A Report to The Nature Conservancy on the Historical and Current Stand Structure in the Sinlahekin Wildlife Area

Schellhaas Forestry, LLC

Richard Schellhaas , Anne Conway, Don Spurbeck

A Report to The Nature Conservancy on the Historical and Current Stand Structure in the Sinlahekin Wildlife Area

Schellhaas Forestry, LLC

Richard Schellhaas, Anne Conway, Don Spurbeck

12/13/2009

Cover Photos taken at Sinlahekin Wildlife Area Blue Lake looking northwest toward Sinlahekin Creek Canyon. Original historic photo at Okanogan Co. Historical Society.

Acknowledgements: The authors thank Dale Swedberg for his assistance, information and photographs. Todd Chaudhry, and Dale Swedberg for their review, comments and suggestions. We also thank Eric Spurbeck for his assistance in the data collection and review of this report.

Table of Contents

Introduction

Forests in the Douglas-fir and ponderosa pine series (Franklin and Dryness 1988) on the eastern slope of the Washington Cascades historically developed under a predominantly high frequency, low-severity fire regime, although fires of moderate and high severity also occurred (Agee 1994, Everett *et al.* 1999b). Previous studies on the Okanogan National Forest found historical mean fire-free intervals of 10 to 24 years (Finch 1984), 7.5 to 7.7 years (Ohlson 1996), and 6.3 to 11.4 years (Everett *et al.* 2000). These frequent, low-intensity fires prevented large amounts of fuel from accumulating and limited the establishment of young trees while causing minimal mortality to the established overstory trees (Agee 1994). Resulting forest stands were mostly open and park-like (Plummer 1902, Cowlin *et al.* 1942, Gorman 1899).

During the last century, fires have been excluded from many of these stands. As a result, surface fuels and thickets of small trees have developed to a point where high-intensity, stand-replacing fires are becoming increasingly common (Covington and Moore 1994, Arno *et al.* 1995, Camp 1999). Since fire suppression began around 1910, eastern Washington forests have been dramatically altered. Both stocking levels and species composition have changed (Everett *et al.* 1996) with trees in the Douglas-fir, ponderosa pine plant series increasing in density by 422% (Everett *et al.* 2007). This increase in tree density has favored the climax species, Douglas-fir.

A change in species composition has created a forest health problem, putting these stands at risk to both insects and diseases that are attracted to low-vigor, stressed trees (Flanagan 1998). In turn there is an increase in both live and dead fuels, predisposing these sites to stand replacement fires (Agee 1993, Agee 1994, Schellhaas *et al.* 2000). Forests like these along with others in Eastern Washington are no longer in sync with the inherent historical fire regimes (Everett *et al.* 1996, 2000). This stand and similar sites were once dominated by mature ponderosa pine and western larch and were maintained by frequent low to mixed severity fires every 5 – 12 years (Schellhaas *et al.* 2002).

The following graph (Figure 1) shows fires which burned near Frosty Creek (7 miles west of Republic) in Okanogan County from 1600 to present.

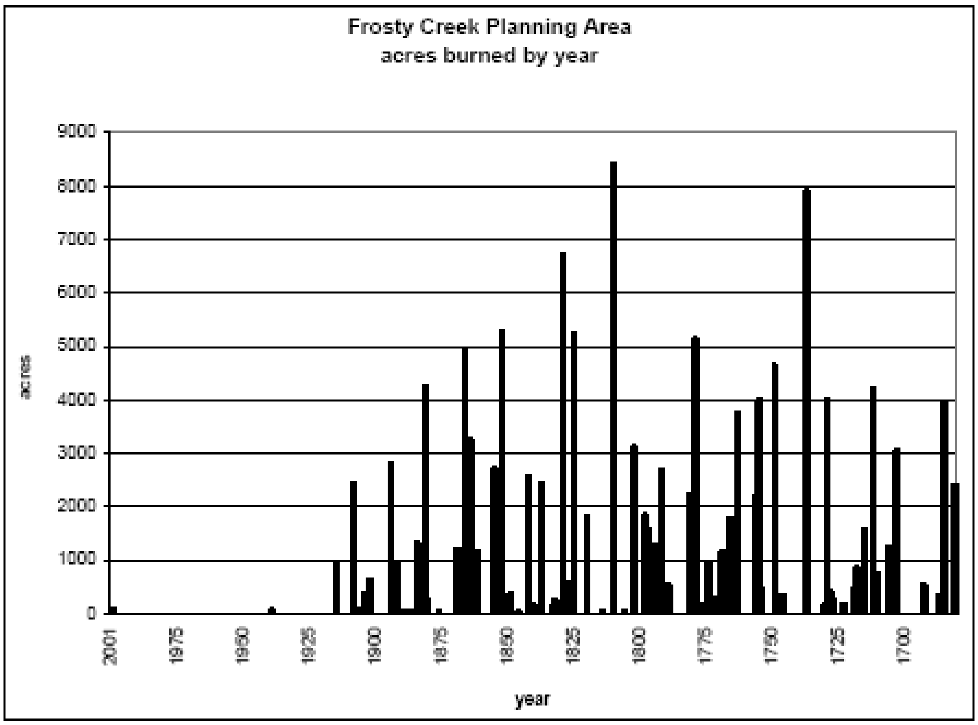


Figure 1. Note the dramatic decrease in the number and sizes of fires after 1910 (fire suppression era). This is the trend for Eastern Washington forests (Schellhaas 2002).

By utilizing tree-ring analysis we were able to reconstruct stand conditions for the last 113 years. The most direct and presumably most accurate approach to reconstruct pre-settlement vegetation is through the use of live and dead plant materials (Bonnicksen and Stone 1982). We chose this time frame because the 1896 fire was the last major historical fire and assessing stand conditions any further back in time would return biased results due to the loss of the tree record and the confounding effects of past fires. One hundred years ago these forests were not affected by the changes in the historical fire regimes that began shortly after 1900 (Arno *et al.* 1995).

The goal of this study is to quantify historical diameter distributions, tree densities and species compositions that were found in the Sinlahekin and Sarsapkin Creek units prior to 1900.

Site Selection

Two areas were selected within the Sinlahekin Valley for this study (Figure 2). The Sarsapkin and Sinlahekin units were selected for study by the Sinlahekin Wildlife Area manager and the Eastern Washington Forests Program Manager for The Nature Conservancy. The Sinlahekin Creek unit (54 acres) and the Sarsapkin Creek Unit (56 acres) are both on the west side of the Sinlahekin Valley and located on alluvial fans at the base of their individual drainages with streams flowing through them. The elevation is approximately 1800 feet on very gentle slopes (<10%). Both units are forested on extremely rocky shallow soils. They are in the PIPO *(Pinus ponderosa*)/ PSME *(Pseudotsuga menziesii*) and PSME/ SYAL *(Symphoricarpus albus*) plant associations (Clinton and Lillybridge 1983, Lillybridge *et al.*, 1996). There is a trace of western larch in the Sinlahekin unit.

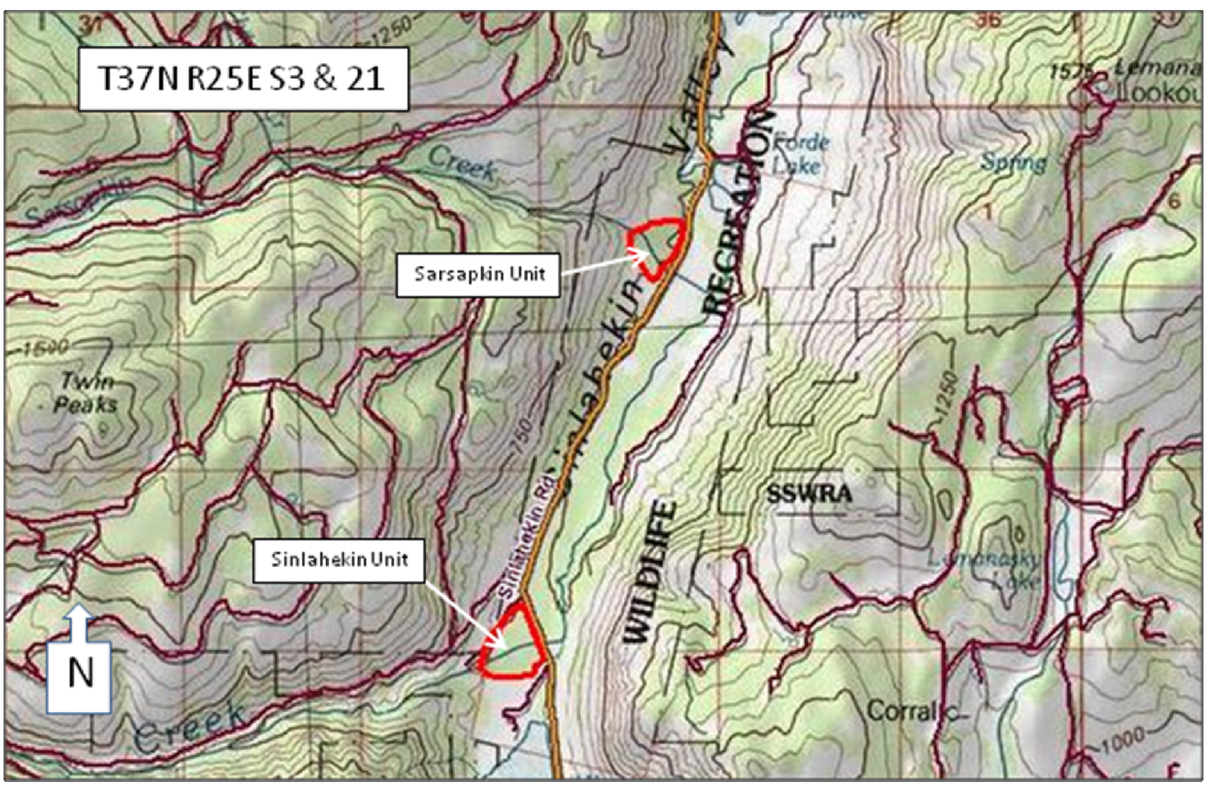


Figure 2. Study Areas

To determine historic stand structure it is best to sample undisturbed areas since logging or prescribed fire could confound the ability to reconstruct historical stand conditions (Ohlson and Schellhaas 2002). The Sarsapkin unit is still essentially intact with only a few remnant stumps from logging in the late 1930s. Conversely, the Sinlahekin unit has been disturbed by two extensive logging entries; first in the late 1930s and again in approximately 1970. The logging activities removed most of the mature overstory and the remnant stumps are highly decomposed making it difficult to reconstruct the original tree diameters and ages.

Field Methods

Stand types within the Sinlahekin and Sarsapkin units were delineated into three crown cover classes using current (2006) aerial photos. <u>Stand Type A</u> in greater than 70% crown cover, <u>Stand Type B</u> is 40 to 70% crown cover and <u>Stand Type C</u> is 10 to 40% crown cover (Figure 3, 4). The sampling design was a stratified random sample (Avery 1967) where 27 1/10 acre fixed radius plots were installed. Both stands A and B had 6 plots each and stand C had 15 plots. All plots were evenly distributed within each stand type. This sample will yield an 80% confidence interval plus or minus 20% of the mean. The coefficient of variation (CV) for stands A and B is 46% and 71% for stand C.

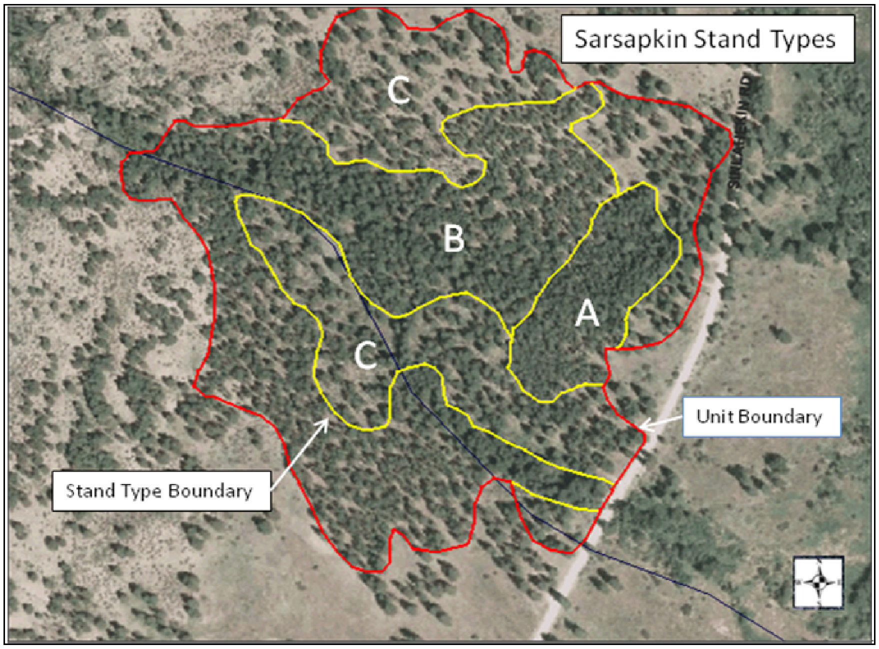


Figure 3

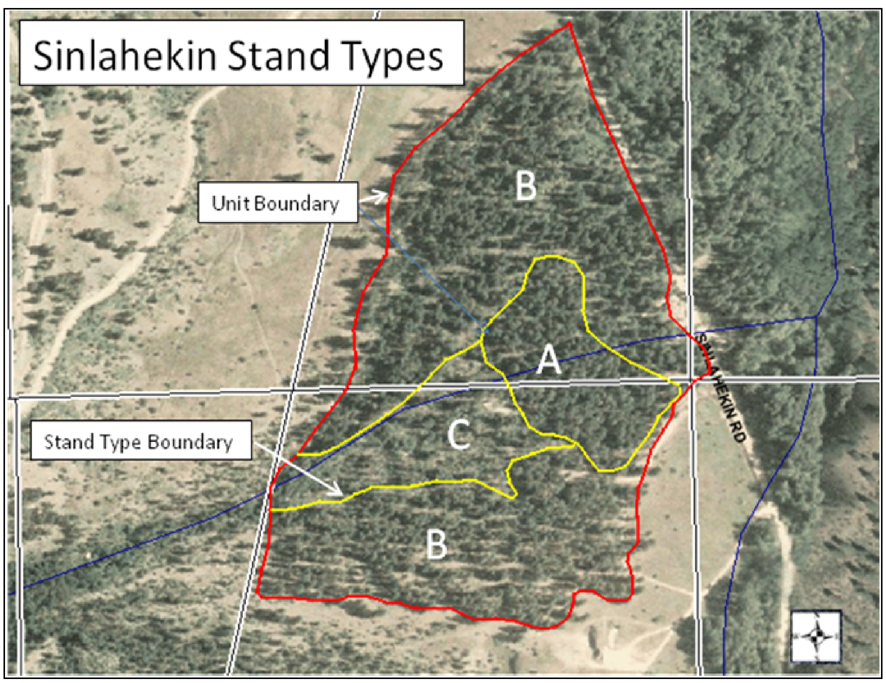


Figure 4

On each plot we recorded the following data: GPS location, elevation, aspect, percent slope, plant association, percent crown cover, basal area, disturbance and forest health (signs of insects or disease).

Plot radius was marked with red pin flags and all live trees, snags, logs and stumps were numbered with chalk. Each item was mapped as a GPS waypoint and/or measured for distance and azimuth taken from plot center. Trees were identified by species, diameter at breast height (DBH), total height and crown ratio. Increment cores were collected at breast height on the uphill side of all live trees >2" DBH. A total of 340 trees were cored. Increment cores were also taken on some trees at both stump and DBH to determine number of years to reach DBH. There were only a few trees less than 2" DBH and those ages were estimated by internodal growth.

Snags, logs, and stumps were identified to species and measured for diameter, height, and decay class. We used decay classes adapted from Thomas *et al.* (1979). A class 1 snag or log is recently dead and class 5 is fully decomposed. A minimum of two live trees per species were measured for DBH and at stump height (usually 1 foot above the ground) to determine a ratio to adjust stump diameters to DBH. This ratio was used to convert trees to their original DBH. This adjusted DBH was also used to determine if those trees would be in on a 20 basal area factor (BAF) plot using limiting distance tables. To help date the logging entries, live trees were cored adjacent to cut stumps to see if ring patterns showed a release date.

To determine the fire history of these units we collected 25 fire scar samples from live trees, snags, logs and stumps using the methods described by Arno and Sneck (1977). The 15 scar samples from the Sarsapkin unit came from snags (Figure 5), logs, stumps and live trees and were distributed throughout the entire area. Good quality samples were more limited in the Sinlahekin unit. The 10 samples collected cover the north and west area of this unit and were mostly from cut stumps. We did collect a few live samples further upstream outside this unit to determine the last fire year.

Figure 5

Analysis methods

Snag, log, and stump data were adjusted for time since death. For snags and logs, time of death was based on decay class.

Everett *et al.* (1999a) examined snags and logs resulting from past fires of known dates and calculated the average time required to reach decay classes 1 through 5 for different species and size classes. We used this information to infer the mean time since death. For example: an 18" DBH Douglas-fir snag would require an average of 20 years to reach class 3 and 80 years to class 5. In this case we would indicate the decay class 3 snag resulted from a tree that died in 1989 and the decay class 5 snag from a tree that died in 1929. Growth increments and tree diameter would be calculated prior to those times. We based time of death on mean rates of decay but recognize that these rates may be variable (Harmon *et al.* 1985).

Fire History

Both tree cores and fire scar samples were dated using the cross-dating procedure as described by Stokes and Smiley (1968). A tree ring chronology was used from the 20Mile forest report (Schellhaas *et al.* 2002b). The 20Mile area is 16 miles north of Winthrop, Washington in the Chewuck river drainage and 22 miles west of the sample units. Determining the exact year of a fire through cross-dating depends on developing an accurate master chronology, or time series of tree-ring widths in which the climate signal is maximized (Stokes and Smiley 1968, Fritts 1976). Tree growth on dry, rocky outcrops such as on the 20Mile area is limited by available soil moisture, which changes in response to annual precipitation. Cores were sampled from trees growing on these harsher sites and have well-defined narrow growth rings in dry years and distinct wide rings in wet years.

Building the master chronology for the cited report involved measuring each ring from 14 climatically sensitive tree-cores on a Velmex sliding stage micrometer with Acu-Rite encoder using

MeasureJ2X software (2001). The tree-ring measurements were then validated for dating accuracy with the COFECHA software program (Holmes *et al.* 1986) that also produced a graphical master chronology of tree-ring widths representing wet and dry years (Figure 6) analogous to the skeleton plot described by Stokes and Smiley (1968). There was an exceptionally robust inter-correlation (0.675) between the measured tree cores that resulted in an extremely accurate master tree-ring chronology. This chronology included the period from 1599 to 2000 where signature years and recognizable patterns of years were used to cross date fire scars on each sample and assign the correct calendar year to each scar (Figure 6) (Madany *et al.* 1982, Dietrich and Swetnam 1984, Brown and Swetnam 1994, Grissino-Mayer 1995a). Cross dating was facilitated by developing a list of marker years (Yamaguchi 1991) that could be readily identified on many of the fire-scar sections.

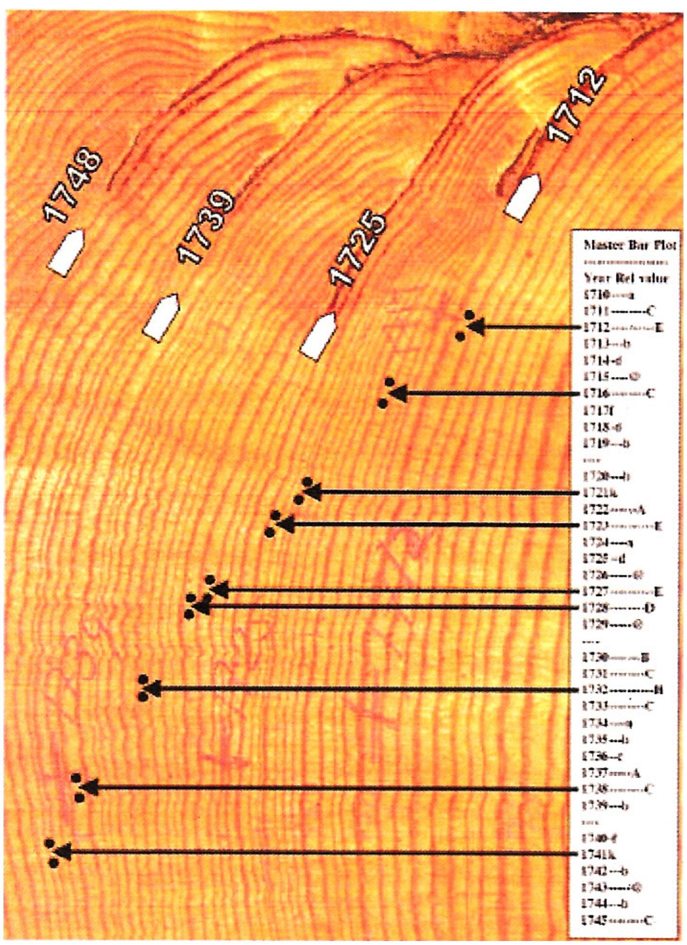


Figure 6. Part of the output of the computer program COFECHA is a "Master Bar Plot" of relative tree-ring widths (a segment is shown left). The bars show the relative width of each year's ring with the longer the bar, the wider the ring. Lower-cased letters signify rings narrower than the local mean while upper-cased letters represent rings wider than average. Note how the wide and narrow rings shown on the bar plot match ring patterns on the fire-scar sample (black arrows) enabling precise fire years to be established (white arrows). (Schellhaas *et al.* 2002)

Isolated spot fires were detected as a single event from a single fire scar sample. Including these marginal fire events in a larger "Area Frequency" inequitably skews the average fire-free interval. With these small fires the ecological impacts are negligible. Therefore single spot fires were excluded from our fire frequency analysis. Exclusion of the spot fire event from the area frequencies only serves to support an already conservative conclusion.

Establishment of historical stands

Historical stocking levels along with their inherent fire regimes can be used as a benchmark for forest management (Fulé *et al.* 1997). To define historic conditions we first need to define what we call "historical". Information about the specific forest structure and composition of historic stands is limited and other studies of historic forest conditions in this area have defined historic as early as 1935 (Harrod *et al.* 1999) and as late as 1956 (Huff *et al.* 1995). Because fire suppression had already affected forest structure and composition by the mid 1900's (Huff *et al.* 1995, McNeil and Zobel 1980), we believe an earlier point of reference would better represent historical forest conditions. By the mid 1900's these forests were already 4-7 fire intervals out of synchrony with their inherent fire regime (Ohlson 1996, Everett *et al.* 1999b, 2008, Finch 1984).

Live tree analysis:

Tree cores were mounted in grooved wooden trays then sanded and cross dated using 10x and 30x lenses. Total age of tree cores was determined by the total ring count on each core, with additional rings to reach DBH and, in cases where the pith was missing, additional rings were estimated and added to reach the pith. To estimate the DBH of live trees in 1896 we measured the radius of those cores from the pith to the 1896 year ring and added estimated bark thickness.

Snag and log analysis less than 9 inches DBH:

The number of historical small trees may be underestimated, in part due to their small size since they decay more rapidly than larger trees (Harmon *et al.* 1985, Arno *et al.* 1995b, Fulè *et al.* 1997). Everett *et al.* (2007) found that the majority of current small snags and logs were from trees that died since the last historical fires. The small diameter snags and logs on site were assumed to be from the same cohort of the live trees in the same size class.

Snag and log analysis greater than 9 inches DBH:

A random sample of 57 live tree cores from within all stand types were measured for radial growth from piths to 1989 (20 year decay point), 1969 (40 year decay point), and 1929 (80 year decay point). These are the time periods required to reach decay classes 3, 4 and 5 respectively (Figure 7).

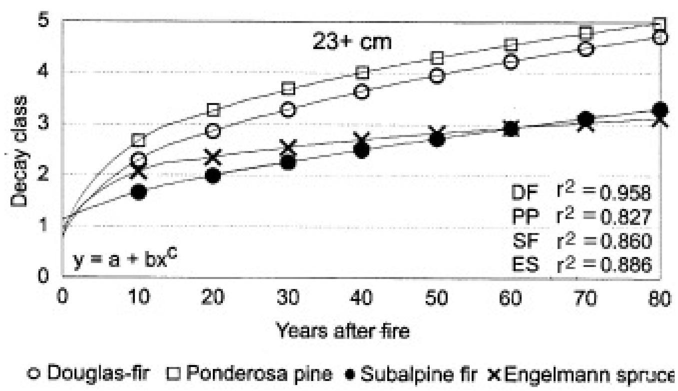


Figure 7 (Everett *et al.* 1999)

Periodic annual increments were used to represent three decay class age groups; 20 years for class 3, 40 years for class 4 and 80 years for class 5 (Figure 8). The average live tree periodic annual increment (PAI) for these three time periods was used to reconstruct dead trees back in time. The average rings per inch (RPI) for these time periods were:

Periodic Annual Increment

			Average Rings per Inch			
			Sinlahekin		Sarsapkin	
Decay Class	Years		PIPO	PSME	PIPO	PSME
3	1969 - 1989	20 yrs	17.3	17.7	12.5	18.6
4	1929 - 1969	40 yrs	16.9	18.2	11.4	16.9
5	pith - 1929	80 yrs	14.2	14.4	10.7	13.8

Figure 8

For example: A 25" decay 5 PIPO log in Sarsapkin (similar to the one shown below Figure9) was assumed to have died in 1929. We reduced the DBH by 2" every 11 (10.7) years until germination date of 1796. This tree was about 19" DBH in 1896 and part of the historical stand.

Figure 9 Decay Class 5 log in Sinlahekin unit

Stumps:

For stumps, the date of harvest was inferred from "release" dates noted on cores of adjacent live trees (Arno *et al.* 1995, Cochran and Barrett 1998, Oliver and Larson 1996). By using the stump diameter ratio from live trees we assumed that the DBH was 80% of stump diameter on cut trees. The two logging release dates were approximately 1937 and 1970 (Figure 10). As with the snags and logs we regressed these stumps back in time from their estimated DBH's using the average rings per inch (Figure 8) from pith to 1937 and 1970.

Figure 10. This photo from the Sinlahekin unit shows the difference between the 1937 stump at left and the 1970 stump on the right.

Example: A 30" diameter ponderosa pine stump in the Sinlahekin unit had an estimated 24" DBH (based on stump/DBH ratio of 80%) and was cut in 1970. From 1970 we reduced the estimated DBH by 2" every 17 years (based on periodic annual increment Figure 8) back to 1896 as a 15" tree. This stump/tree was part of the historical stand. Using the limiting distance, these DBH's were also used to determine if these trees would have been included in the historic 20 BAF plot.

As described earlier, the fact that the Sinlahekin unit has had two major logging entries made it much more difficult to assess historical stand structure.

Results

The exact number of trees in historical stands may never be known, especially in the smaller size classes. Based on the inherent fire regimes and the difficulty observed in the successful establishment of natural regeneration for these forests, the number of historical small trees was likely to have been low (White 1985). Prior to 1900, most of the small, understory trees that became established during a short fire-free interval were killed by subsequent fires (Agee 1994). Historical accounts of forests in these plant associations also make reference to the lack of understory trees (Plummer 1902, Gorman 1899). In the Southwest ponderosa pine forests, Fulè *et al.* (1997) suggested that smaller trees were unlikely to be a substantial component of the pre-settlement forest structure.

Figure 11 shows 75% of existing live trees in the Sarsapkin unit regenerated following the 1896 fire disturbance during the settlement (1890's) and suppression eras (after 1910).

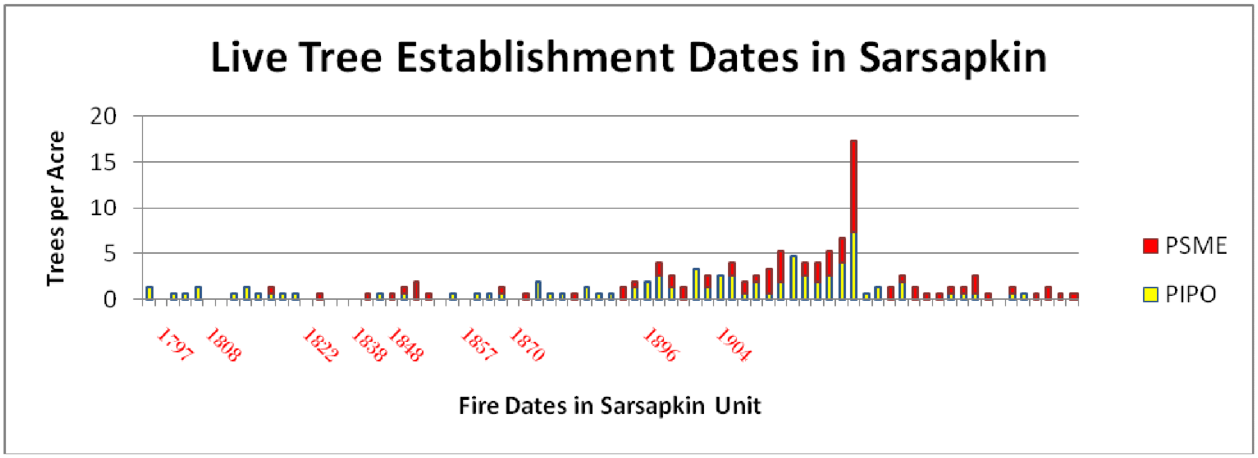


Figure 11

Historical stand structure results for this study are based on stand conditions following the 1896 fire and prior to the settlement era. In the Sarsapkin unit and all stand types, this was the last, large historical fire. There were several smaller fires after 1896, but not of significant area and they occurred during the settlement and suppression eras. There is an overall increase in tree density between historical and current conditions (Tables 1 – 12, pages 29 - 40), measured in terms of trees per acre and basal area.

The current basal area has increased in all stand types (Figure 12, 13) over historical levels except for Sinlahekin stand C.

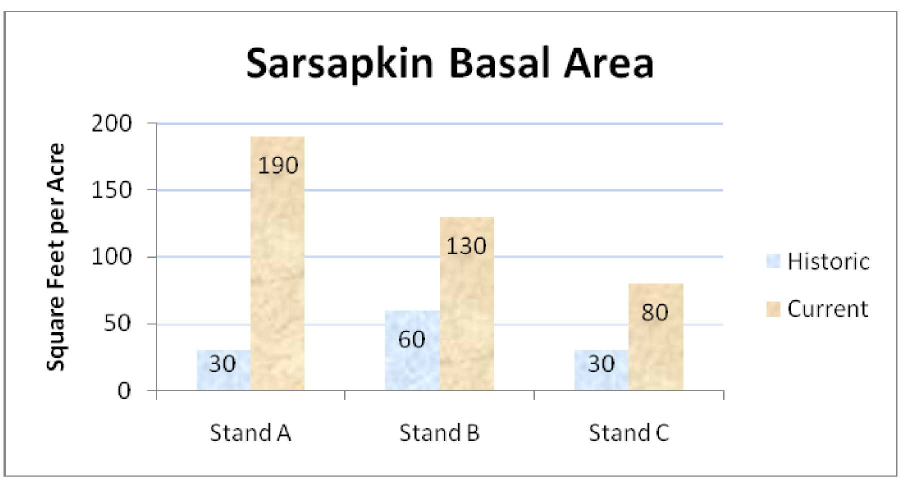


Figure 12

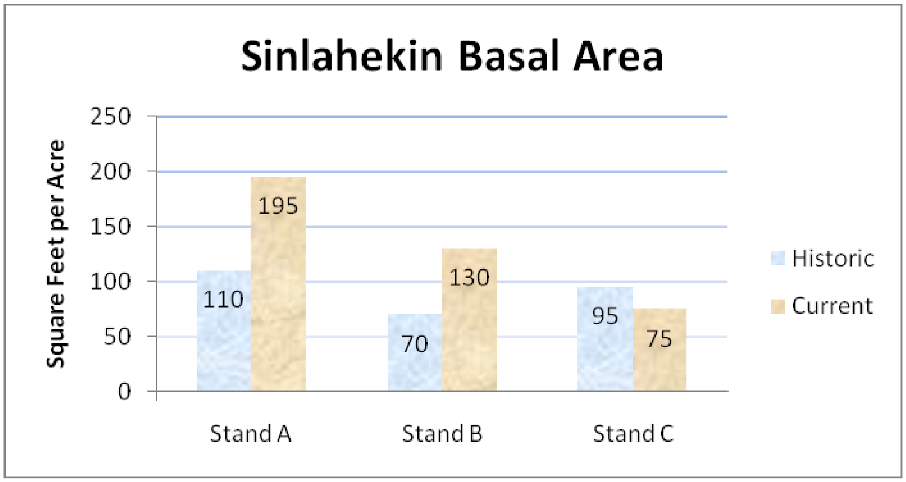


Figure 13

The two timber harvests in the Sinlahekin unit have created an artificial crown class condition particularly in the C stand type. This stand type was classified by the low number of overstory trees and larger openings created by the last logging. This disturbance confounds the results for the Sinlahekin Stand C.

There are 78% more large trees per acre in the current stands than in 1896 (Figure 14).

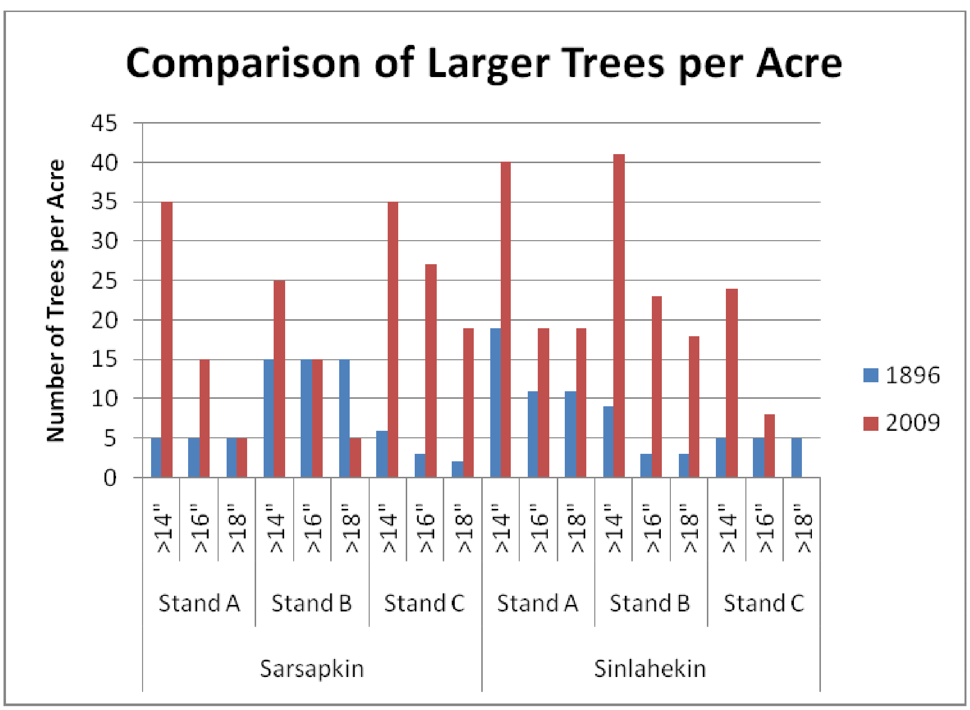


Figure 14

Tree density by Stand Type

Refer to pages 41 – 47 (Tables 13 – 18) for a graphic visualization of each stand type. These graphics produced by Stand Visualization System software (McGaughey 1994), display a random spatial arrangement based on stand plot data extrapolated to a one acre representation.

The historical trees per acre in these stands are similar to those found in the Hot/Dry/Shrub/Grass plant association group (Ohlson and Schellhaas 2002) where there were 70 trees per acre. See appendix for table of plant association groups.

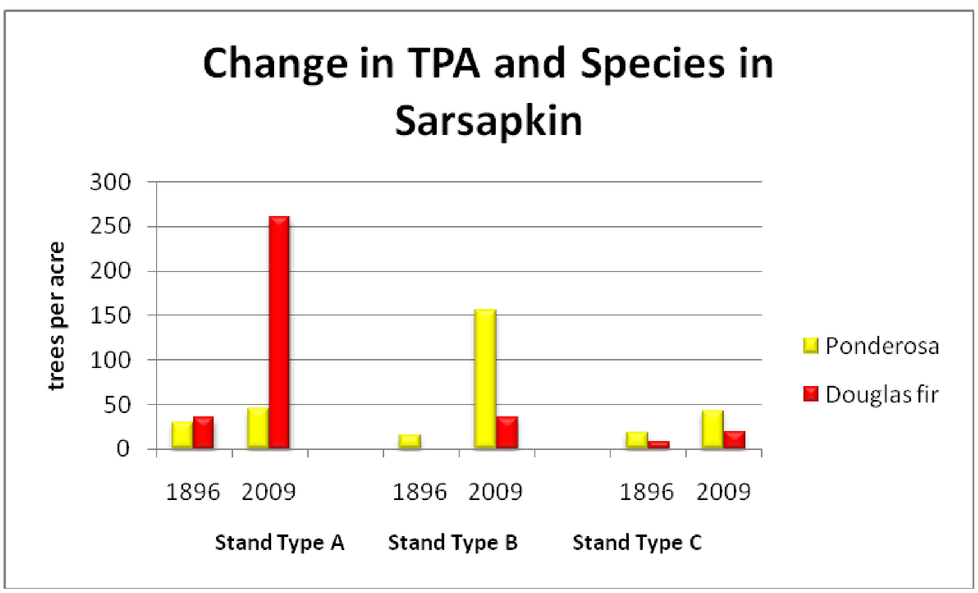


Figure 15

***Sarsapkin Stand Type A* (Tables 1,2)**

There are 4.6 times as many trees per acre today than in 1896 and a major shift in species composition from 1896 -2009. The current stands consist of 15% ponderosa pine and 85% Douglas-fir as compared to the historical stand which has 46% ponderosa pine and 54% Douglas-fir (Figure15). This stand currently contains an active Goshawk nest site.

Sarsapkin Stand Type A

Sarsapkin Stand Type B *(Tables 3,4)*

The current stand has 12.5 times more trees per acre than the historical stand (Figure 15). The species composition has shifted to include 18% Douglas-fir. There were only 15 trees per acre in the historical stand. This low number of trees per acre was the result of heterogeneity in this stand type, with scattered openings on a dry site.

Sarsapkin Stand Type C *(Tables 5,6)*

There are 2.3 times as many trees in the current stand. The 2009 species composition is similar to that in the 1896 stand. Analysis was done on 10 of the original 11 stand plots. One plot was predominantly regenerating pine and not characteristic of the stand. The unusually high numbers of seedlings skewed the data and was removed as an outlier.

Sarsapkin Stand Type C

The historical Sinlahekin Stand A is similar to the Cool/Dry/Shrub/Herb plant association group with 198 trees per acre and Stand Types B and C resemble the Warm/Dry/Shrub/Herb plant association group at 127 trees per acre (Ohlson and Schellhaas 2002). See appendix for table of plant association groups.

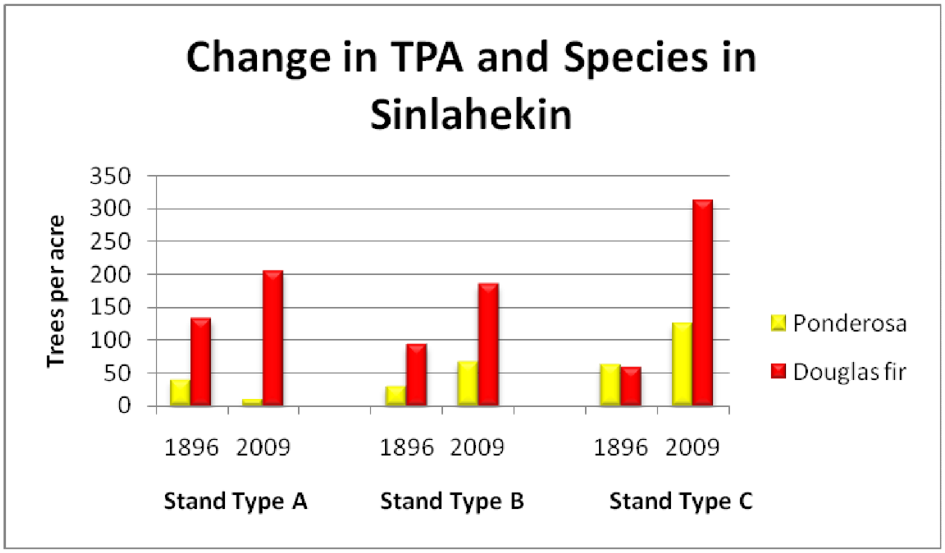


Figure 16

***Sinlahekin Stand Type A** (Tables 7,8)*

Current stocking levels are similar to the historical density. The 1896 stand had 50% of trees less than 2” DBH. This is the result of the 1870 fire. The subsequent 1896 fire may not have affected this area (Figure 16).

***Sinlahekin Stand Type B** (Tables 9,10)*

Current trees per acre are two times the 1896 level. Like Stand Type A, 68% of the historical trees per acre were less than 2” DBH. The species composition is comparable in both the 2009 and 1896 stands. Overall there are currently more trees per acre in all size classes (Figure 16).

Sinlahekin Stand Type B

***Sinlahekin Stand Type C** (Tables 11, 12)*

The current stand is 3.7 times denser than the historic stand with a 24% increase in Douglas-fir and a 24% decrease in ponderosa pine. Seventy eight percent of the current stand is in the seedling, sapling size class (less than 2” DBH) as a result of the 1970’s logging disturbance (Figure 16).

The increase in density throughout the early 1900s represents an understory reinitiating phase of stand development following fire exclusion (Oliver and Larson 1990, O’Hara *et al.* 1996). Under the historical fire regime, recruitment of new cohorts likely occurred in pulses following fires; however, with the exception of a few individuals, these cohorts would have been destroyed during subsequent fires. In the absence of repeated fires since 1896, these post-fire cohorts have persisted. Many of these stands are now in a stem exclusion stage (Oliver and Larson 1990, O’Hara *et al.* 1996) where total tree density is declining because of competition for site resources. Arno *et al.* (1995) also report losses of live trees in recent decades on plots in similar forest types in western Montana.

Since the historical stand structure was a multi cohort stand, we used 20 year cohorts that captured several disturbances within that time period. The current stand is predominantly a “single” cohort following the 1896 fire. Note the increase in trees per acre as a result of fire exclusion from these stands. Also note how frequent fires kept the number of trees per acre lower (Figure17). The current stand is now in the stem exclusion phase (Oliver and Larson 1990). This phase of development is due to the lack of disturbance preventing new cohorts from establishing.

Cohort establishment dates are not shown for the Sinlahekin unit due to the past logging entries.

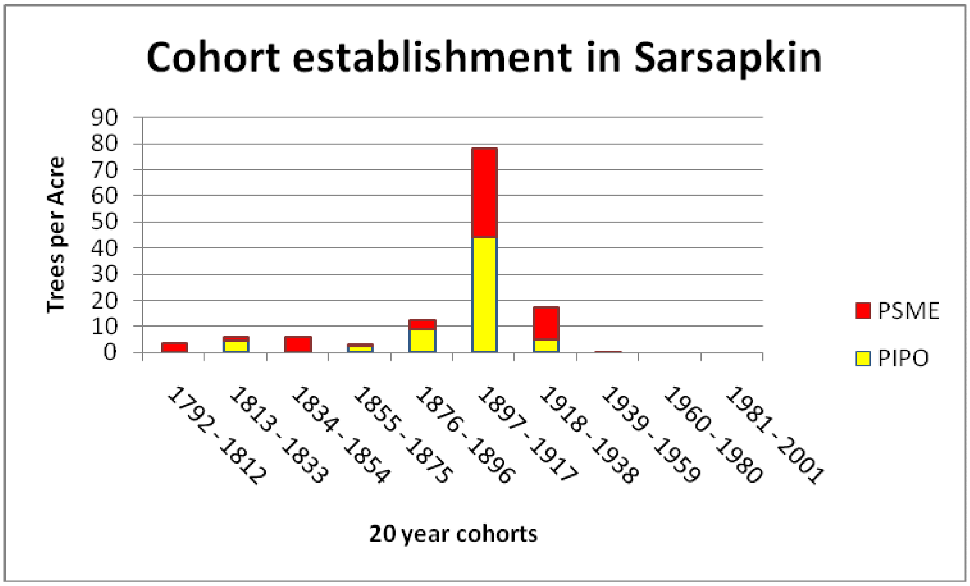


Figure 17

Fire History

We cross dated 25 fire scar samples to determine historical fire regimes for the Sarsapkin (*n*=15) and Sinlahekin (*n*=10) units. Evidence of older fire events are lost to decay or subsequent fires. Consequently the integrity of fire free interval (FFI) assessment diminishes with time.

The earliest fire dates we were able to determine were 1674 for the Sarsapkin unit and 1601 in the Sinlahekin unit. Although we documented fires at these early dates we were compelled to establish the beginning of the "period of reliability" (Touchan *et al.* 1996) at 1792 for Sarsapkin and 1768 for Sinlahekin. These dates represent the earliest point in time when at least three samples recorded the same fire event. We therefore determined the "historical" or "pre-settlement" period as 1792-1896 and 1768-1896 for the Sarsapkin and Sinlahekin units respectively.

A total of 36 fire dates were found in the Sarsapkin unit and 41 in the Sinlahekin unit. Some fire years were recorded on a majority of the samples indicating that these fires burned over the entire area where samples were collected (Figure 18, 19). This assumption is made based on the sampling intensity or the large number of scar samples by unit size. The 56 acre Sarsapkin unit averaged one scar sample every 3.7 acres and the 54 acre Sinlahekin unit averaged one sample every 5.4 acres. Some trees were as young as 12 years old with a stump diameter of less than 2 inches when they were first scarred by fire. These trees survived to live through subsequent fires indicating low severity fire.

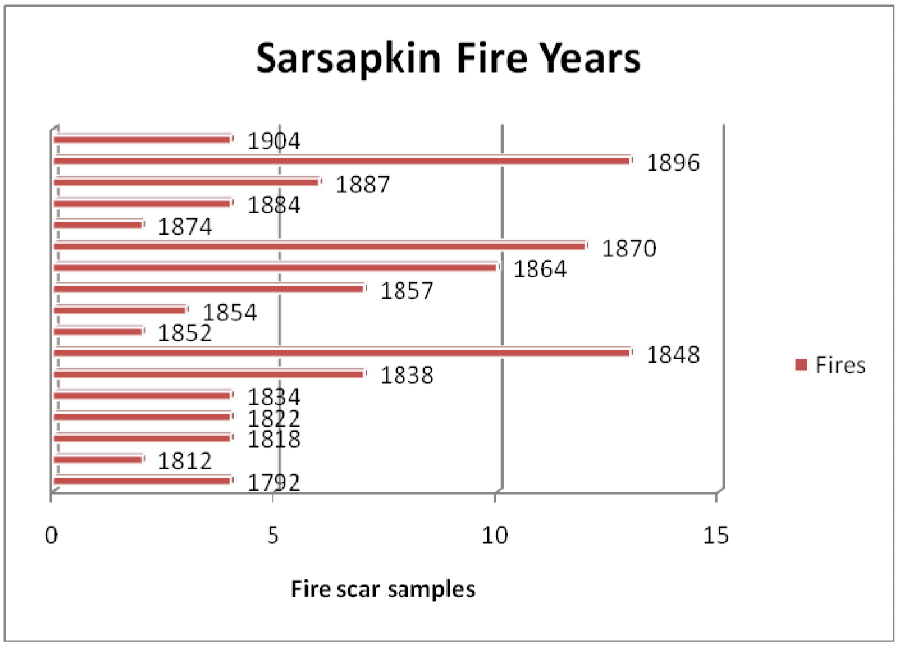


Figure 18

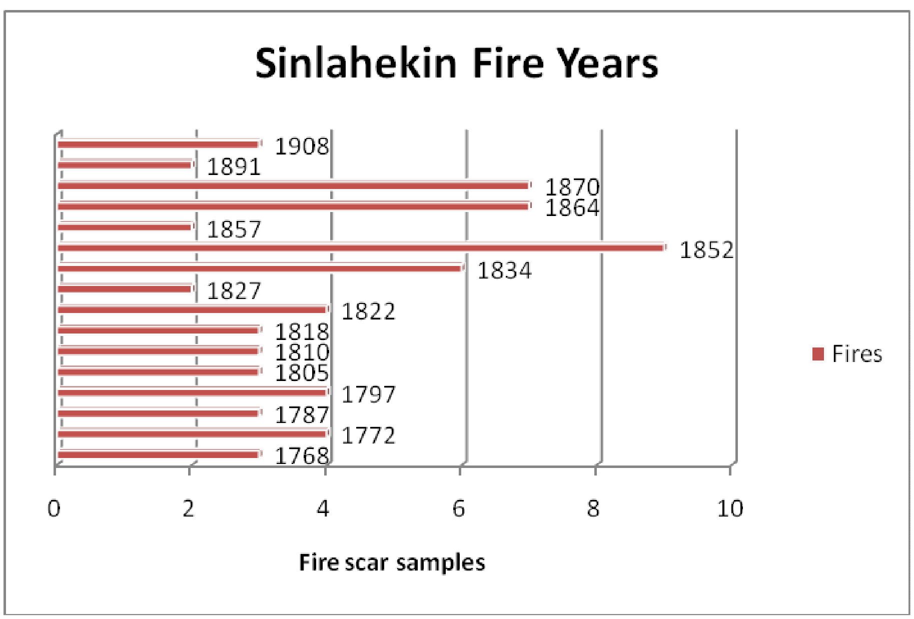


Figure 19

The same fires occurred on both north and south sides of the creeks 44% of the time at Sarsapkin and 53% in Sinlahekin. Also, there were seven common fire years in both units with the 1870 and 1864 fires being the largest (Figure 20).

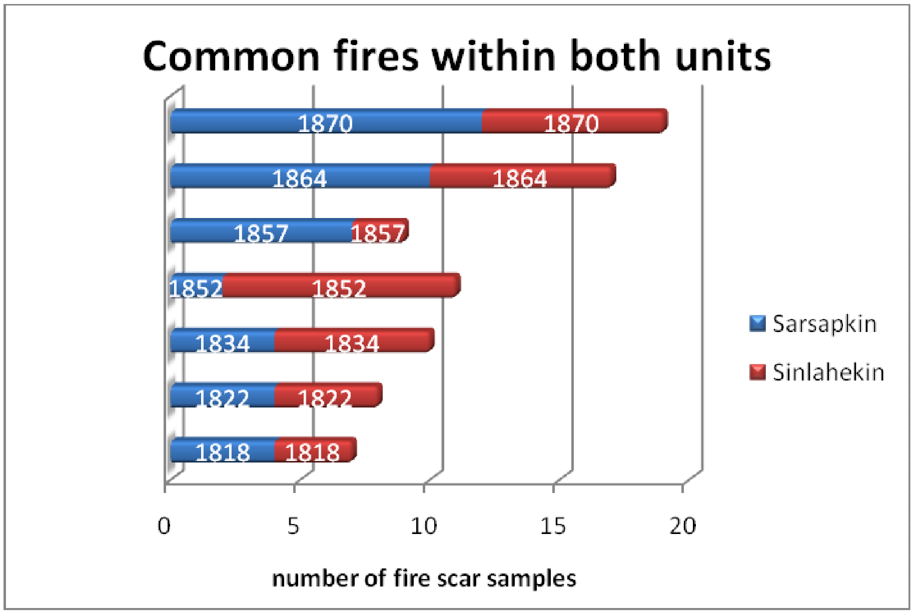


Figure 20

Short fire frequencies suggest that this area was historically dominated by species more tolerant of fire such as ponderosa pine and western larch, since even low severity fires would kill trees that were more sensitive to fire. Findings here are similar to those reported by Schellhaas *et al.* (2002) on the eastern portion of the Okanogan National Forest. Douglas-fir would have been a component of early forests, but since it is quite intolerant of fire when very young (Arno 1988), would have been restricted to areas that burned somewhat less frequently or represented in discrete cohorts that established and persisted during one of the longer fire free intervals. Fire-free intervals greater than about 17 years could have allowed Douglas-fir to establish and grow tall enough to create a fuel ladder to the overstory (Figure 21). Subsequent fires might then have become stand replacing in those areas (Everett *et al.* 2000).

Composite Fire Free Interval

	Sarsapkin 1896 -1792	Sinlahekin 1896 - 1768
Mean	6.1	8.5
Min	2	4
Max	16	18

Figure 21

Both the Sinlahekin and Sarsapkin units experienced a high frequency, low severity fire regime. However, fires following maximum intervals would have had some mixed severity results (Schellhaas *et al.* 2002). Fire history is usually separated into three time periods – pre-settlement era, settlement era and fire suppression era. There is an abrupt change in fire frequency after 1896. This 1896 fire was considered to be the last major historical fire from the pre-settlement era and is evident on a majority of samples (71%) from the Sarsapkin unit (Figure 18). This date is consistent with the settlement of Sinlahekin Valley back to the late 1880s and early 1890s (Dale Swedberg – pers. comm.2009).

Determining the last major fire in the Sinlahekin unit was more difficult. The last logging entry had removed all the larger/older trees. This left us with severely decomposed stumps and logs to sample. The outer fire scars on most of these samples had decomposed or fallen off, making it difficult to ascertain a “last large fire” date. To help determine the last historical major fire, we cut 2 fire scar samples from live trees upslope and upstream about ¼ mile from the unit. These live samples showed the 1896 fire and a fire in 1891. We assumed that based on fire behavior, a fire from the Sinlahekin unit could have spread upslope to this area. We assigned the 1896 fire year to both units as the last major fire. There has been a dramatic reduction in fire occurrence since this date as a result of settlement in the 1890’s and fire suppression beginning after 1910.

Conclusions

The primary reason for the difference between the historical and current stand structure in these forests has been the change in the disturbance regime. Fire history research in eastern Washington forest indicates that current conditions reflect an absence of fire that is from 9 to 16 times longer than at any time since the 16th century (Finch 1984, Ohlson 1996, Everett *et al.* 2000, Schellhaas *et al.* 2002, 2007).

Forest stand structures and species compositions have been altered since 1896. Our conclusions agree with other research in the eastern Cascades indicating current stand density increases of 2 - 7 fold over historical conditions (Everett *et al.* 1996, Ohlson 1996, Camp 1999, Ohlson and Schellhaas 2002). The increase is likely a result of decreased mortality of small trees in the absence of fire over the past century. What were once open stands of predominantly ponderosa pine are now dominated by a dense layer of Douglas-fir. These younger cohorts have also breached the discontinuity between ground and crown fuels that existed under the historical disturbance regime, increasing the potential for stand replacement crown fires. These same conditions are described by LANDFIRE as Fire Regime Condition Class (FRCC) 3 (LANDFIRE, 2009).

There may have been more western larch in the Sinlahekin unit than currently exists. Increased stand density has resulted in higher rates of mortality for the shade intolerant larch and natural regeneration of this species in these fully-stocked stands is very unlikely (Schmidt and Shearer 1995). Changes in stand density over the past century reflect the timing of the last historical fire event in individual stands. Seedling establishment following the last fire continued until stands were fully stocked by mid-1900. During the past few decades, stand density has decreased in many stands while basal area has continued to increase. This competition-induced mortality has also added to fuel loads in these stands.

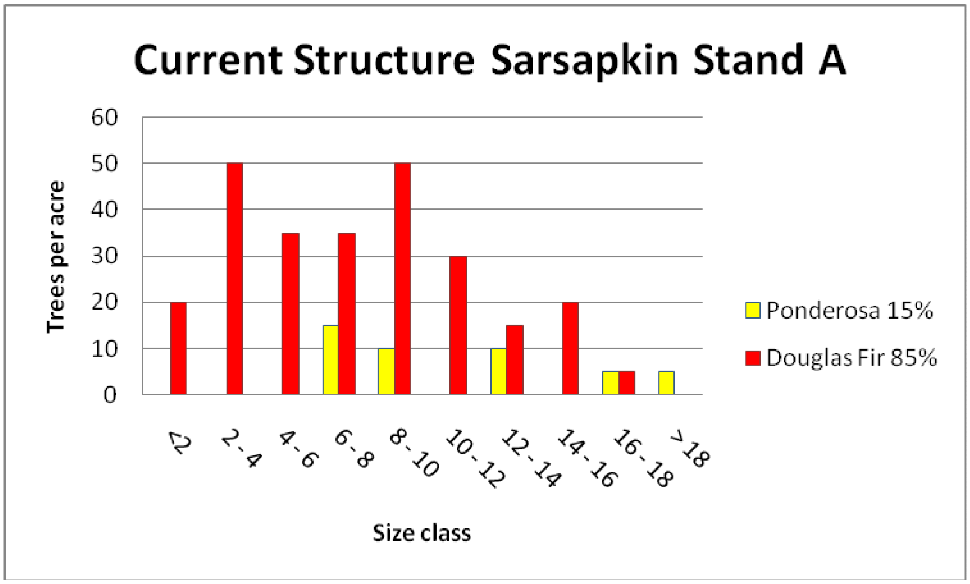
Douglas-fir and ponderosa pine forest stands no longer have fire regimes within the historic range of variation. Increased stand density predisposes these sites to catastrophic wildfires or insect and disease outbreaks. Thinning and prescribed fire are management tools that are commonly used to reduce the potential for catastrophic wildfires (Graham *et al.* 1999). They may also be useful in restoring historical stand conditions in these dry forests. These management activities can also be used to increase the heterogeneity of fuel across the landscape, thereby reducing the potential spread of high severity fires. Where western larch is being eliminated it will be necessary to create adequate openings to ensure the successful natural or artificial regeneration and establishment of this seral species (Schmidt and Shearer 1992). In the long term, these treatments should improve ecosystem integrity by creating forest structure that is sustainable under the inherent disturbance regime (Agee and Johnson 1988, Everett *et al.* 1999b).

Historically, fires did not always discriminate between riparian and adjacent forests. Generally, fires burned less frequently in riparian areas indicating that the moist vegetation acted as a barrier to the spread of fire in some cases. However, when fires did occur in the riparian area, if conditions were right, they burned more severely due to the higher fuel levels (Everett *et al.* 2003). The Washington State Department of Natural Resources also acknowledges this in their Forest Practices Rules by designing them to mimic eastside disturbance regimes (WAC 222-30-022).

Maintaining tree radial growth rates at <15 RPI will ensure vigorous, healthy trees which in turn will help resist insect and disease attacks (Hall 1983). Thinning overstocked stands will not only improve growth and forest health but will also lower the risk of stand replacement wildfire.

Use of the means and ranges of historical fire frequency and stocking levels could be used as a guide which would help supplement LANDFIRE planning and management goals. These historical disturbances could be used to design a spatial and temporal mosaic pattern of treatments and patch sizes to fragment stand and fuel continuities. This would help ensure the sustainability of these forests.

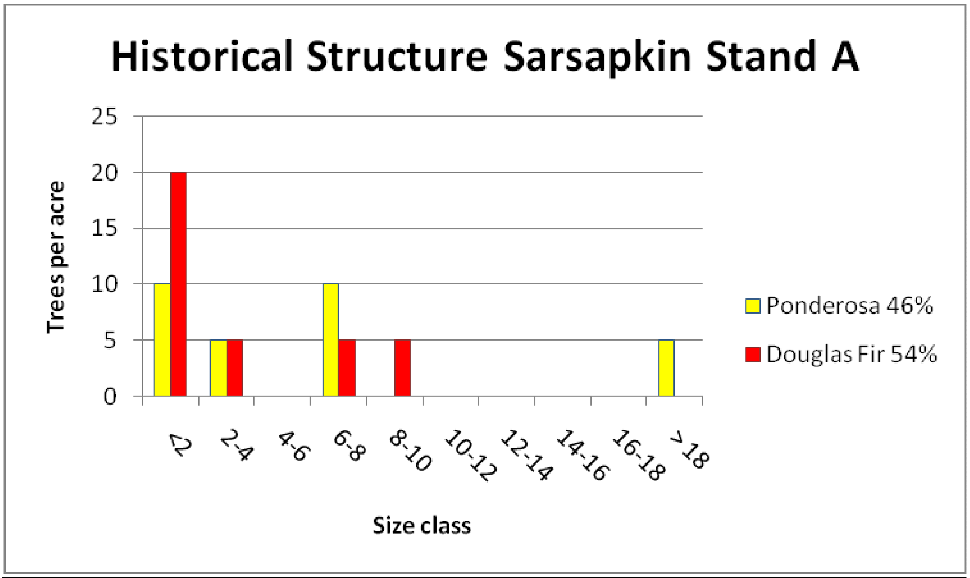
Tables



DBH	Ponderosa	Doug. Fir	Total
<2	0	20	20
2 - 4	0	50	50
4 - 6	0	35	35
6 - 8	15	35	50
8 - 10	10	50	60
10 - 12	0	30	30
12 - 14	10	15	25
14 - 16	0	20	20
16 - 18	5	5	10
> 18	5	0	5
Total	45	260	305

Mean trees per acre	St. Dev.	Range
305	18.17	250 - 360

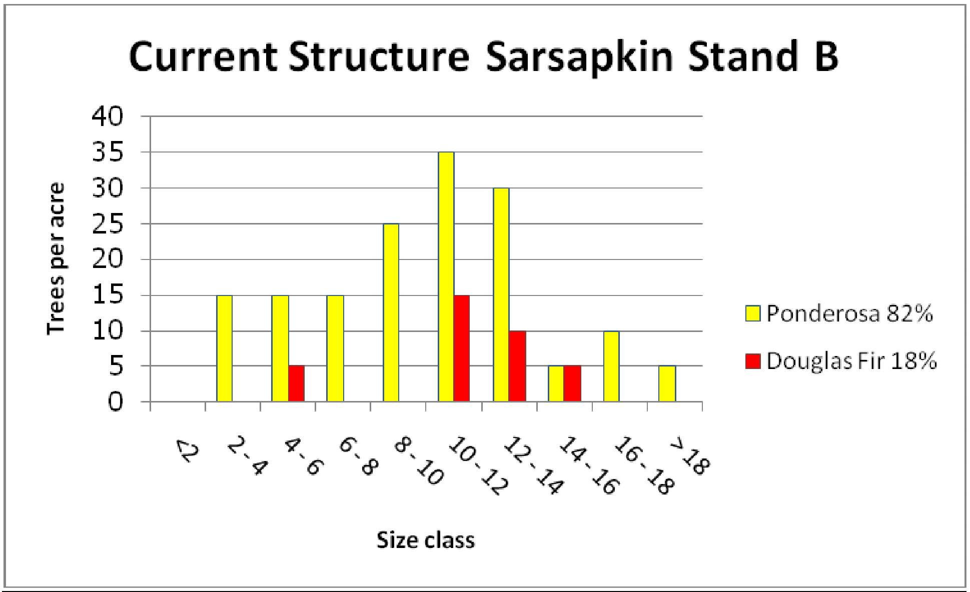
Table 1



DBH	Ponderosa	Doug. Fir	Total
<2	10	20	30
2-4	5	5	10
4-6	0	0	0
6-8	10	5	15
8-10	0	5	5
10-12	0	0	0
12-14	0	0	0
14-16	0	0	0
16-18	0	0	0
> 18	5	0	5
Total	30	35	65

Mean trees per acre	St. Dev.	Range
65	9.73	20 - 120

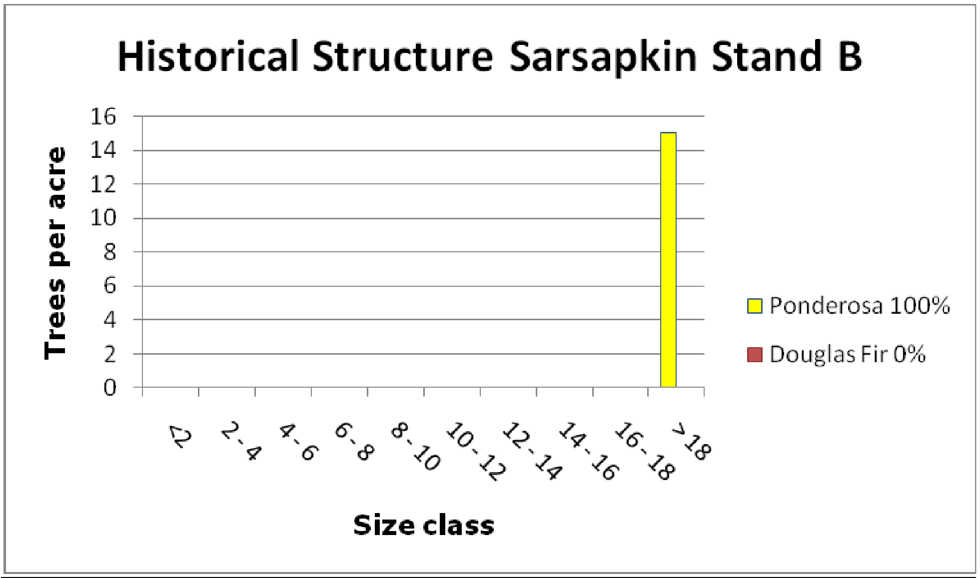
Table 2



DBH	Ponderosa	Doug. Fir	Total
<2	0	0	0
2 - 4	15	0	15
4 - 6	15	5	20
6 - 8	15	0	15
8 - 10	25	0	25
10 - 12	35	15	50
12 - 14	30	10	40
14 - 16	5	5	10
16 - 18	10	0	10
> 18	5	0	5
Total	155	35	190

Mean trees per acre	St. Dev.	Range
190	14.95	140 - 240

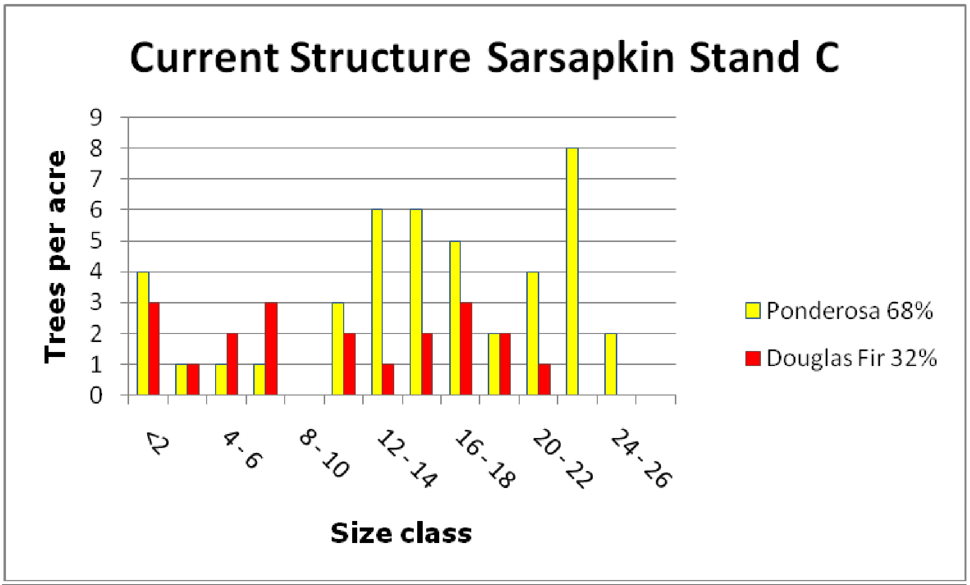
Table 3



DBH	Ponderosa	Doug. Fir	Total
<2	0	0	0
2 - 4	0	0	0
4 - 6	0	0	0
6 - 8	0	0	0
8 - 10	0	0	0
10 - 12	0	0	0
12 - 14	0	0	0
14 - 16	0	0	0
16 - 18	0	0	0
> 18	15	0	15
Total	15	0	15

Mean trees per acre	St. Dev.	Range
15	4.74	10 - 20

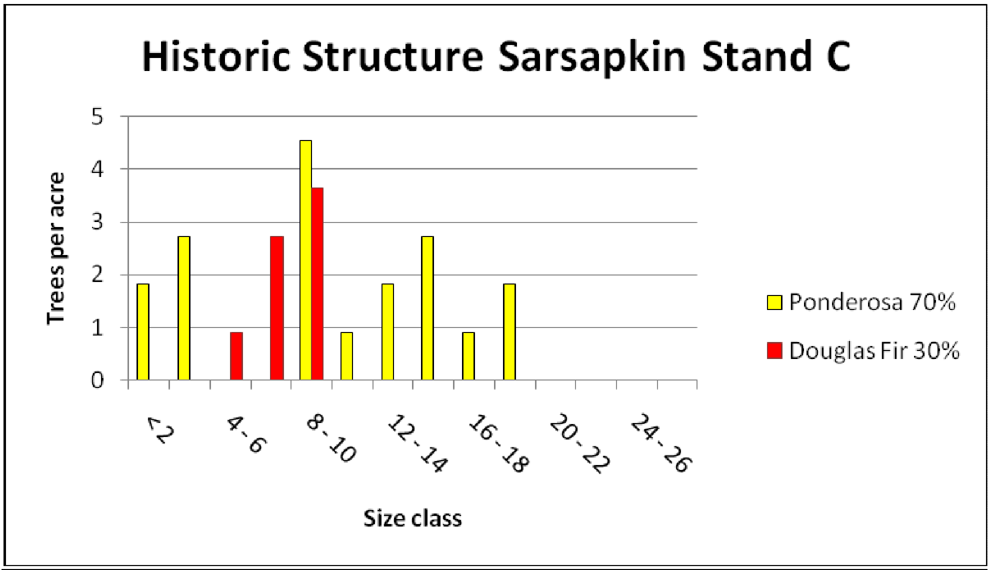
Table 4



DBH	Ponderosa	Doug. Fir	Total
<2	4	3	7
2 - 4	1	1	2
4 - 6	1	2	3
6 - 8	1	3	4
8 - 10	0	0	0
10 - 12	3	2	5
12 - 14	6	1	7
14 - 16	6	2	8
16 - 18	5	3	8
18 - 20	2	2	4
20 - 22	4	1	5
22 - 24	8	0	8
24 - 26	2	0	2
>26	0	0	0
totals	43	20	63

Mean trees per acre	St. Dev.	range
63	3.00	30 - 210

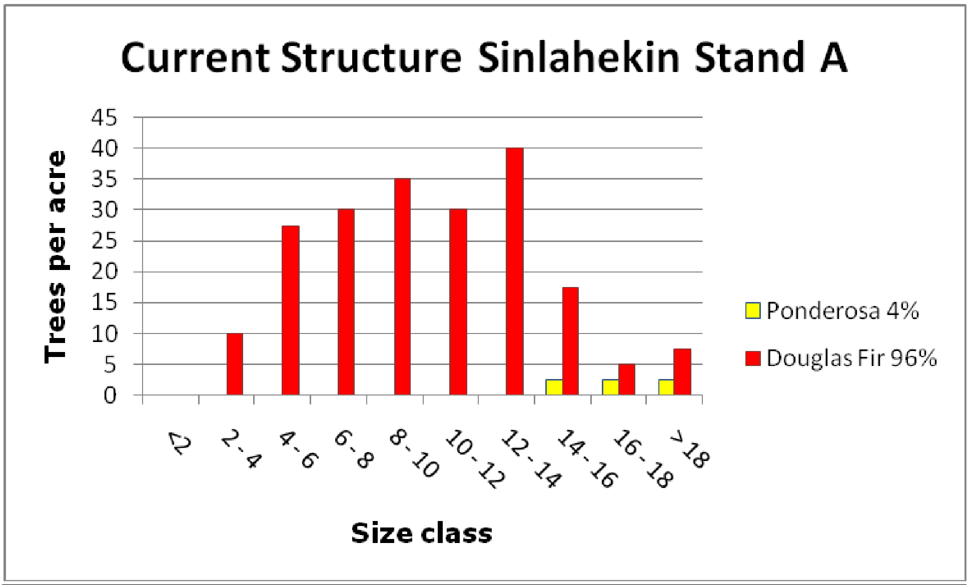
Table 5



DBH	Ponderosa	Doug. Fir	total
< 2	2	0	2
2 - 4	3	0	3
4 - 6	0	1	1
6 - 8	0	3	3
8 - 10	5	4	9
10 - 12	1	0	1
12 - 14	2	0	2
14 - 16	3	0	3
16 - 18	1	0	1
18 - 20	2	0	2
20 - 22	0	0	0
22 - 24	0	0	0
24 - 26	0	0	0
>26	0	0	0
totals	19	8	27

Mean trees per acre	St. Dev.	range
27	6.48	0 - 90

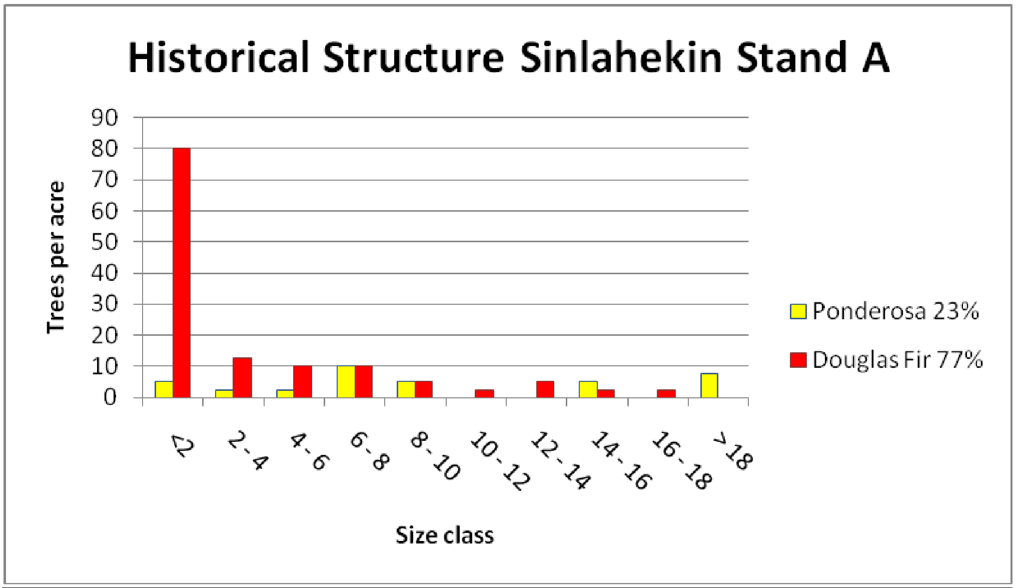
Table 6



DBH	Ponderosa	Doug. Fir	Total
<2	0	0	0
2 - 4	0	10	10
4 - 6	0	28	28
6 - 8	0	30	30
8 - 10	0	35	35
10 - 12	0	30	30
12 - 14	0	40	40
14 - 16	3	18	21
16 - 18	3	5	8
> 18	3	8	11
Total	9	204	213

Mean trees per acre	St. Dev.	Range
213	13.35	110 - 310

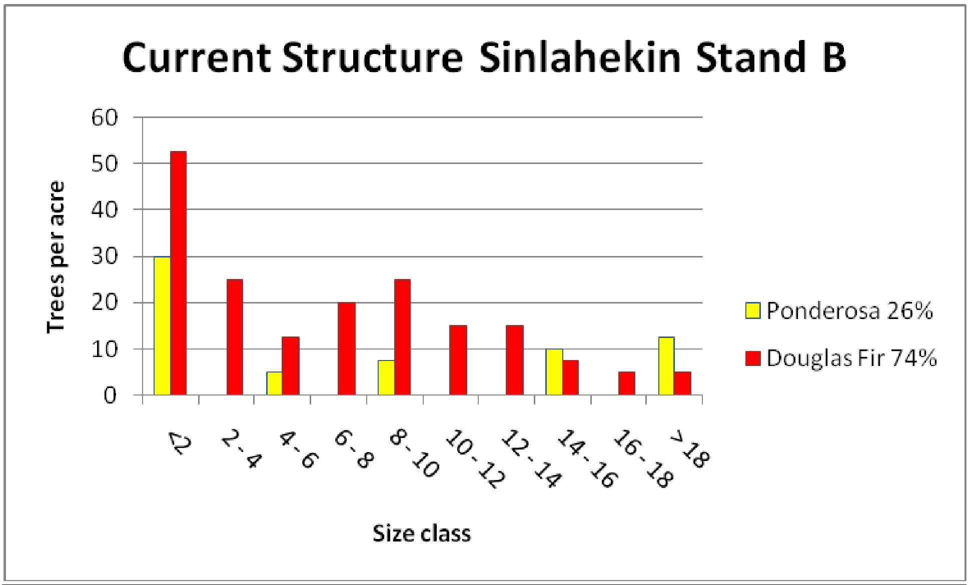
Table 7



DBH	Ponderosa	Doug. Fir	Total
<2	5	80	85
2 - 4	3	13	16
4 - 6	3	10	13
6 - 8	10	10	20
8 - 10	5	5	10
10 - 12	0	3	3
12 - 14	0	5	5
14 - 16	5	3	8
16 - 18	0	3	3
> 18	8	0	8
Total	39	132	171

Mean trees per acre	St. Dev.	Range
171	24.61	70 - 300

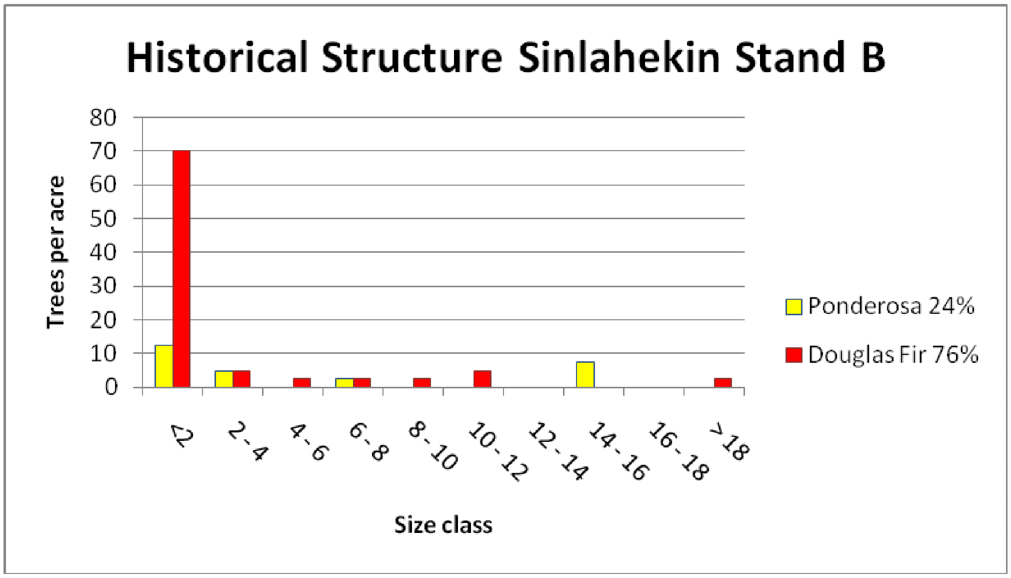
Table 8



DBH	Ponderosa	Doug. Fir	Total
<2	30	53	83
2 - 4	0	25	25
4 - 6	5	13	18
6 - 8	0	20	20
8 - 10	8	25	33
10 - 12	0	15	15
12 - 14	0	15	15
14 - 16	10	8	18
16 - 18	0	5	5
> 18	13	5	18
Total	66	184	250

Mean trees per acre	St. Dev.	Range
250	7.5	90 - 380

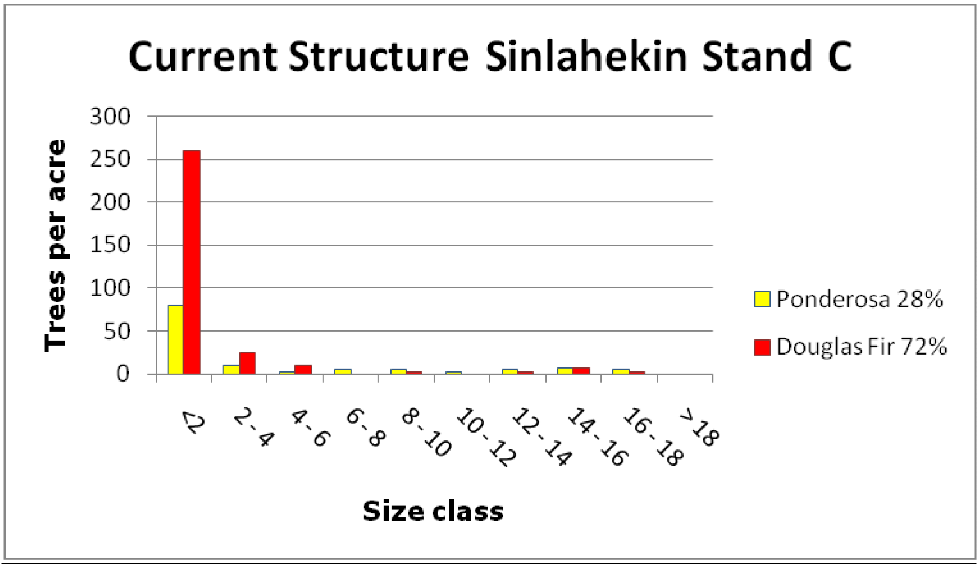
Table 9



DBH	Ponderosa	Doug. Fir	Total
<2	13	70	83
2 - 4	5	5	10
4 - 6	0	3	3
6 - 8	3	3	6
8 - 10	0	3	3
10 - 12	0	5	5
12 - 14	0	0	0
14 - 16	8	0	8
16 - 18	0	0	0
> 18	0	3	3
Total	29	92	121

Mean trees per acre	St. Dev.	Range
121	25.06	60 - 260

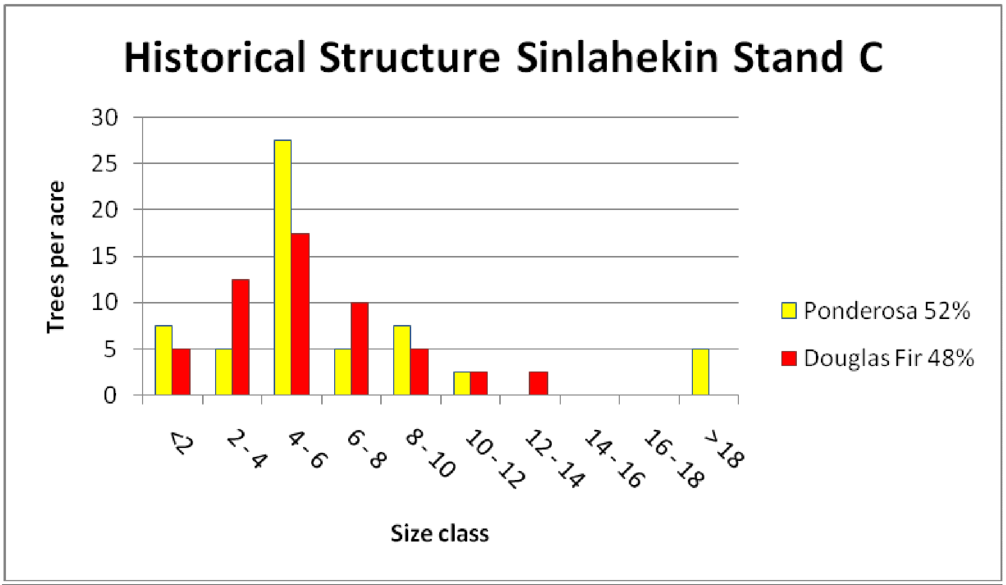
Table 10



DBH	Ponderosa	Doug. Fir	Total
<2	80	260	340
2 - 4	10	25	35
4 - 6	3	10	13
6 - 8	5	0	5
8 - 10	5	3	8
10 - 12	3	0	3
12 - 14	5	3	8
14 - 16	8	8	16
16 - 18	5	3	8
> 18	0	0	0
Total	124	312	436

Mean trees per acre	St. Dev.	Range
436	10.34	290 - 560

Table 11



DBH	Ponderosa	Doug. Fir	Total
<2	8	5	13
2 - 4	5	13	18
4 - 6	28	18	46
6 - 8	5	10	15
8 - 10	8	5	13
10 - 12	3	3	6
12 - 14	0	3	3
14 - 16	0	0	0
16 - 18	0	0	0
> 18	5	0	5
Total	62	57	119

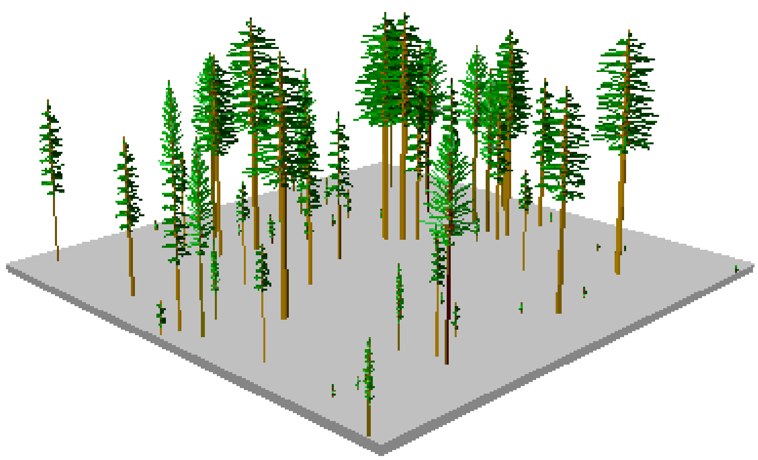
Mean trees per acre	St. Dev.	Range
119	13.34	40 - 160

Table 12

Visualizations

Sarsapkin Stand Type A

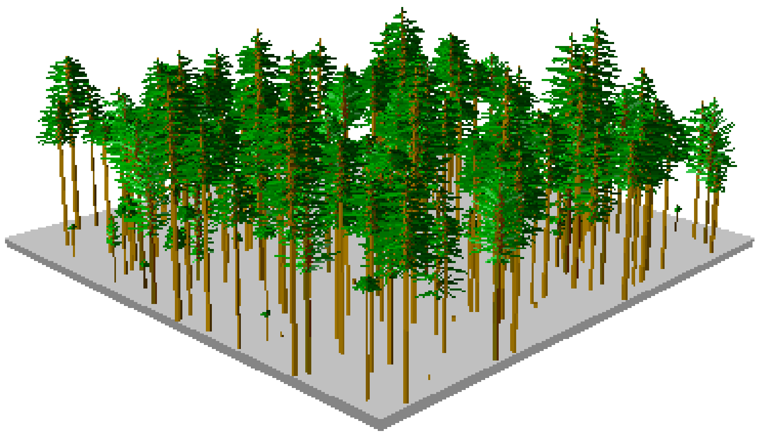
Current (2009) 305 trees per acre



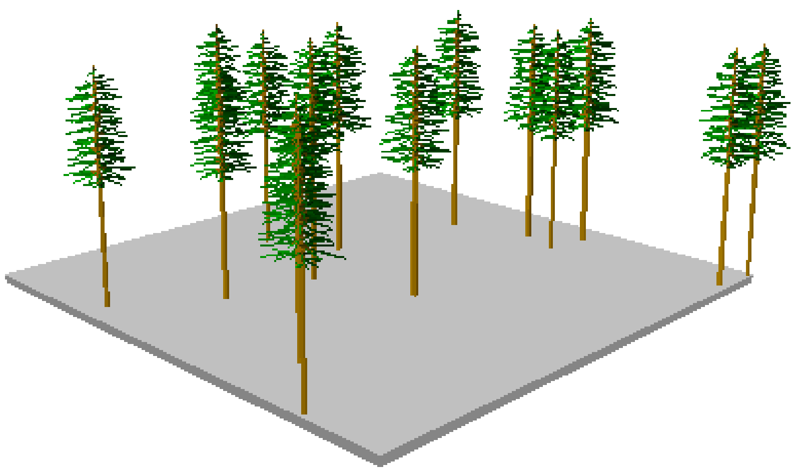
Historical (1896) 65 trees per acre

Table 13

Sarsapkin Stand Type B



Current (2009) 190 trees per acre

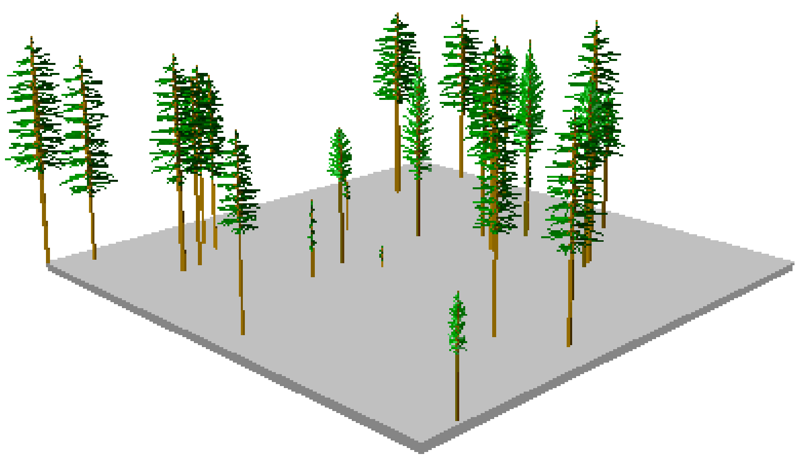


Historical (1896) 15 trees per acre

Table 14

Sarsapkin Stand Type C

Current (2009) 63 trees per acre

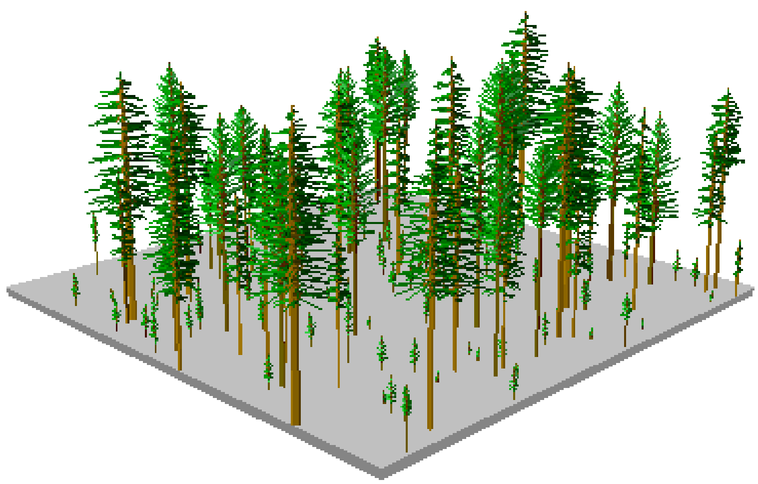


Historical (1896) 27 trees per acre

Table 15

Sinlahekin Stand Type A

Current (2009) 213 trees per acre

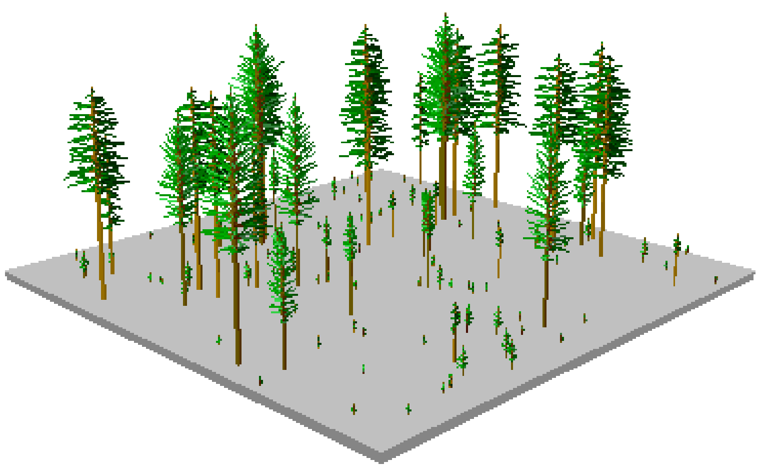


Historical (1896) 171 trees per acre

Table 16

Sinlahekin Stand Type B

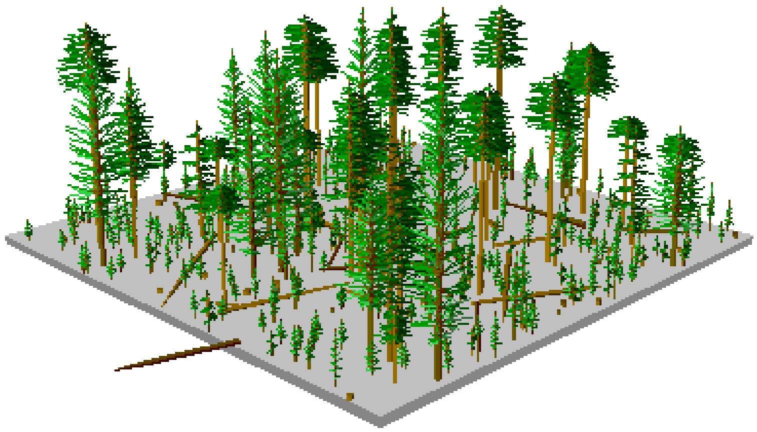
Current (2009) 250 trees per acre



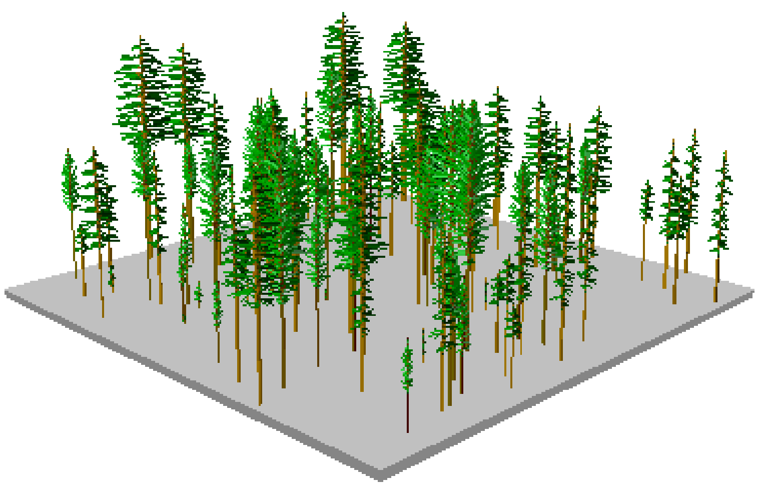
Historical (1896) 121 trees per acre

Table 17

Sinlahekin Stand Type C



Current (2009) 436 trees per acre



Historical (1896) 119 trees per acre

Table 18

References

Agee, J.K. and D.J. Johnson. 1988. Ecosystem management for parks and wilderness. University of Washington Press, Seattle, WA.

Agee, J.K. 1993. Fire Ecology of Pacific Northwest Forests. Island Press, Washington, DC.

Agee, J.K. 1994. Fire and weather disturbances in terrestrial ecosystems of the eastern Cascades. Gen. Tech. Rep. PNW-GTR-320. Portland, OR: US Dept. of Agriculture, Forest Service, Pacific Northwest Research Station. 52p.

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

Arno, S.F. and K.M. Sneck. 1977. A method for determining fire history in coniferous forest of the mountain west. INT-GTR-42. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station.

Avery, T. Eugene. 1967. Forest Management. McGraw – Hill Book Company. NY. p 140.

Bonnicksen, T.M. and E.C. Stone. 1982. Reconstruction of a presettlement giant sequoia-mixed conifer forest community using the aggregation approach. Ecology, 63(4): 1134-1148.

Brown, P.M., Swetnam, T.W., 1994. A cross-dated fire history from coast redwood near Redwod National Park, CA. Can. J. For. Res. 24: 21-31.

Camp, A.E. 1999. Age structure and species composition changes resulting from altered disturbance regimes on the eastern slopes of the Cascades Range, Washington. Journal of Sustainable Forestry, 9(3/4): 39-67.

Cochran, P.H. and J.W. Barrett. 1998. Thirty-five year growth of thinned and unthinned ponderosa pine in the Methow Valley of northern Washington. Res. Pap. PNW-RP-502. Portland, OR. US Dept. of Agriculture, Forest Service, Pacific Northwest Research Station. 24p.

Covington, W.W. and M.M. Moore. 1994. Southwestern ponderosa forest structure: changes since Euro-American settlement. J. For. 92: 39-47.

Cowlin, R.W., P.A. Briegleb, and F.L. Moravets. 1942. Forest resources of the ponderosa pine region of Washington and Oregon. U.S. Department of Agriculture, Forest Service. Misc. Publ. #490. 99 p.

Dieterich, J.H., Swetnam, T.W., 1984. Dendrochronology of fire-scarred ponderosa pine. For. Sci. 30: 238-247.

Everett, R., D. Baumgartner, P. Ohlson, R. Schellhaas. 2008. Structural classes and age structures in 1860 and 1940 reconstructed fir-pine stands of eastern Washington. Western North American Naturalist. 68(3) pp. 278 – 290.

Everett, R., D. Baumgartner, P. Ohlson, R. Schellhaas, R. Harrod. 2007. Development of current stand structure in dry fir-pine forests of eastern Washington. Journal of the Torrey Botanical Society. 134(2), pp. 199 – 214.

Everett, R.L., R. Schellhaas, P. Ohlson, D. Spurbeck and D. Keenum. 2003. Continuity in fire disturbance between riparian and adjacent sideslopes in the Douglas-fir forest series. Forest Ecology and Management 175 (2003) 31 – 47.

Everett, R.L., R. Schellhaas, D. Keenum, D. Spurbeck, and P. Ohlson, 2000. Fire history in the ponderosa pine/Douglas-fir forest on the east slope of the Washington Cascades. J. For. Ecol, and Manage. 129:207-225.

Everett, R.L., J. Lehmkuhl, R. Schellhaas, P. Ohlson, D. Keenum, H. Riesterer and D. Spurbeck. 1999a. Snag dynamics in a chronosequence of 26 wildfires on the east slope of the Washington Cascades. International Journal of Wildland Fire, 9(4): 223-234.

Everett, R.L., R. Schellhaas, D. Keenum, D. Spurbeck, P. Ohlson. 1999b. Fire History in the Ponderosa Pine/Douglas-Fir Forests on the East Slope of the Washington Cascades. Forest Ecology and Management, 129: 207-225.

Everett, R.L., A. Camp and R. Schellhaas. 1996. Building a new forest with fire protection in mind. In: Proceedings of the Society of American Foresters National Convention, Portland, ME,Oct. 28 - Nov. 1, 1995. Bethesda, MD, Society of American Foresters. pp. 192-199.

Fiedler, C.E. and D.A. Lloyd. 1992. Autecology and synecology of western larch. In: Schmidt, W.C. and K.J. McDonald, comps. 1995. Ecology and management of Larix forests: a look ahead. Proceedings of an international symposium; 1992 October 5-9; Whitefish, MT. Gen. Tech. Rep. INT-GTR-319. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 521 p.

Finch, R.B. 1984. Fire history of selected sites on the Okanogan National Forest. Okanogan, WA: U.S. Department of Agriculture, Forest Service, Okanogan National Forest. 22 p.

Flannagan, P.T. 1998. Relationships among disturbance agents in subalpine forest. PhD Dissertation, University of Idaho. 66 pp.

Franklin, J.F. and C.T. Dyrness. 1988. Natural Vegetation of Oregon and Washington. O.S.U. Press, Corvallis, OR. 452 pp.

Fritts, H.C., 1976. Tree Rings and Climate, Academic Press, London.

Fulè, P.Z., W.W. Covington and M.M. Moore. 1997. Determining reference conditions for ecosystem management of southwestern ponderosa pine forests. Ecological Applications, 7(3): 895-908.

Gorman, M.W. 1899. Eastern part of the Washington forest reserve. 19th annual report, part V. Washington D.C. U.S. Department of the Interior, Geological survey. pp. 315-350.

Graham, R.T., A.E. Harvey, T.B. Jain and J.R. Tonn. 1999. The effects of thinning and similar stand treatments on fire behavior in Western forests. Gen. Tech. Rep. PNW-GTR-463. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 27 p.

Grissino-Mayer, H.D., 1995. Tree-ring reconstructions of climate and fire history at El Malpais National Monument, New Mexico. Ph.D. Dissertation, University of Arizona, Tucson.

Harmon, M.E., J.F. Franklin, F.J. Swanson, P. Sollins, S.V. Gregory, J.D. Lattin, N.H. Anderson, S.P. Cline, N.G. Aumen, J.R. Sedell, G.W. Lienkaemper, K. Cromack, Jr., and K.W. Cummins. 1985. Ecology of coarse woody debris in temperate ecosystems. Advances in Ecological Research 15:133-302.

Harrod, R.J., B.H. McRae and W.E. Hartl. 1999. Historical stand reconstruction in ponderosa pine forests to guide silvicultural prescriptions. Forest Ecology and Management, 114: 433-446.

Holmes, R.L., Adams, R.K., Fritts, H.C., 1986. Quality control of crossdating and measuring: a users manual program COFECHA. In: Tree-Ring Chronologies of Western North America: California, eastern Oregon and northern Great Basin. Laboratory of Tree-Ring Research, University of Arizona, Tucson, AZ. pp 41-49.

Huff, M.H., R.D. Ottmar, E. Alvarado, R.E. Vihnanek, J.F. Lehmkuhl, P.F. Hessburg and R.L. Everett. 1995. Historical and current forest landscapes in eastern Oregon and Washington. Part II: Linking vegetation characteristics to potential fire behavior and related smoke production. Gen. Tech. Rep.

PNW-GTR-355. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 43 p.

LANDFIRE. 2009, January. Homepage of the LANDFIRE Project, U.S. Department of Agriculture, Forest Service; U.S. Department of Interior, Online Available: http://www.landfire.gov/index.php 9/17/09.

Lillybridge, T.R., B.L Kovalchik, C.K Williams and B.G. Smith. 1995. Field guide for forested plant associations of the Wenatchee National Forest. Gen. Tech. Rep. PNW-GTR-359. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 335 p.

Madany, M.H., Swetnam, T.W., West, N.E., 1982. Comparison of two approaches for determining fire dates from tree scars. For. Sci. 28: 856-861.

McGaughey, B. 1994. Stand visualization system 1.50. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

McNeil, R.C. and D.B. Zobel. 1980. Vegetation and fire history of a ponderosa pine and white fir forest in Crater Lake National Park. Northwest Science, 54: 30-46.

O'Hara, K.L., P. Latham, P. Hessburg and B. Smith. 1996. A structural classification for inland northwest forest vegetation. Western Journal of Applied Forestry, 11(3): 97-102.

Ohlson, T.H. 1996. Fire regimes of the ponderosa pine-Douglas-fir/beardless bluebunch wheatgrass plant association in the Methow Valley of North Central Washington. MS thesis, Pullman, WA: Washington State University. 87 p.

Ohlson, P. and R. Schellhaas 2001. Historical and current stand structure in Douglas-fir and ponderosa pine forests. Unpublished report. pp 30.

Oliver, C.D. and B.C. Larson. 1996. Forest stand dynamics. New York, Wiley, 520 pp.

Plummer, F.G., 1902. Forest conditions of the Cascade Range, Washington. Professional paper No. 6. Series H, Forestry. U.S. Department of Interior, U.S. Geological survey. Gov. printing office, Washington, DC.

Schellhaas, R., D.Spurbeck, P. Ohlson, D. Keenum, A. Conway 2002. Report to the Okanogan and Wenatchee National Forests on the results of the Frosty Creek Planning Area fire history research. Pacific Northwest Research Station, Wenatchee, WA. 79pp.

Schellhaas, R., D. Spurbeck, P. Ohlson, D. Keenum. A. Conway. 2003. Report to the Okanogan and Wenatchee National Forests on the results of the Twentymile Planning Area fire history research. Pacific Northwest Research Station, Wenatchee, WA, 67pp.

Thomas, J.W., R.G. Anderson, C. Maser and E.L. Bull. 1979. Snags. In: Wildlife habitats in managed forests, the Blue Mountains of Oregon and Washington (J.W. Thomas, editor). U.S. Department of Agriculture, Forest Service. Agriculture handbook No. 553. Washington D.C. pp 60-77

Touchan, R., Allen, C.D., Swetnam, T.W., 1996. Fire history and climatic patterns in ponderosa pine and mixed-conifer forests of the Jemez Mountains, northern New Mexico. In: Allen, C.D. (tech. ed.). Fire effects in southwestern forests: Proceedings of the second La Mesa fire symposium. 1994 March 29-31. Los Alamos, NM. Gen.Tech. Rep. RM-GTR-286. Fort Collins, CO: USDA Forest Service, Rocky Mountain Forest and Range Experiment Station. 216 p.

Schmidt, W.C. and R.C. Shearer. 1992. Larix occidentalis: a pioneer of the North American west. In: Schmidt, W.C. and K.J. McDonald, comps. 1995. Ecology and management of Larix forests: a look ahead.

Proceedings of an international symposium; 1992 October 5-9; Whitefish, MT. Gen. Tech. Rep. INT-GTR-319. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 521 p.

Stokes, M.A. and T.L. Smiley. 1968. An introduction to tree-ring dating. The University of Chicago Press, Chicago, IL.

White, Alan S. 1985. Presettlement regeneration patterns in a southwestern ponderosa pine stand. Ecology, 66(2): 589-594.

Williams, C.K., B. Kelly, B. Smith and T. Lillybridge. 1995. Forested plant associations of the Colville National Forest. Gen. Tech. Rep. PNW-GTR-360. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 375 p.

Washington State Department of Natural Resources. 2001. Forest Practices Rules, Title 222 WAC.

Yamaguchi, D.K., 1991. A simple method for cross-dating increment cores from living trees. Can. J. For. Sci. 21: 414-416.

Appendix

Plant Association Groups (PAGs) with respective Plant Associations (Lillybridge *et al.* 1995, Harrod *et al.* 1999)

Hot/Dry/Shrub/Grass (HDSG)

Pinus ponderosa/Agropyron spicatum

Pseudotsuga menziesii/Agropyron spicatum

Pinus ponderosa/Purshia tridentata/Agropyron spicatum

Pseudotsuga menziesii/Purshia tridentata/Agropyron spicatum

Pseudotsuga menziesii/Symphoricarpos albus/Agropyron spicatum

Warm/Dry/Shrub/Herb (WDSH)

Pseudotsuga menziesii/Arctostaphylos uva-ursi

Pseudotsuga menziesii/Arctostaphylos uva-ursi/Purshia tridentata

Pseudotsuga menziesii/Spirea betulifolia var. lucida

Cool/Dry/Grass (CDG)

Pseudotsuga menziesii/Arctostaphylos uva-ursi/Calamagrostis rubescens

Pseudotsuga menziesii/Purshia tridentata/Calamagrostis rubescens

Pseudotsuga menziesii/Spirea betulifolia var. lucida/Calamagrostis rubescens