9/96



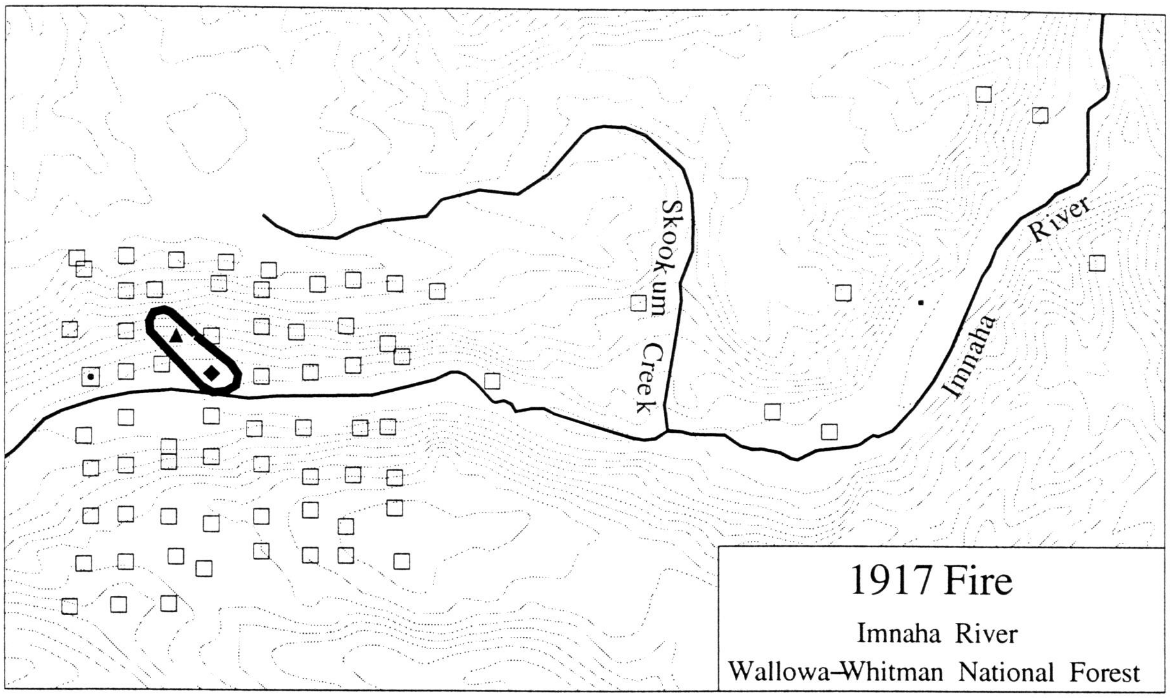


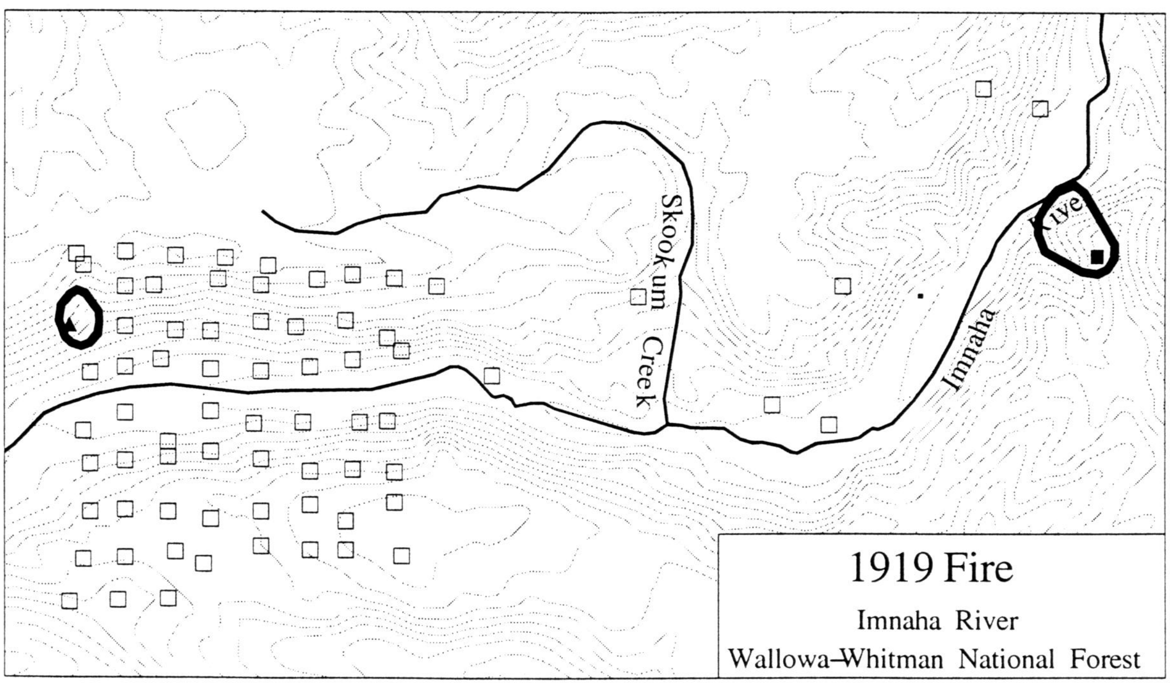
Scale = 1:85000, Contour Interval = 150 ft

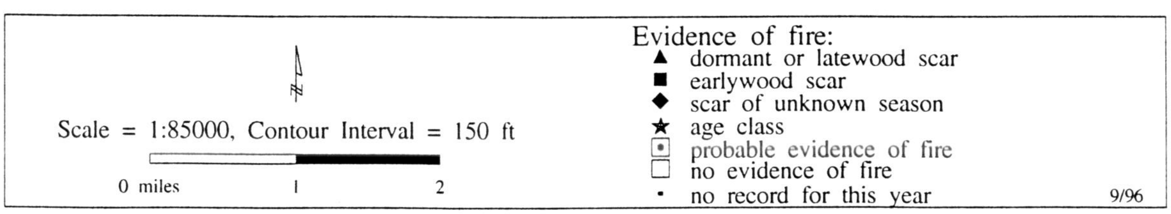
0 miles 1 2

Evidence of fire:
- ▲ dormant or latewood scar
- ■ earlywood scar
- ◆ scar of unknown season
- ★ age class
- ⊡ probable evidence of fire
- □ no evidence of fire
- · no record for this year

9/96

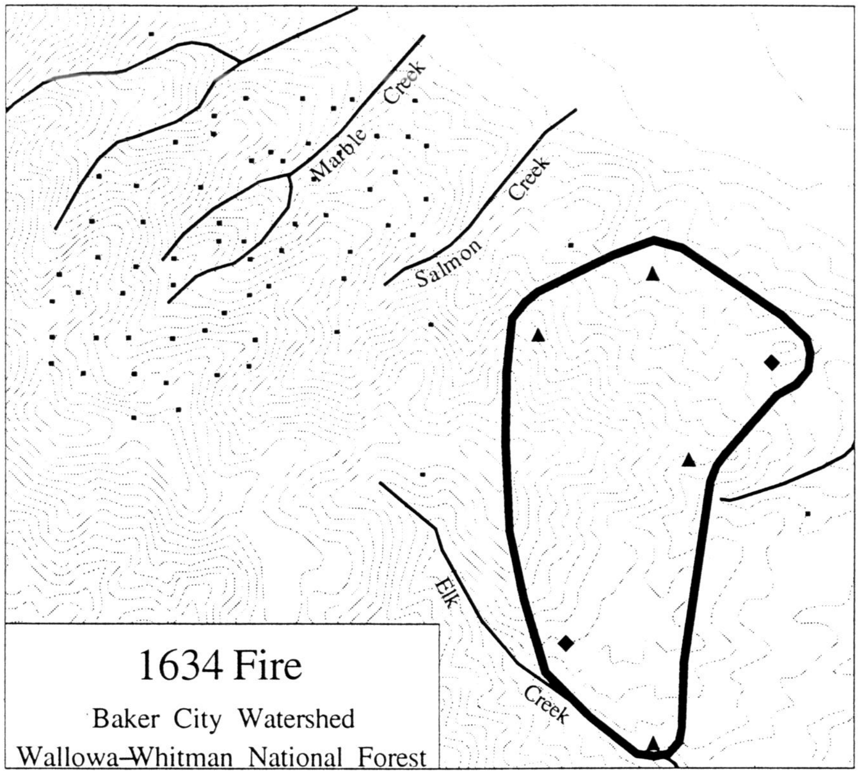

Skookum Creek
Imnaha River
1917 Fire
Imnaha River
Wallowa-Whitman National Forest

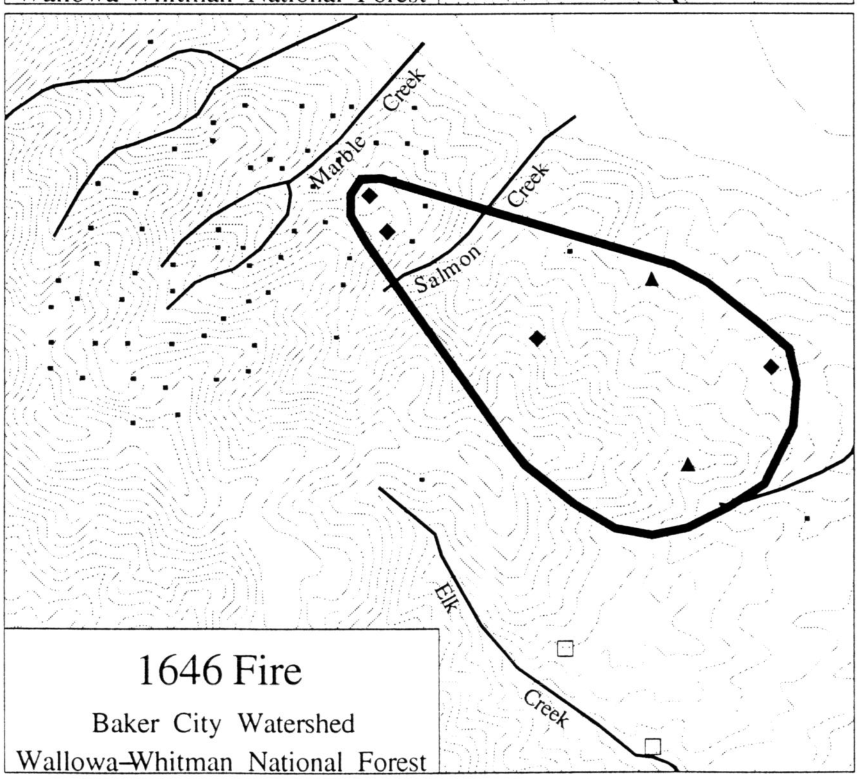

Skookum Creek
Imnaha River
1919 Fire
Imnaha River
Wallowa-Whitman National Forest


Scale = 1:85000, Contour Interval = 150 ft
0 miles
1
2
Evidence of fire:
▲ dormant or latewood scar
■ earlywood scar
◆ scar of unknown season
★ age class
probable evidence of fire
no evidence of fire
no record for this year
9/96

Appendix F: Baker: Fire maps

Evidence of fire was mapped at Baker for every year in dry forests which had at least two scars. Individual fire events could not be identified in the mesic forests at this site. The maps show the intra-annular position of the scar is also indicated. Plots indicating as having probable evidence of fire are those for which the only evidence was an abrupt increase or decrease in ring width. Plots having no evidence of fire in a given year had recording trees for that year but did not have scars or an age class for that year. Plots indicated as having no record for a given year are plots that were sampled but had no trees recording during that year. Fire boundaries are shown as a heavy line.



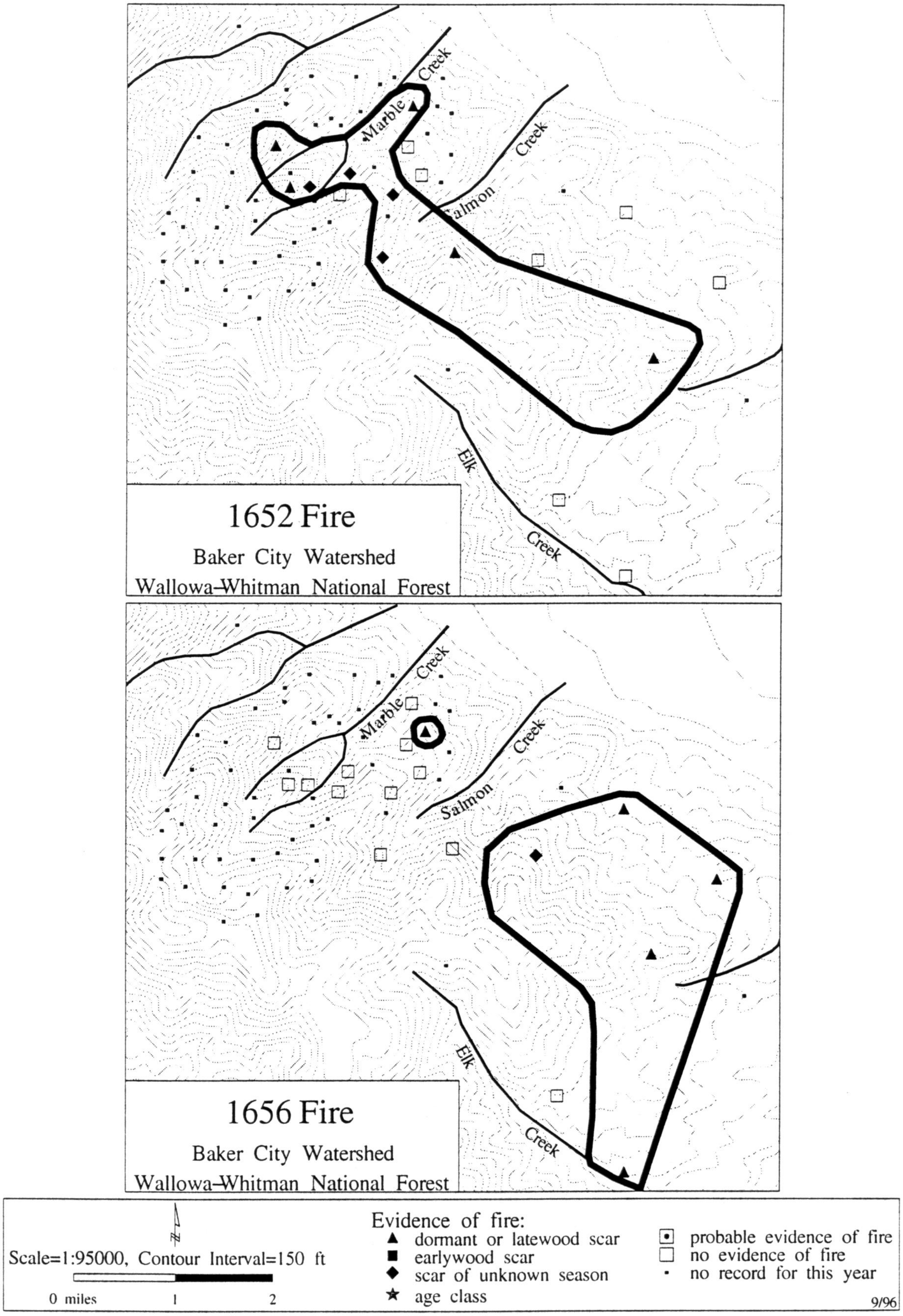


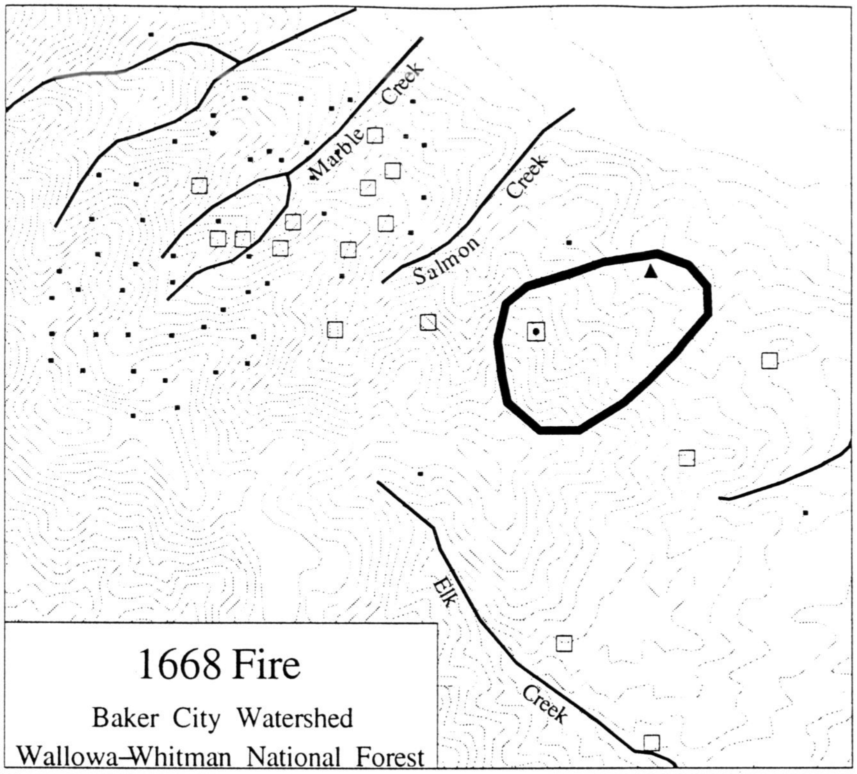
Scale=1:95000, Contour Interval=150 ft

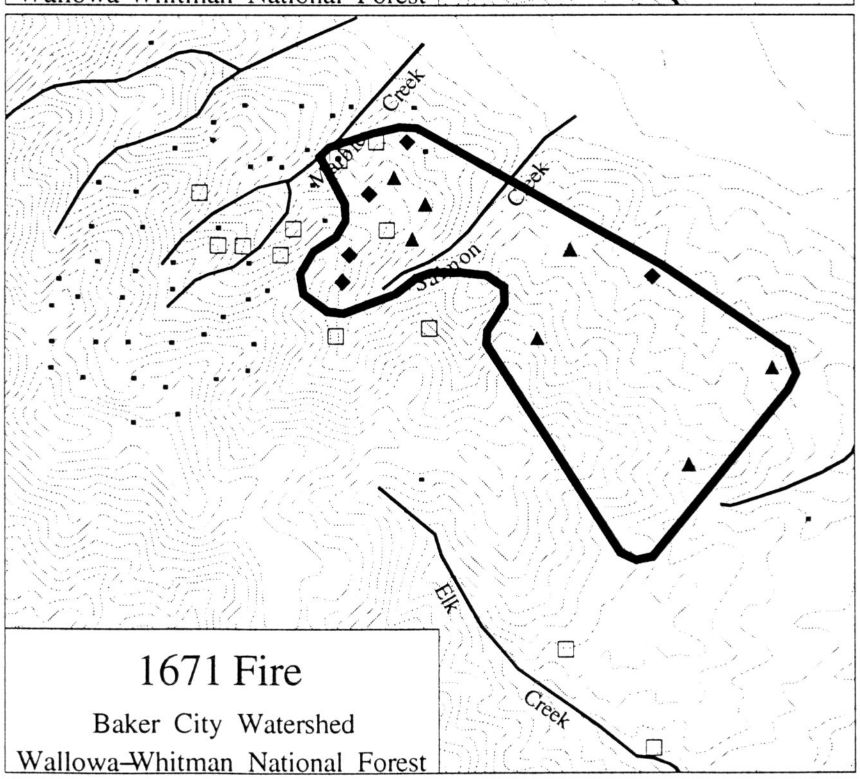
0 miles 1 2

Evidence of fire:
- ▲ dormant or latewood scar
- ■ earlywood scar
- ◆ scar of unknown season
- ★ age class
- ⊡ probable evidence of fire
- □ no evidence of fire
- · no record for this year

9/96


Marble Creek
Salmon Creek
Elk Creek
1652 Fire
Baker City Watershed
Wallowa-Whitman National Forest
Marble Creek
Salmon Creek
Elk Creek
1656 Fire
Baker City Watershed
Wallowa-Whitman National Forest
Scale=1:95000, Contour Interval=150 ft
0 miles
1
2
Evidence of fire:
▲ dormant or latewood scar
■ earlywood scar
◆ scar of unknown season
★ age class
probable evidence of fire
no evidence of fire
no record for this year
9/96



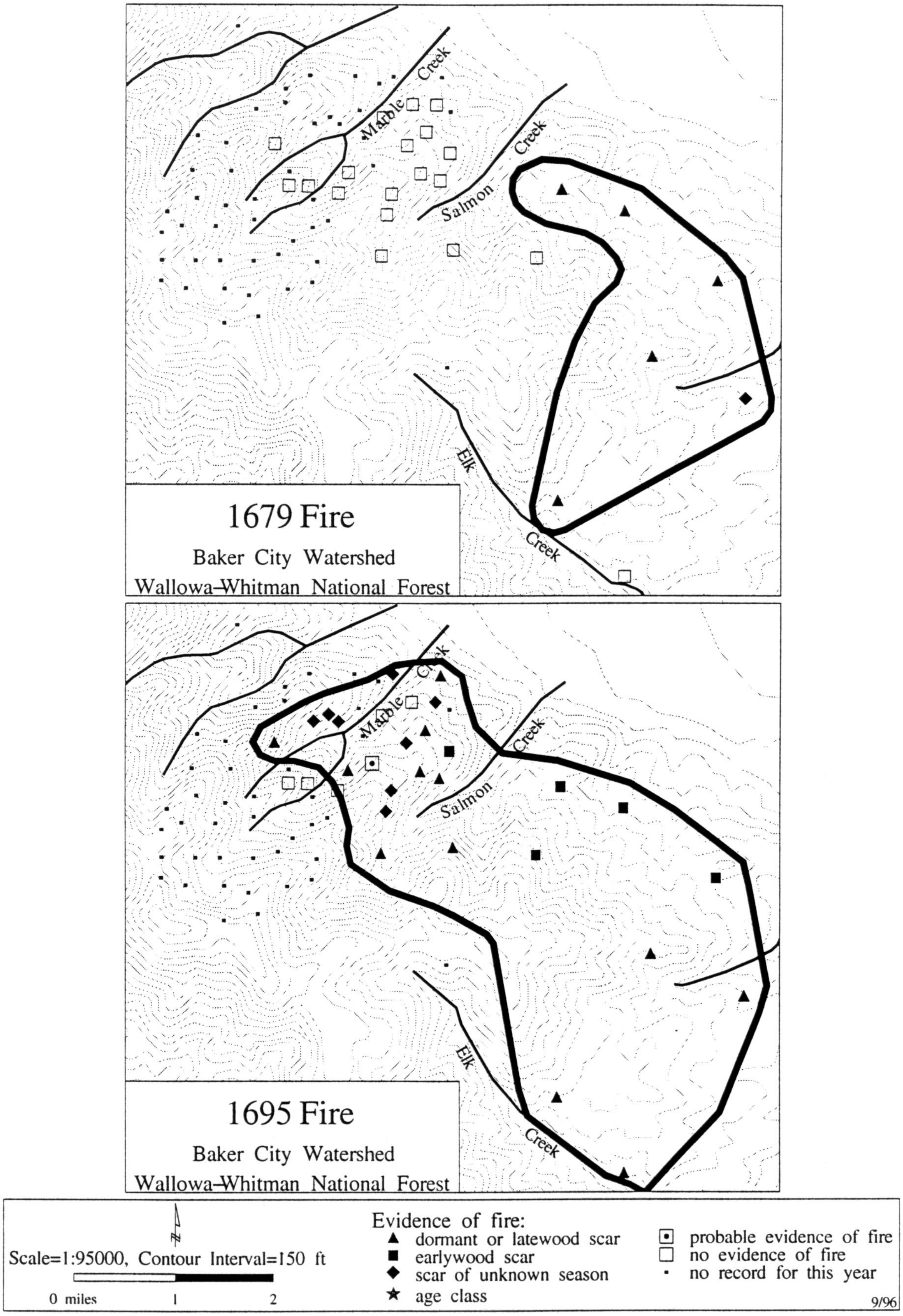


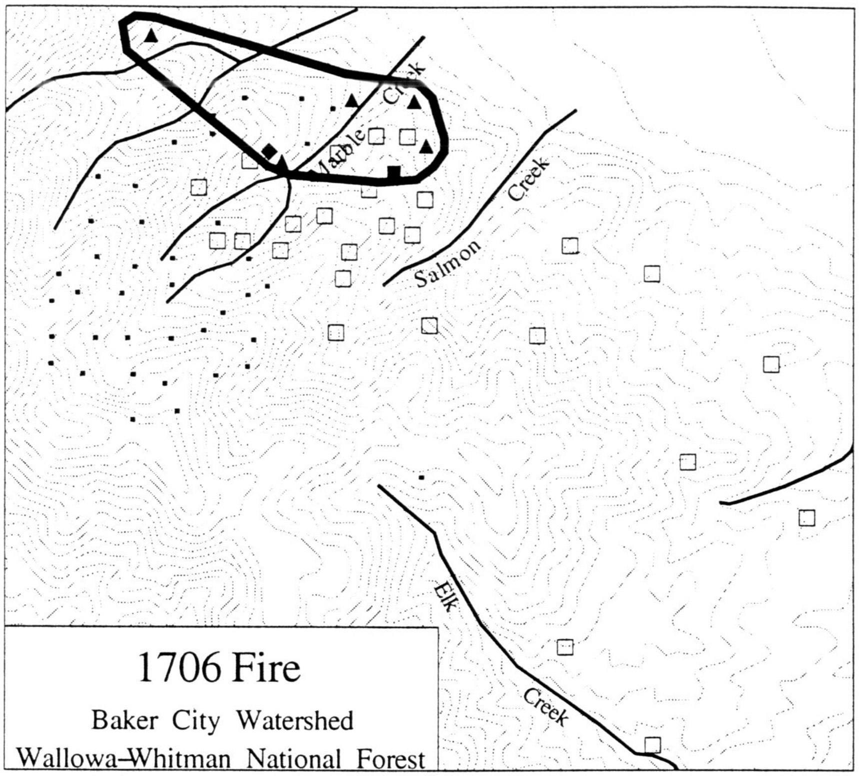
Scale=1:95000, Contour Interval=150 ft

0 miles 1 2

Evidence of fire:
- ▲ dormant or latewood scar
- ■ earlywood scar
- ◆ scar of unknown season
- ★ age class
- ⊡ probable evidence of fire
- □ no evidence of fire
- · no record for this year

9/96

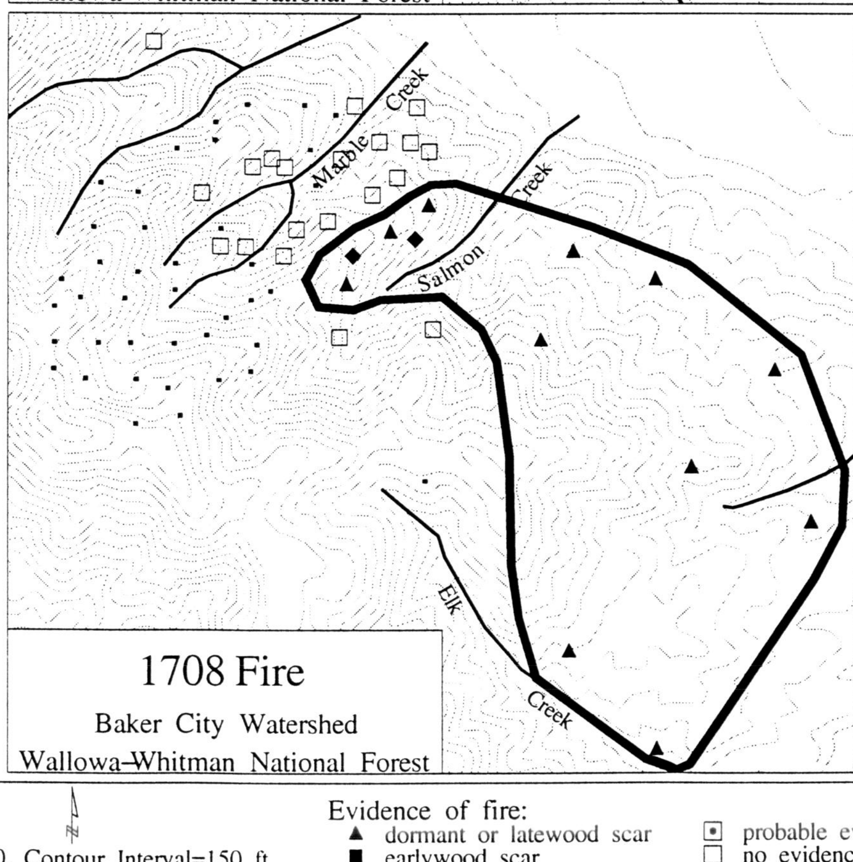

Marble Creek
Salmon Creek
Elk Creek
1679 Fire
Baker City Watershed
Wallowa-Whitman National Forest
Marble Creek
Salmon Creek
Elk Creek
1695 Fire
Baker City Watershed
Wallowa-Whitman National Forest
Scale=1:95000, Contour Interval=150 ft
0 miles
1
2
Evidence of fire:
dormant or latewood scar
earlywood scar
scar of unknown season
age class
probable evidence of fire
no evidence of fire
no record for this year
9/96



1706 Fire

Baker City Watershed

Wallowa-Whitman National Forest



1708 Fire

Baker City Watershed

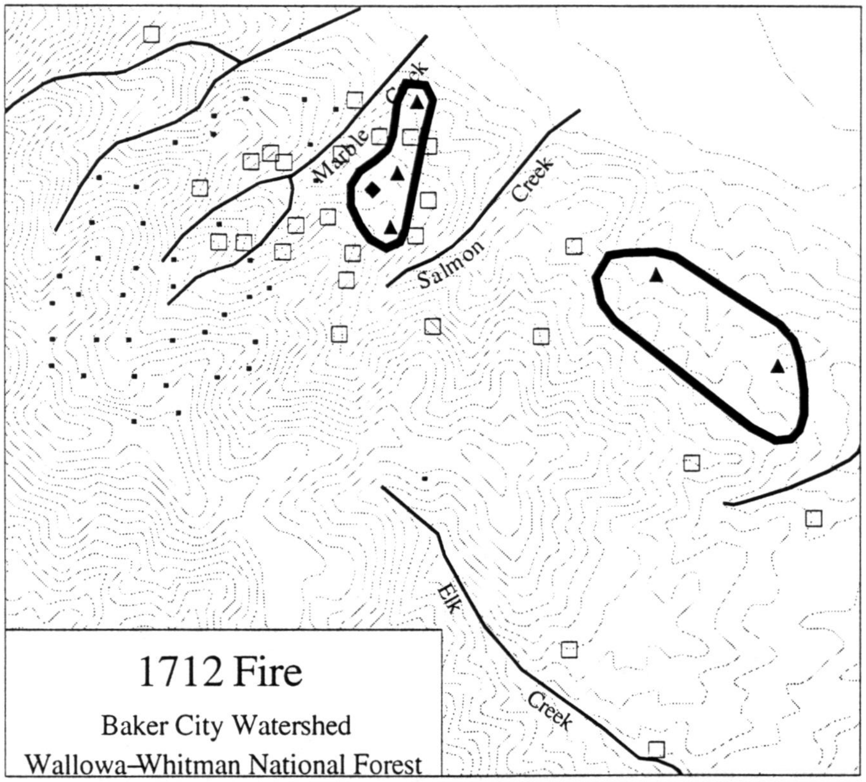
Wallowa-Whitman National Forest

Scale=1:95000, Contour Interval=150 ft

0 miles 1 2

Evidence of fire:
- ▲ dormant or latewood scar
- ■ earlywood scar
- ◆ scar of unknown season
- ★ age class
- ⊡ probable evidence of fire
- □ no evidence of fire
- · no record for this year

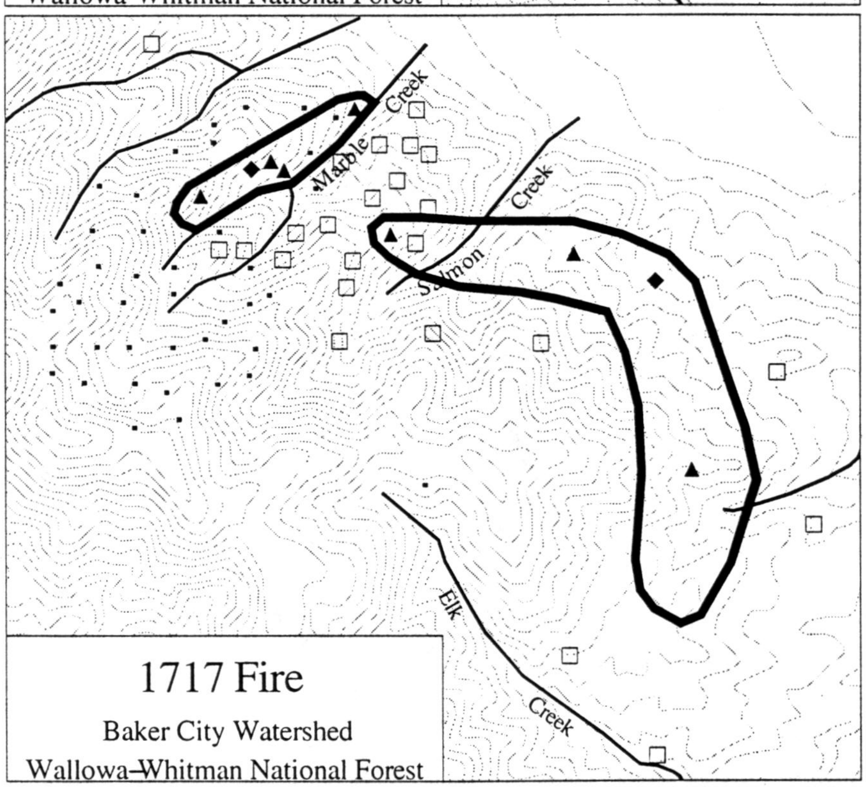
9/96



1712 Fire

Baker City Watershed

Wallowa-Whitman National Forest



1717 Fire

Baker City Watershed

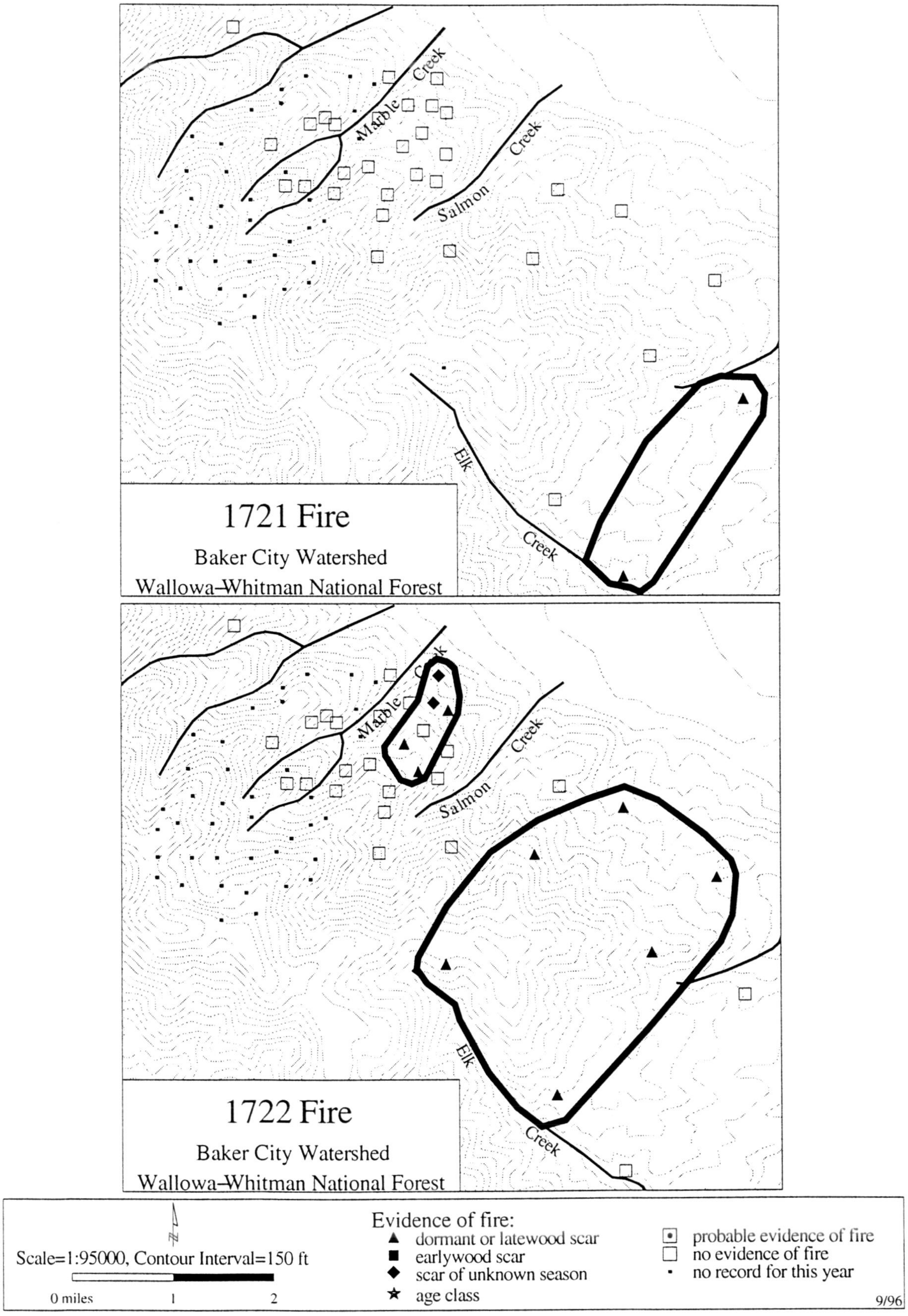
Wallowa-Whitman National Forest

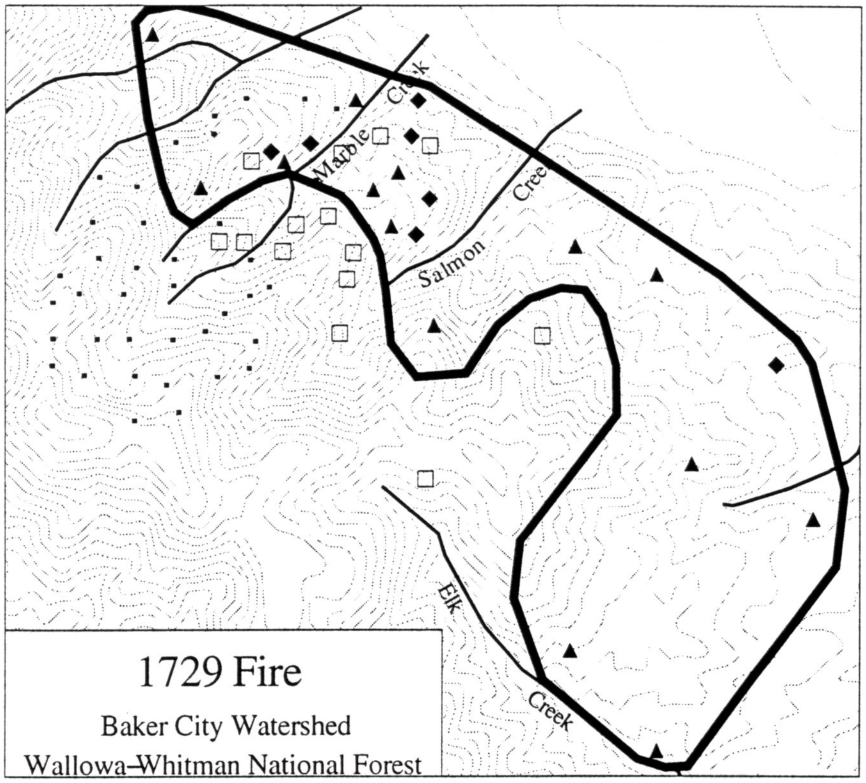
Scale=1:95000, Contour Interval=150 ft

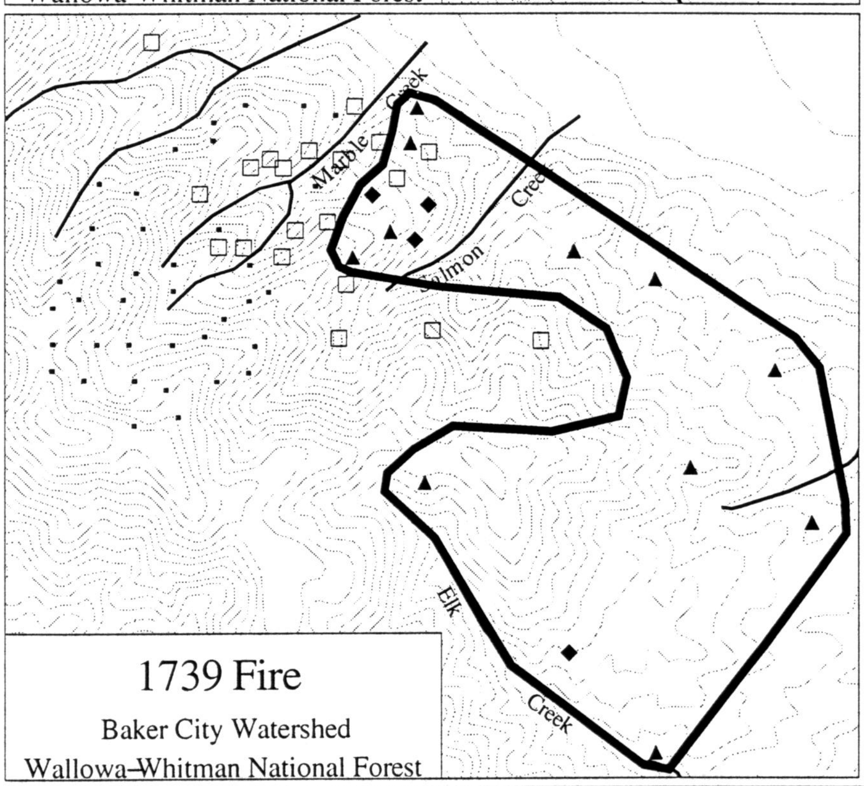
0 miles 1 2

Evidence of fire:
- ▲ dormant or latewood scar
- ■ earlywood scar
- ◆ scar of unknown season
- ★ age class
- ⊡ probable evidence of fire
- □ no evidence of fire
- · no record for this year

9/96


1721 Fire
Baker City Watershed
Wallowa-Whitman National Forest
Marble Creek
Salmon Creek
Elk Creek
1722 Fire
Baker City Watershed
Wallowa-Whitman National Forest
Marble Creek
Salmon Creek
Elk Creek
Scale=1:95000, Contour Interval=150 ft
0 miles
1
2
Evidence of fire:
dormant or latewood scar
earlywood scar
scar of unknown season
age class
probable evidence of fire
no evidence of fire
no record for this year
9/96





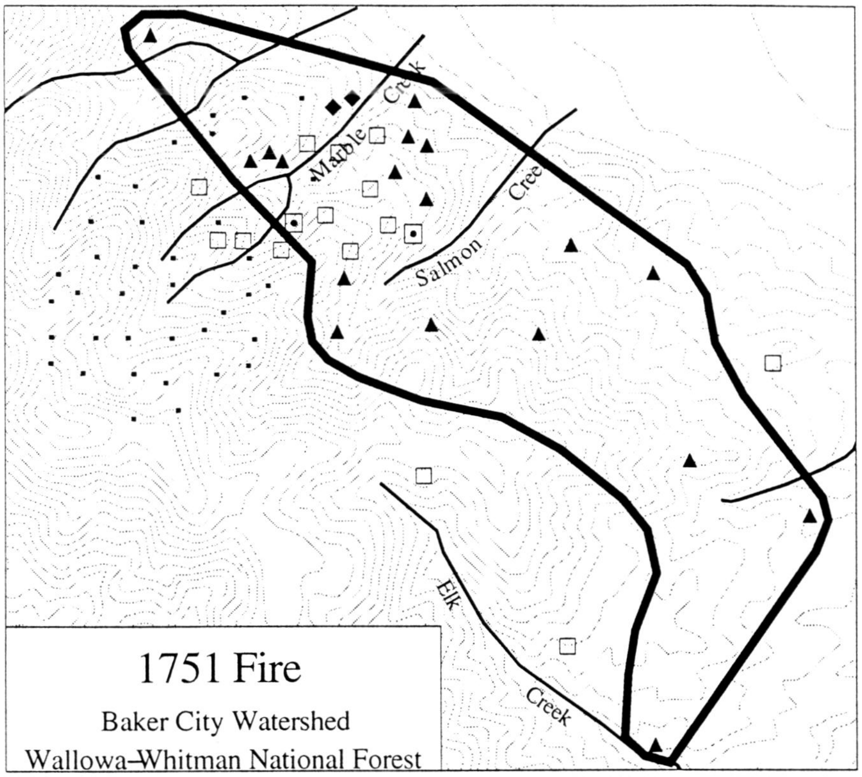
N

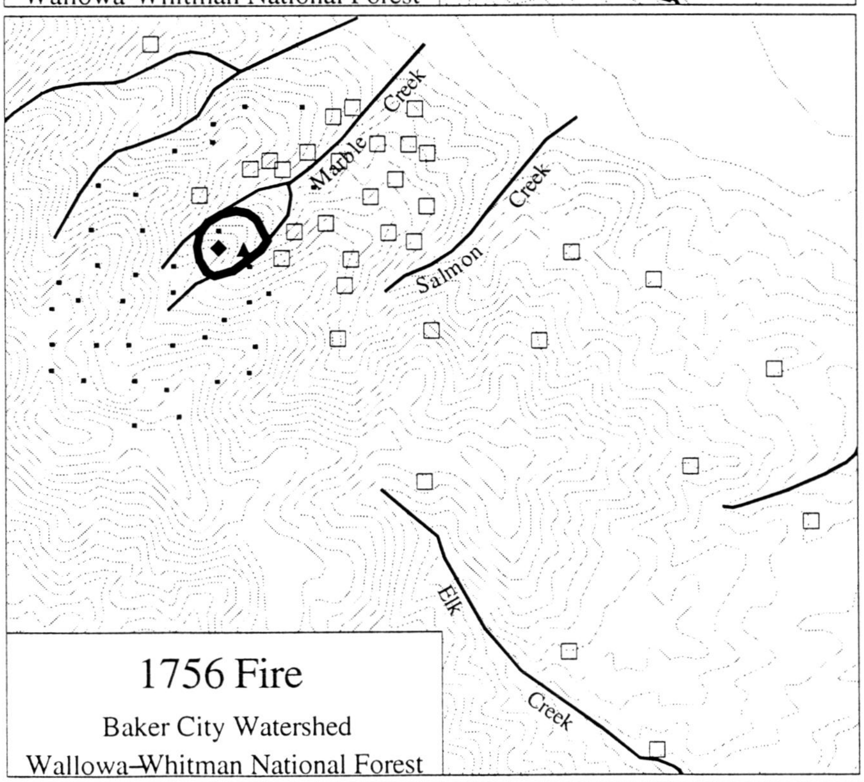
Scale=1:95000, Contour Interval=150 ft

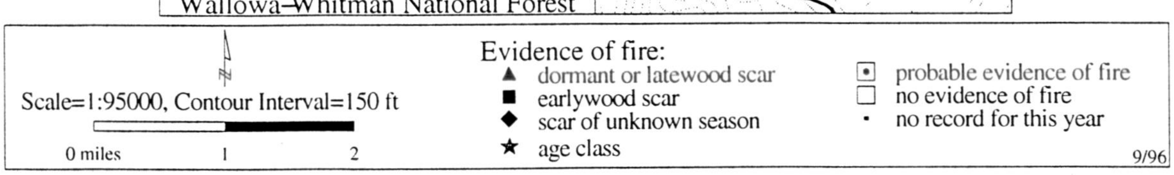
0 miles 1 2

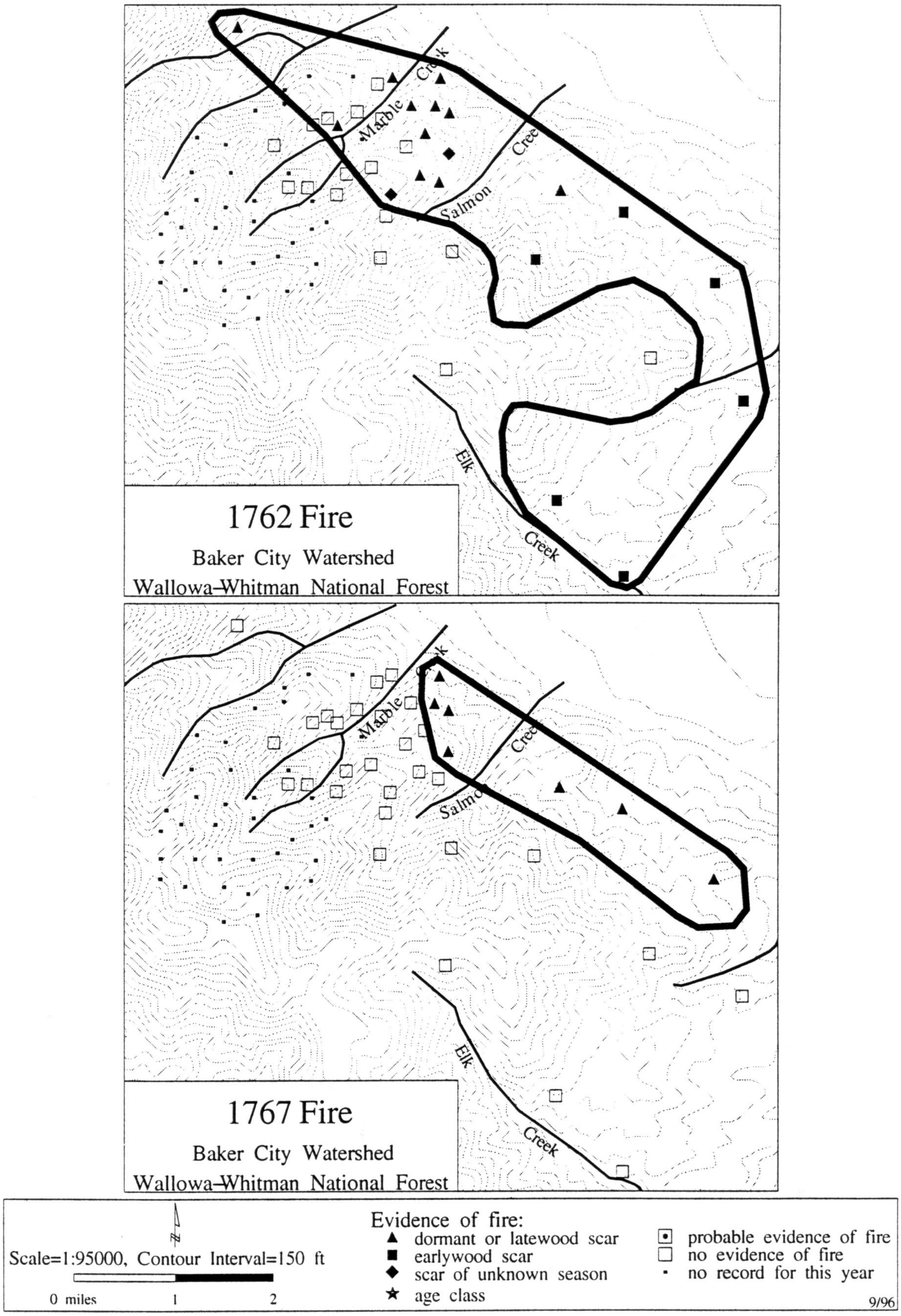
Evidence of fire:
- ▲ dormant or latewood scar
- ■ earlywood scar
- ◆ scar of unknown season
- ★ age class
- ⊡ probable evidence of fire
- □ no evidence of fire
- · no record for this year

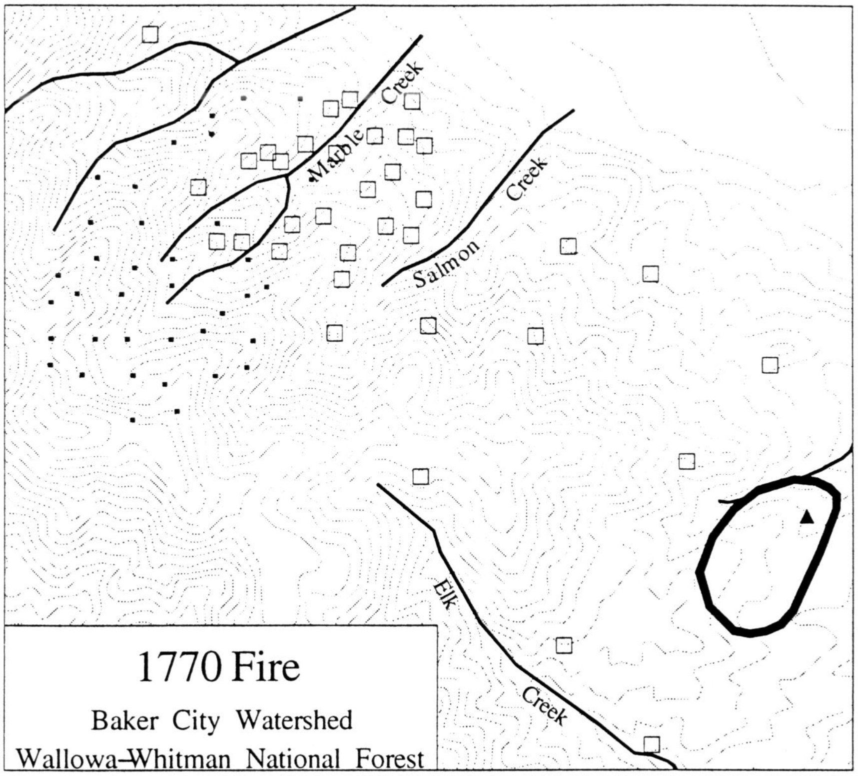
9/96

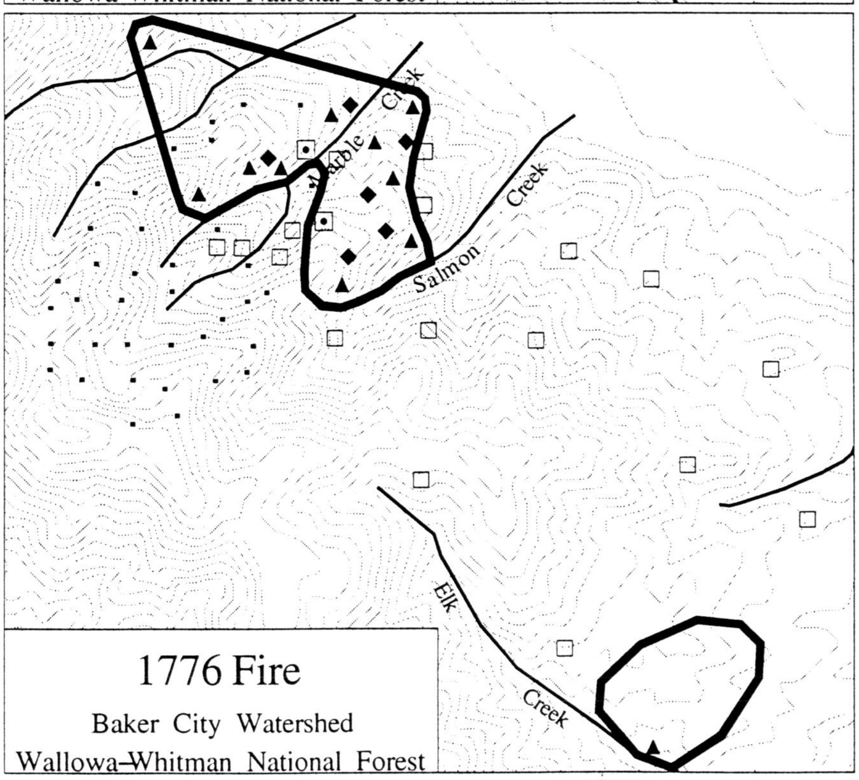

Marble Creek
Salmon Creek
Elk Creek
1751 Fire
Baker City Watershed
Wallowa-Whitman National Forest


Marble Creek
Salmon Creek
Elk Creek
1756 Fire
Baker City Watershed
Wallowa-Whitman National Forest


Scale=1:95000, Contour Interval=150 ft
0 miles
1
2
Evidence of fire:
dormant or latewood scar
earlywood scar
scar of unknown season
age class
probable evidence of fire
no evidence of fire
no record for this year
9/96


Marble Creek
Salmon Creek
Elk Creek
1762 Fire
Baker City Watershed
Wallowa-Whitman National Forest
1767 Fire
Baker City Watershed
Wallowa-Whitman National Forest
Scale=1:95000, Contour Interval=150 ft
0 miles
1
2
Evidence of fire:
dormant or latewood scar
earlywood scar
scar of unknown season
age class
probable evidence of fire
no evidence of fire
no record for this year
9/96



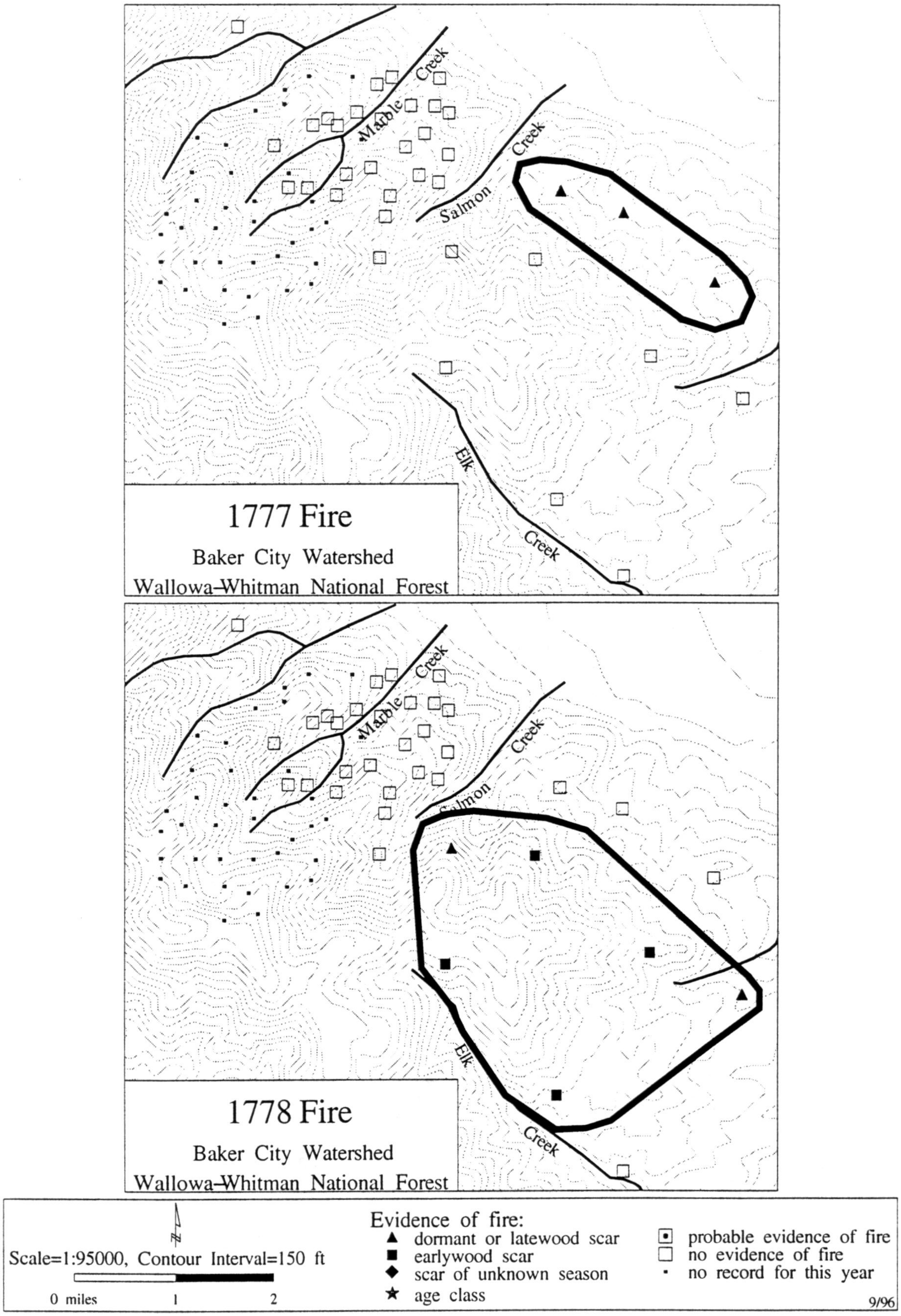


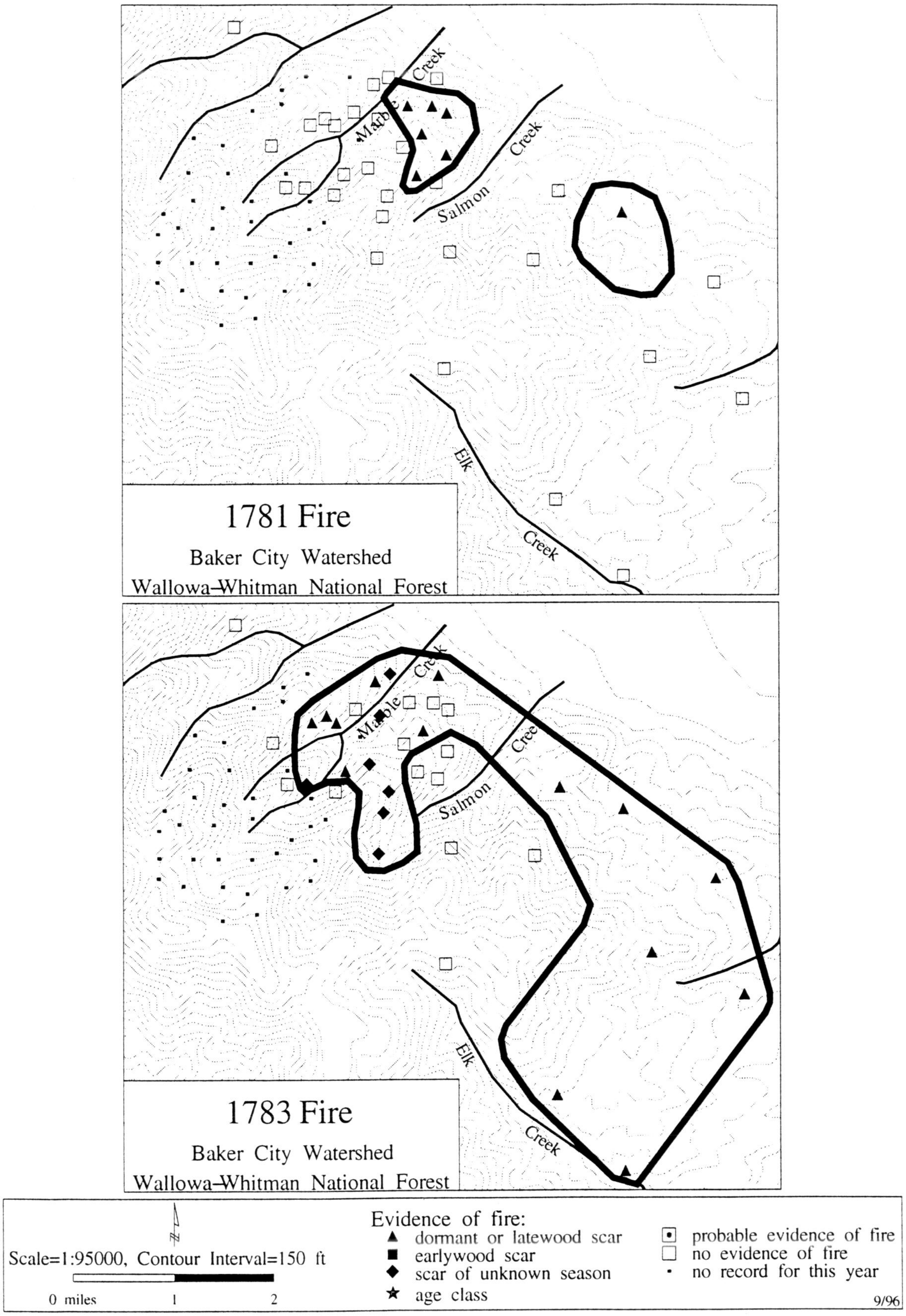
Scale=1:95000, Contour Interval=150 ft

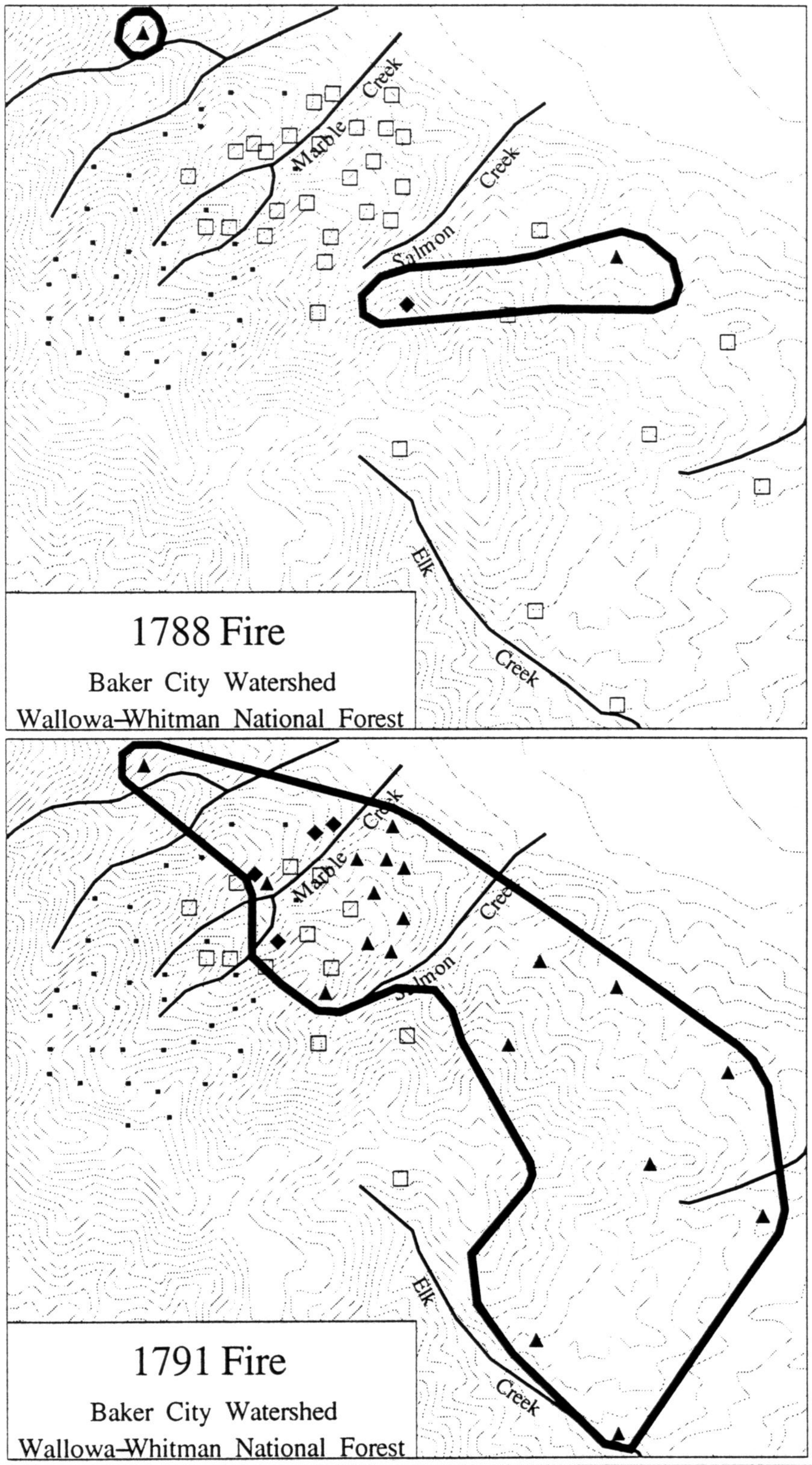
0 miles 1 2

Evidence of fire:
- ▲ dormant or latewood scar
- ■ earlywood scar
- ◆ scar of unknown season
- ★ age class
- ⊡ probable evidence of fire
- □ no evidence of fire
- · no record for this year

9/96


Marble Creek
Salmon Creek
Elk Creek
1777 Fire
Baker City Watershed
Wallowa-Whitman National Forest
Marble Creek
Salmon Creek
Elk Creek
1778 Fire
Baker City Watershed
Wallowa-Whitman National Forest
Scale=1:95000, Contour Interval=150 ft
0 miles
1
2
Evidence of fire:
dormant or latewood scar
earlywood scar
scar of unknown season
age class
probable evidence of fire
no evidence of fire
no record for this year
9/96


Marble Creek
Salmon Creek
Elk Creek
1781 Fire
Baker City Watershed
Wallowa-Whitman National Forest
Marble Creek
Salmon Creek
Elk Creek
1783 Fire
Baker City Watershed
Wallowa-Whitman National Forest
N
Scale=1:95000, Contour Interval=150 ft
0 miles
1
2
Evidence of fire:
dormant or latewood scar
earlywood scar
scar of unknown season
age class
probable evidence of fire
no evidence of fire
no record for this year
9/96

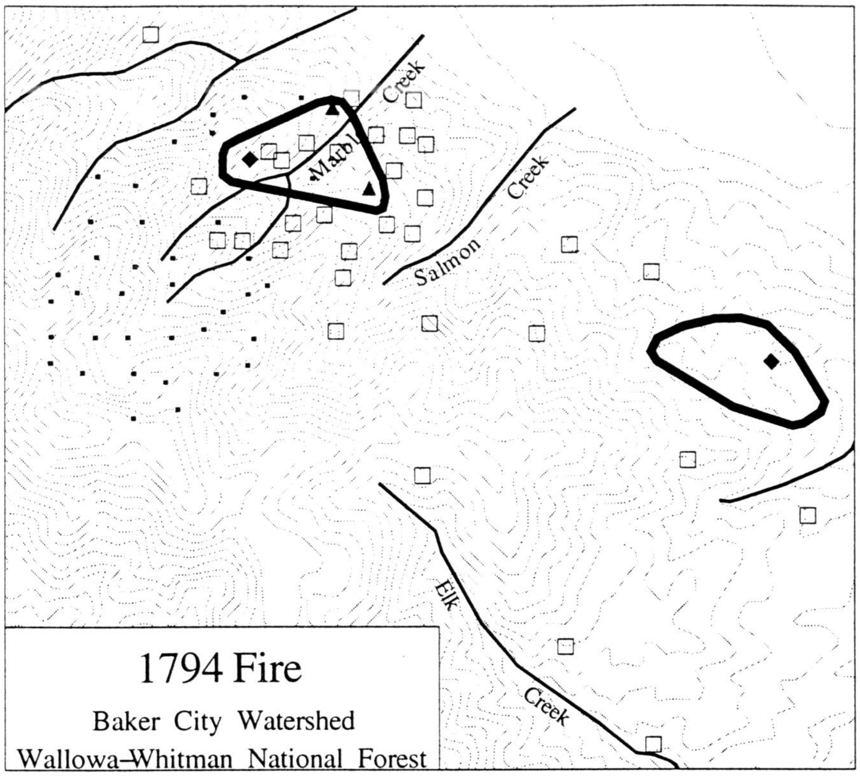


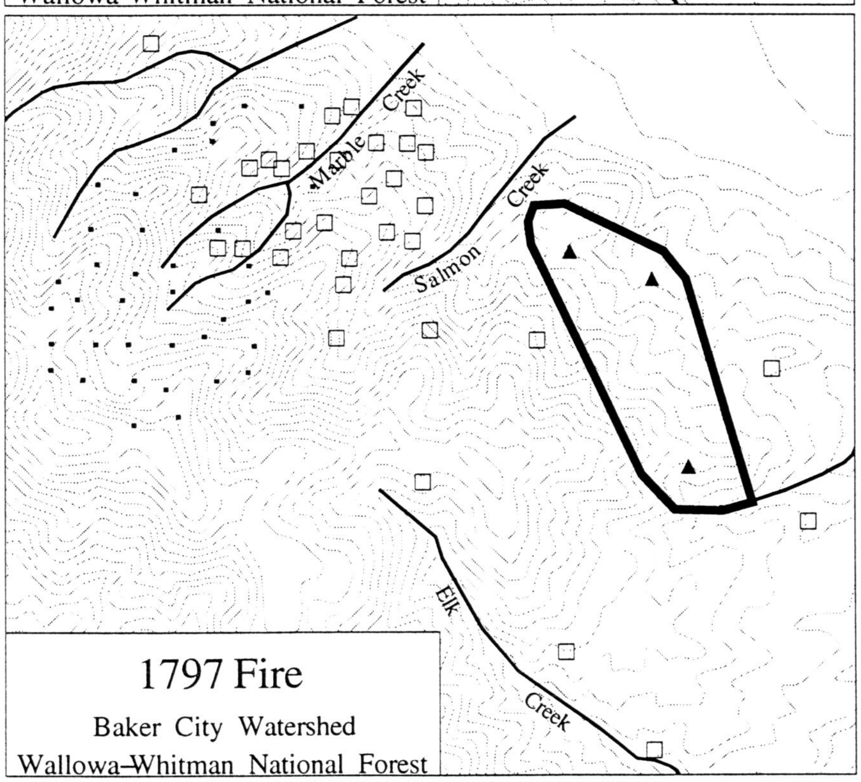
Scale=1:95000, Contour Interval=150 ft

0 miles 1 2

Evidence of fire:
- ▲ dormant or latewood scar
- ■ earlywood scar
- ◆ scar of unknown season
- ★ age class
- ⊡ probable evidence of fire
- □ no evidence of fire
- · no record for this year

9/96



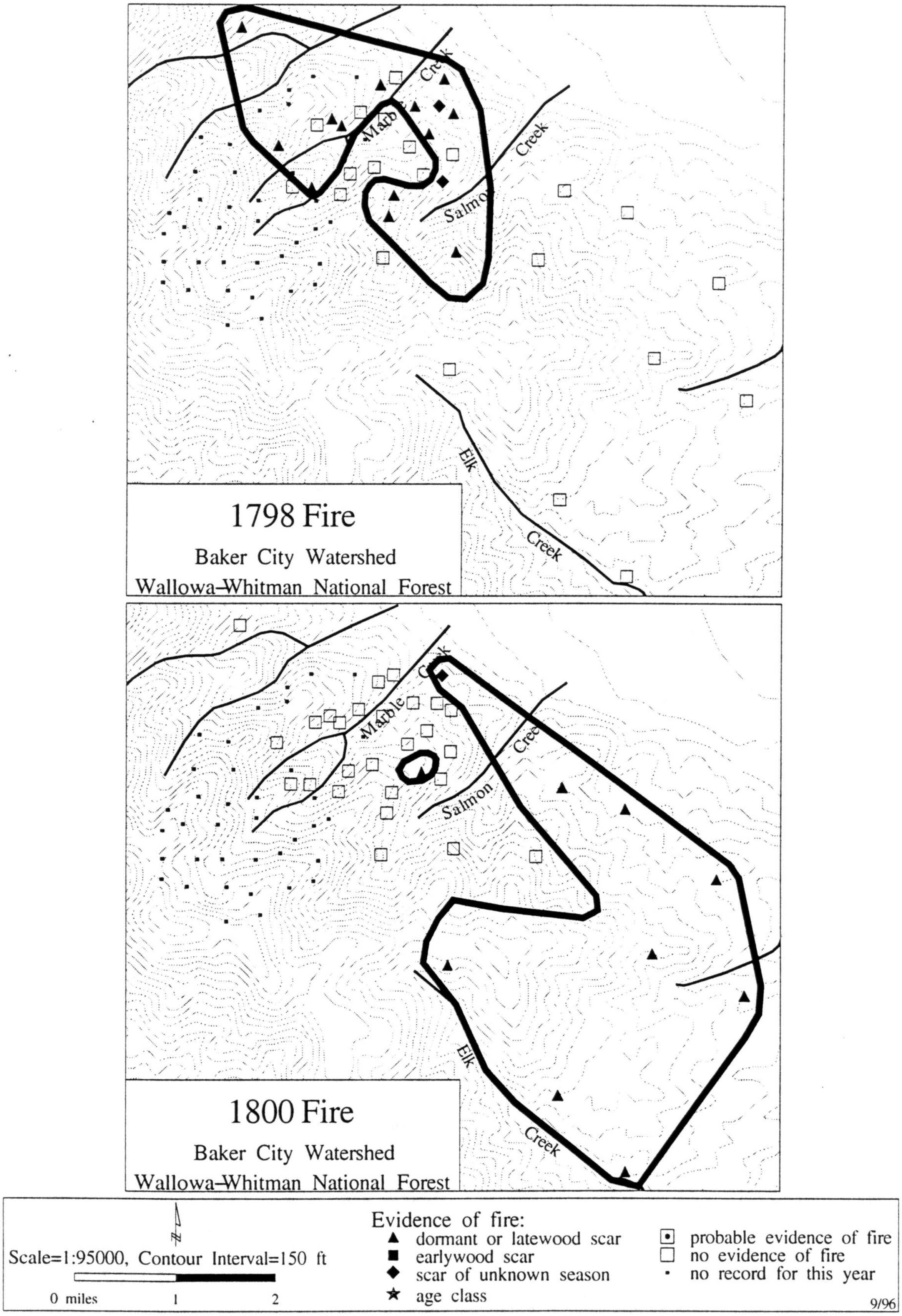


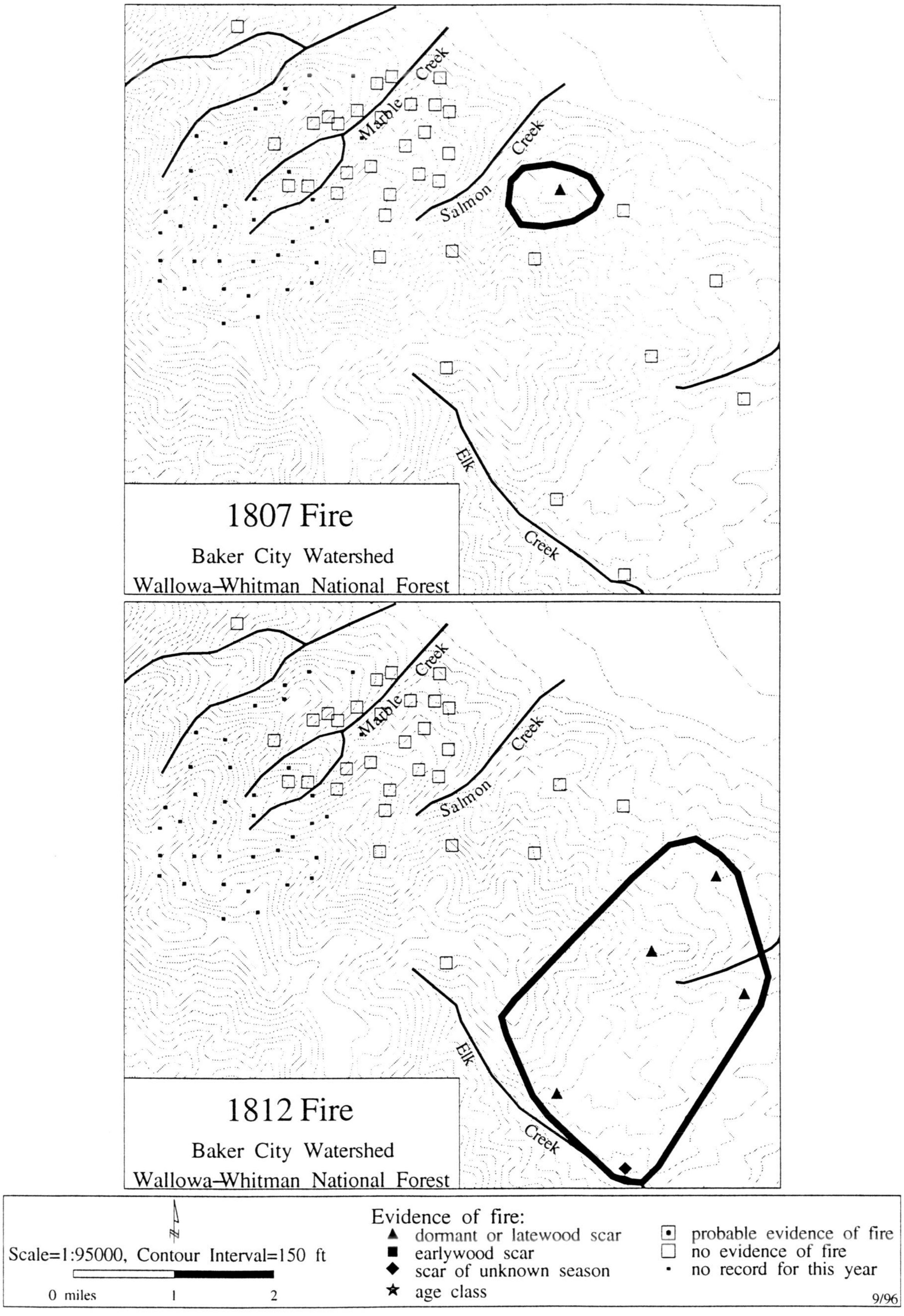
Scale=1:95000, Contour Interval=150 ft

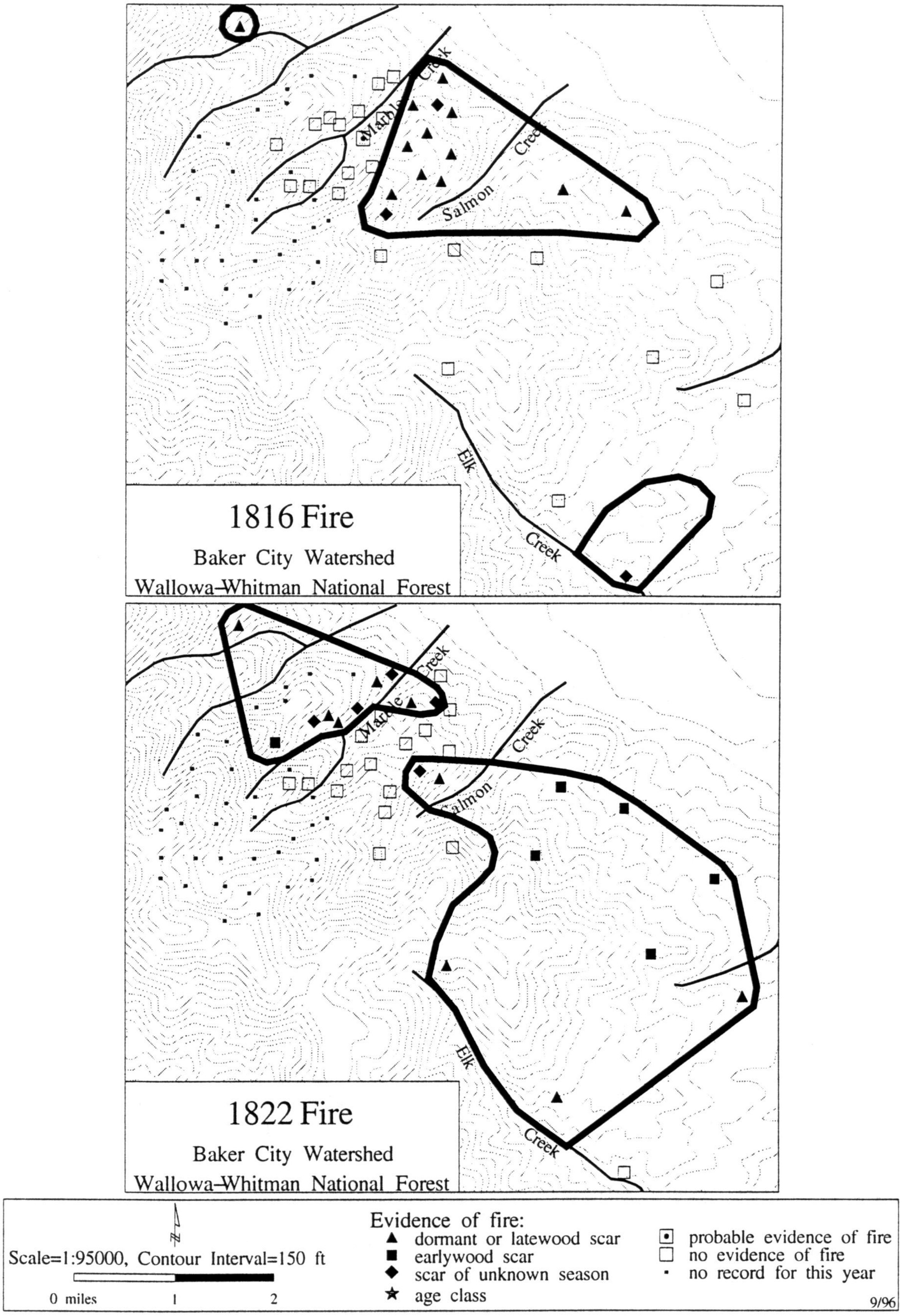
0 miles 1 2

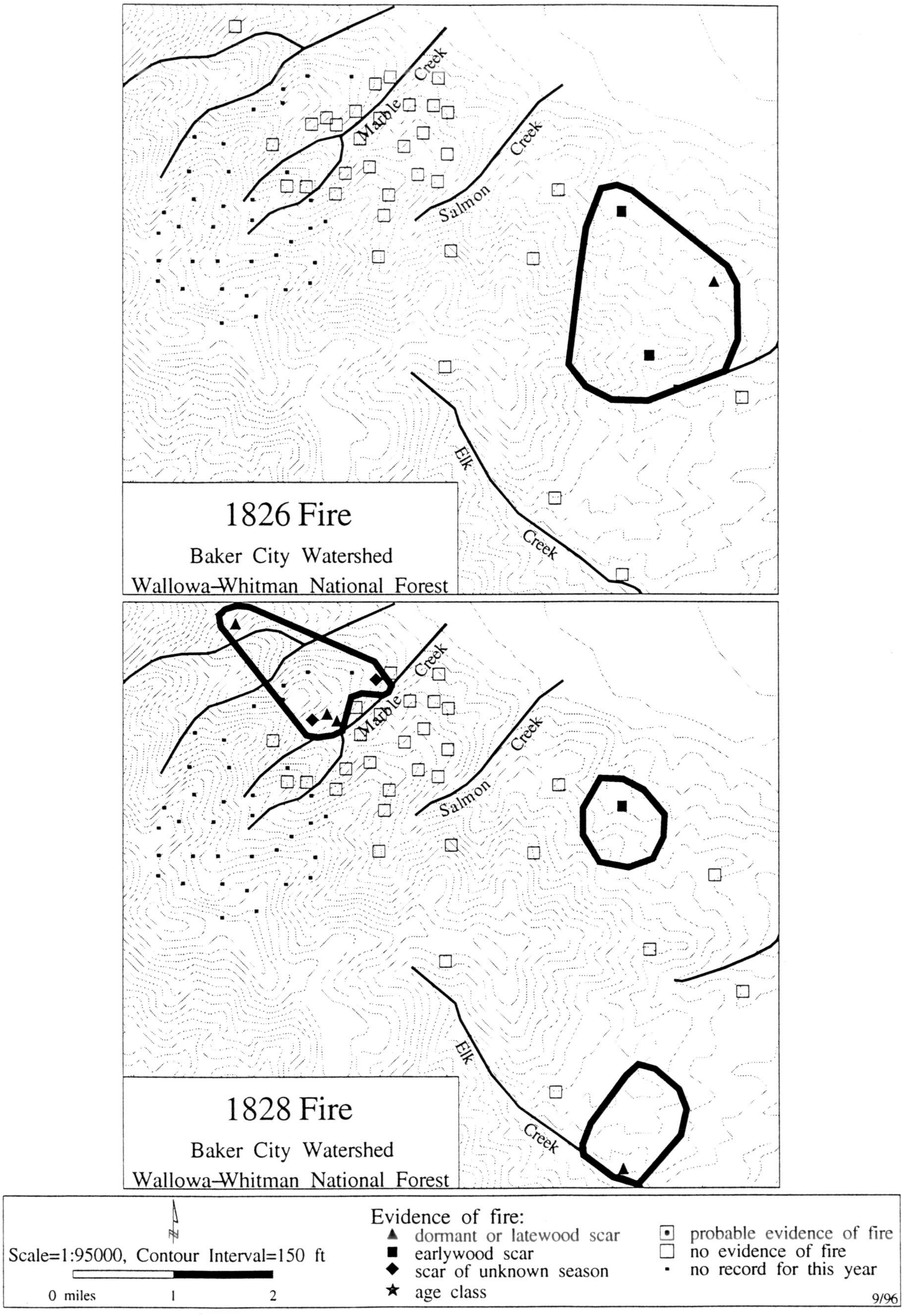
Evidence of fire:
- ▲ dormant or latewood scar
- ■ earlywood scar
- ◆ scar of unknown season
- ★ age class
- ⊡ probable evidence of fire
- □ no evidence of fire
- ▪ no record for this year

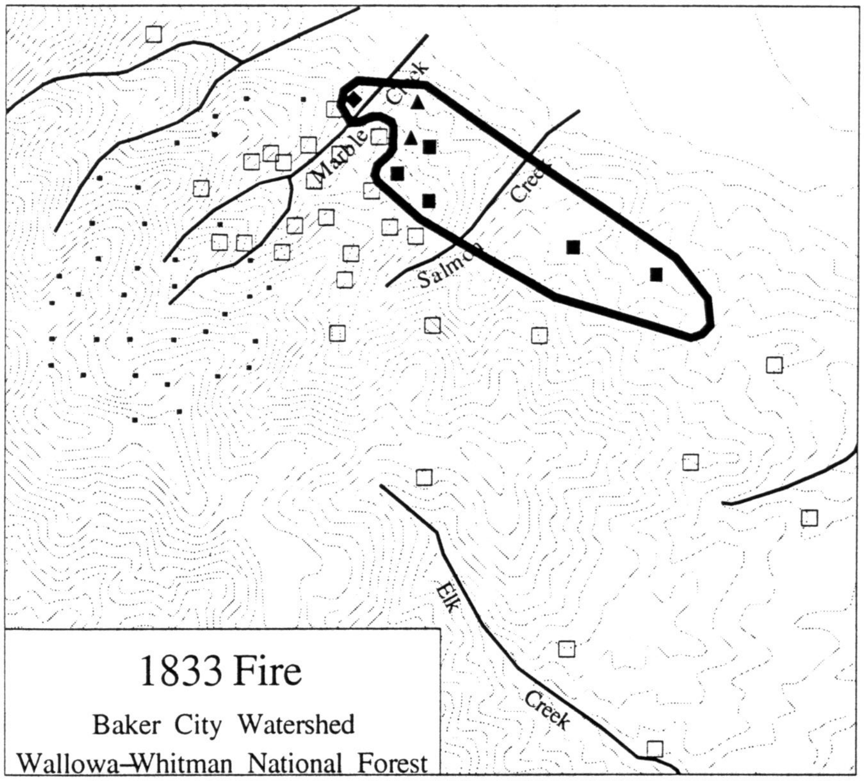
9/96


Marble Creek
Salmon Creek
Elk Creek
1798 Fire
Baker City Watershed
Wallowa-Whitman National Forest
1800 Fire
Baker City Watershed
Wallowa-Whitman National Forest
Scale=1:95000, Contour Interval=150 ft
0 miles
1
2
Evidence of fire:
dormant or latewood scar
earlywood scar
scar of unknown season
age class
probable evidence of fire
no evidence of fire
no record for this year
9/96


1807 Fire
Baker City Watershed
Wallowa-Whitman National Forest
Marble Creek
Salmon Creek
Elk Creek
1812 Fire
Baker City Watershed
Wallowa-Whitman National Forest
Marble Creek
Salmon Creek
Elk Creek
Scale=1:95000, Contour Interval=150 ft
0 miles 1 2
Evidence of fire:
▲ dormant or latewood scar
■ earlywood scar
◆ scar of unknown season
★ age class
probable evidence of fire
no evidence of fire
no record for this year
9/96


Marble Creek
Salmon Creek
Elk Creek
1816 Fire
Baker City Watershed
Wallowa-Whitman National Forest
Marble Creek
Salmon Creek
Elk Creek
1822 Fire
Baker City Watershed
Wallowa-Whitman National Forest
Scale=1:95000, Contour Interval=150 ft
0 miles
1
2
Evidence of fire:
dormant or latewood scar
earlywood scar
scar of unknown season
age class
probable evidence of fire
no evidence of fire
no record for this year
9/96

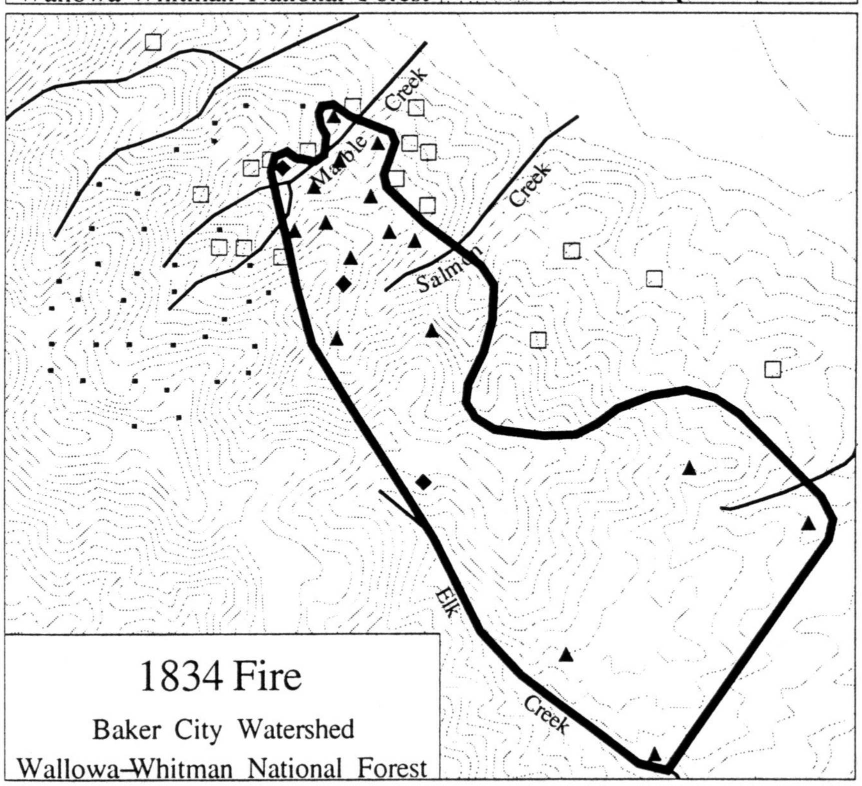

Marble Creek
Salmon Creek
Elk Creek
1826 Fire
Baker City Watershed
Wallowa-Whitman National Forest
Marble Creek
Salmon Creek
Elk Creek
1828 Fire
Baker City Watershed
Wallowa-Whitman National Forest
N
Scale=1:95000, Contour Interval=150 ft
0 miles 1 2
Evidence of fire:
dormant or latewood scar
earlywood scar
scar of unknown season
age class
probable evidence of fire
no evidence of fire
no record for this year
9/96



1833 Fire

Baker City Watershed

Wallowa-Whitman National Forest



1834 Fire

Baker City Watershed

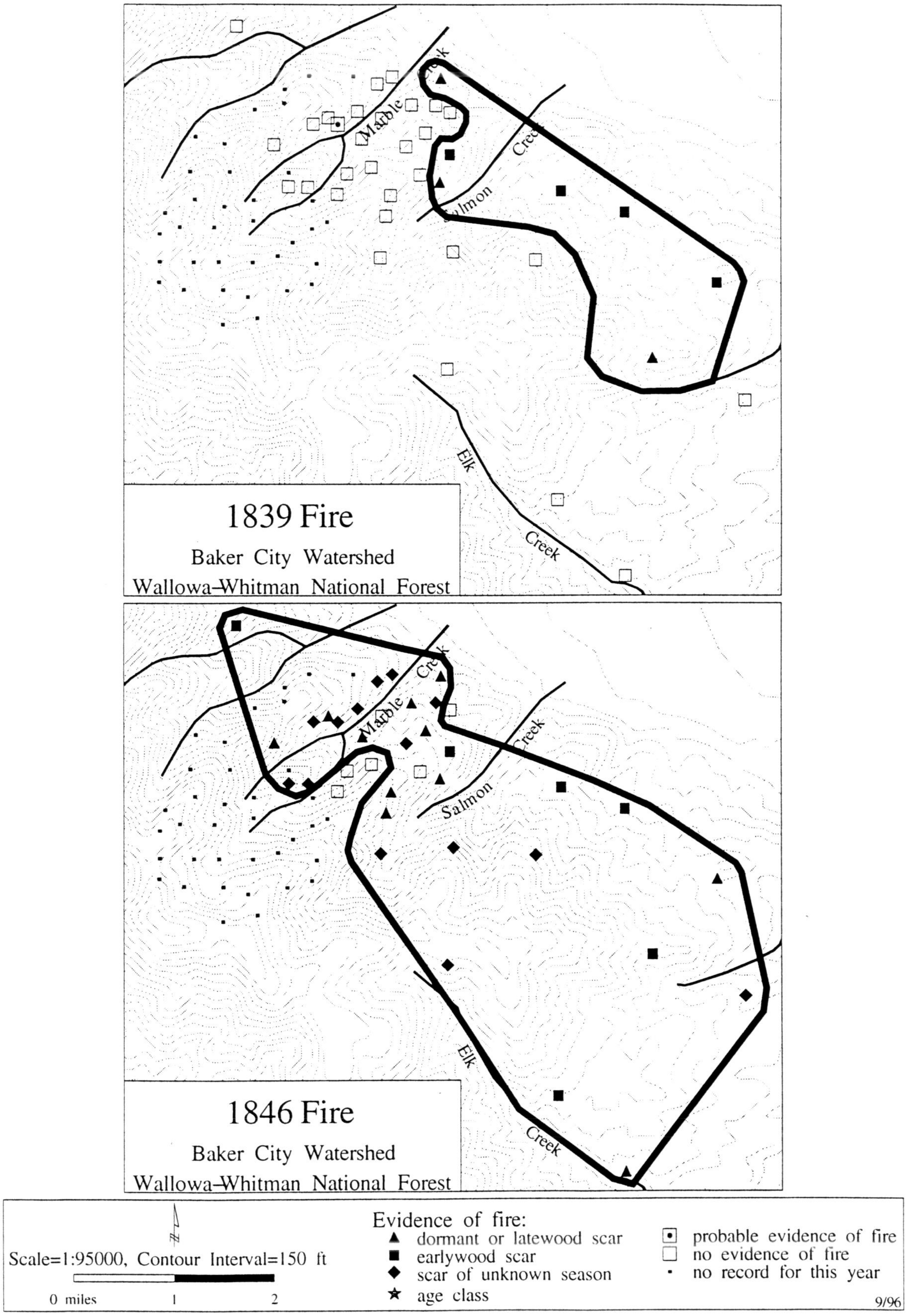
Wallowa-Whitman National Forest

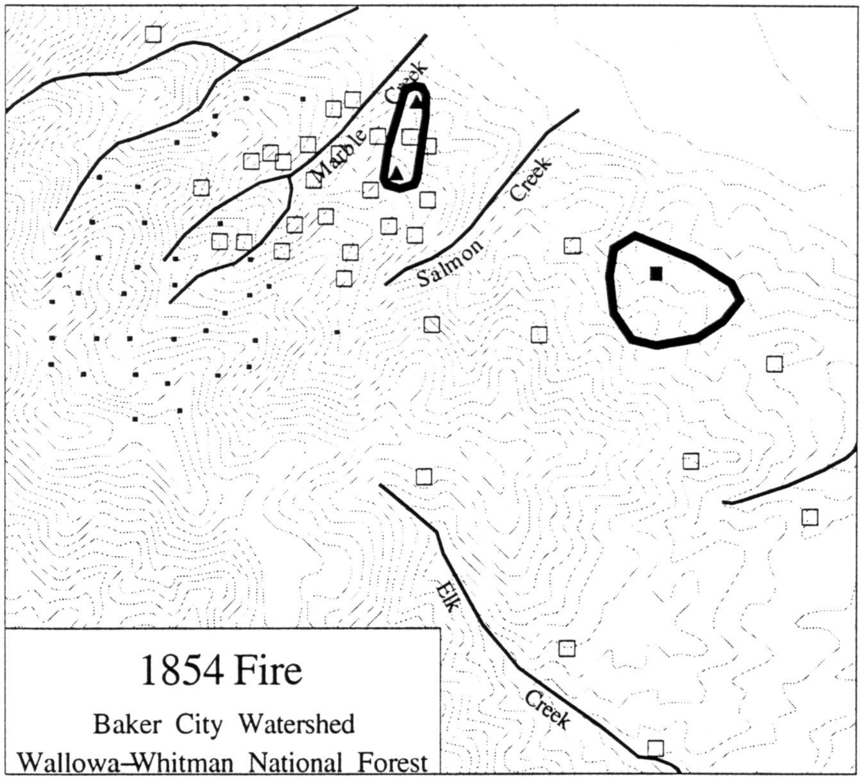
Scale=1:95000, Contour Interval=150 ft

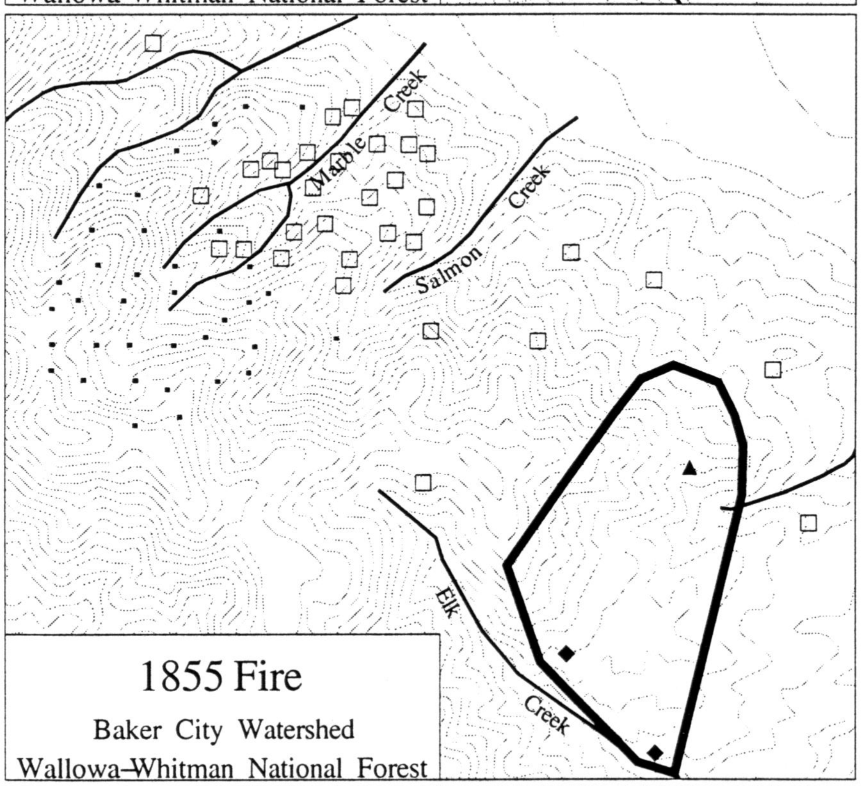
0 miles 1 2

Evidence of fire:
- ▲ dormant or latewood scar
- ■ earlywood scar
- ◆ scar of unknown season
- ★ age class
- ⊡ probable evidence of fire
- □ no evidence of fire
- · no record for this year

9/96


Marble
Creek
Salmon
Creek
Elk
Creek
1839 Fire
Baker City Watershed
Wallowa-Whitman National Forest
Marble
Creek
Salmon
Creek
Elk
Creek
1846 Fire
Baker City Watershed
Wallowa-Whitman National Forest
Scale=1:95000, Contour Interval=150 ft
0 miles
1
2
Evidence of fire:
dormant or latewood scar
earlywood scar
scar of unknown season
age class
probable evidence of fire
no evidence of fire
no record for this year
9/96



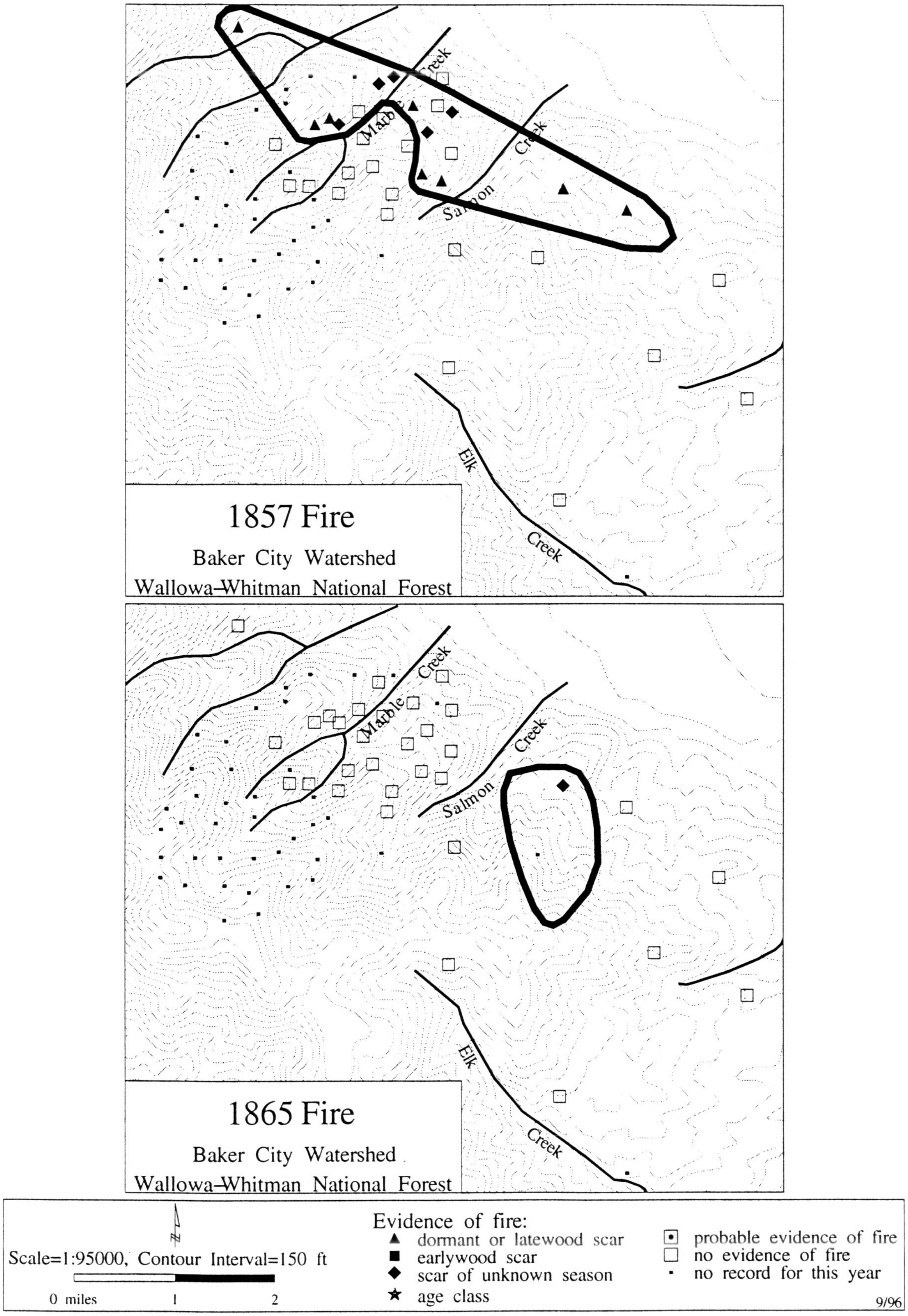


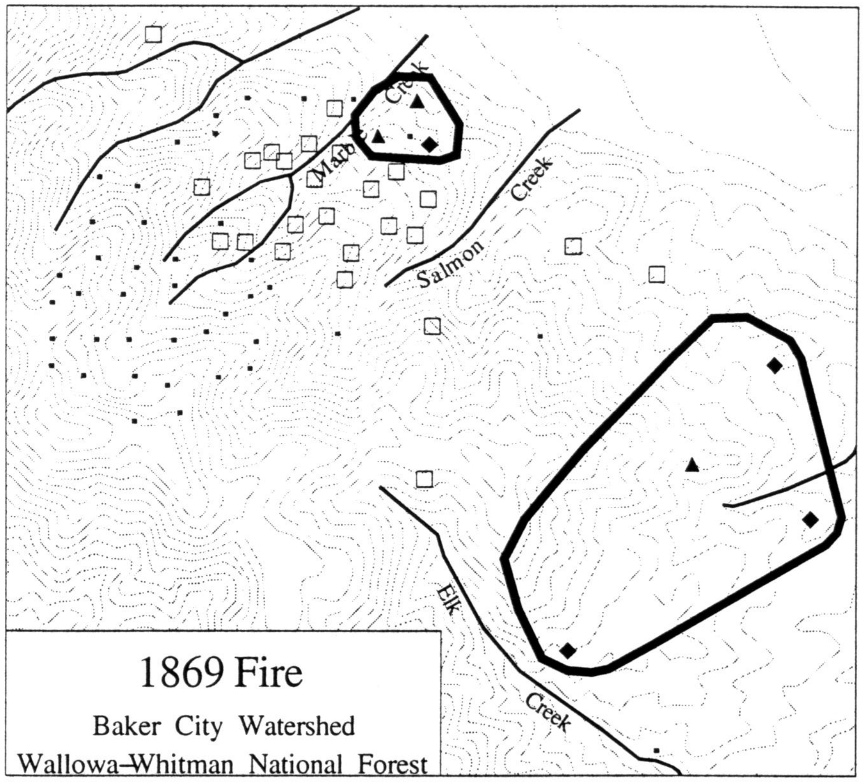
Scale=1:95000, Contour Interval=150 ft

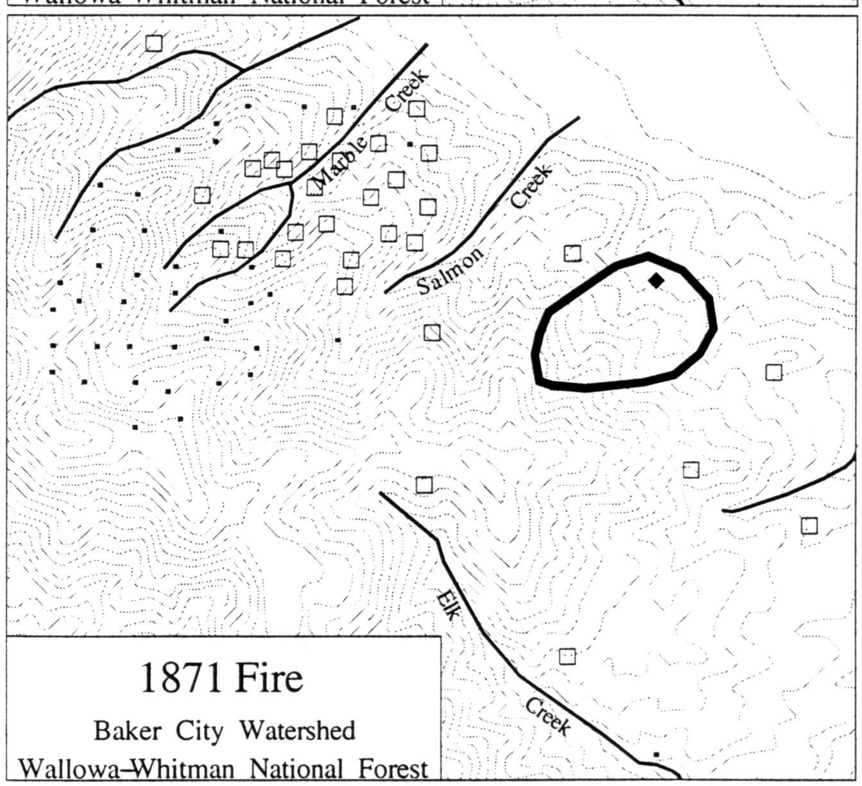
0 miles 1 2

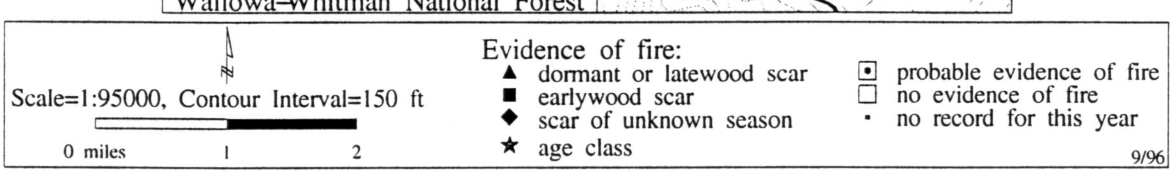
Evidence of fire:
- ▲ dormant or latewood scar
- ■ earlywood scar
- ◆ scar of unknown season
- ★ age class
- ⊡ probable evidence of fire
- □ no evidence of fire
- · no record for this year

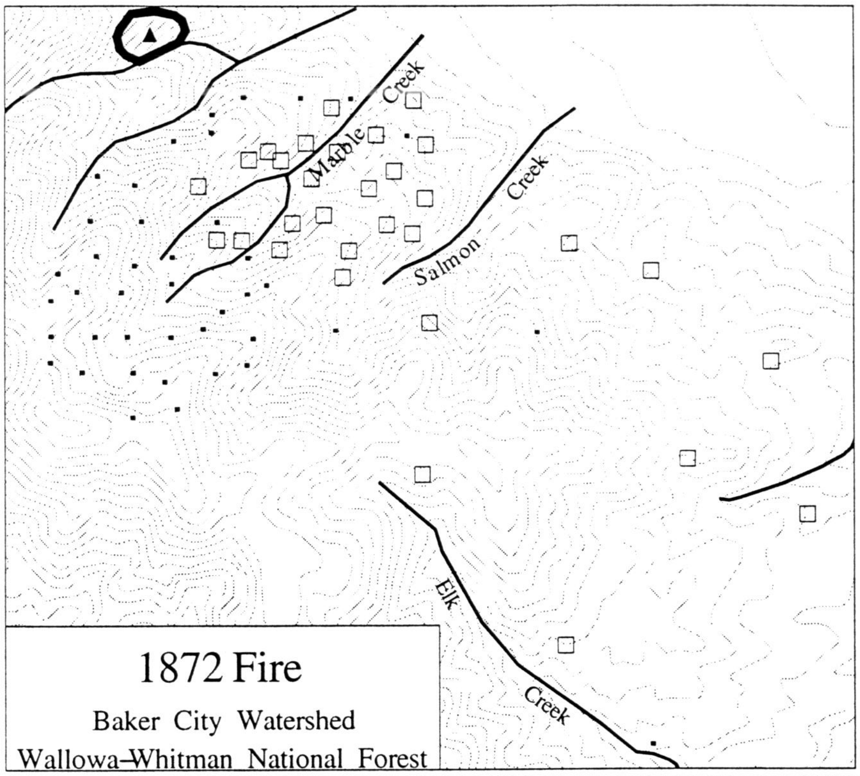
9/96

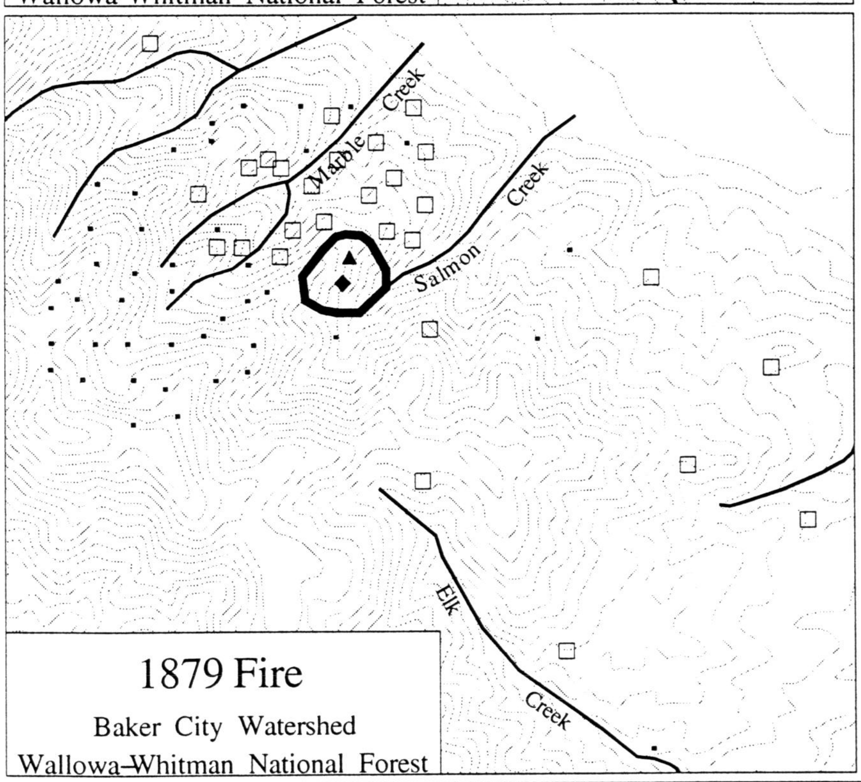

Marble Creek
Salmon Creek
Elk Creek
1857 Fire
Baker City Watershed
Wallowa-Whitman National Forest
1865 Fire
Baker City Watershed
Wallowa-Whitman National Forest
Scale=1:95000, Contour Interval=150 ft
0 miles
1
2
Evidence of fire:
dormant or latewood scar
earlywood scar
scar of unknown season
age class
probable evidence of fire
no evidence of fire
no record for this year
9/96


Marble Creek
Salmon Creek
Elk Creek
1869 Fire
Baker City Watershed
Wallowa-Whitman National Forest


Marble Creek
Salmon Creek
Elk Creek
1871 Fire
Baker City Watershed
Wallowa-Whitman National Forest


N
Scale=1:95000, Contour Interval=150 ft
0 miles
1
2
Evidence of fire:
▲ dormant or latewood scar
■ earlywood scar
◆ scar of unknown season
★ age class
⊡ probable evidence of fire
□ no evidence of fire
▪ no record for this year
9/96



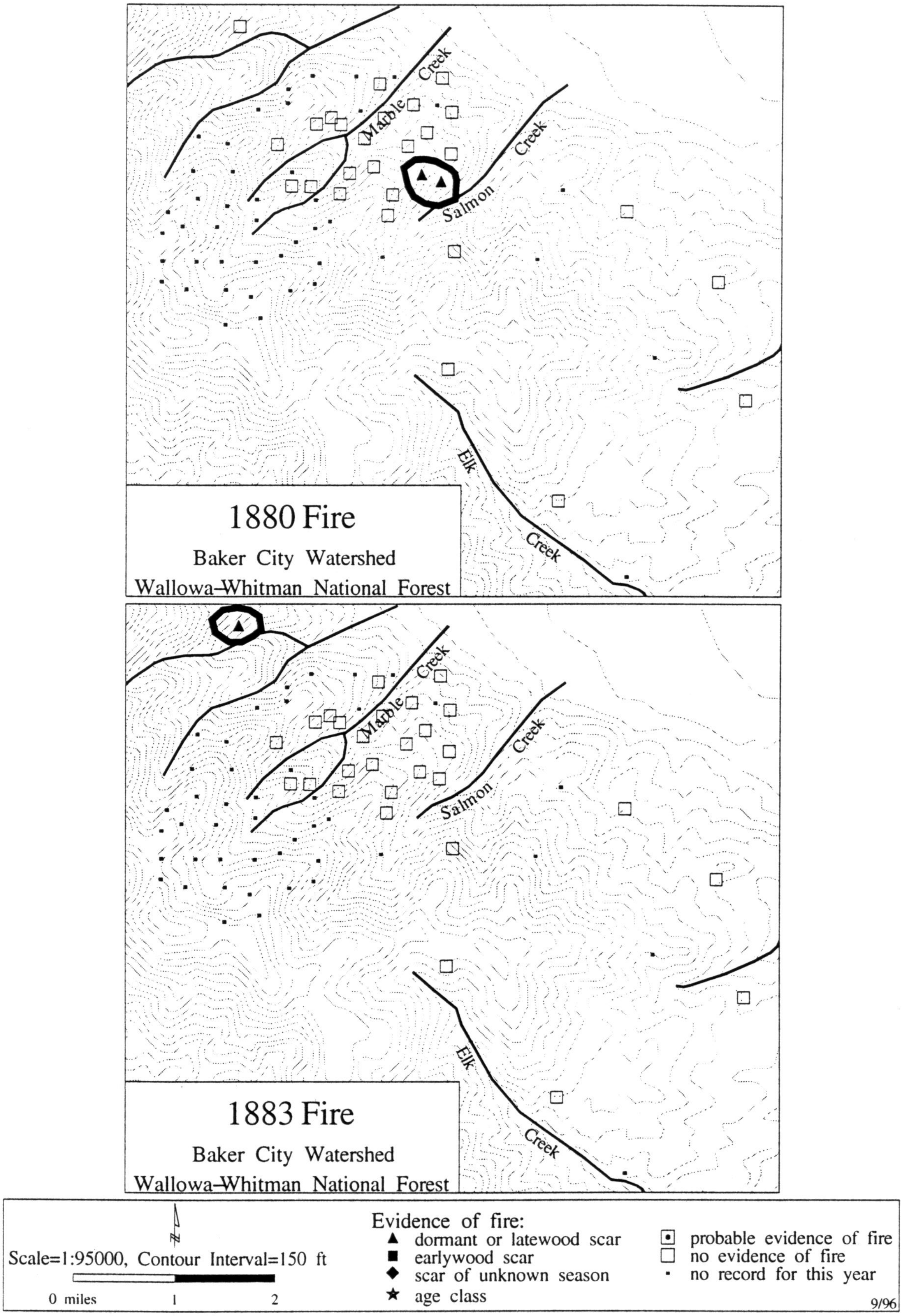


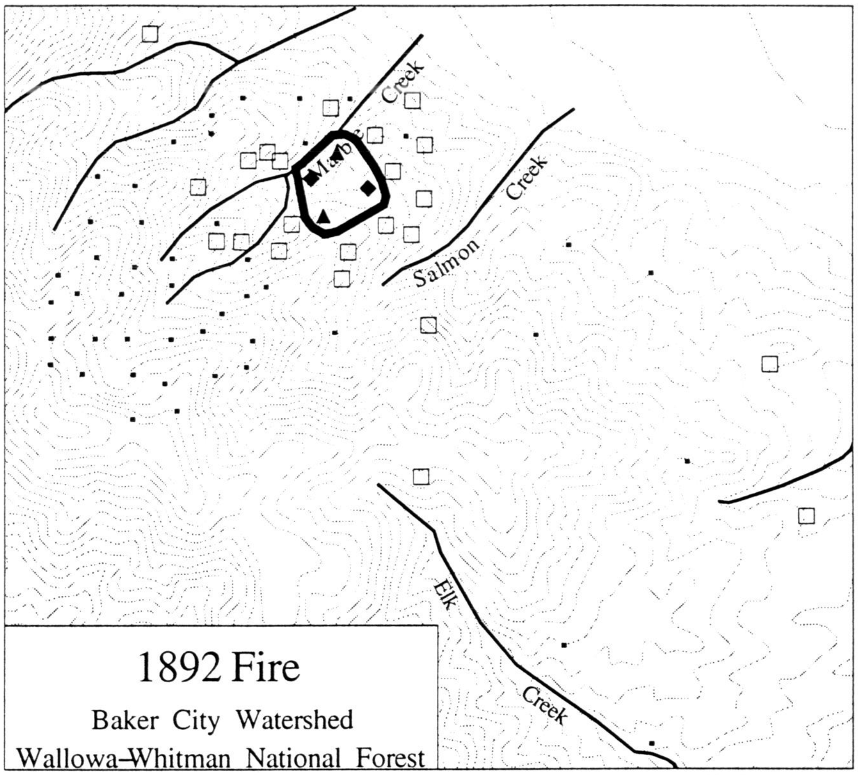
Scale=1:95000, Contour Interval=150 ft

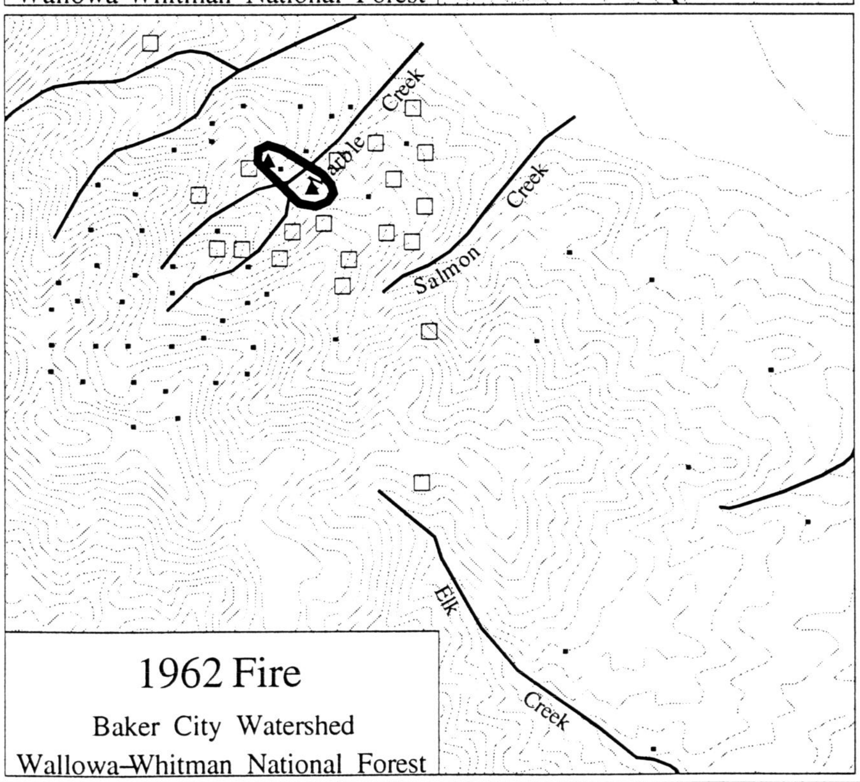
0 miles 1 2

Evidence of fire:
- ▲ dormant or latewood scar
- ■ earlywood scar
- ◆ scar of unknown season
- ★ age class
- ⊡ probable evidence of fire
- □ no evidence of fire
- · no record for this year

9/96


Marble Creek
Salmon Creek
Elk Creek
1880 Fire
Baker City Watershed
Wallowa-Whitman National Forest
Marble Creek
Salmon Creek
Elk Creek
1883 Fire
Baker City Watershed
Wallowa-Whitman National Forest
N
Scale=1:95000, Contour Interval=150 ft
0 miles
1
2
Evidence of fire:
dormant or latewood scar
earlywood scar
scar of unknown season
age class
probable evidence of fire
no evidence of fire
no record for this year
9/96





Scale=1:95000, Contour Interval=150 ft

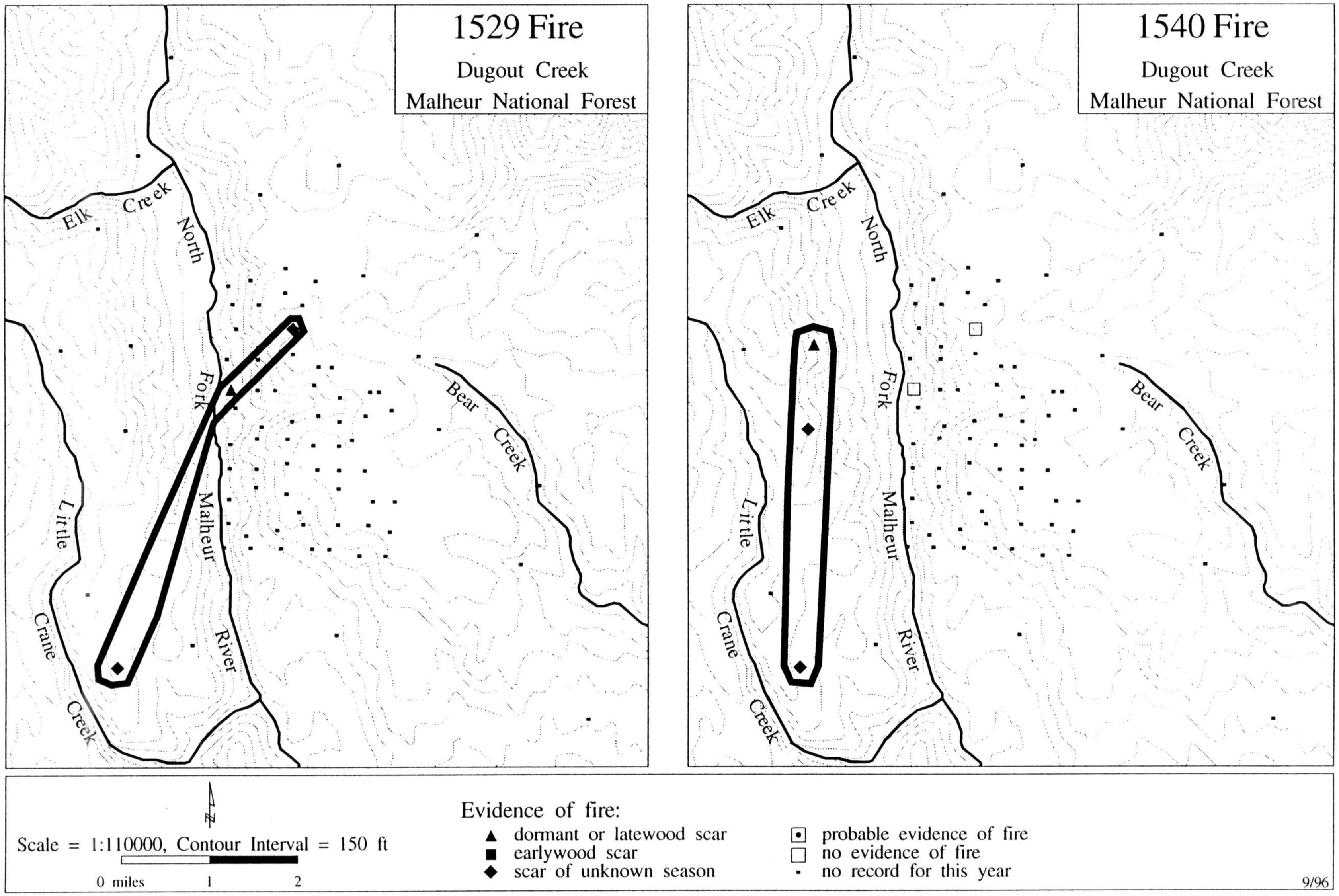
0 miles 1 2

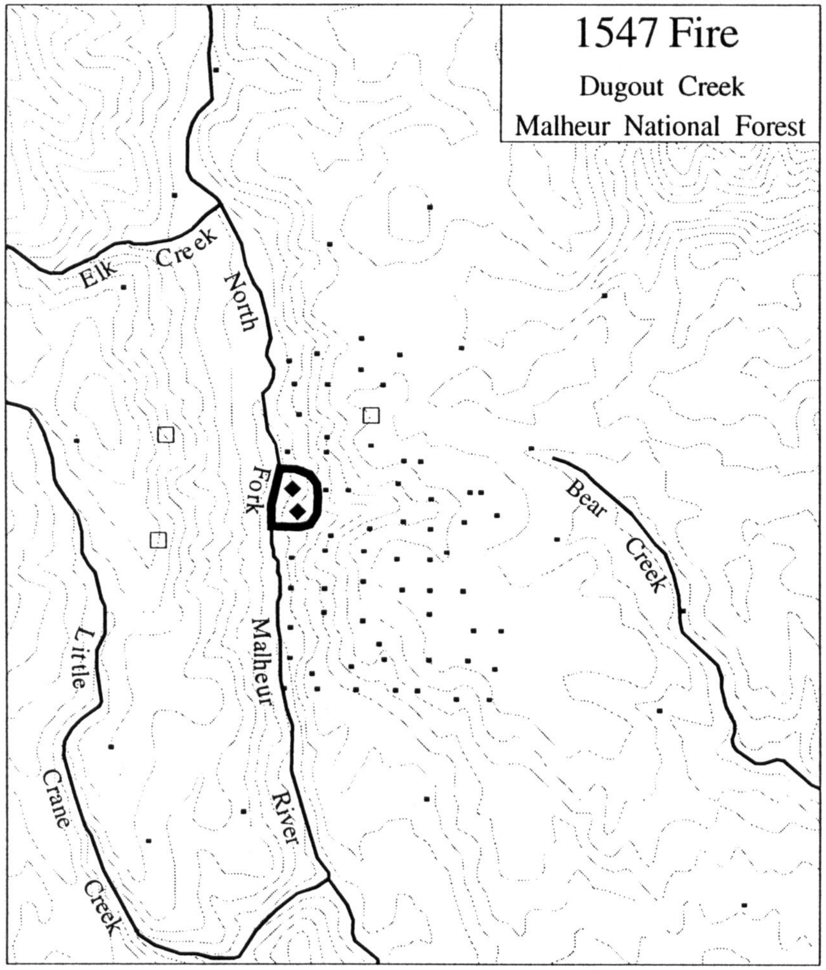
Evidence of fire:
- ▲ dormant or latewood scar
- ■ earlywood scar
- ◆ scar of unknown season
- ★ age class
- ⊡ probable evidence of fire
- □ no evidence of fire
- · no record for this year

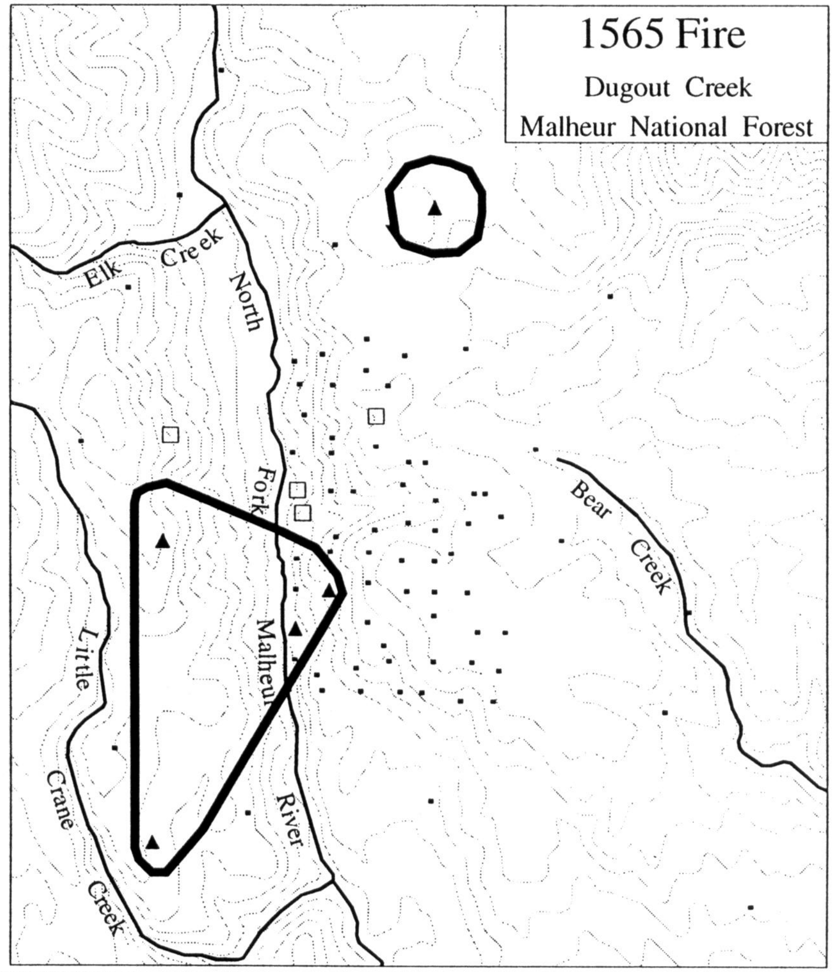
9/96

APPENDIX G: DUGOUT: FIRE MAPS

Evidence of fire was mapped at Dugout for every year in dry forests which had at least two scars. There are no mesic forests at this site. The maps show the intra-annular position of the scar is also indicated. Plots indicating as having probable evidence of fire are those for which the only evidence was an abrupt increase or decrease in ring width. Plots having no evidence of fire in a given year had recording trees for that year but did not have scars for that year. Plots indicated as having no record for a given year are plots that were sampled but had no trees recording during that year. Fire boundaries are shown as a heavy line.


1529 Fire
Dugout Creek
Malheur National Forest
1540 Fire
Dugout Creek
Malheur National Forest
Elk Creek
North Fork Malheur River
Bear Creek
Little Crane Creek
Scale = 1:110000, Contour Interval = 150 ft
0 miles 1 2
Evidence of fire:
dormant or latewood scar
earlywood scar
scar of unknown season
probable evidence of fire
no evidence of fire
no record for this year
9/96





N

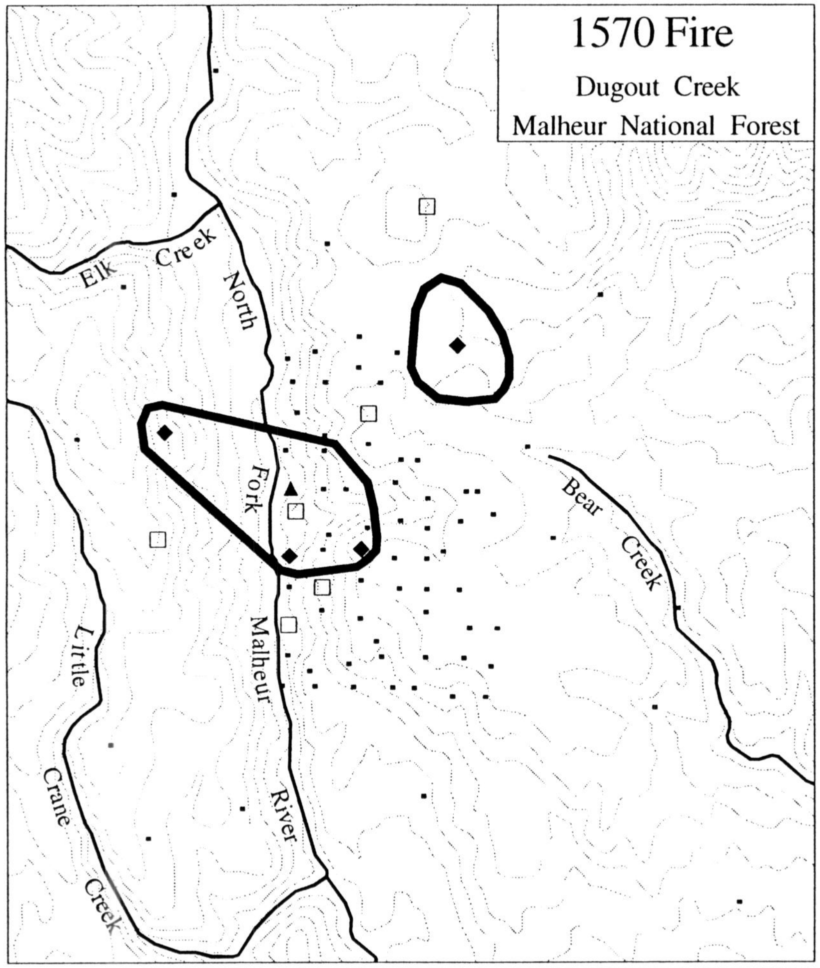
Scale = 1:110000, Contour Interval = 150 ft

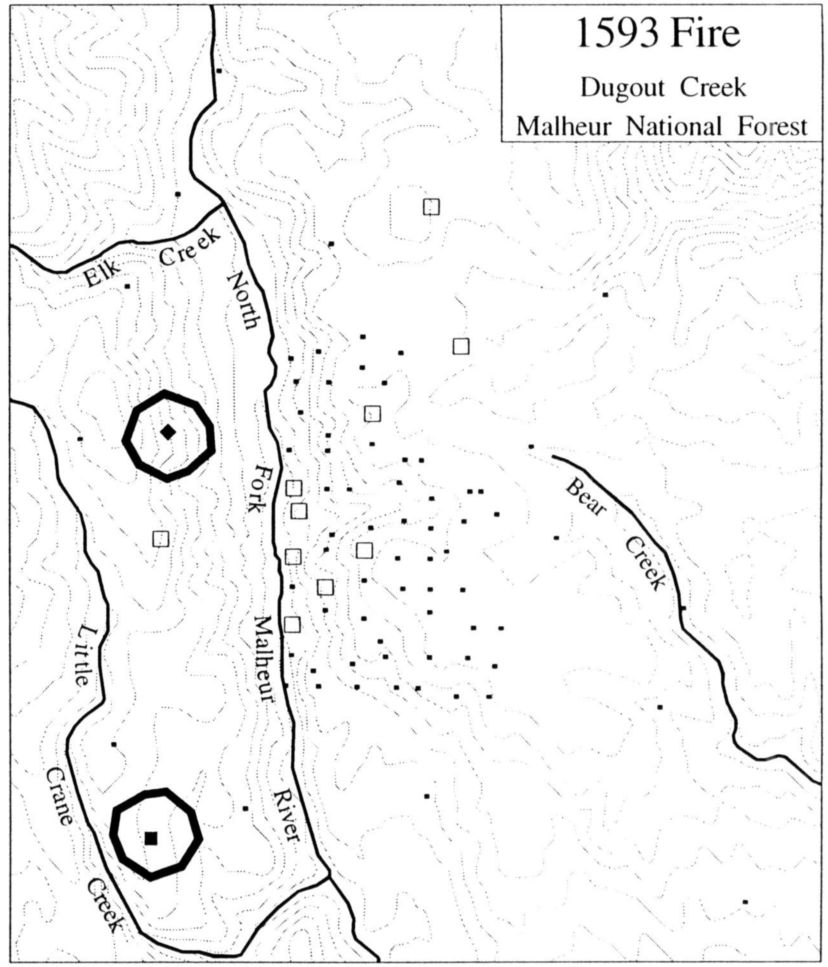
0 miles 1 2

Evidence of fire:

- ▲ dormant or latewood scar
- ■ earlywood scar
- ◆ scar of unknown season
- ⊡ probable evidence of fire
- □ no evidence of fire
- ▪ no record for this year

9/96





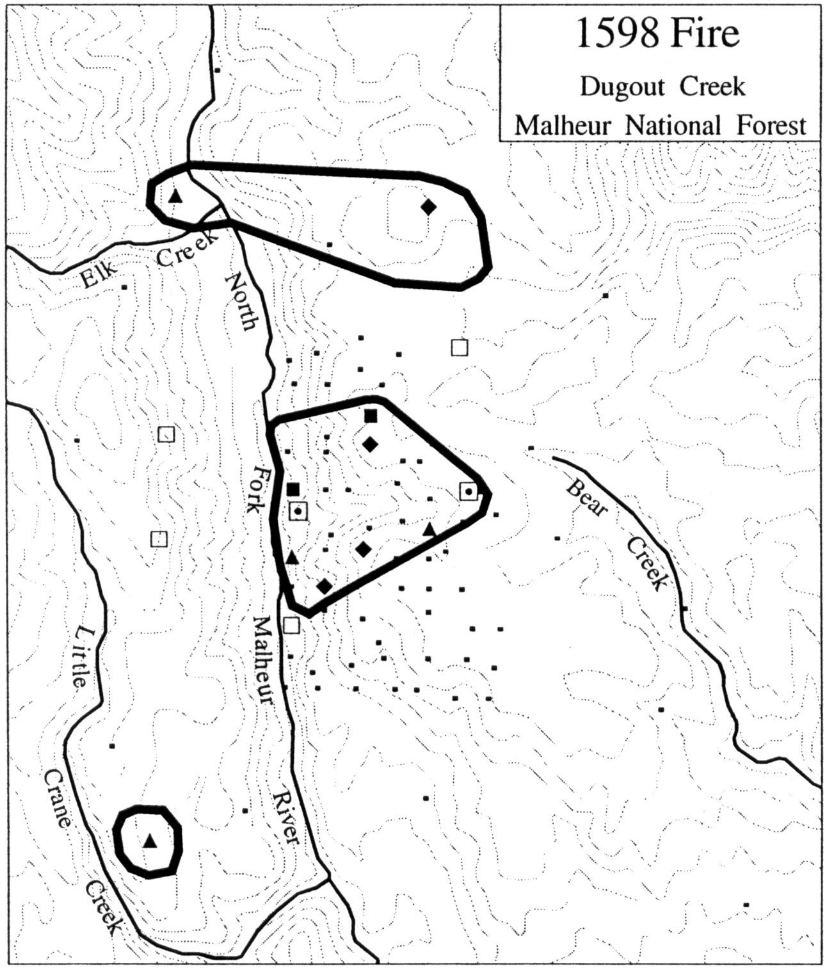
Scale = 1:110000, Contour Interval = 150 ft

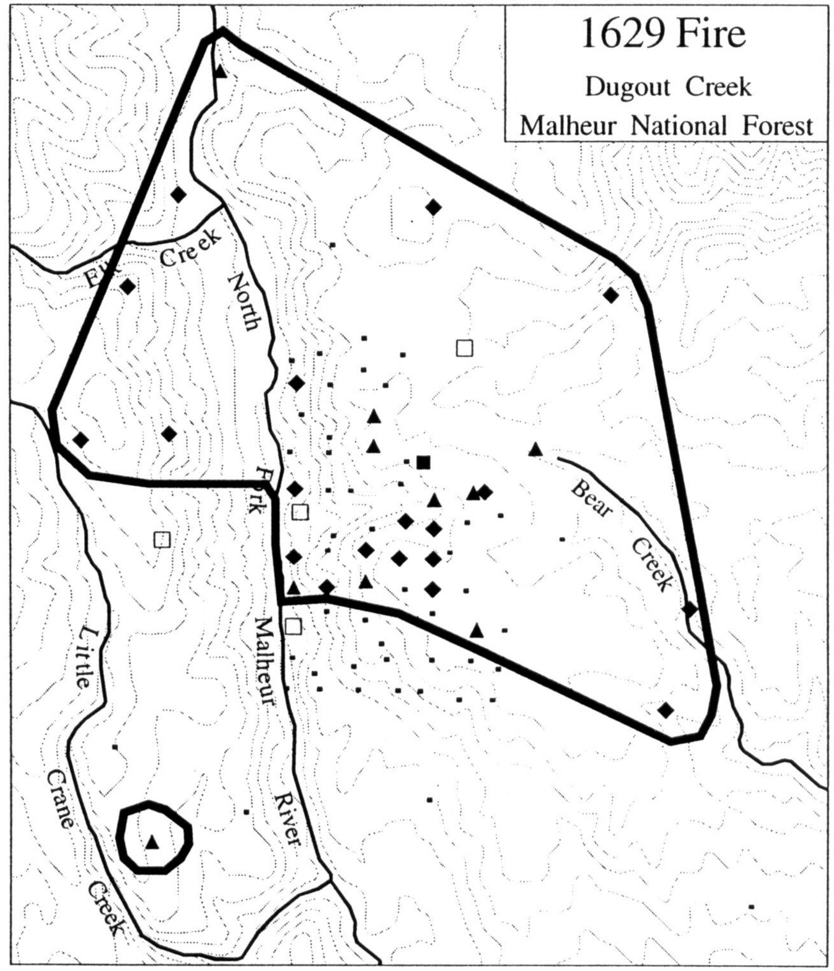
0 miles 1 2

Evidence of fire:

- ▲ dormant or latewood scar
- ■ earlywood scar
- ◆ scar of unknown season
- ⊡ probable evidence of fire
- □ no evidence of fire
- ▪ no record for this year

9/96





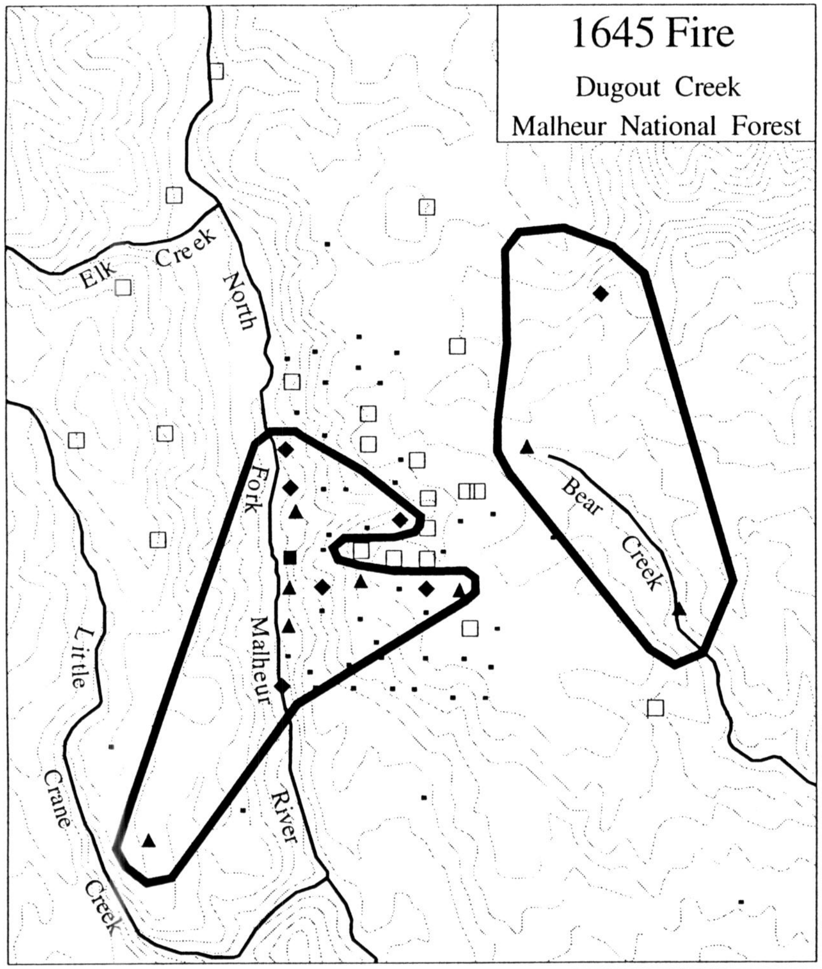
Scale = 1:110000, Contour Interval = 150 ft

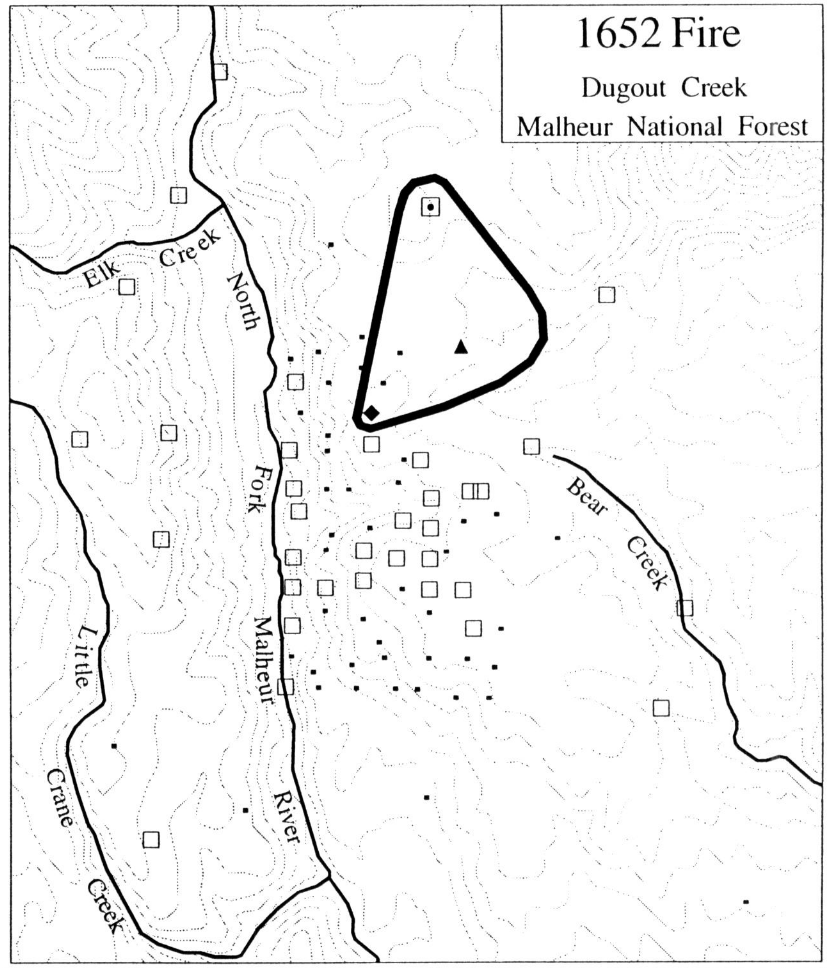
0 miles 1 2

Evidence of fire:

- ▲ dormant or latewood scar
- ■ earlywood scar
- ◆ scar of unknown season
- ⊡ probable evidence of fire
- □ no evidence of fire
- ▪ no record for this year

9/96





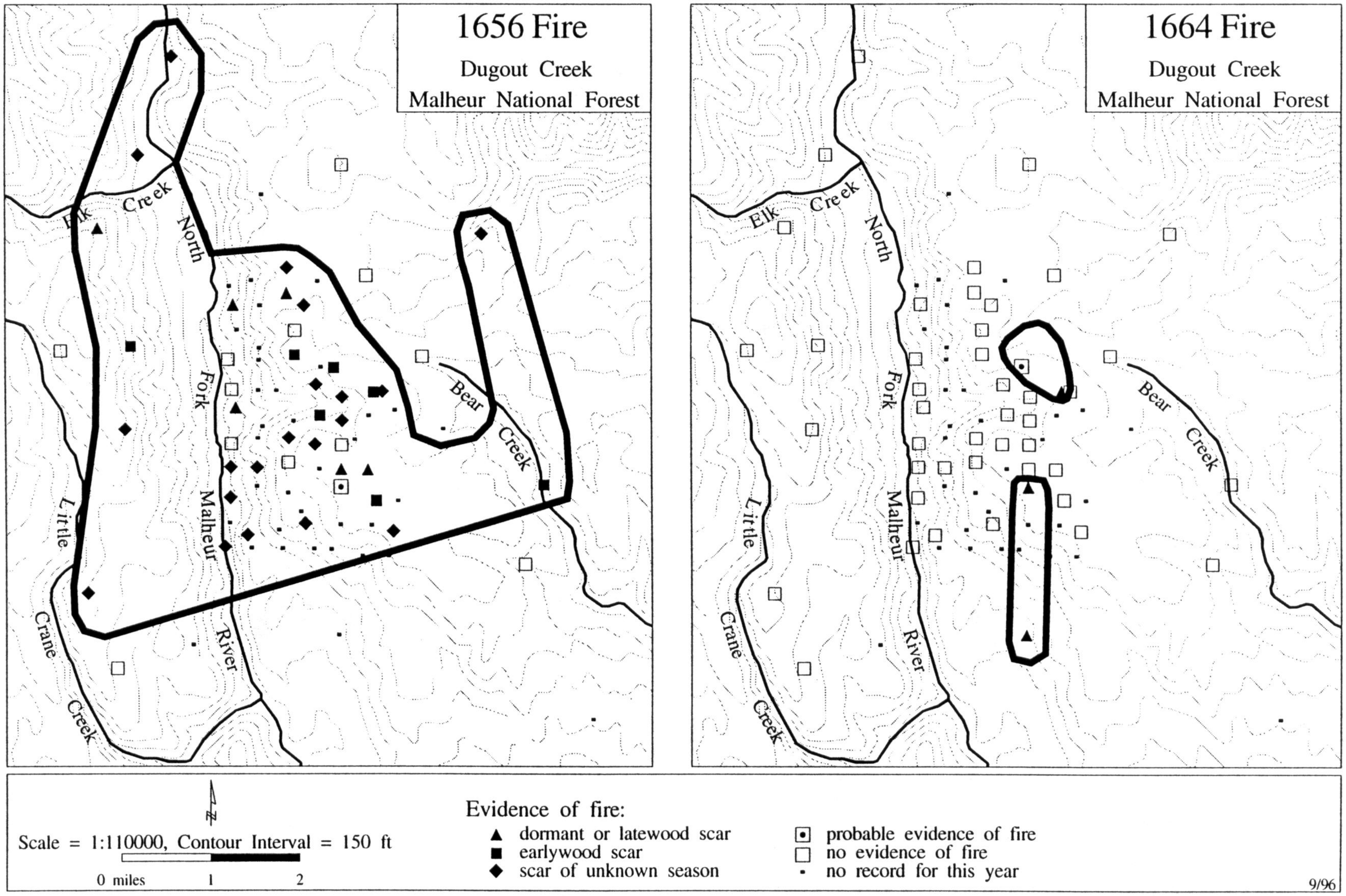
Scale = 1:110000, Contour Interval = 150 ft

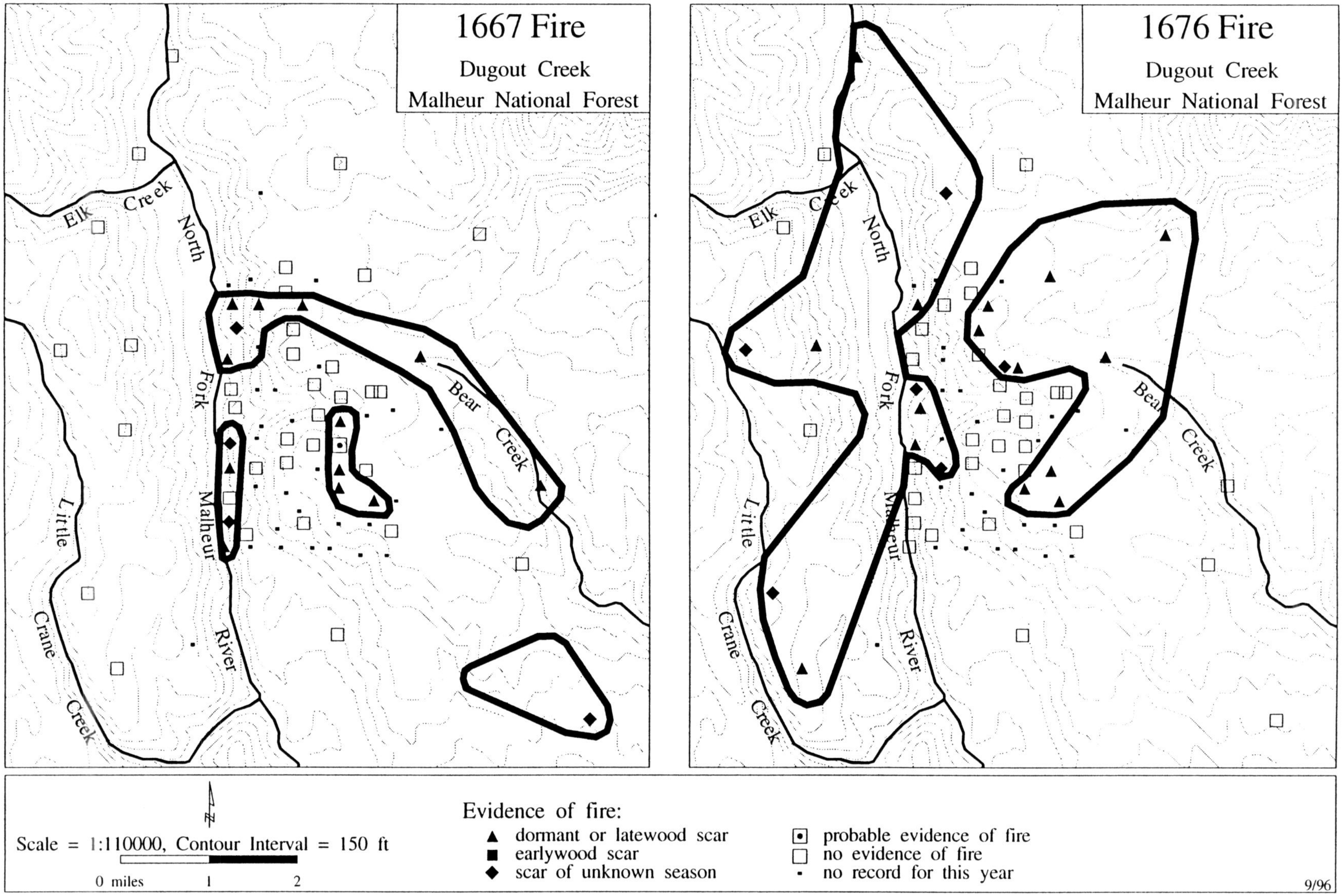
0 miles 1 2

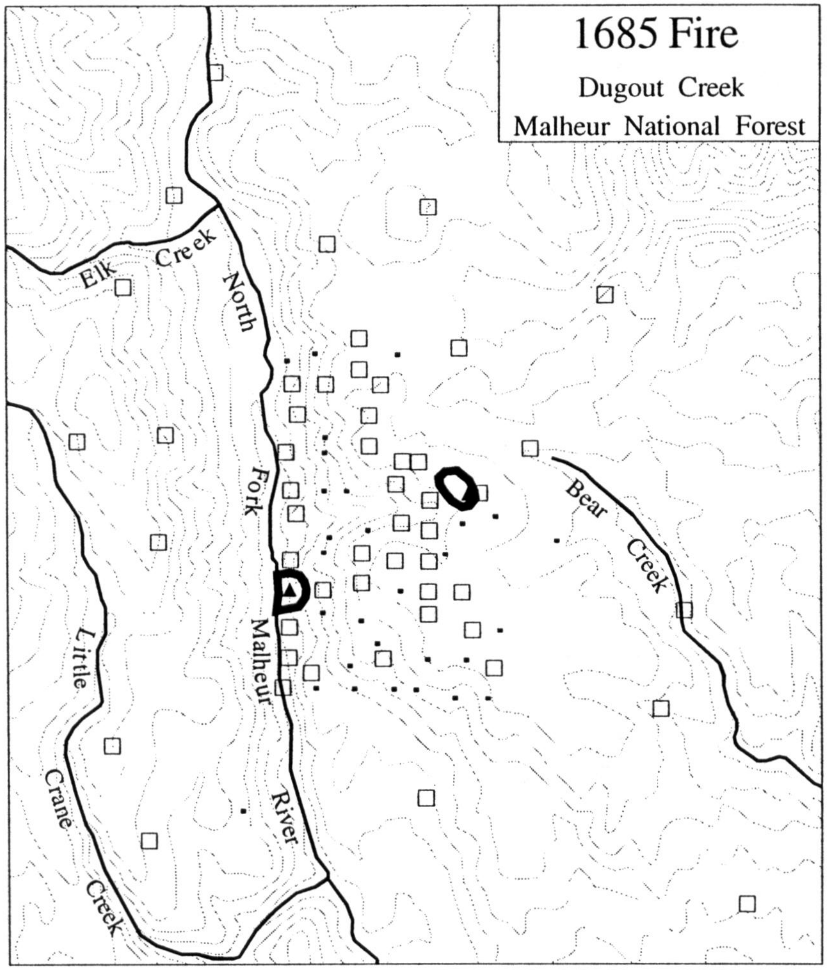
Evidence of fire:

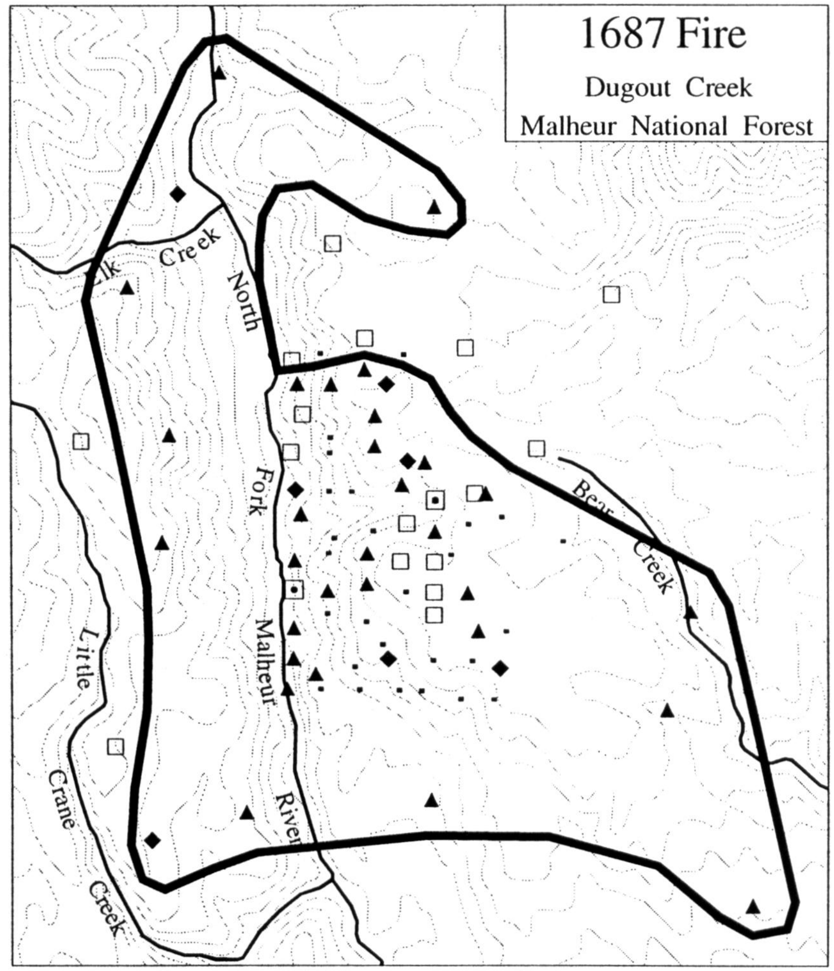
- ▲ dormant or latewood scar
- ■ earlywood scar
- ◆ scar of unknown season
- ⊡ probable evidence of fire
- □ no evidence of fire
- ▪ no record for this year

9/96


1656 Fire
Dugout Creek
Malheur National Forest
1664 Fire
Dugout Creek
Malheur National Forest
Elk Creek
North Fork Malheur River
Bear Creek
Little Crane Creek
Scale = 1:110000, Contour Interval = 150 ft
0 miles 1 2
Evidence of fire:
dormant or latewood scar
earlywood scar
scar of unknown season
probable evidence of fire
no evidence of fire
no record for this year
9/96


1667 Fire
Dugout Creek
Malheur National Forest
1676 Fire
Dugout Creek
Malheur National Forest
Elk Creek
North Fork Malheur River
Bear Creek
Little Crane Creek
Scale = 1:110000, Contour Interval = 150 ft
0 miles 1 2
Evidence of fire:
dormant or latewood scar
earlywood scar
scar of unknown season
probable evidence of fire
no evidence of fire
no record for this year
9/96





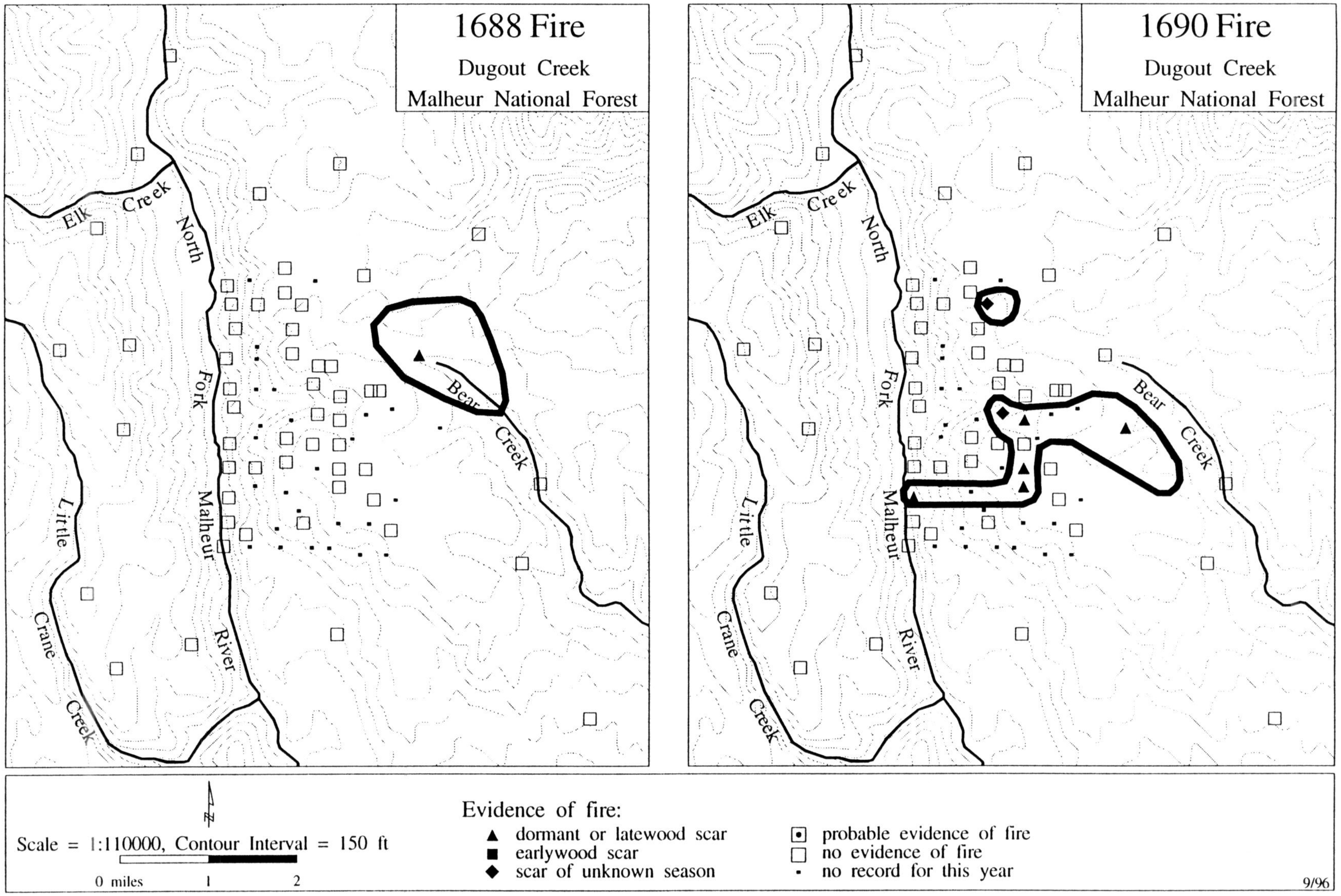
Scale = 1:110000, Contour Interval = 150 ft

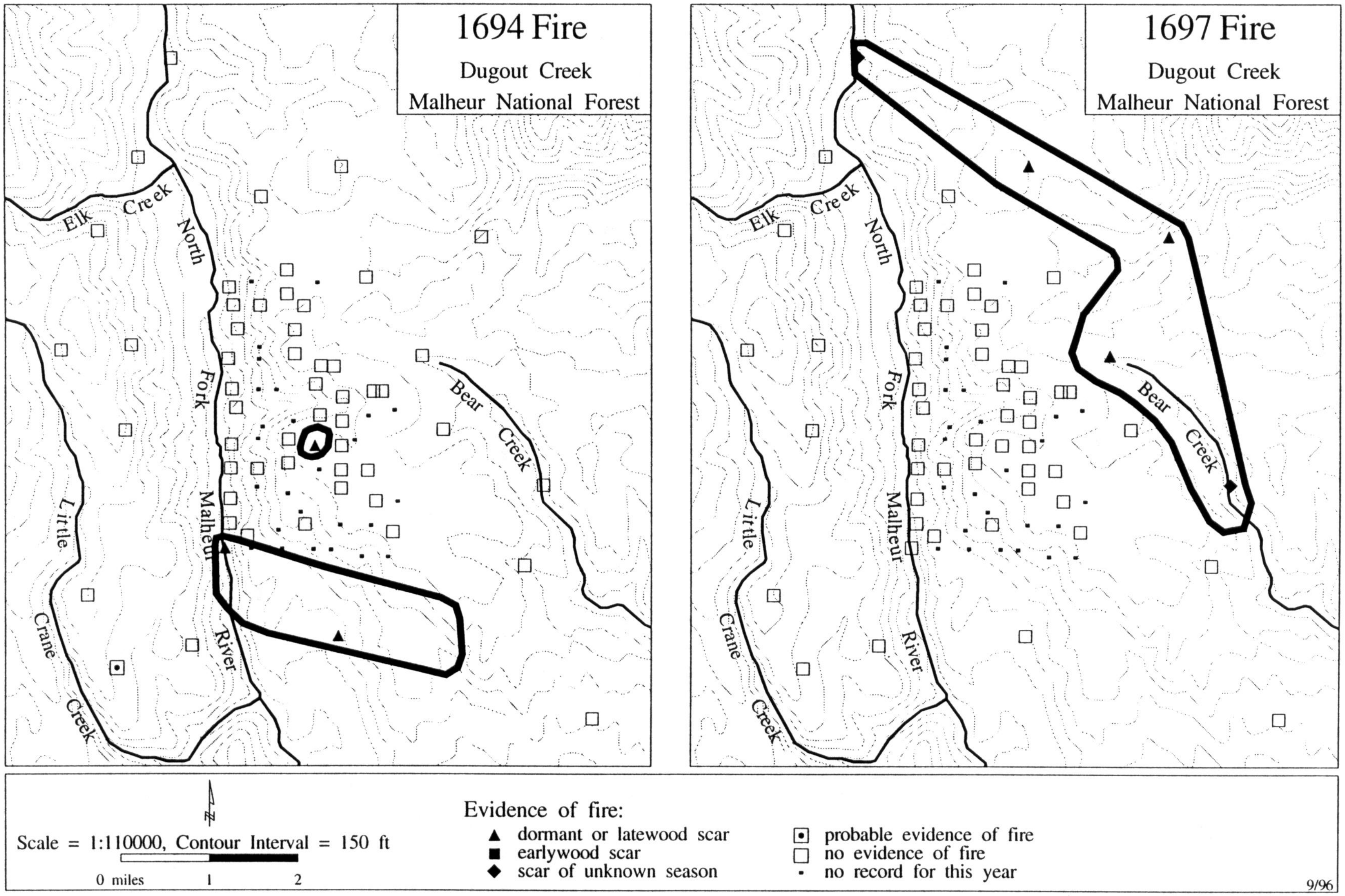
0 miles 1 2

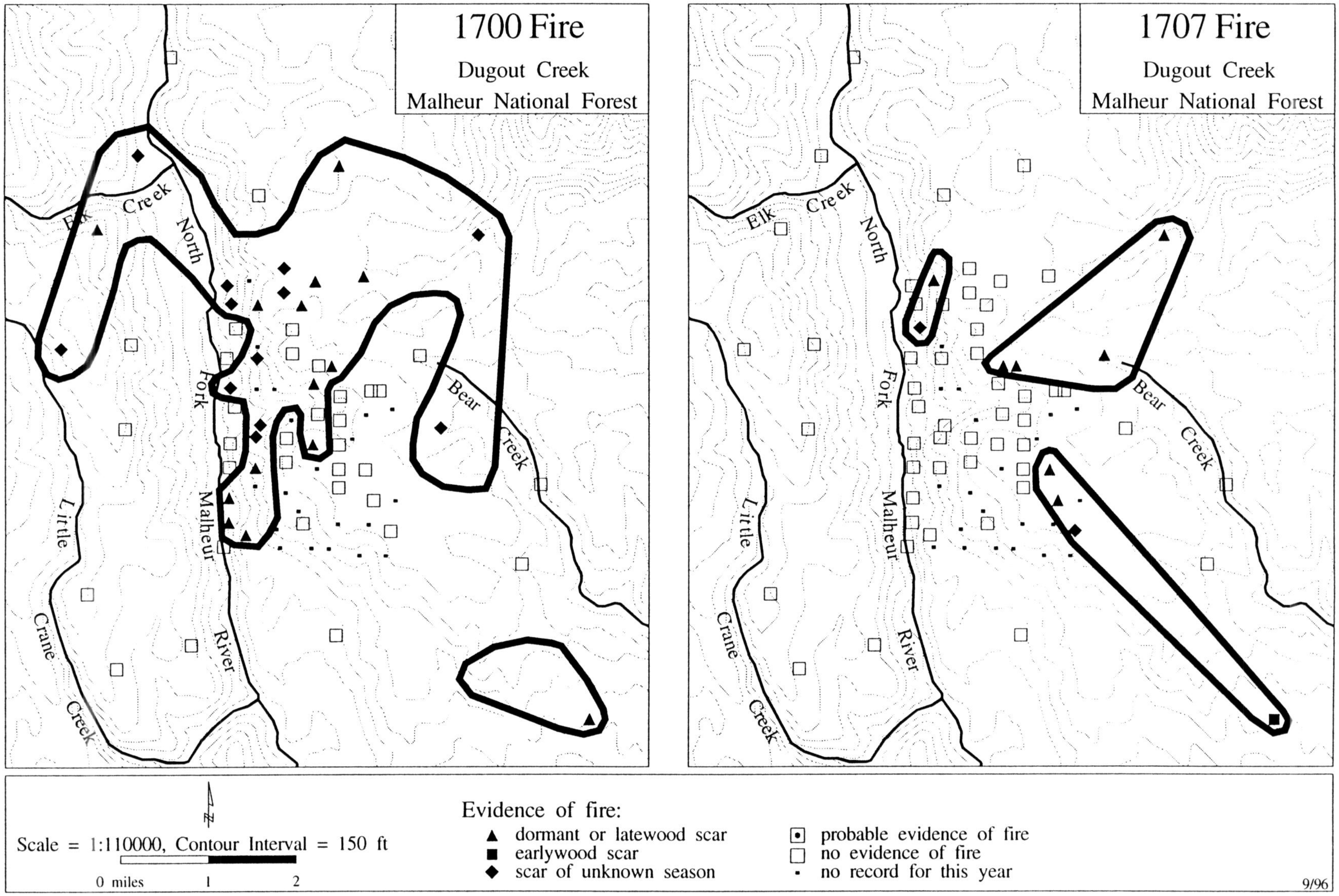
Evidence of fire:

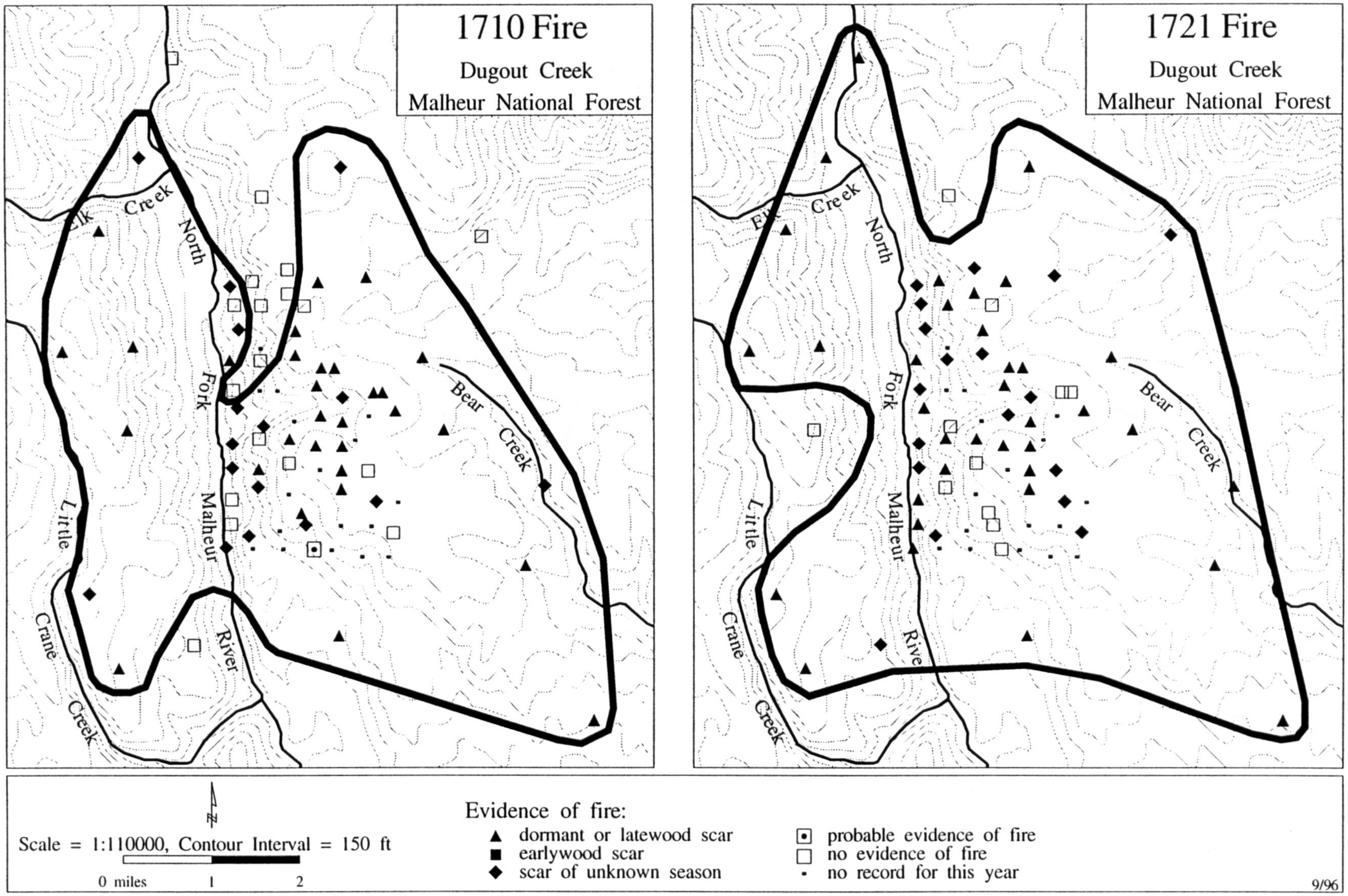
- ▲ dormant or latewood scar
- ■ earlywood scar
- ◆ scar of unknown season
- ⊡ probable evidence of fire
- □ no evidence of fire
- ▪ no record for this year

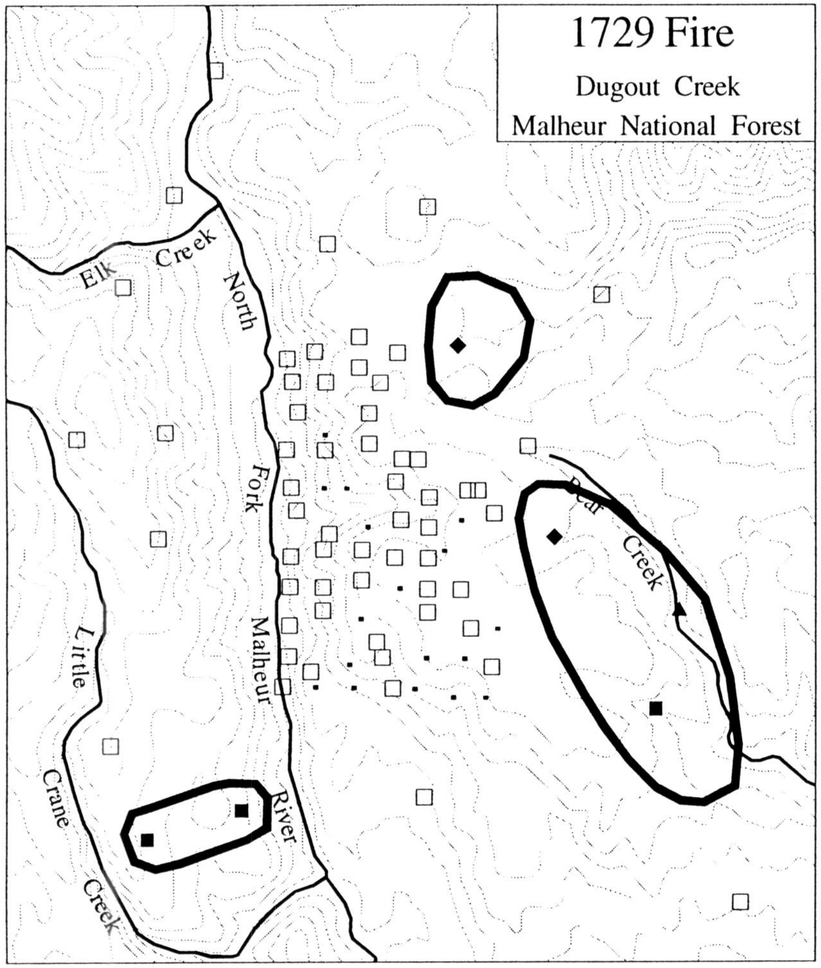
9/96

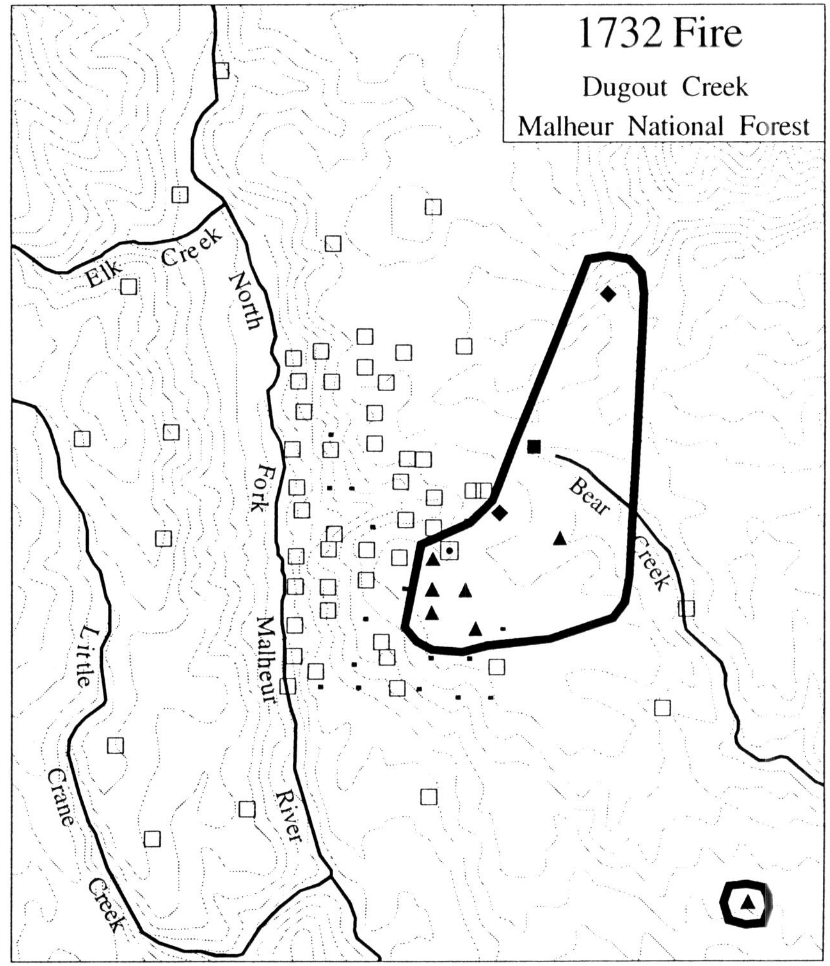

1688 Fire
Dugout Creek
Malheur National Forest
1690 Fire
Dugout Creek
Malheur National Forest
Elk Creek
North Fork Malheur River
Bear Creek
Little Crane Creek
Scale = 1:110000, Contour Interval = 150 ft
0 miles
1
2
Evidence of fire:
dormant or latewood scar
earlywood scar
scar of unknown season
probable evidence of fire
no evidence of fire
no record for this year
9/96


1694 Fire
Dugout Creek
Malheur National Forest
1697 Fire
Dugout Creek
Malheur National Forest
Elk Creek
North Fork Malheur River
Bear Creek
Little Crane Creek
N
Scale = 1:110000, Contour Interval = 150 ft
0 miles
1
2
Evidence of fire:
dormant or latewood scar
earlywood scar
scar of unknown season
probable evidence of fire
no evidence of fire
no record for this year
9/96


1700 Fire
Dugout Creek
Malheur National Forest
1707 Fire
Dugout Creek
Malheur National Forest
Elk Creek
North Fork Malheur River
Bear Creek
Little Crane Creek
Scale = 1:110000, Contour Interval = 150 ft
0 miles 1 2
Evidence of fire:
dormant or latewood scar
earlywood scar
scar of unknown season
probable evidence of fire
no evidence of fire
no record for this year
9/96


1710 Fire
Dugout Creek
Malheur National Forest
1721 Fire
Dugout Creek
Malheur National Forest
Elk Creek
North Fork Malheur River
Bear Creek
Little Crane Creek
Scale = 1:110000, Contour Interval = 150 ft
0 miles
1
2
Evidence of fire:
dormant or latewood scar
earlywood scar
scar of unknown season
probable evidence of fire
no evidence of fire
no record for this year
9/96





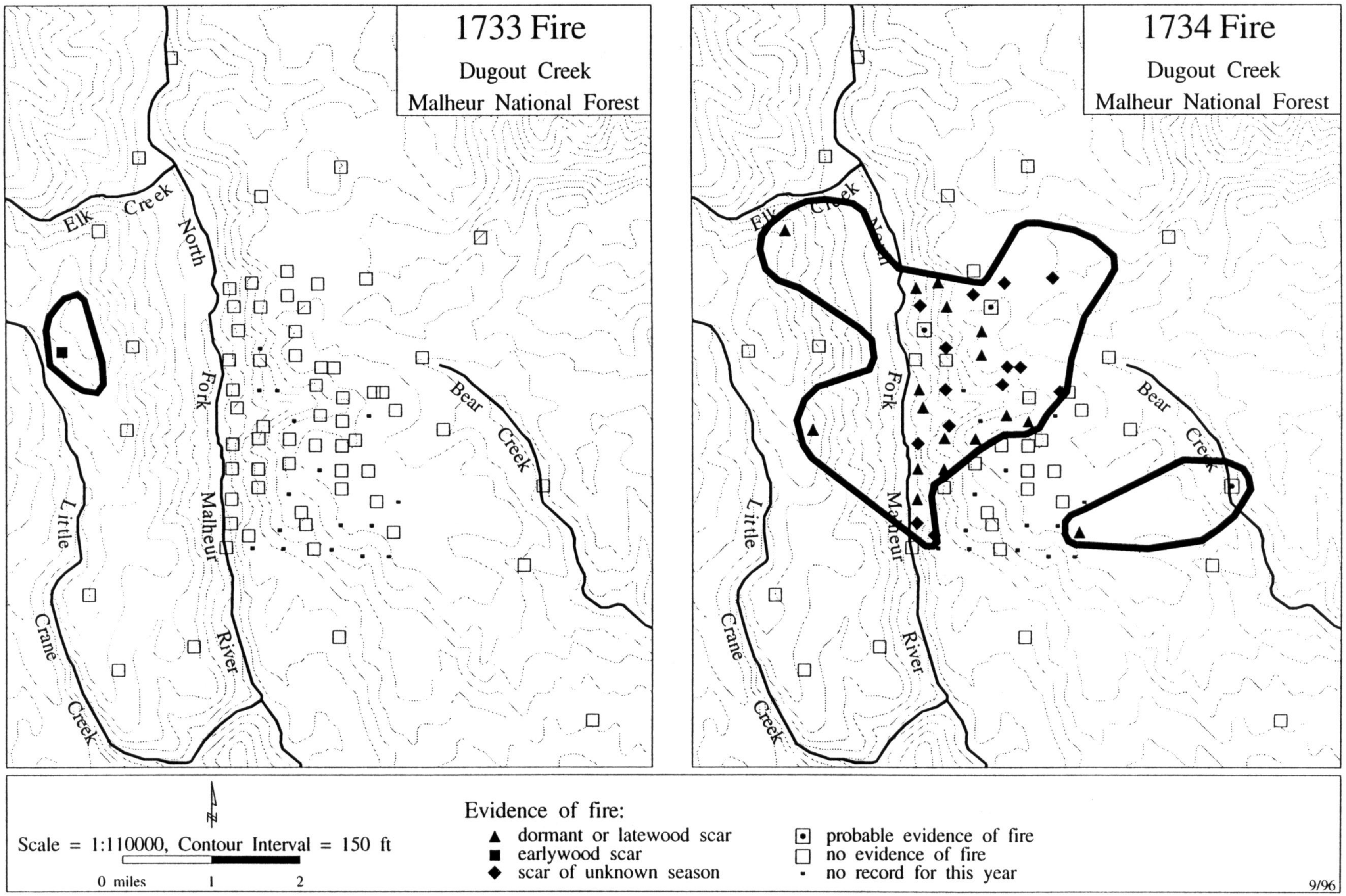
Scale = 1:110000, Contour Interval = 150 ft

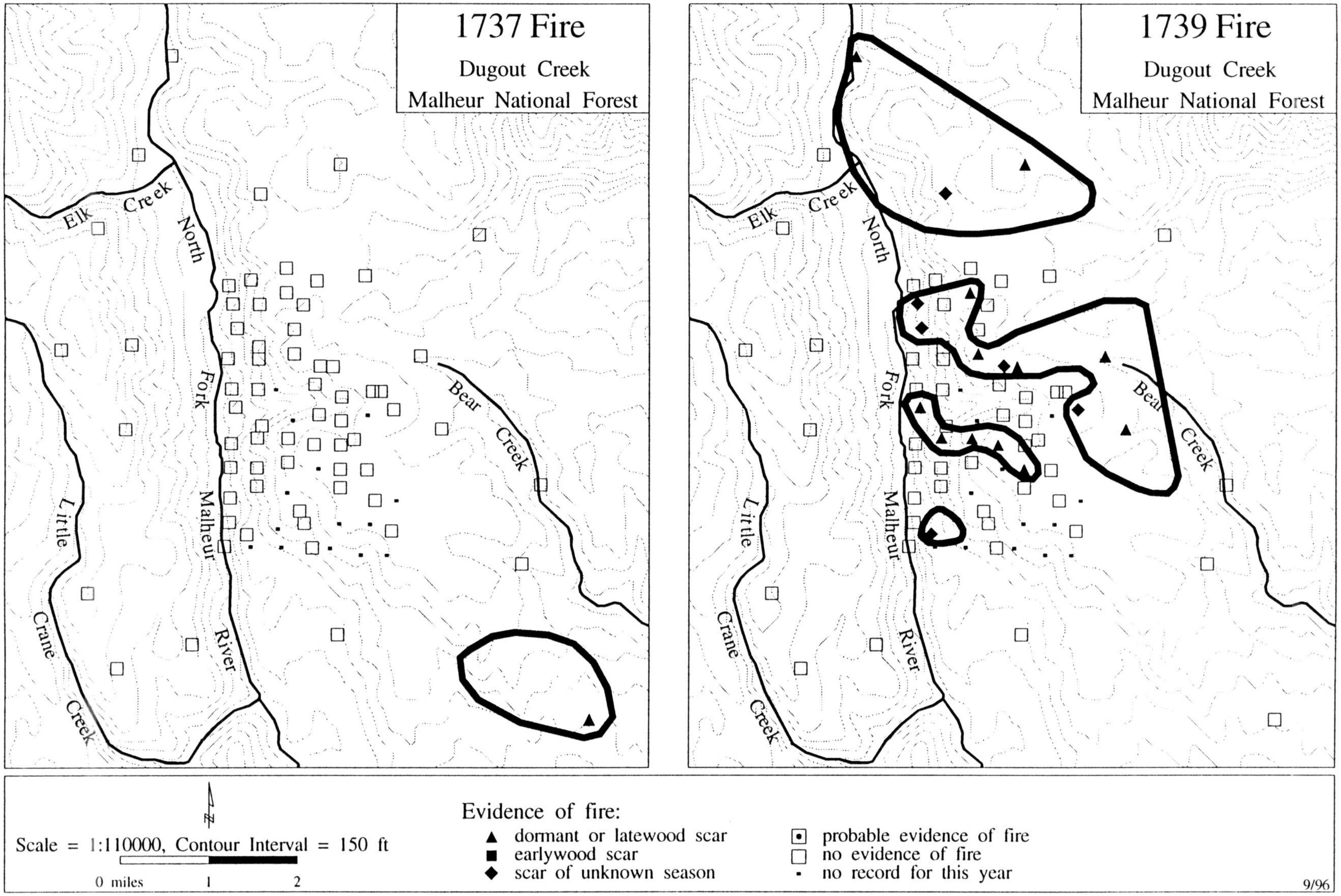
0 miles 1 2

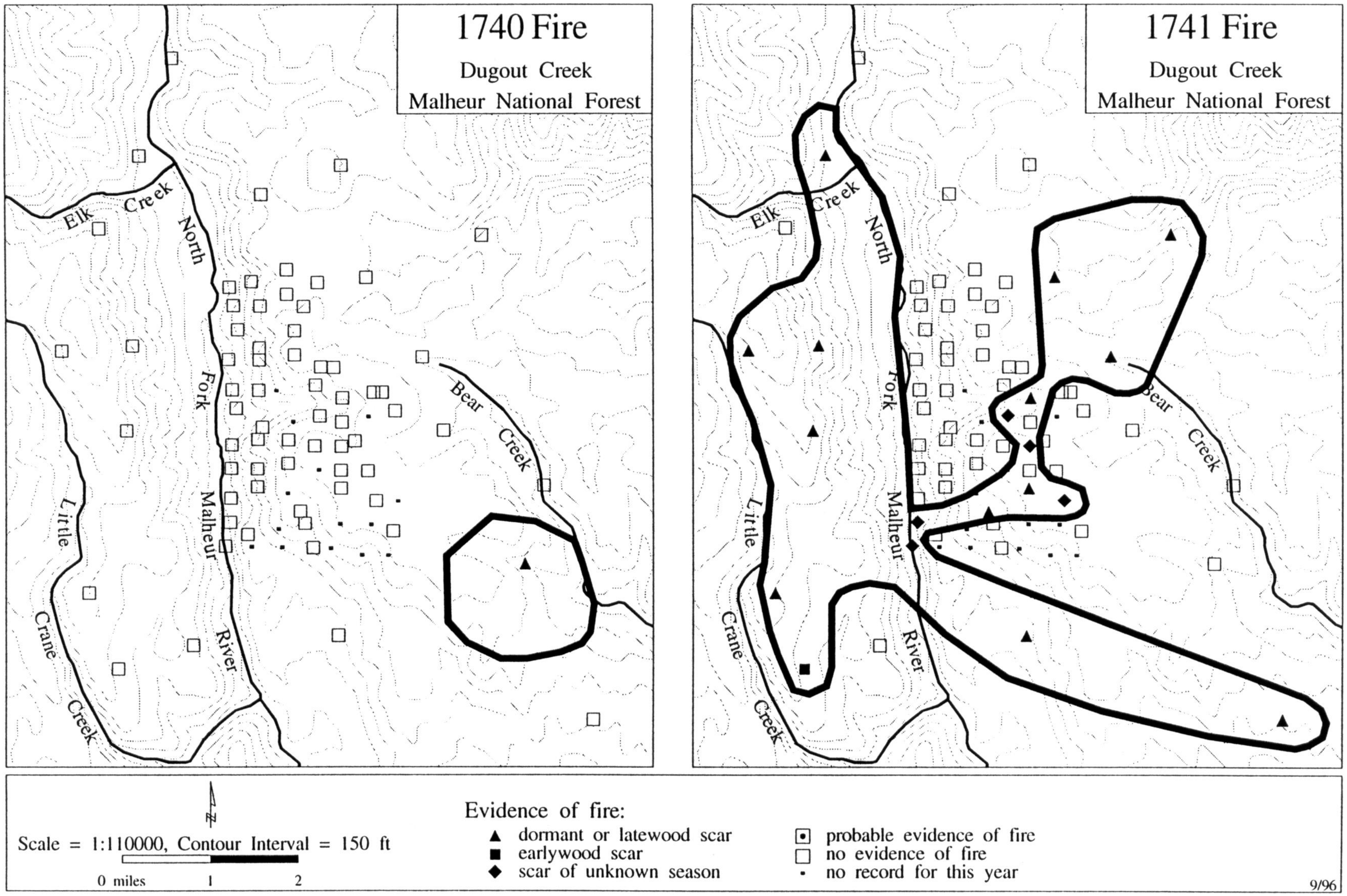
Evidence of fire:

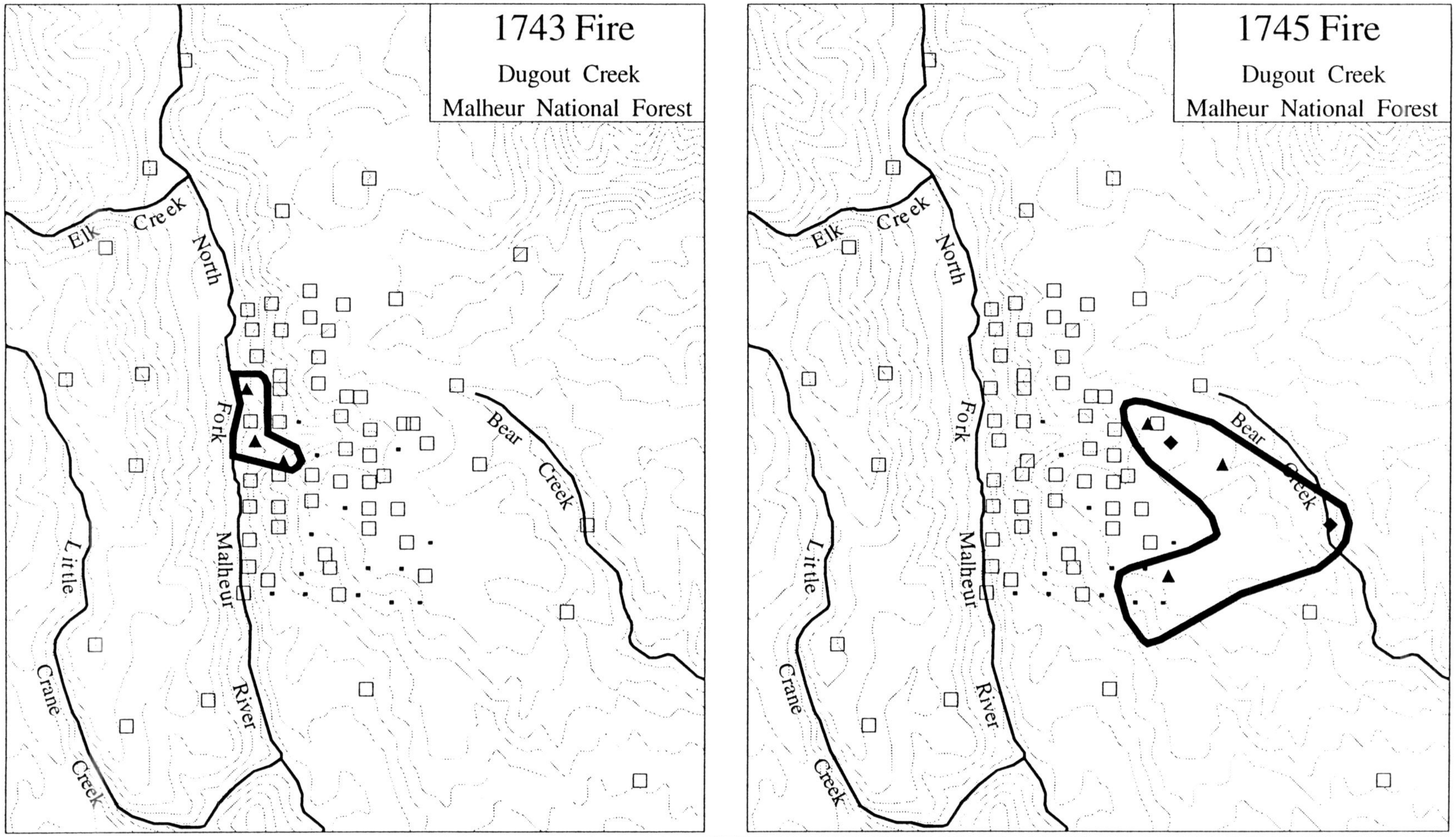
▲ dormant or latewood scar
■ earlywood scar
◆ scar of unknown season
⊡ probable evidence of fire
□ no evidence of fire
▪ no record for this year

9/96


1733 Fire
Dugout Creek
Malheur National Forest
1734 Fire
Dugout Creek
Malheur National Forest
Elk Creek
North Fork Malheur River
Little Crane Creek
Bear Creek
Scale = 1:110000, Contour Interval = 150 ft
0 miles 1 2
Evidence of fire:
dormant or latewood scar
earlywood scar
scar of unknown season
probable evidence of fire
no evidence of fire
no record for this year
9/96


1737 Fire
Dugout Creek
Malheur National Forest
1739 Fire
Dugout Creek
Malheur National Forest
Elk Creek
North Fork Malheur River
Bear Creek
Little Crane Creek
Evidence of fire:
dormant or latewood scar
earlywood scar
scar of unknown season
probable evidence of fire
no evidence of fire
no record for this year
Scale = 1:110000, Contour Interval = 150 ft
0 miles
1
2
9/96


1740 Fire
Dugout Creek
Malheur National Forest
1741 Fire
Dugout Creek
Malheur National Forest
Elk Creek
North Fork Malheur River
Bear Creek
Little Crane Creek
Scale = 1:110000, Contour Interval = 150 ft
0 miles 1 2
Evidence of fire:
dormant or latewood scar
earlywood scar
scar of unknown season
probable evidence of fire
no evidence of fire
no record for this year
9/96



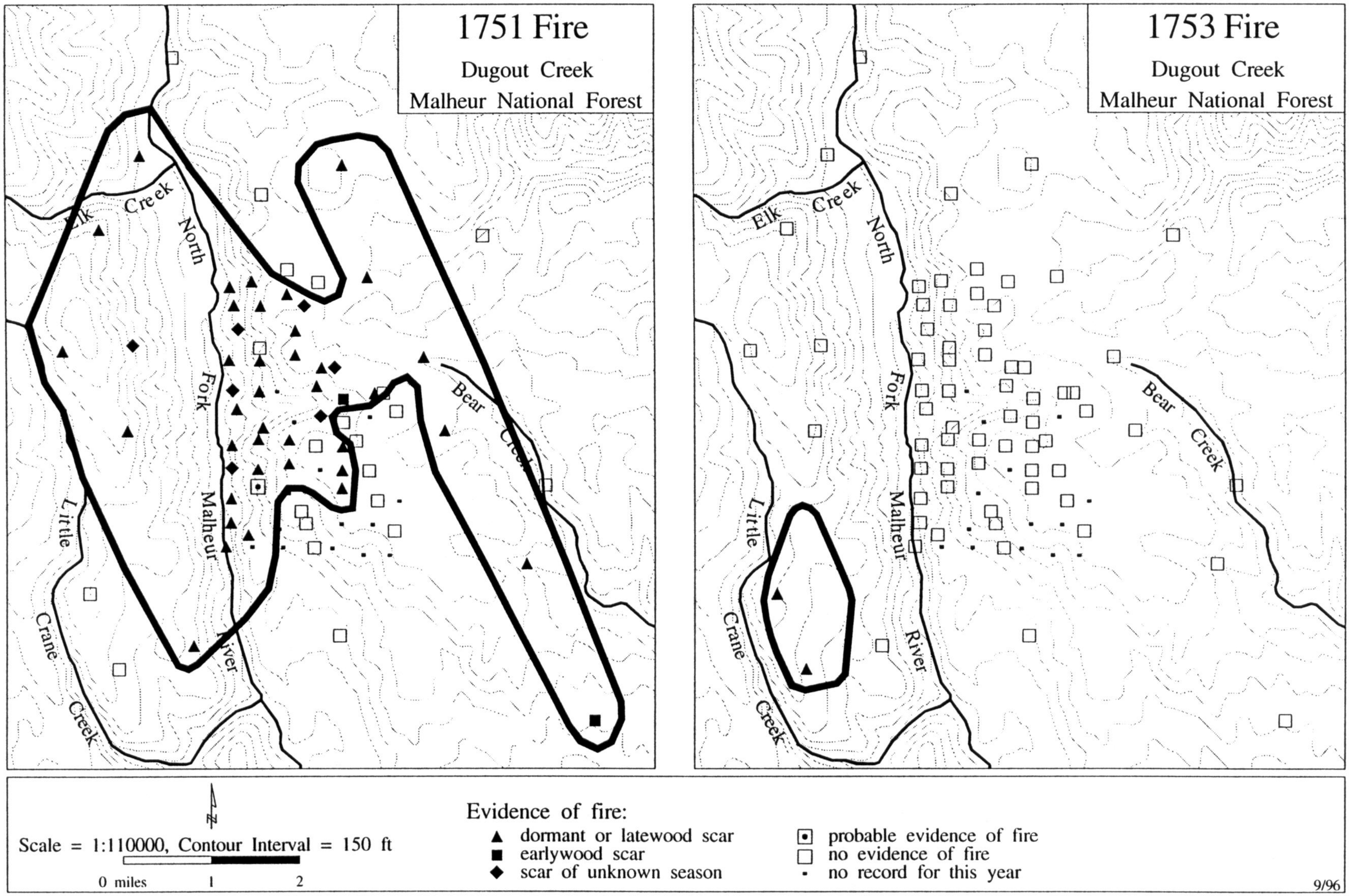
Scale = 1:110000, Contour Interval = 150 ft

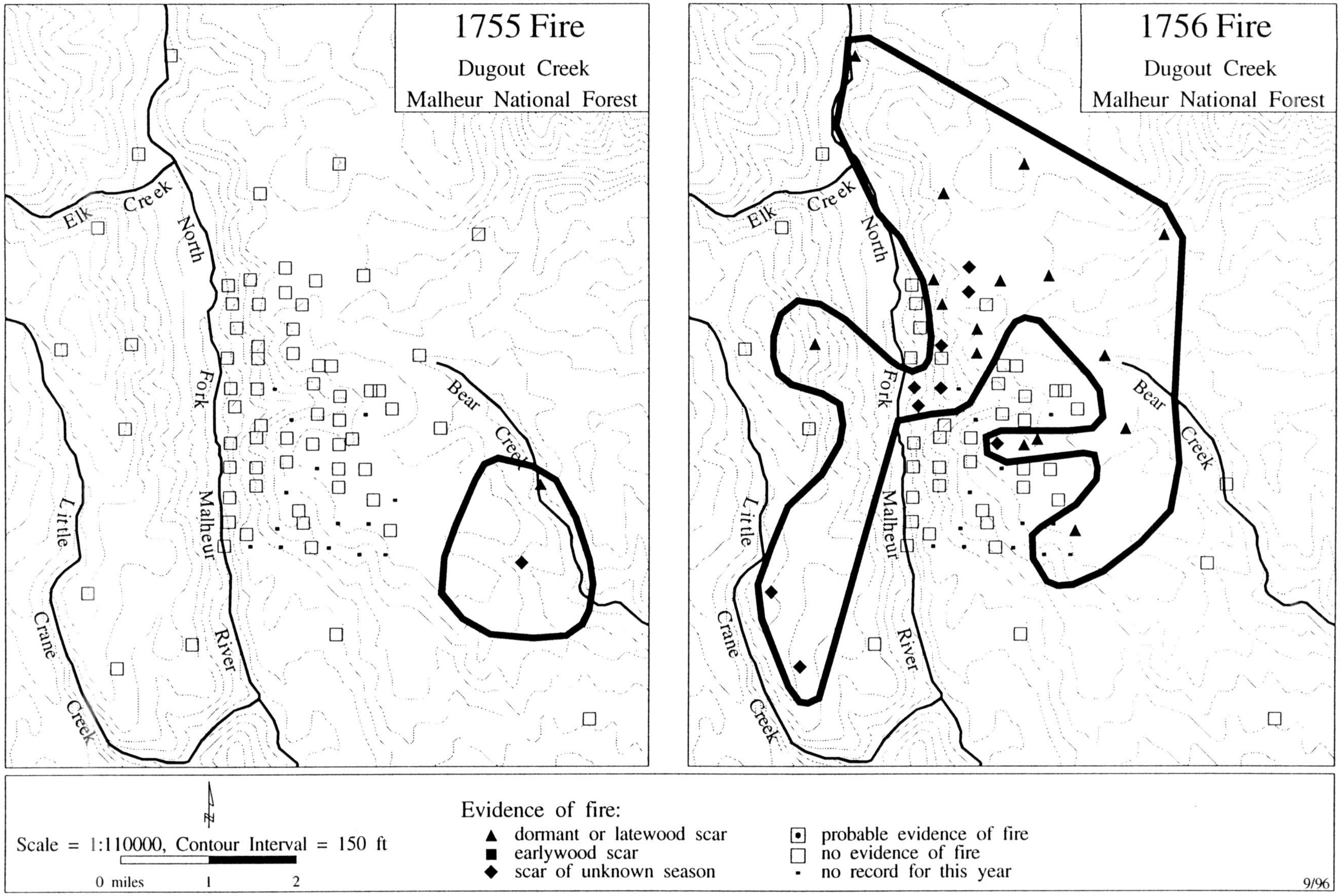
0 miles 1 2

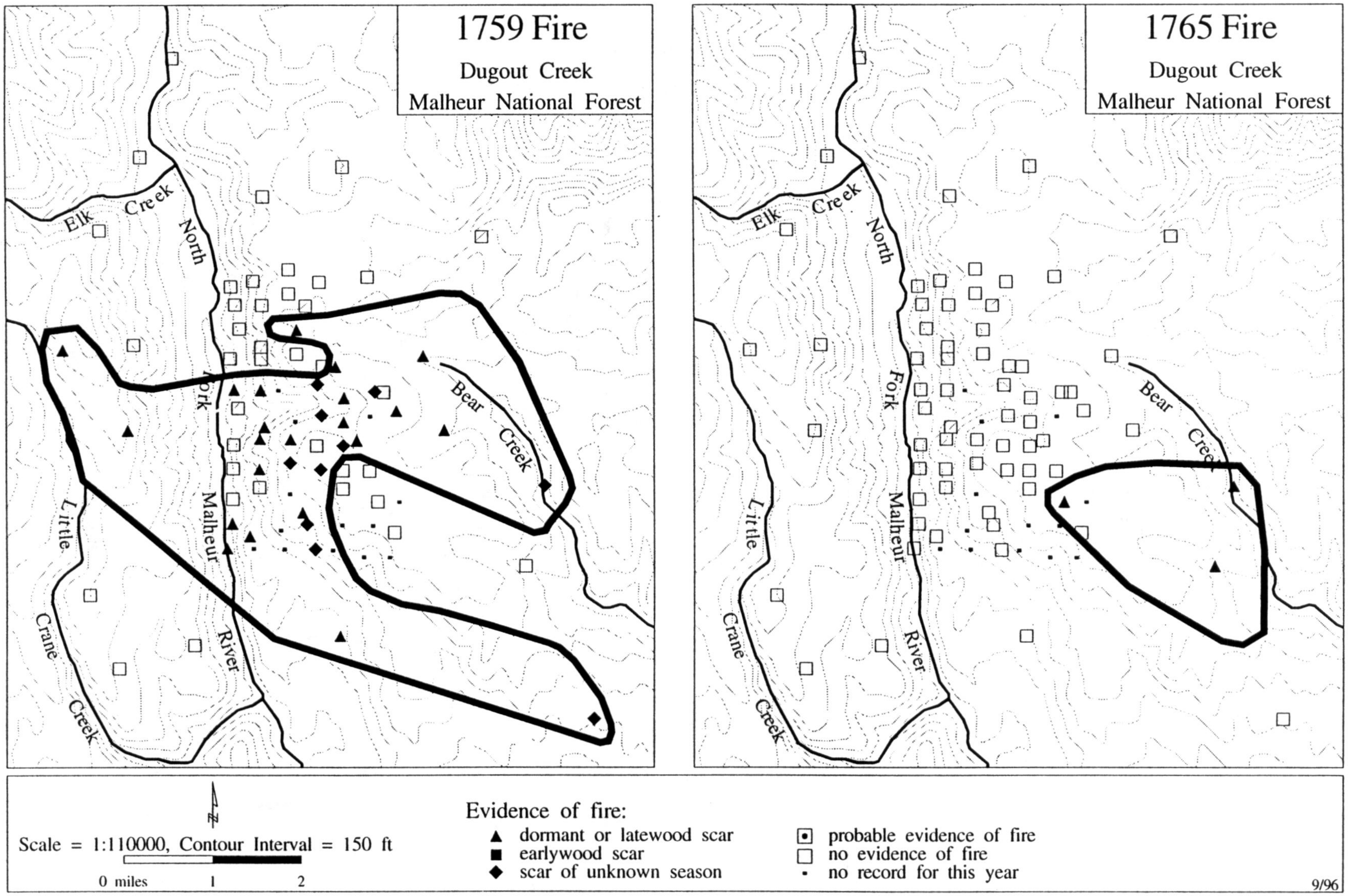
Evidence of fire:

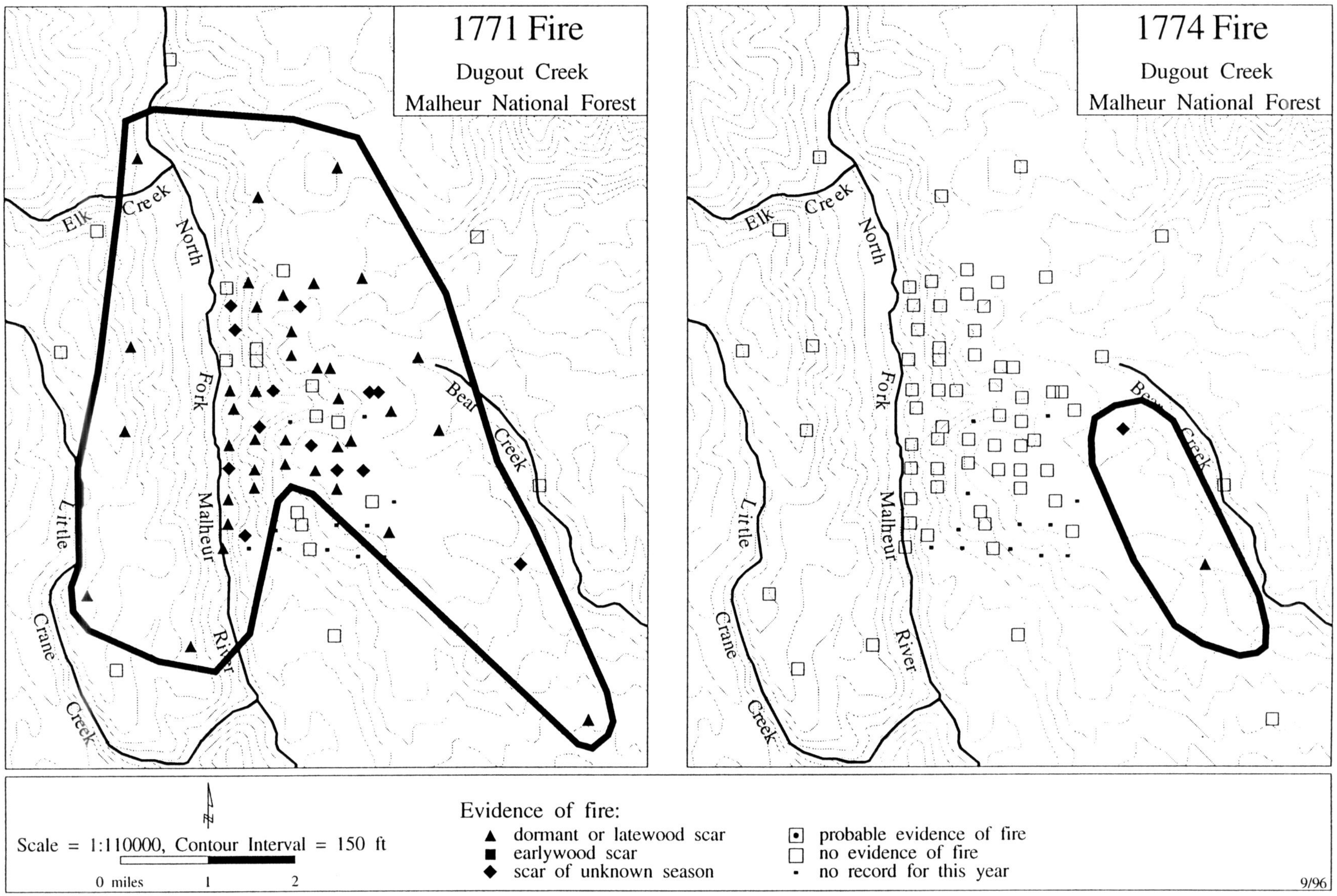
- ▲ dormant or latewood scar
- ■ earlywood scar
- ◆ scar of unknown season
- ⊡ probable evidence of fire
- □ no evidence of fire
- ▪ no record for this year

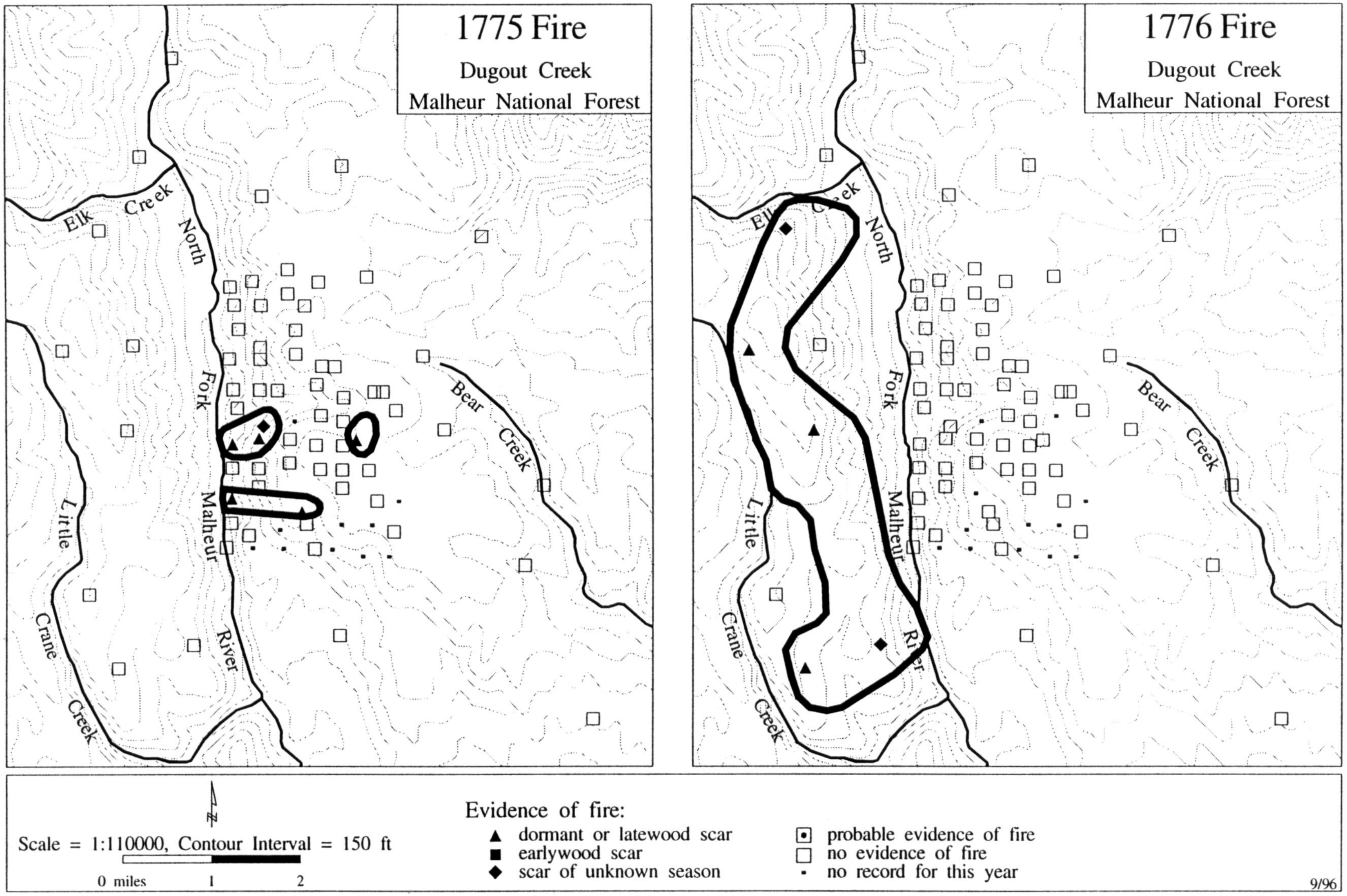
9/96

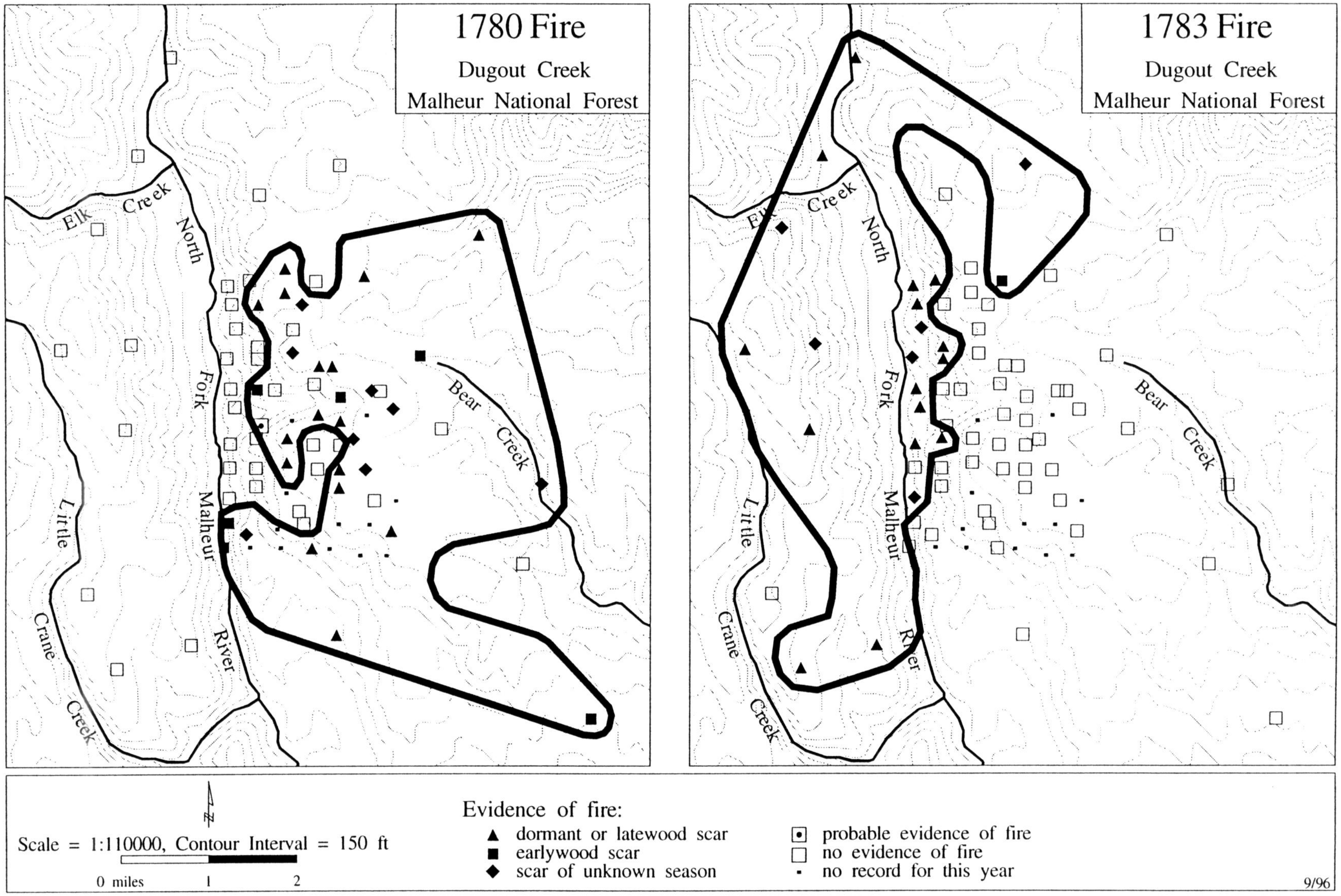

1751 Fire
Dugout Creek
Malheur National Forest
1753 Fire
Dugout Creek
Malheur National Forest
Elk Creek
North Fork Malheur River
Bear Creek
Little Crane Creek
Scale = 1:110000, Contour Interval = 150 ft
0 miles 1 2
N
Evidence of fire:
dormant or latewood scar
earlywood scar
scar of unknown season
probable evidence of fire
no evidence of fire
no record for this year
9/96

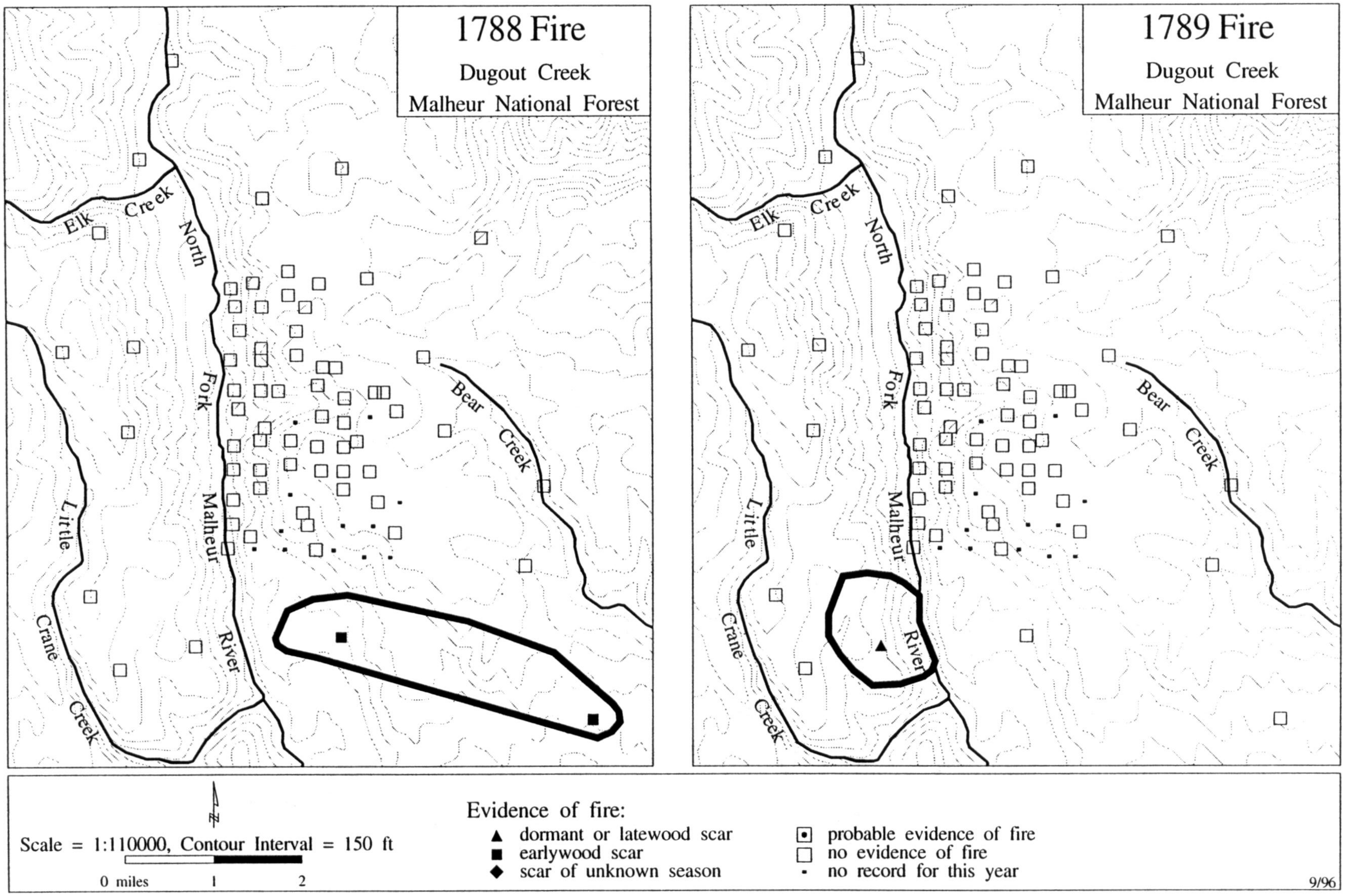

1755 Fire
Dugout Creek
Malheur National Forest
1756 Fire
Dugout Creek
Malheur National Forest
Elk Creek
North Fork Malheur River
Bear Creek
Little Crane Creek
Scale = 1:110000, Contour Interval = 150 ft
0 miles 1 2
N
Evidence of fire:
dormant or latewood scar
earlywood scar
scar of unknown season
probable evidence of fire
no evidence of fire
no record for this year
9/96

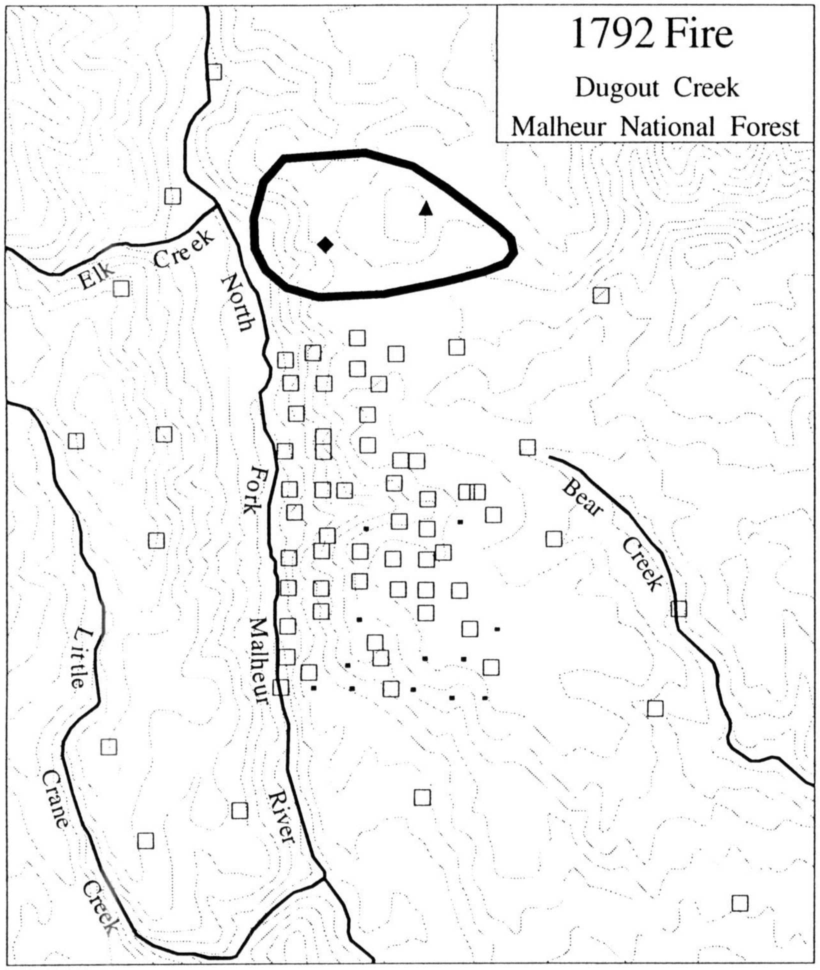

1759 Fire
Dugout Creek
Malheur National Forest
1765 Fire
Dugout Creek
Malheur National Forest
Elk Creek
North Fork Malheur River
Bear Creek
Little Crane Creek
Scale = 1:110000, Contour Interval = 150 ft
0 miles 1 2
Evidence of fire:
dormant or latewood scar
earlywood scar
scar of unknown season
probable evidence of fire
no evidence of fire
no record for this year
9/96

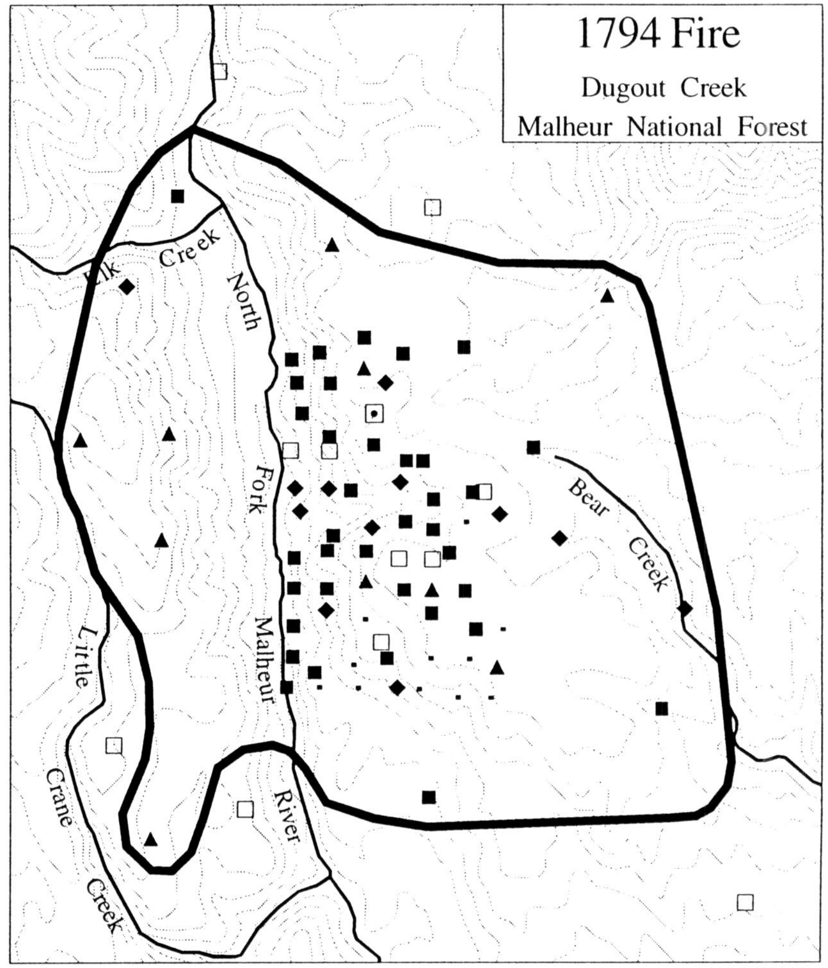

1771 Fire
Dugout Creek
Malheur National Forest
Elk Creek
North Fork Malheur River
Little Crane Creek
Bear Creek
1774 Fire
Dugout Creek
Malheur National Forest
Scale = 1:110000, Contour Interval = 150 ft
0 miles 1 2
Evidence of fire:
dormant or latewood scar
earlywood scar
scar of unknown season
probable evidence of fire
no evidence of fire
no record for this year
9/96


1775 Fire
Dugout Creek
Malheur National Forest
1776 Fire
Dugout Creek
Malheur National Forest
Elk Creek
North Fork Malheur River
Bear Creek
Little Crane Creek
Scale = 1:110000, Contour Interval = 150 ft
0 miles 1 2
Evidence of fire:
▲ dormant or latewood scar
■ earlywood scar
◆ scar of unknown season
probable evidence of fire
no evidence of fire
no record for this year
9/96


1780 Fire
Dugout Creek
Malheur National Forest
Elk Creek
North Fork Malheur River
Bear Creek
Little Crane Creek
1783 Fire
Dugout Creek
Malheur National Forest
Scale = 1:110000, Contour Interval = 150 ft
0 miles
1
2
Evidence of fire:
dormant or latewood scar
earlywood scar
scar of unknown season
probable evidence of fire
no evidence of fire
no record for this year
9/96


1788 Fire
Dugout Creek
Malheur National Forest
1789 Fire
Dugout Creek
Malheur National Forest
Elk Creek
North Fork Malheur River
Bear Creek
Little Crane Creek
Scale = 1:110000, Contour Interval = 150 ft
0 miles
1
2
Evidence of fire:
▲ dormant or latewood scar
■ earlywood scar
◆ scar of unknown season
probable evidence of fire
no evidence of fire
no record for this year
9/96





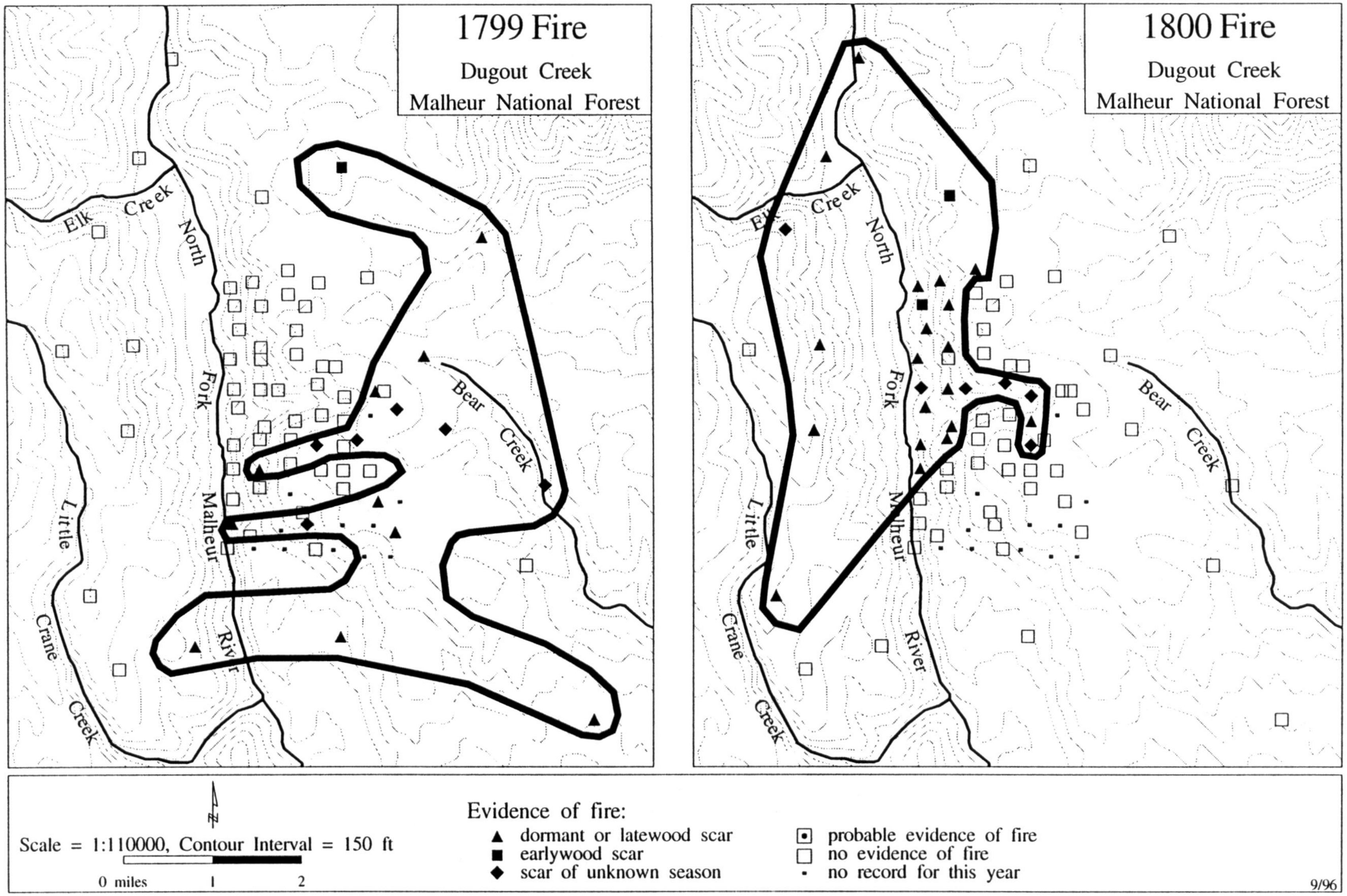
Scale = 1:110000, Contour Interval = 150 ft

0 miles 1 2

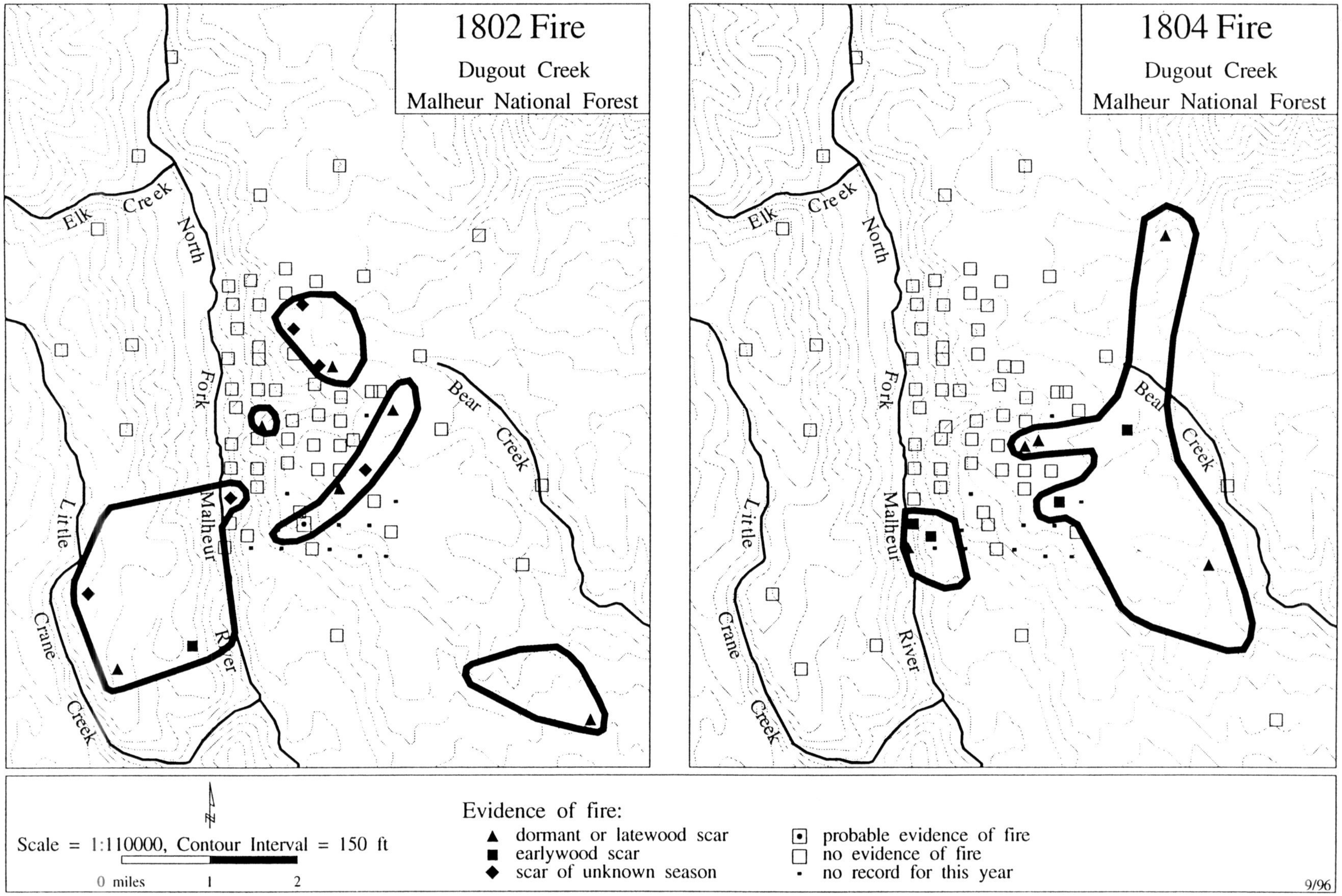
Evidence of fire:

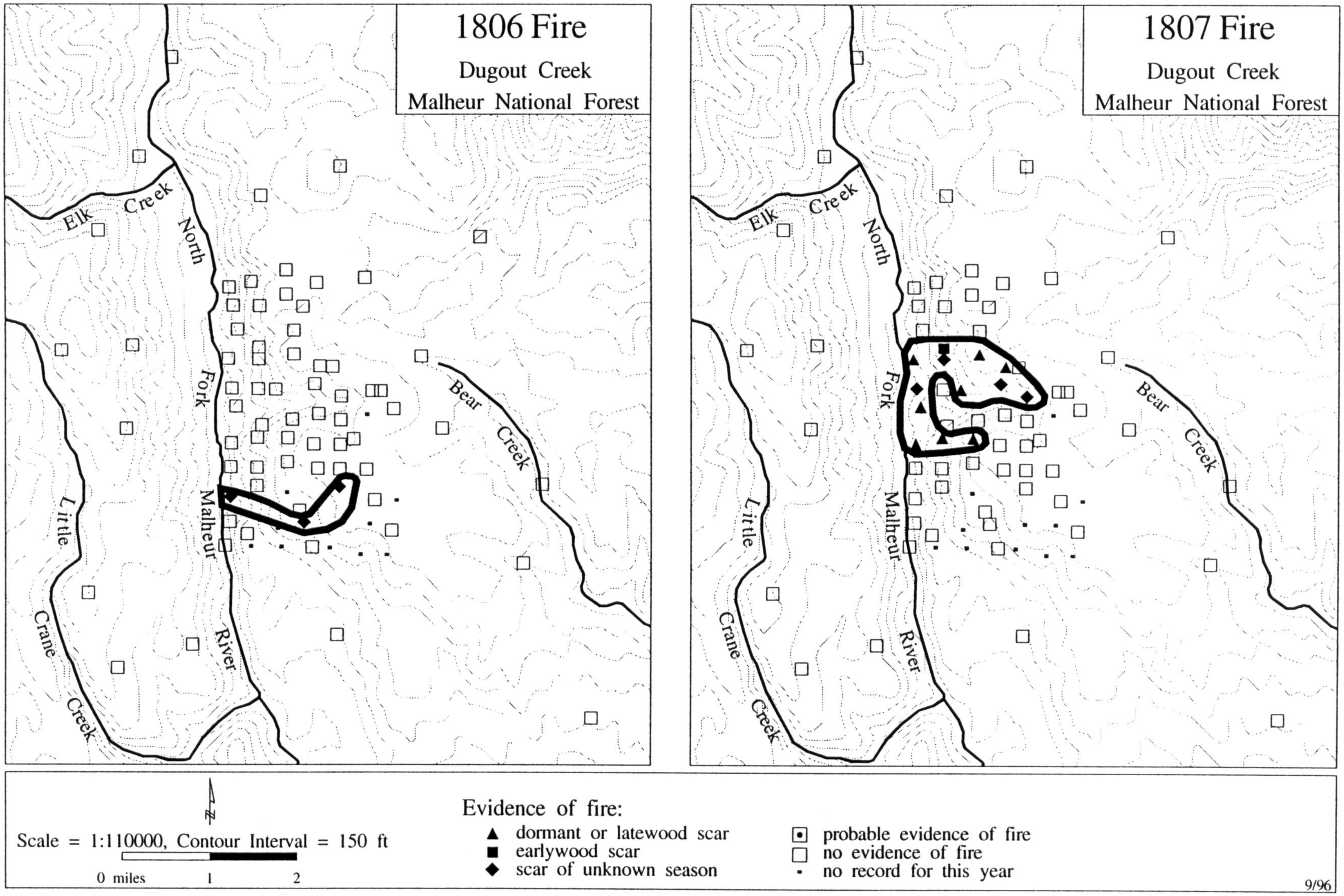
- ▲ dormant or latewood scar
- ■ earlywood scar
- ◆ scar of unknown season
- ⊡ probable evidence of fire
- □ no evidence of fire
- ▪ no record for this year

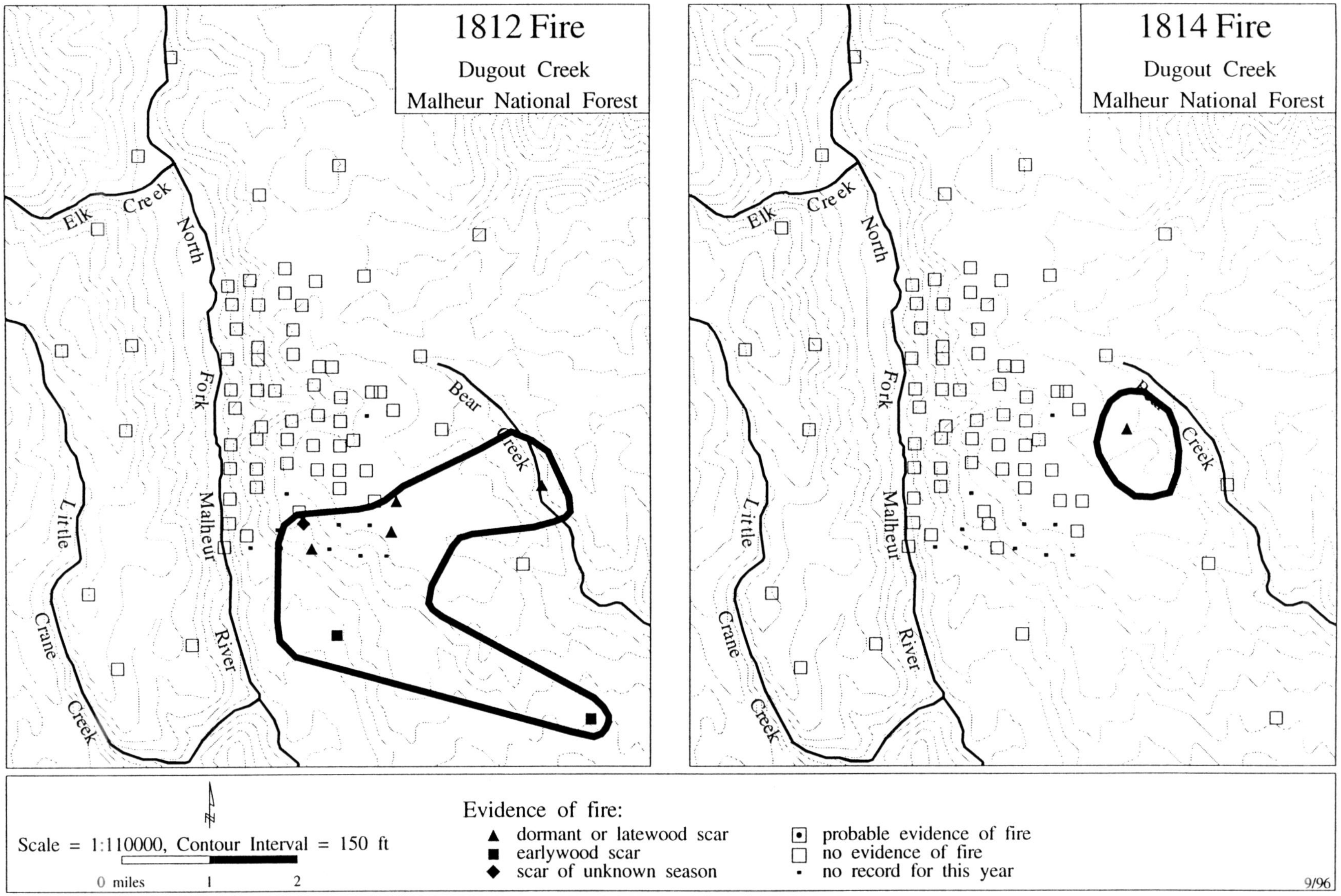
9/96

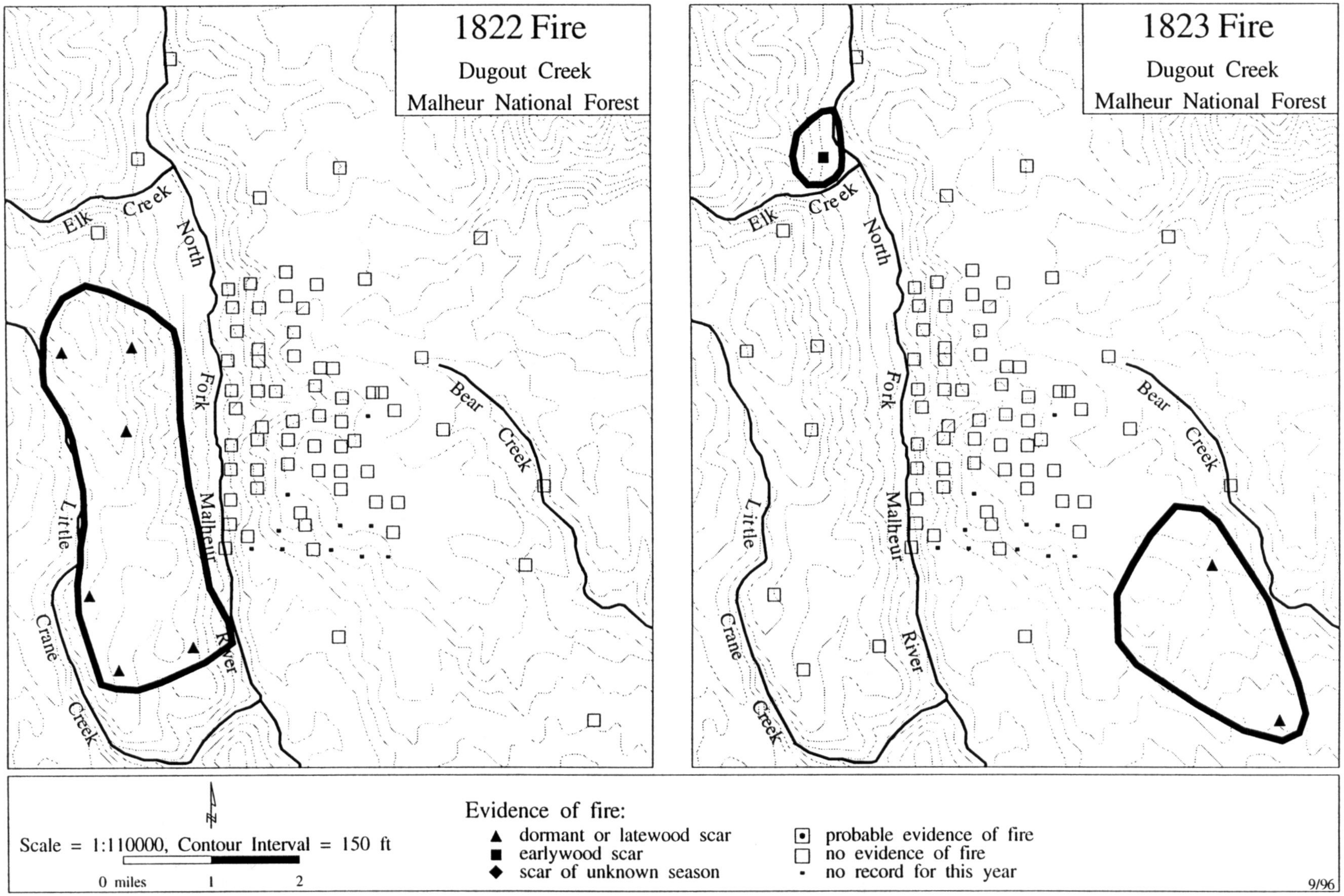


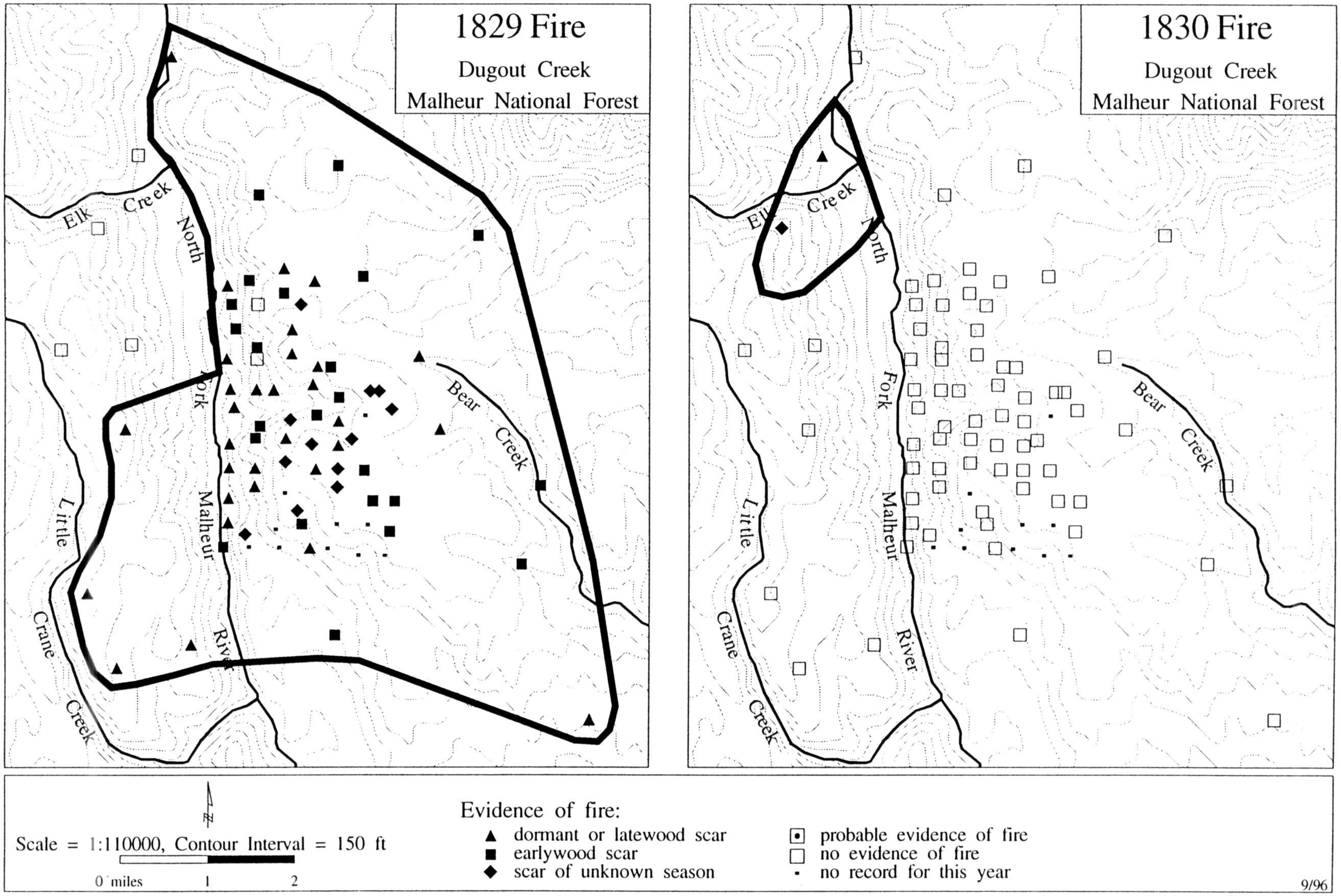
1799 Fire
Dugout Creek
Malheur National Forest
1800 Fire
Dugout Creek
Malheur National Forest
Elk Creek
North Fork Malheur River
Bear Creek
Little Crane Creek
Scale = 1:110000, Contour Interval = 150 ft
0 miles 1 2
Evidence of fire:
dormant or latewood scar
earlywood scar
scar of unknown season
probable evidence of fire
no evidence of fire
no record for this year
9/96

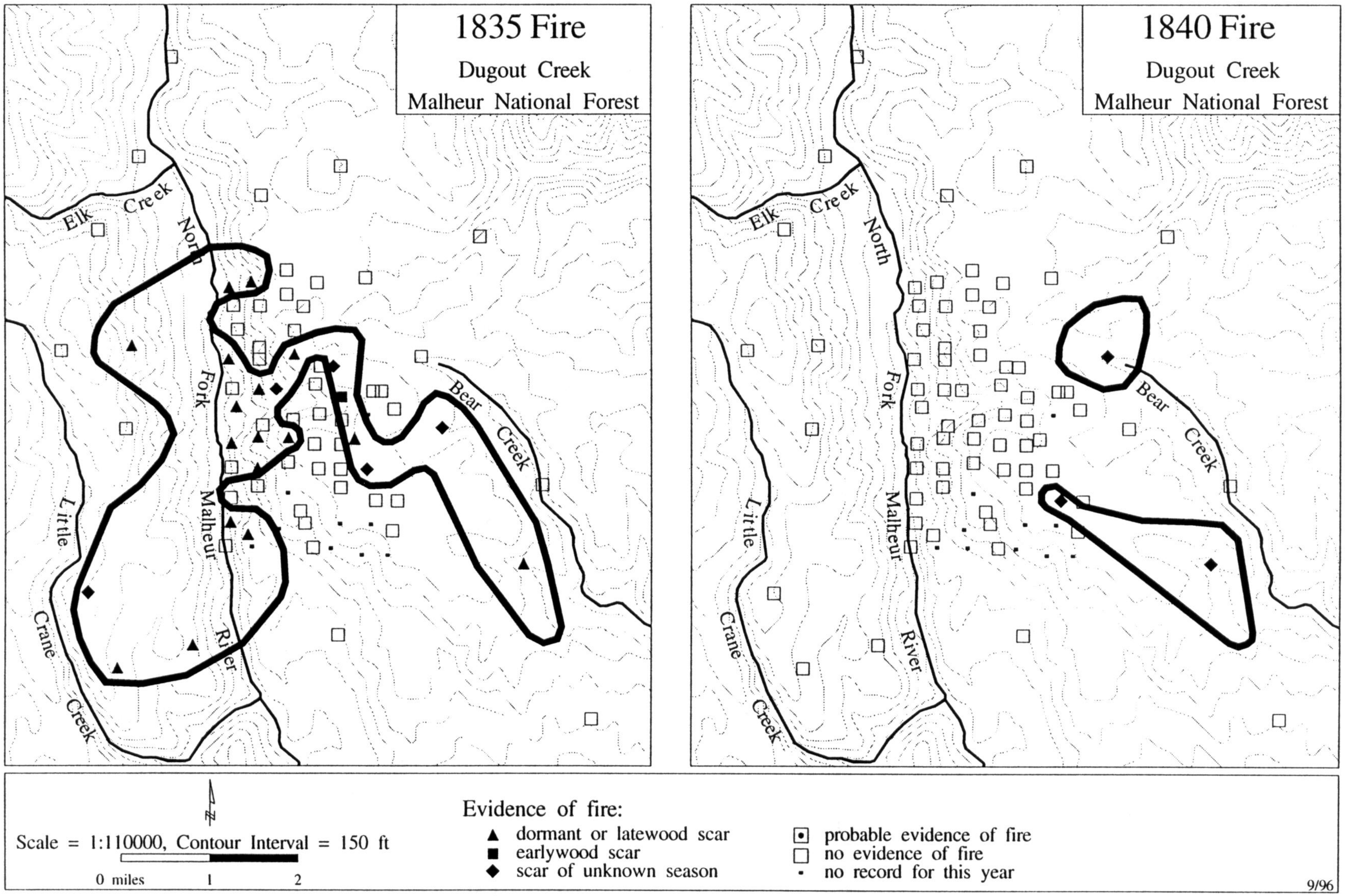

1802 Fire
Dugout Creek
Malheur National Forest
1804 Fire
Dugout Creek
Malheur National Forest
Elk Creek
North Fork Malheur River
Bear Creek
Little Crane Creek
Scale = 1:110000, Contour Interval = 150 ft
0 miles 1 2
Evidence of fire:
dormant or latewood scar
earlywood scar
scar of unknown season
probable evidence of fire
no evidence of fire
no record for this year
9/96

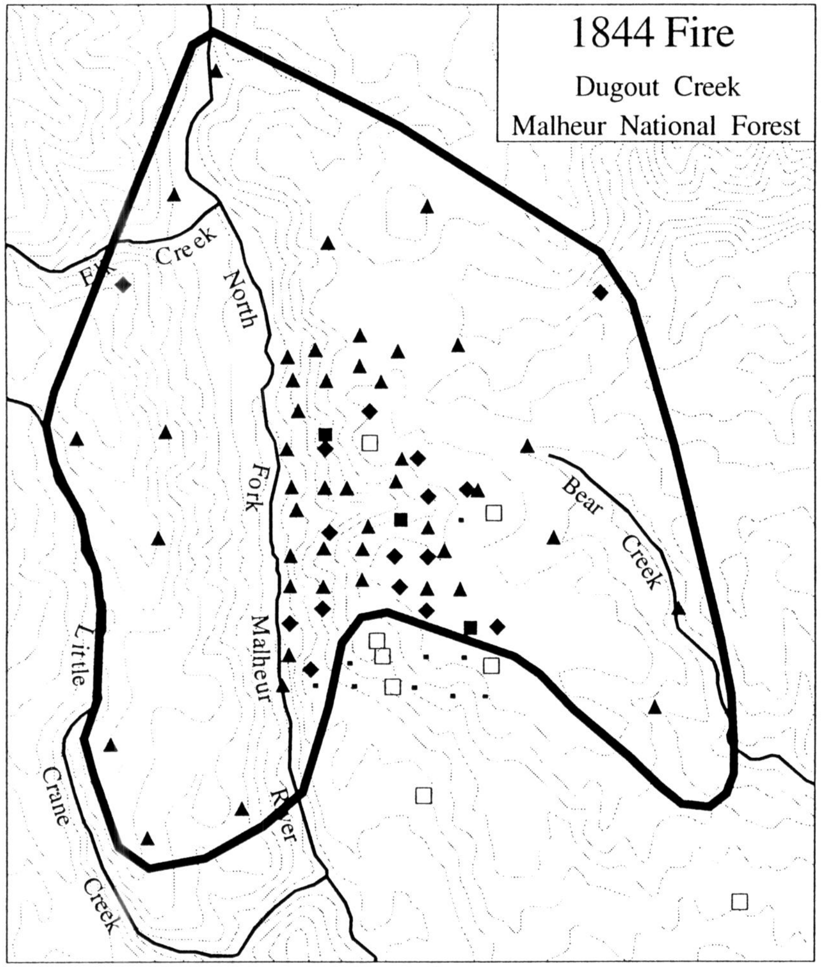

1806 Fire
Dugout Creek
Malheur National Forest
1807 Fire
Dugout Creek
Malheur National Forest
Elk Creek
North Fork Malheur River
Bear Creek
Little Crane Creek
Scale = 1:110000, Contour Interval = 150 ft
0 miles 1 2
Evidence of fire:
▲ dormant or latewood scar
■ earlywood scar
◆ scar of unknown season
probable evidence of fire
no evidence of fire
no record for this year
9/96

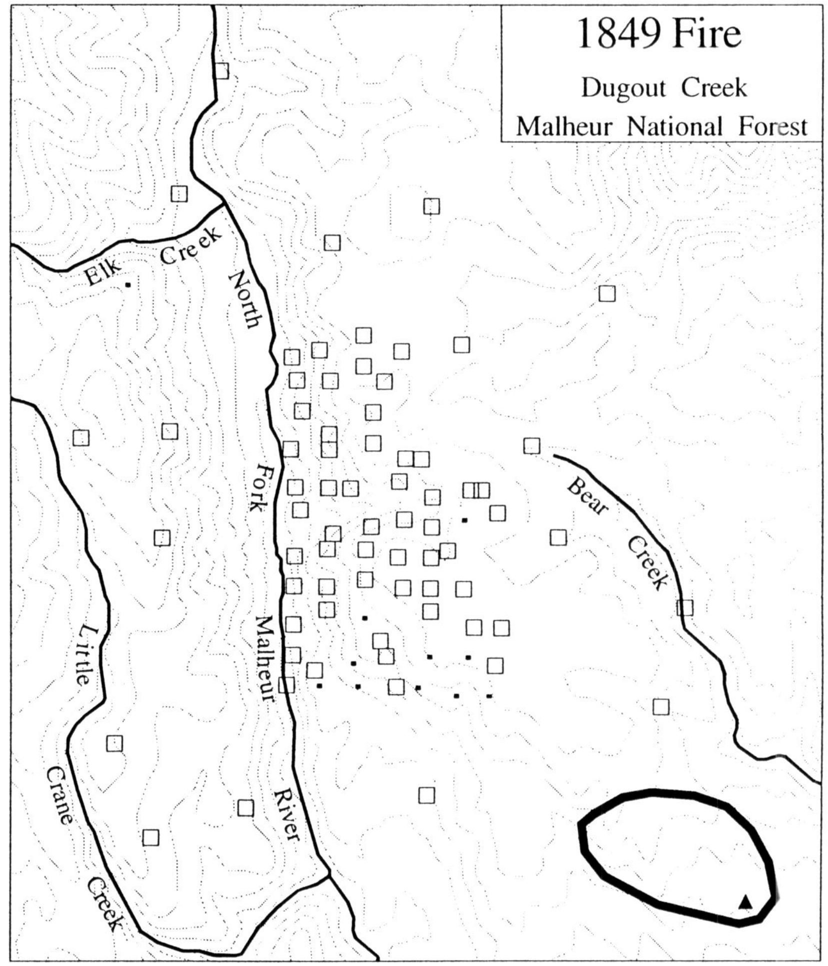

1812 Fire
Dugout Creek
Malheur National Forest
Elk Creek
North Fork Malheur River
Little Crane Creek
Bear Creek
1814 Fire
Dugout Creek
Malheur National Forest
Elk Creek
North Fork Malheur River
Little Crane Creek
Creek
Scale = 1:110000, Contour Interval = 150 ft
0 miles 1 2
Evidence of fire:
▲ dormant or latewood scar
■ earlywood scar
◆ scar of unknown season
probable evidence of fire
no evidence of fire
no record for this year
9/96


1822 Fire
Dugout Creek
Malheur National Forest
1823 Fire
Dugout Creek
Malheur National Forest
Elk Creek
North Fork Malheur River
Bear Creek
Little Crane Creek
Scale = 1:110000, Contour Interval = 150 ft
0 miles 1 2
Evidence of fire:
dormant or latewood scar
earlywood scar
scar of unknown season
probable evidence of fire
no evidence of fire
no record for this year
9/96


1829 Fire
Dugout Creek
Malheur National Forest
Elk Creek
North Fork Malheur River
Bear Creek
Little Crane Creek
1830 Fire
Dugout Creek
Malheur National Forest
Elk Creek
North Fork Malheur River
Bear Creek
Little Crane Creek
Scale = 1:110000, Contour Interval = 150 ft
0 miles 1 2
Evidence of fire:
dormant or latewood scar
earlywood scar
scar of unknown season
probable evidence of fire
no evidence of fire
no record for this year
9/96


1835 Fire
Dugout Creek
Malheur National Forest
Elk Creek
North Fork Malheur River
Bear Creek
Little Crane Creek
1840 Fire
Dugout Creek
Malheur National Forest
Elk Creek
North Fork Malheur River
Bear Creek
Little Crane Creek
N
Scale = 1:110000, Contour Interval = 150 ft
0 miles
1
2
Evidence of fire:
dormant or latewood scar
earlywood scar
scar of unknown season
probable evidence of fire
no evidence of fire
no record for this year
9/96





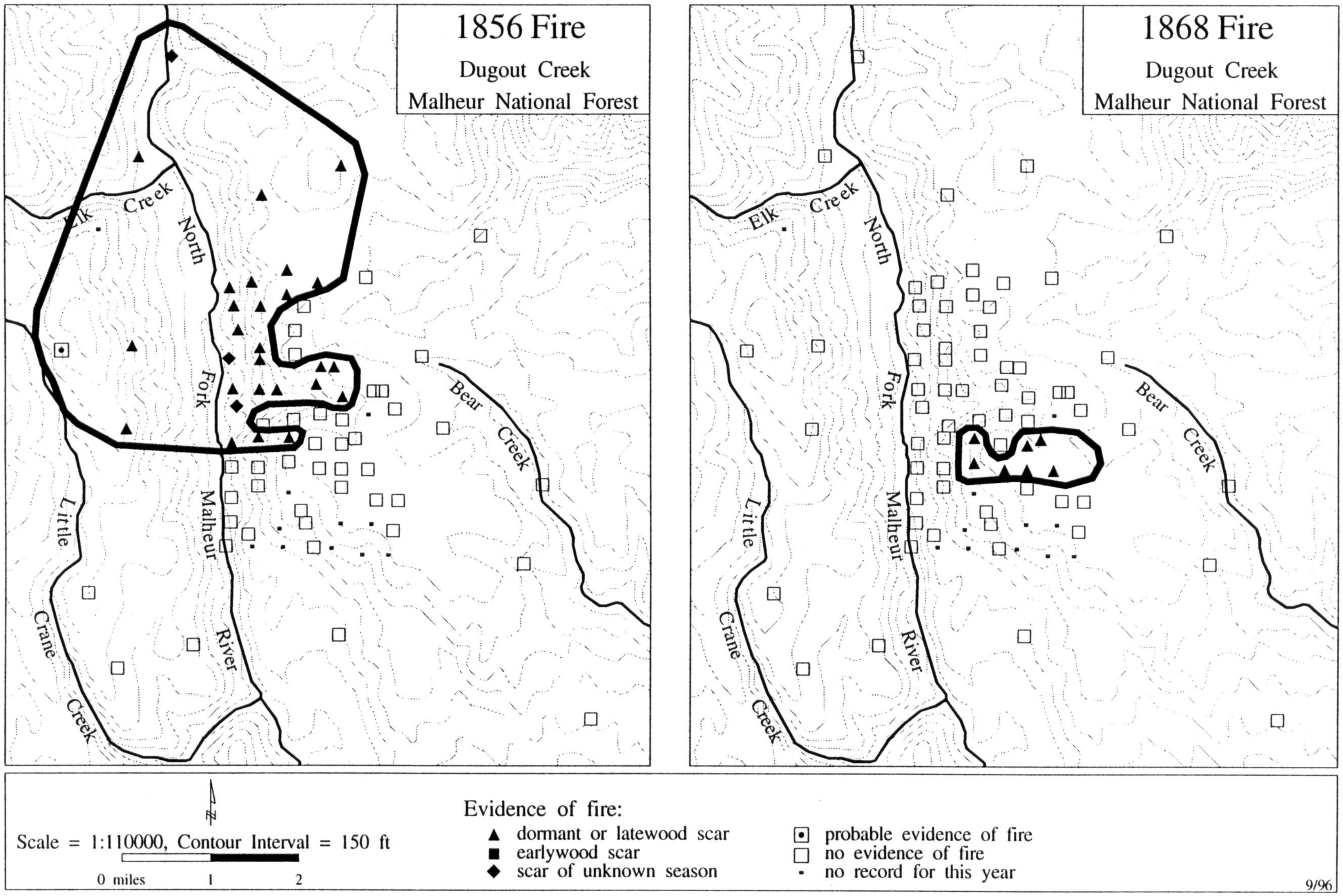
Scale = 1:110000, Contour Interval = 150 ft

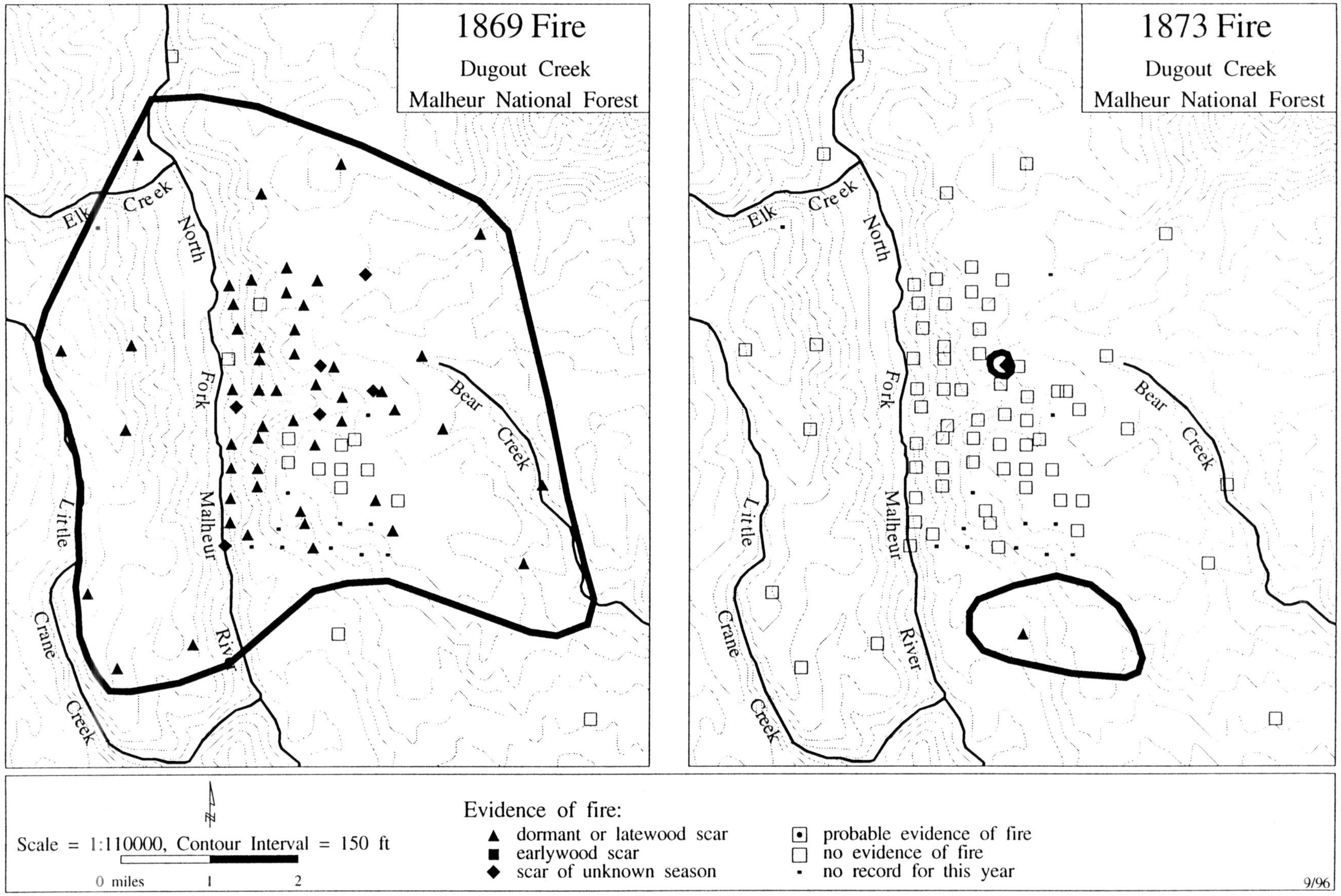
0 miles 1 2

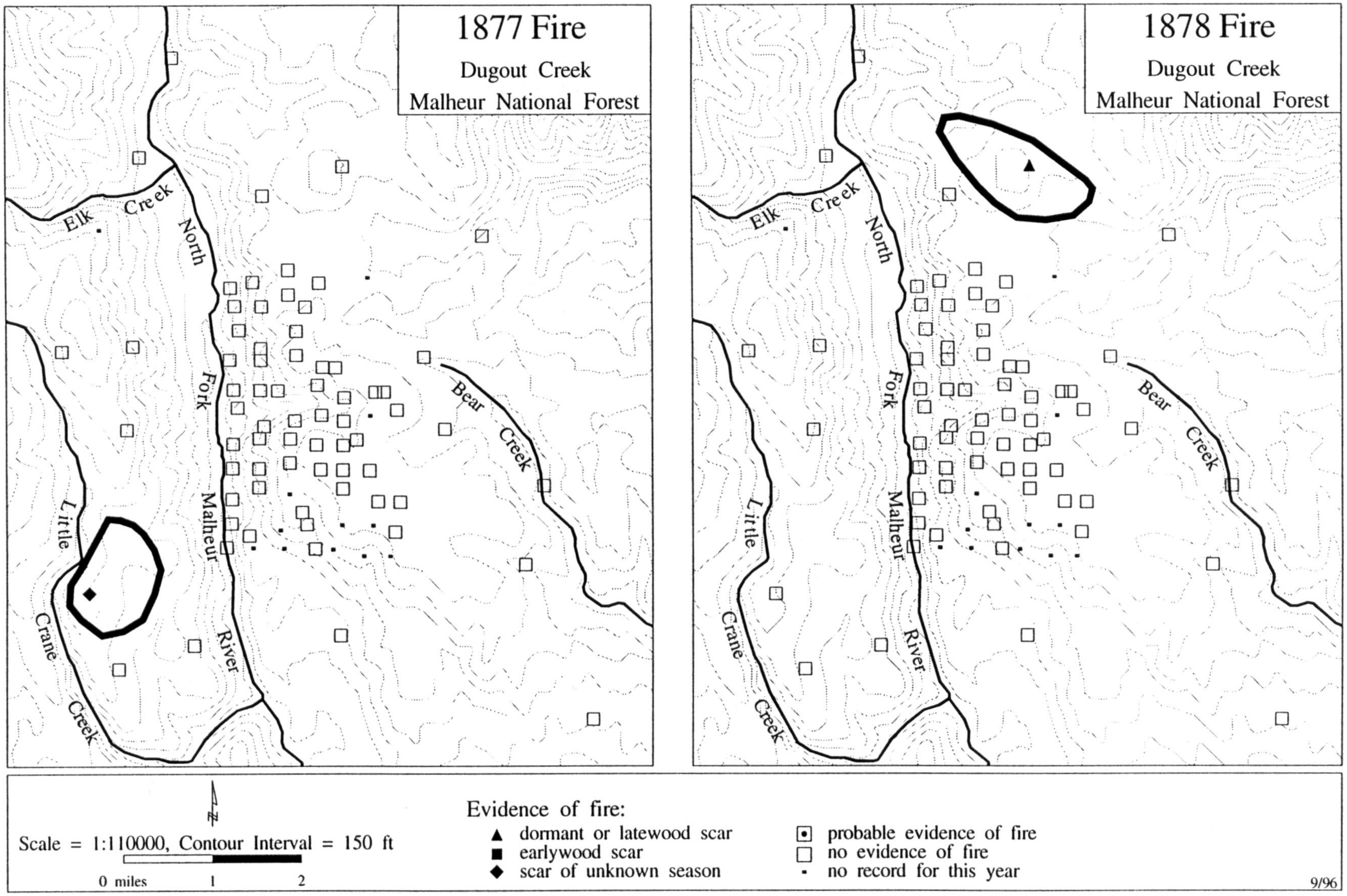
Evidence of fire:

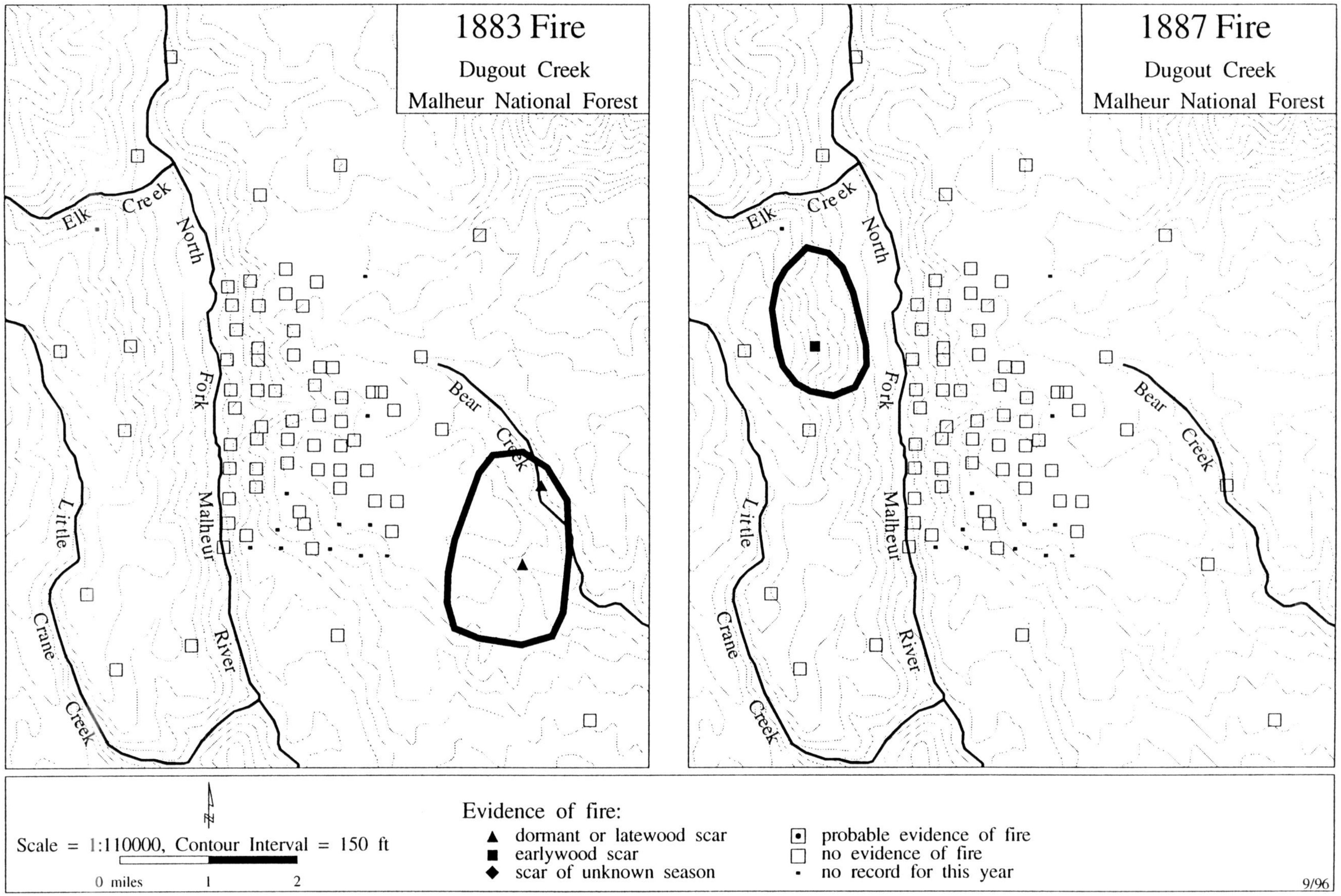
- ▲ dormant or latewood scar
- ■ earlywood scar
- ◆ scar of unknown season
- ⊡ probable evidence of fire
- □ no evidence of fire
- ▪ no record for this year

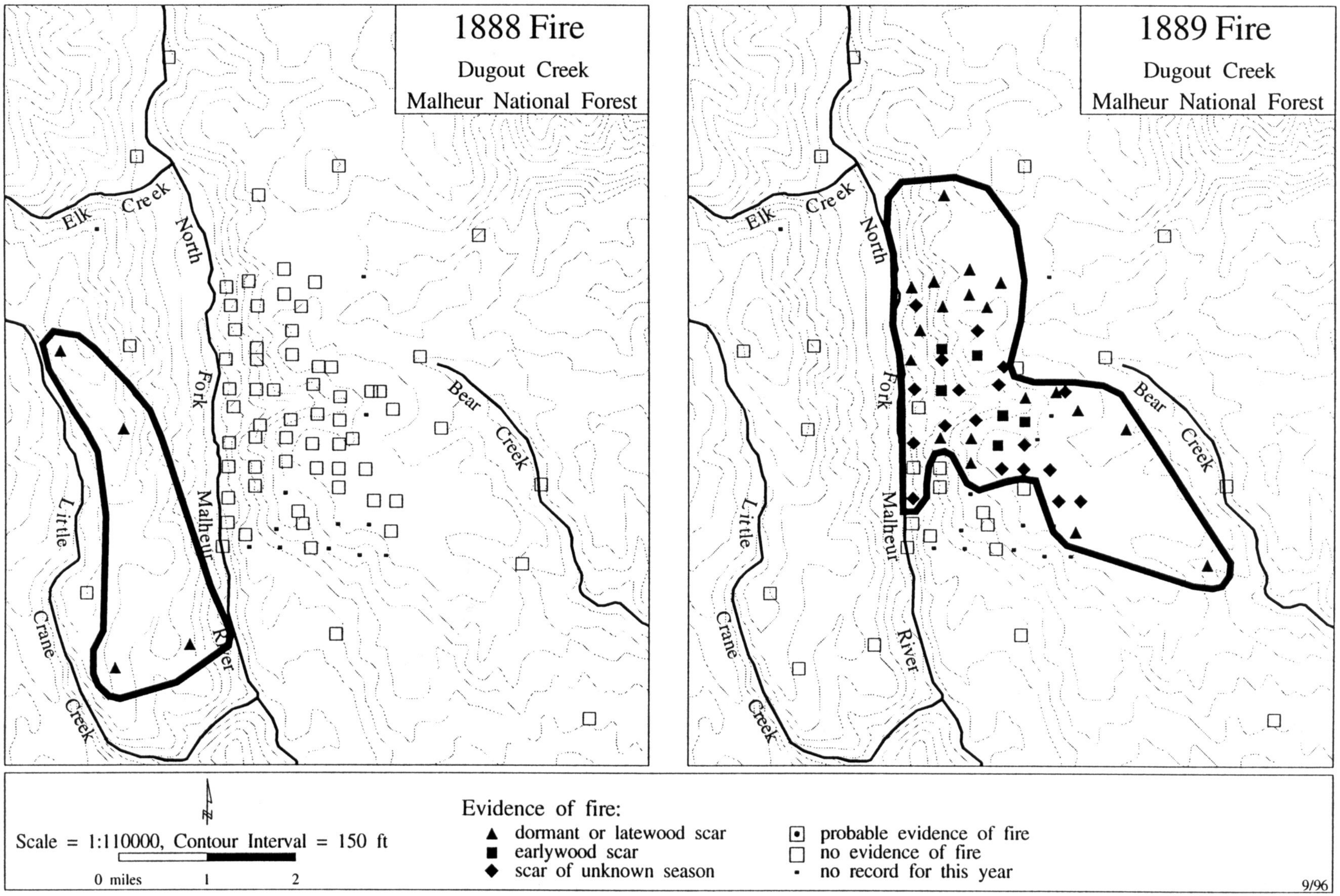
9/96

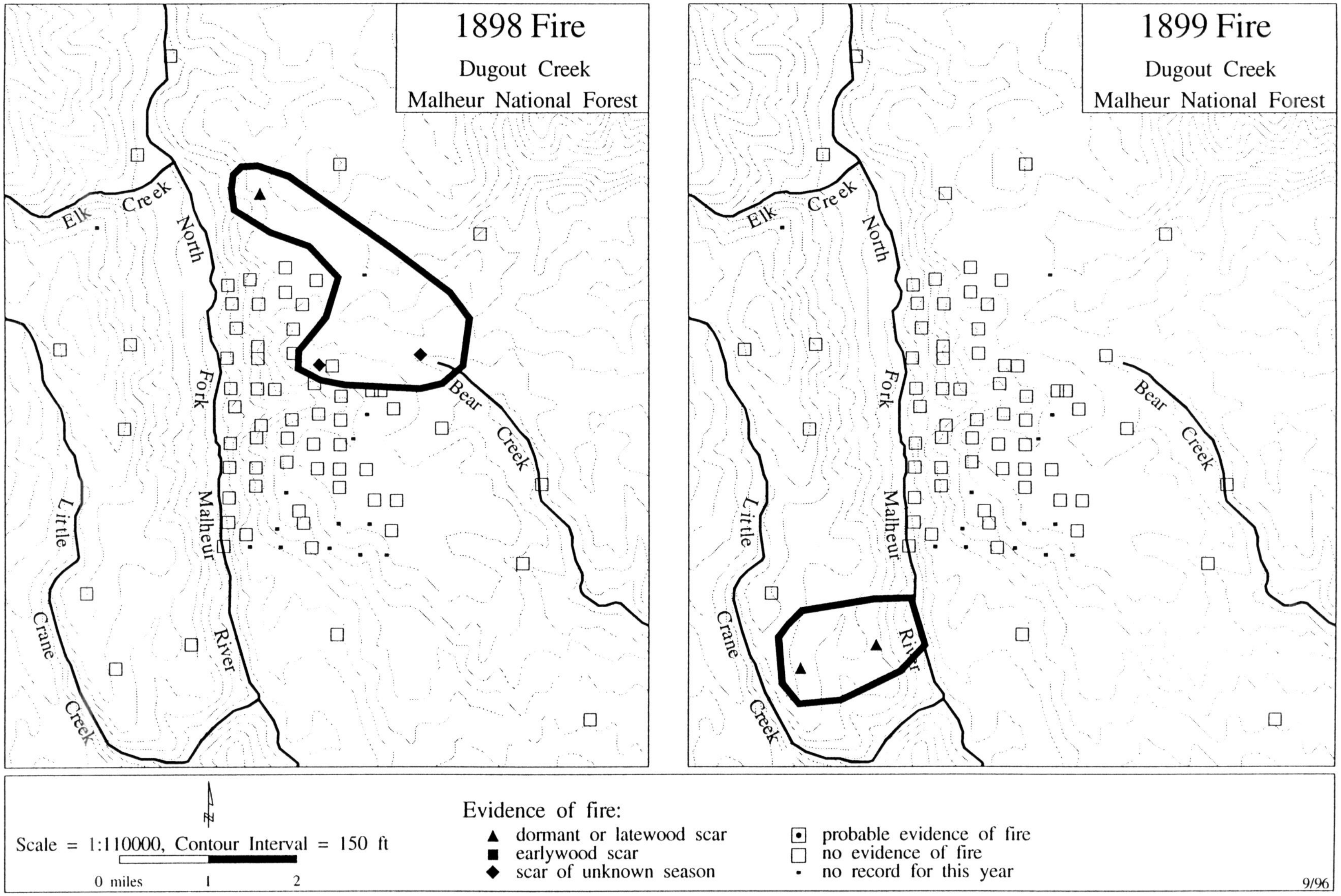

1856 Fire
Dugout Creek
Malheur National Forest
Elk Creek
North Fork Malheur River
Little Crane Creek
Bear Creek
1868 Fire
Dugout Creek
Malheur National Forest
Elk Creek
North Fork Malheur River
Little Crane Creek
Bear Creek
Scale = 1:110000, Contour Interval = 150 ft
0 miles 1 2
Evidence of fire:
dormant or latewood scar
earlywood scar
scar of unknown season
probable evidence of fire
no evidence of fire
no record for this year
9/96

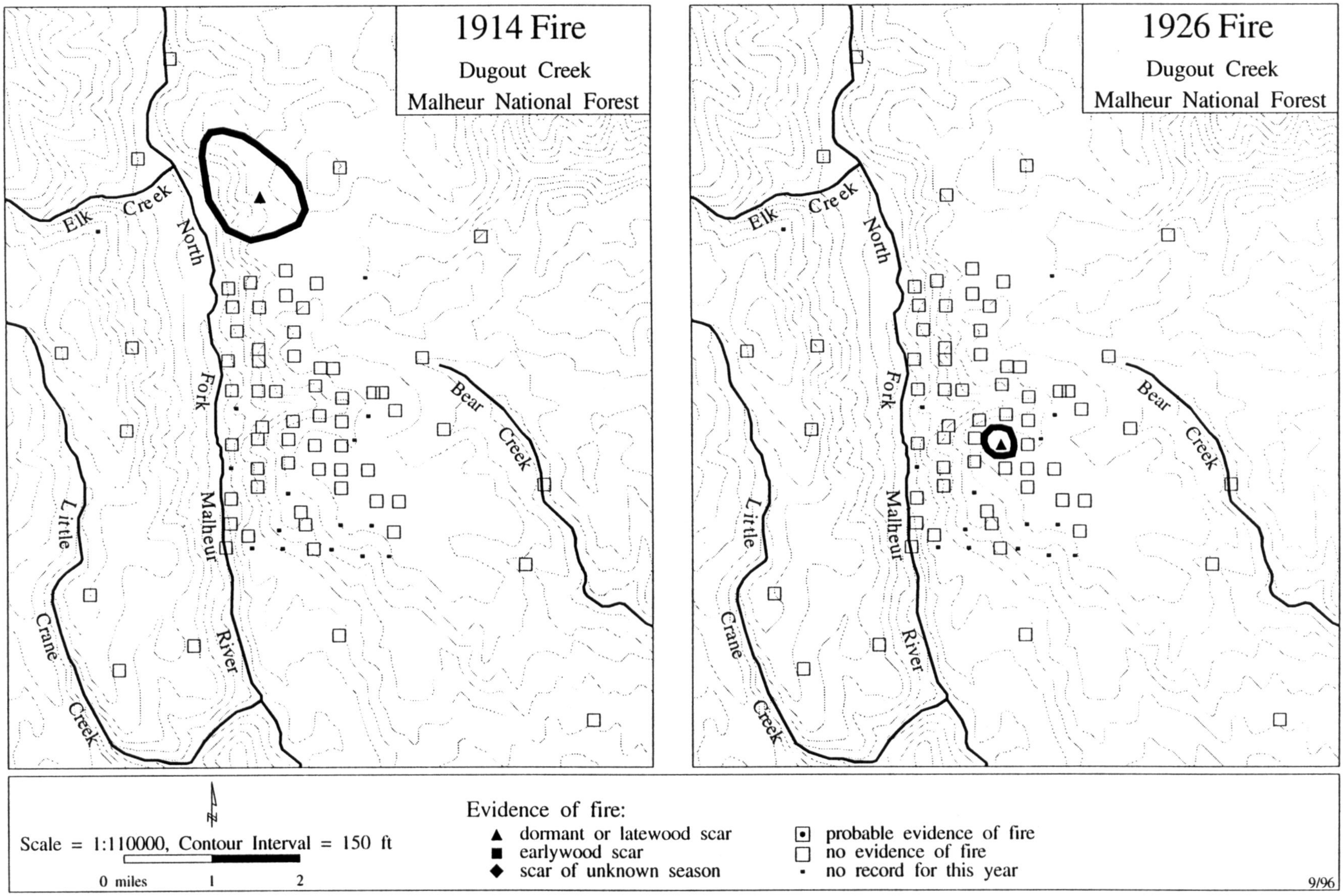

1869 Fire
Dugout Creek
Malheur National Forest
1873 Fire
Dugout Creek
Malheur National Forest
Elk Creek
North Fork Malheur River
Bear Creek
Little Crane Creek
Scale = 1:110000, Contour Interval = 150 ft
0 miles 1 2
Evidence of fire:
dormant or latewood scar
earlywood scar
scar of unknown season
probable evidence of fire
no evidence of fire
no record for this year
9/96


1877 Fire
Dugout Creek
Malheur National Forest
1878 Fire
Dugout Creek
Malheur National Forest
Elk Creek
North Fork Malheur River
Bear Creek
Little Crane Creek
Scale = 1:110000, Contour Interval = 150 ft
0 miles 1 2
Evidence of fire:
dormant or latewood scar
earlywood scar
scar of unknown season
probable evidence of fire
no evidence of fire
no record for this year
9/96


1883 Fire
Dugout Creek
Malheur National Forest
1887 Fire
Dugout Creek
Malheur National Forest
Elk Creek
North Fork Malheur River
Bear Creek
Little Crane Creek
Scale = 1:110000, Contour Interval = 150 ft
0 miles 1 2
Evidence of fire:
dormant or latewood scar
earlywood scar
scar of unknown season
probable evidence of fire
no evidence of fire
no record for this year
9/96


1888 Fire
Dugout Creek
Malheur National Forest
Elk Creek
North Fork Malheur River
Bear Creek
Little Crane Creek
1889 Fire
Dugout Creek
Malheur National Forest
Elk Creek
North Fork Malheur River
Bear Creek
Little Crane Creek
Scale = 1:110000, Contour Interval = 150 ft
0 miles 1 2
Evidence of fire:
▲ dormant or latewood scar
■ earlywood scar
◆ scar of unknown season
probable evidence of fire
no evidence of fire
no record for this year
9/96


1898 Fire
Dugout Creek
Malheur National Forest
Elk Creek
North Fork Malheur River
Bear Creek
Little Crane Creek
1899 Fire
Dugout Creek
Malheur National Forest
Elk Creek
North Fork Malheur River
Bear Creek
Little Crane Creek
Scale = 1:110000, Contour Interval = 150 ft
0 miles
1
2
Evidence of fire:
▲ dormant or latewood scar
■ earlywood scar
◆ scar of unknown season
probable evidence of fire
no evidence of fire
no record for this year
9/96


1914 Fire
Dugout Creek
Malheur National Forest
Elk Creek
North Fork Malheur River
Little Crane Creek
Bear Creek
1926 Fire
Dugout Creek
Malheur National Forest
Elk Creek
North Fork Malheur River
Little Crane Creek
Bear Creek
Scale = 1:110000, Contour Interval = 150 ft
0 miles 1 2
Evidence of fire:
dormant or latewood scar
earlywood scar
scar of unknown season
probable evidence of fire
no evidence of fire
no record for this year
9/96

APPENDIX H: FIRE INTERVALS IN DRY FORESTS

In this appendix, we provide details of the distribution of fire intervals in dry forests at each of the four sampling sites.

Table H1. Fire intervals, in years, for dry forests (1687-1900). Data are percentiles of the sampled interval distribution summed over all plots at each site. These data are plotted in Figure 15.

Site	Number of intervals	percentile 10th	25th	50th	75th	90th
Tucannon	107	11	15	23	50	91
Imnaha	200	12	17	25	36	51
Baker	393	5	7	11	16	25
Dugout	922	5	8	12	20	25

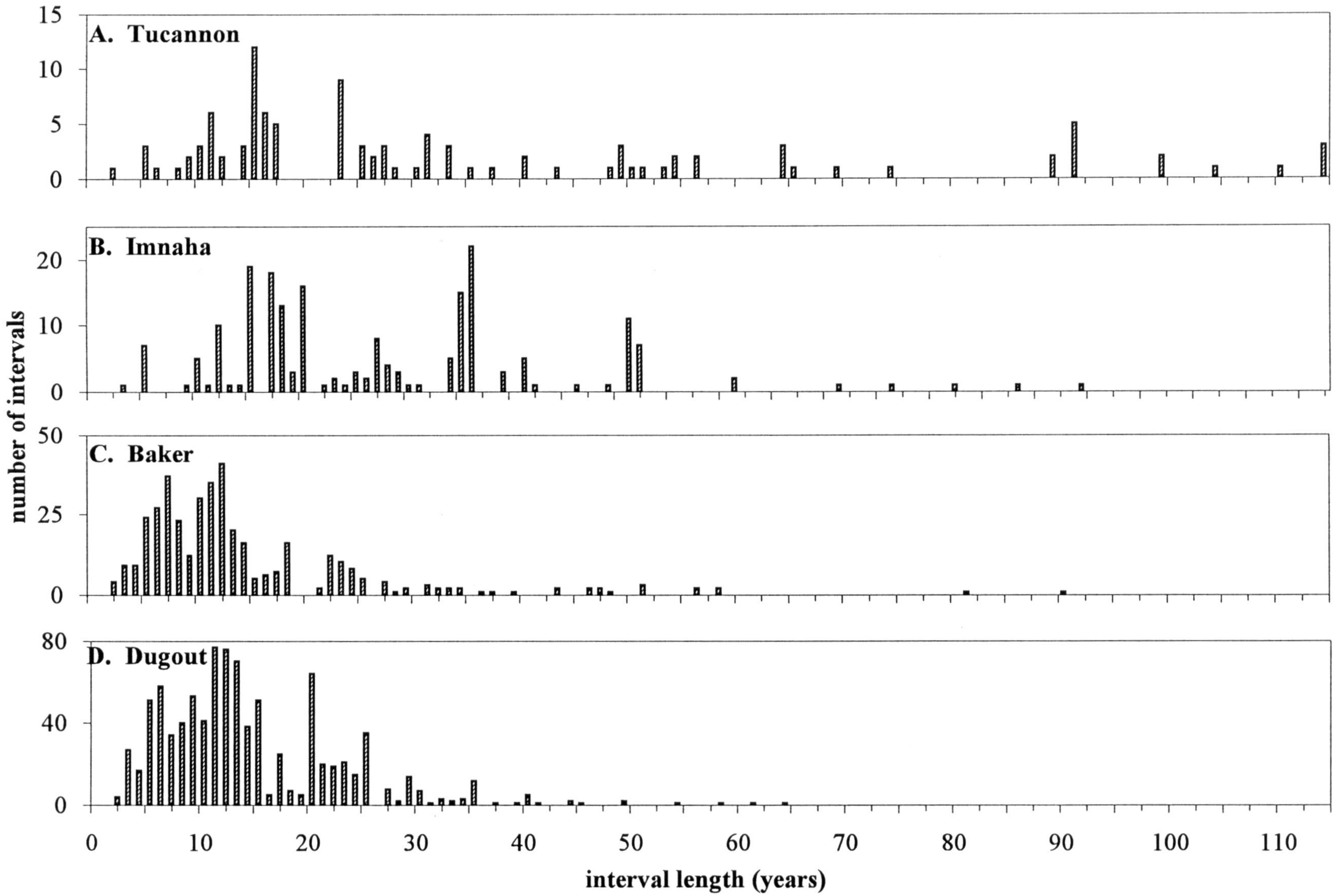


Figure H1. Distribution of fire intervals in dry forests, by interval length classes. Data are summed over all plots at each site. These data show the skewed distribution typical of fire intervals. These data are summarized in Figure 15.