WINTER IN THE OUACHITAS –
THREE MANSCRIPTS ON SHORTLEAF PINE (*PINUS ECHINATA* MILL.) AND SEVERE WINTER STORMS

By

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ABSTRACTS

MANUSCRIPT I

Eleven new *Pinus echinata* Mill. site chronologies from the Ouachita Mountains of Oklahoma and Arkansas were created, then combined into a single master chronology (the Ouachita Chronology), the longest site chronology (Babylon Bluff) dating back to 1781. Elevation of sampled locations ranged from 147 to 334 m. Slopes (measured with a clinometer) ranging from 0 to 30% and all aspects (measured with a hand-held compass) except northeast were represented. Elevation affects precipitation and, hence, site quality; slope and aspect affect the intensity of in-coming solar radiation and the degree of moisture stress. Except for Babylon Bluff, which had 12 missing rings and was on a rocky and difficult site, there were only 11 missing rings, all occurring in severe storm years (1963, 1992 and 2001). False rings occurred frequently near the pith. Two years (1912 and 1952), both with June droughts, produced false rings in most trees; this was so common it was used as a cross-dating marker. The chronology meets the standard of an Expressed Population Signal (EPS) greater than 0.85 for the years 1783 to 2009 and the 13-tree minimum for the years 1872 to 2009. Over 300 series cover the interval from 1980 to 2007. It is suitable for climatology, weather reconstructions, dendroecology and dendroarcheology, climate change and weather studies, and the author is using them to provide cross-dates for sawlogs recovered from the bottom of a 19th-century mill pond near Idabel, Oklahoma.

MANUSCRIPT II

Severe winter storms cause serious damage to trees, timber and power lines each year. In the Ouachita Mountains historical records of these storms extend back only 117 years and are often of low quality with missing data. A severe winter storm signal in *Pinus echinata* Mill. allows this record to be extended back 264 years. Tree ring data is used to predict storm occurrence and the predictions compared with historical records using Cohen's Kappa, a measure of concordance between two discrete data sets. Drought may be associated with the occurrence of severe winter storms; use of the Palmer Drought Severity Index (PDSI) to detrend tree ring data is a risky proposition. The winter storm signal is consistent with injury to the tree by trunk breakage, branch loss and bending. Broken trees have wider growth rings than unbroken trees, both before and after the storm. This suggests greater exposure to ice accumulation by large crowns. On high-quality sites missing rings occur only in severe storm years. An equation comparing the first two ring widths following a storm to the following two rings and matching this with proportions of trees showing growth loss, works well in identifying storm years. Average recurrence interval between major winter storms is 17 years (range: 16 to 20); two out of three known ice storm years produce trunk breakage. Study results can be used for partial assessment of economic risk to growers of *Pinus echinata*. Further research could allow ice storms to be distinguished from wind storms and lesser winter (snow) storms using a combination of seven-year standardized ring widths applied to pines and the two-part signal detected by Lafon and Speer (2002) in oaks. After correction for winter storm occurrence, previous and current year's ring thicknesses might be used to predict second and third-quarter drought and/or precipitation. Corrected ring thicknesses could be used to improve estimates of past drought intensities. Collectively, tree ring chronologies make a powerful tool for weather and climate studies at a finer scale than is possible with any other proxy.

MANUSCRIPT III

Ice storms occur every year in the southern United States and are among the most-disruptive influences on southern pines. Many variables affect tree breakage and amount of height lost to ice damage. Multiple linear regression and logistic methods were used to find models that predicted the probability and height of the break during an ice storm. Diameter (DBH), total height (THt), live crown ratio (LCR), height of the lowest live limb (CHt) and height of ice-caused breakage (BHt) data were obtained from Oklahoma State University's (OSU's) ongoing growth and yield study of *Pinus echinata* Mill. (shortleaf pine) in southeast Oklahoma and southwest Arkansas. Stands were naturally-regenerated, even-aged stands ranging between 31 and 106 years old; although, one tree dated to 1881. Pre-ice storm stocking in December 2000 ranged from 9.5 square meters per hectare to 34.6 $m^2 ha^{-1}$. Pre-storm DBHs ranged from 0.191m to 0.460m. Series data were also obtained from the Univeristy of Arkansas' Shortleaf Canyon Chronology (Cerny 2009), supplemented with series from an adjacent site, Babylon Bluff, which is the western-most known stand of *P. echinata*. Shortleaf Canyon is an old-growth stand consisting of mature trees of a variety of ages growing in a rocky canyon. Measurements for the OSU study were made using diameter tapes (DBH to nearest 0.025cm at a height of 1.37m), lazer hypsometers, clinometers and tapes (BHt, CHt and THt to nearest 0.035m, measured from ground on the high side of the tree). A multiple linear model using DBH, THt and LCR to predict BHt accounted for a total of 22.3% of total variation in break height. A simpler model used THt alone to predict BHt and accounted for 15.4% of total variation. Two logistic models using THt and DBH were used to estimate the probability of tree breakage and had a p-value = 0.0001 (THt) and p-value = 0.0277 (DBH), respectively. The logistic model using THt alone gave a range of 12.2% to 36.4% probability of breaking, a range great enough to use in growth simulators. These models have practical applications in timber marking, financial management of timber resources and in computer simulations of forest growth.

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CHAPTER I

(MANUSCRIPT I)

SHORTLEAF PINE (*PINUS ECHINATA* MILL.) CHRONOLOGY FOR THE WESTERN MOUNTAINS OF OKLAHOMA AND ARKANSAS

INTRODUCTION

The Ouachita Mountains are located in western Arkansas and eastern Oklahoma. The highest peak is Mount Magazine (839m), also the highest point in Arkansas. They are folded mountains. Unique in North America, the four principle ranges are oriented east-west, rather than north-south. This creates considerable variation in plant and animal communities on opposite sides of the ridges with hardwood forest predominating on wetter (northern aspect, bottomland, lower hill and deep soils) sites and pines on drier (southern aspect, hilltop, hillside and shallow soils) ones. Climate of the Ouachita Mountains is humid subtropical. Summers are hot and winters mild. Monthly mean daily temperatures range from -1° to 34° C. Mean annual precipitation is about 138cm (Figure 1), occurs mostly as rain and is fairly evenly distributed throughout the year (Adams et al. 2004).

The objective of this study was to produce a master *Pinus echinata* chronology for the western Ouachita Mountains covering the period of modern climate records (1905 to 2009) for use in future weather and climate studies and to produce a set of chronologies covering the period of greatest increase in atmospheric carbon dioxide (1960 to 2009). *P. echinata* chronologies were last collected from southwestern Arkansas and southeastern Oklahoma in the early 1980s (Stahle 1979; Stahle 1980; Stahle et al. 1982a; Stahle et al. 1982b). Since then there has been only one published *P. echinata* chronology

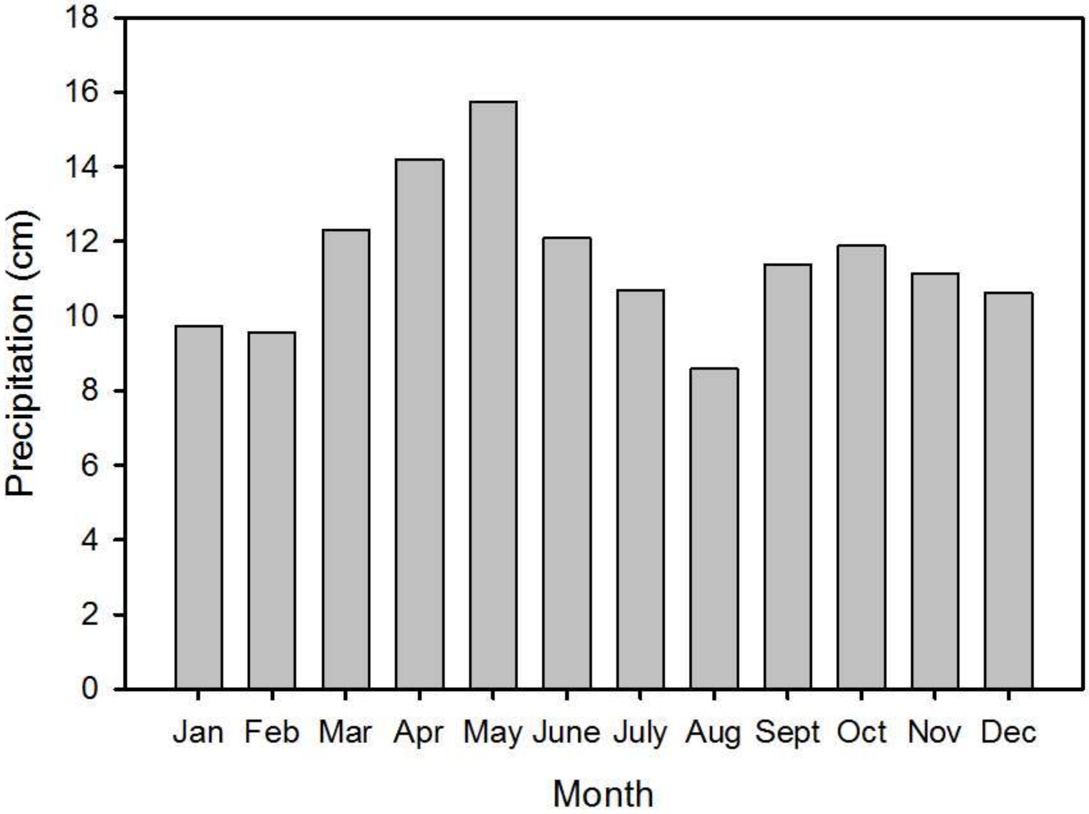

Figure 1. Average monthly precipitation (cm) for Mena, Arkansas, 1906-2010. Tree ring width is most sensitive to the dry months (July, August, September and to a lesser extent, January and February).

from this area and that one, Gee Creek, was located on the with which to study the divergence phenomenon (in which growth ring width is becoming Ozark National Forest (Stambaugh and Guyette 2003). The shortage of more-recent chronologies with which to study the divergence phenomenon (in which growth ring width is becoming decoupled from precipitation and is starting to decouple from precipitation and is starting to respond to atmospheric carbon dioxide levels) (D’Arrigo et al. 2008) and other climate change and weather issues was noted by Mann (2012) in his book on “The Hockey Stick Controversy. ”

I relied on a regional growth-and-yield study to develop the new chronology. Between 1985 and 1987 Oklahoma State University (OSU) installed a *P. echinata* growth study on the Ouachita National Forest. One hundred eighty-two new 0.08ha plots were installed and an additional eighteen plots from a previous study were included and updated. Plots were re-measured at approximately five-year intervals since then, most-recently in 2012. The original study plan called for a maximum tree age of 90, which in 1985 would have allowed no tree dating from before 1895 into the study. When 486 increment cores were collected in 2007 to 2009 for an ice storm study, several older trees were found, including one dating to 1881. As only two cores in the OSU growth-and-yield study had beginning dates (not pith dates) after 1985, and the vast majority of cores were from before 1980, an opportunity arose to create a new chronology that covered the years since the last Ouachita site chronologies were published (1982).

The oldest instrumental record for a weather station on the Ouachita National Forest was from Dallas, Arkansas beginning September 4, 1896 (Clarke 1896). The Dallas station was closed on December 31, 1905 and never reopened. The weather station at Mena, Arkansas began operation on January 1, 1906 (Alciatore 1906) and except for six-month gaps in 1910 and 1979/1980, operated almost continuously since. Thus there were, at most, 78 years (1905 through 1982) of data for calibrating Ouachita chronologies.

Geographically, sampling sites were distributed from Babylon Bluff (35° 25’ N, 95° 50’ W) in the northwest corner, to Caddo Gap (34° 27’ N, 93° 30’ W) in more-or-less the southeast corner (Figure 2) and from Russellville, Arkansas (35° 17’ N, 93° 08’ W) in the northeast to Broken Bow, Oklahoma (34° 01’ N, 94° 44’ W) in the southwest. There were four previously published site chronologies from the Ouachita Mountains (Figure 3). Three others (Drury House, Gee Creek and Mount Magazine) used for comparisons in this study, were in the Ozark National Forest.[1]

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[1] Mount Magazine, though geologically one of the Ouachita Mountains and an Arkansas State Park, is surrounded by the Ozark National Forest.

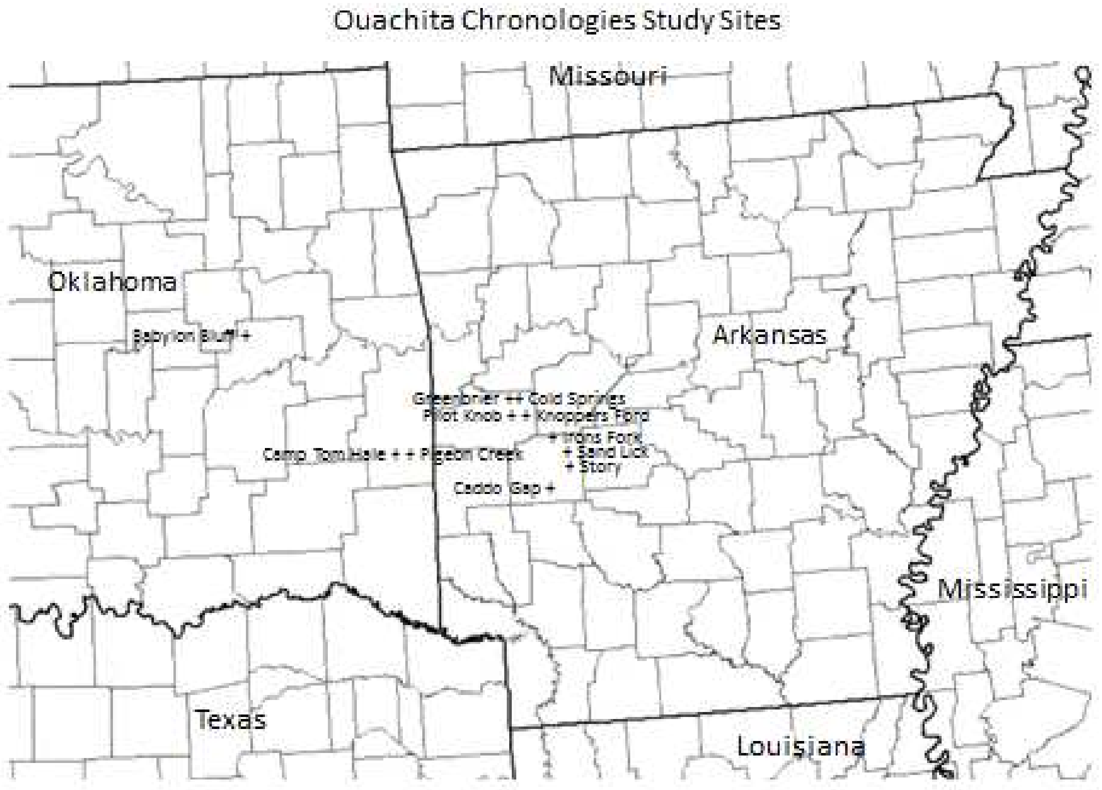

Figure 2. Ouachita Site Chronologies locations. Babylon Bluff, located on private land, is an old growth stand and the western-most occurrence of *Pinus echinata*. All other sites are second-growth stands on the Ouachita National Forest. Map data from National Atlas of the United States, United State Department of the Interior, 2013.

Characteristics of *P. echinata*

P. echinata is found from southeast Texas to central Pennsylvania and from eastern Oklahoma to the Atlantic Ocean. Its range extends slightly farther west and north than that of loblolly pine (*P. taeda* L.) and it tolerates drier and colder sites than do other southern pines. Its best (fastest commercial volume growth) development is in Arkansas. Average precipitation ranges from 114 to 140cm. The 10° C average annual temperature isoline approximates the northern limit of its range (Lawson 1990). In its seedling stage stage it can tolerate loss of its needles by burning and the heavy bark and lofty crown of mature trees protect them from most fire damage.

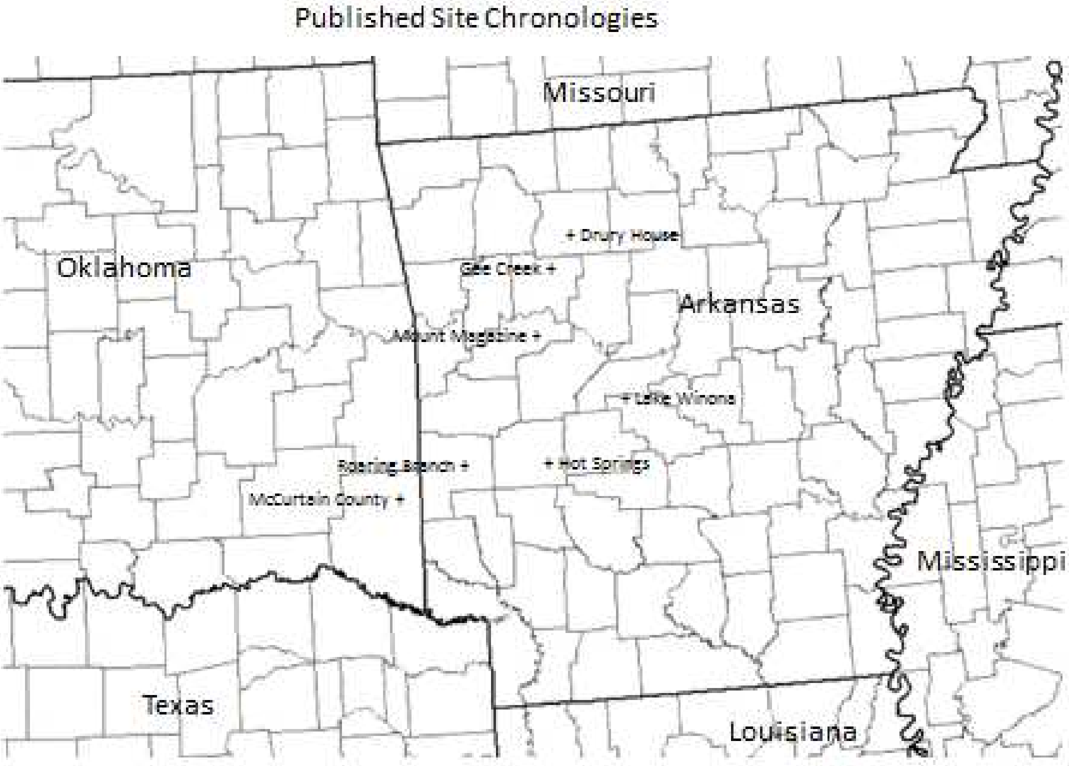

Figure 3. National Climatatic Data Center *Pinus echinata* site chronologies. Drury House, Gee Creek and Mount Magazine are on the Ozark National Forest. All others are on the Ouachita National Forest. Map data from National Atlas of the United States, United States Department of the Interior, 2013.

P. echinata has distinct annual rings with clear differentiation between early and late wood. False rings are frequent in juvenile wood and in years with June droughts (Figure 4. Missing rings occur in years following extreme winter storms and on dry, rocky sites where missing (“zero”) rings occur as a result of drought, storms, injury and other, unknown, causes.

On the Ouachita National Forest *P. echinata*’s most-common understory associate is sweet-gum (*Liquidamber styraciflua* L.) when the site index[2] exceeds 25.9m and red maple (*Acer rubrum* L.) when

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[2] Site index is the height to which a tree will grow at a specified (base) age. For shortleaf pine in this study, the base age is 50 years. Site index is considered a measure of site quality. Damaged trees are excluded from site index calculations.

Figure 4. End grain of *P. echinata* showing early wood, late wood, false ring and resin canals. Banding pattern in late wood is a product of variable rainfall. Used by permission of Eric Meier, The Wood Database (www.wood-database.com).

the site index is less than 19.8m, both on a 50-year basis (Stevenson et al. 2008). Between 19.8m and 25.9m, shortleaf pine has many understory associates.

METHODS

Cores from the growth-and-yield study were grouped into ten site chronologies, based on proximity. All chronologies contained at least 22 series (a list of ring width measurements made from one increment core), in this case, each from a separate tree. Different series could result from different readings of a core and from different cores of the same tree. Elevation ranged from 147m to 334m. All aspects except northeast were represented. Slopes ranged from nearly flat to 30%; compression wood was not a problem. All sites were logged at least once prior to stand establishment. Plots were thinned to pre-determined densities at establishment of the growth-and-yield study (1985 to 1987), then thinned again between 1995 and 1997. Topography included upland, hillside and lower hill sites (Table 1). No bottomland sites were included; although, two (Greenbrier and Cold Springs) were on deep soils on lower hill sites only meters from the Petit Jean River. Though there was no evidence the sites were ever covered with water, flooding during extremely wet years was a possibility.

Babylon Bluff near Henryetta, Oklahoma, consisted of two parts, Babylon Bluff on the south (west[3]) side of the Canadian River and Shortleaf Canyon on the north (east[3]) side, essentially the same stand. Shortleaf Canyon was old growth, but Babylon Bluff was horse- logged about 1900, except for two small, rocky, inaccessible canyons where old growth trees remained. Logs were skidded to the river and floated to Fort Smith, Arkansas (Babylon 2009). Cerny (2009) collected 42 shortleaf pine cores from Shortleaf Canyon. In 2010 the author collected another six cores from the Babylon Bluff canyons. These were added to the 42 from Shortleaf Canyon to create the Babylon Bluff site chronology.

On the Babylon Bluff/Shortleaf Canyon site, old, dominant or co-dominant trees were selected for sampling on the basis of a line-plot cruise. Though not on a cruise plot, tree slpx22 was included in the chronology because of its age. Cores were taken at a height of 0.30m. On growth-and-yield plots, cores were taken at DBH (1.37m) on the side toward the plot center, so that all directions were represented. No plot exceeded a 30% slope; compression wood was not a problem. Because the sample was intended for an ice storm study, two broken and two unbroken trees from each plot were cored, if present. When this provided too few samples from unbroken trees, all remaining trees on each plot were sampled.

Nine sites had series that could not be cross-dated. Cross-dating failure could result from mistakes in reading the core (usually multiple mistakes), suppression, release, different microsites, disease or canopy gaps. On two sites - Camp Tom Hale and Greenbrier - all trees were succesffuly cross-dated. Trees that could not be cross-dated were removed from the dataset. The highest number of excluded trees

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[3] The Canadian River flows north to south at this point.

Table 1. Basic characteristics of *P. echinata* sampling locations in the Ouachita Mountains. The area covered extends from Babylon Bluff near Henryetta, Oklahoma, in the northwest to Story near Mount Ida, Arkansas, in the southeast.

Site	Latitude N	Longitude W	Elevation (m)	Slope (%)	Aspect	Topography.
Babylon Bluff	35°25’	95°50’	187	20	SE	Hillside
Caddo Gap	34°27’	93°30’	248	10	N	Lower hill
Camp Tom Hale	34°45’	94°53’	225	12	SW	Hillside
Cold Springs	35°03’	93°53’	154	10	N	Lower hill
Greenbrier	35°01’	94°03’	147	10	NW	Lower hill
Irons Fork	34°45’	93°28’	206	0	-----	Upland
Knoppers Ford	35°00’	93°51’	231	30	W	Hillside
Pigeon Creek	34°38’	94°32’	334	25	W	Hillside
Pilot Knob	35°00’	94°03’	244	20	S	Hillside
Sand Lick	34°44’	93°27’	260	25	S	Hillside
Story	34°40’	93°28’	218	10	SE	Upland

was at Babylon Bluff (12 out of 48; 25%); this was also the highest proportion of excluded trees (Table 2).

Samples included many suppressed and intermediate trees. Those with intercorrelations below 35% were dropped from the dataset, except for two series which were retained because of their age. These two (Babylon Bluff bbr001B and Story p198t008) had intercorrelations of 26% and 28%, respectively. Cross-dating for these two trees was checked by comparing them with the McCurtain County and Lake Winona chronologies.

False rings occurred on nearly every core, especially near the pith. The 1912 and 1952 rings both had pronounced false rings; both years had June droughts. Missing rings were identified by cross-dating with cores from nearby trees. Except for Babylon Bluff which was on a dry, rocky site, missing rings occurred only in the 1963, 1992 and 2001 rings (Table 2). In one instance, both 2001 and 2002 were missing.

The widest *average* TRW was at Greenbrier (2.334mm) and the narrowest at Babylon Bluff (1.514mm); the average was 1.800mm. Minimum TRW was 0.020mm (Caddo Gap and Story); the maximum TRW was 9.652mm (Knoppers Ford). The lowest standard deviation was at Story (0.677mm)

Table 2. Basic site chronology information for naturally regenerated, even-aged *Pinus echinata* stands in the Ouachita Mountains of Oklahoma and Arkansas, USA. Babylon Bluff had 12 of the 23 missing rings observed. Excluding Babylon Bluff which was on a dry, rocky site, all missing rings occurred in severe storm years (1963, 1992 and 2001).

Site	Time Span	Length (yrs)	Trees	Cores	Trees Excluded	Missing Rings
Babylon Bluff	1781-2009	229	55	48	71	12
Caddo Gap	1915-2009	95	25	23	2	0
Camp Tom Hale	1967-2009	43	29	29	0	2
Cold Springs	1941-2008	68	48	46	2	1
Greenbrier	1946-2007	62	32	32	0	0
Irons Fork	1932-2007	76	29	27	2	3
Knoppers Ford	1924-2007	84	25	24	1	0
Pigeon Creek	1943-2009	67	26	22	4	0
Pilot Knob	1940-2007	68	27	25	2	2
Sand Lick	1929-2007	79	47	39	8	1
Story	1888-2007	120	45	43	2	2

and the highest was at Camp Tom Hale (1.063mm). The highest value of mean sensitivity was at Babylon Bluff (0.461) and the lowest was at Greenbrier (0.339) (Table 3).

The longest site chronology (Babylon Bluff) contained 229 years; the shortest (Camp Tom Hale) contained 43 years (Table 2). The Ouachita Chronology overlapped other *P. echinata* chronologies from the area by 229 years. Other local chronologies had lengths of 247 years – Hot Springs (Stahle et al. 1982b), 312 years – Lake Winona (Stahle 1980), 295 years – McCurtain County (Stahle et al. 1982a), 90 years – Mount Magazine (Estes 1961) and 263 years – Roaring Branch) (Stahle et al. 1982c). Sample depth from 1957 to 2007 is over 300 series; from 1980 to 2007 it is over 330 series, important periods for study of the divergence problem (Mann 1998; D'Arrigo et al. 2008). It has a total sample depth of 352 series (Figure 5), almost seven times that of the next largest chronology, McCurtain County (52 series).

Cores were air-dried and glued on wooden mounts, then sanded with progressively finer sand paper finishing with nine-micron grit. TRW was measured to the nearest 0.010mm using a Velmex measuring system and a 30X binocular microscope, then checked for cross-dating errors using COFECHA (Holmes 1983; Grissino-Mayer 2001). When necessary, measurements were repeated and rechecked. Series with intercorrelations less than 35% were deleted from the sample. The oldest two

Table 3. Tree ring statistics for raw chronologies including mean tree ring width, standard deviation (STD), minimum and maximum TRW, mean sample segment length (mssl), initial year of Expressed Population Signal (EPS>0.85), EPS for included years and mean sensitivity (MS).

Site	Mean(mm)	STD(mm)	Min-Max(mm)	mssl(yrs)	EPS>0.85	EPS[1]	MS
Babylon Bluff	1.51	0.82	0.06-9.07	124	1783	0.976	0.461
Caddo Gap	1.91	0.75	0.02-1.27	65	1916	0.851	0.391
Camp Tom Hale	2.21	1.06	0.31-9.15	34	1967	0.927	0.339
Cold Springs	2.09	1.05	0.07-8.95	60	1941	0.928	0.366
Greenbrier	2.33	0.92	0.30-8.42	58	1952	0.860	0.333
Irons Fork	1.73	0.74	0.21-8.17	60	1932	0.859	0.349
Knoppers Ford	1.79	0.78	0.08-9.65	76	1924	0.863	0.404
Pigeon Creek	2.05	0.72	0.06-4.83	54	1943	0.850	0.335
Pilot Knob	1.82	0.81	0.06-7.05	55	1952	0.859	0.371
Sand Lick	1.75	0.68	0.06-5.80	56	1929	0.925	0.399
Story	1.58	0.68	0.02-8.17	73	1888	0.914	0.390
Ouachita[2]	1.80	0.83	0.02-9.65	68	1783	0.993	0.393

[1] Applies to years since EPS became greater than 0.85, inclusive.

[2] Values listed apply to the master chronology and are not averages of the component site chronologies.

trees were cross-dated by comparison with the McCurtain County Chronology (Stahle et al. 1982a) and Lake Winona Chronology (Stahle 1980). Pointer year (PY) analysis identified possible climate signals in the site chronologies. Autocorrelation going back three years was removed from the data. No series out of 472 had significant autocoreelation in the fourth year. When a series failed to show significant autocorrelation at the 95% level of confidence, it was used as is. Each series was detrended using a logarithmic decay curve, then transformed to give each series equal weight before being averaged by year to create the site chronology. If a series could not be detrended at the 95% level of confidence, it was used as is (Figure 6). Series were not smoothed. The same process that was used to create the site chronologies was used for the regional chronology. EPS (below) was calculated for each site chronology using Baillie-Pilcher *t* (t_{BP})[4] and *r* (r_{BP})[5] values (Baillie and Pilcher 1973) (Table 4).

The Ouachita chronology meets the EPS > 0.85 requirement for dendroclimatology for the years 1783 to 2009 and a thirteen tree minimum for the years 1872 to 2009. Over 300 series cover the period from 1980 to 2007. To give series equal weights, an average ring width for each series and a grand mean for the site chronology were calculated. Each year's ring width was then multiplied by the grand mean and divided by the average for its series. These were then averaged by year to yield the site chronologies. The same process was used to produce the master chronology.

Signal strength was tested using the EPS (Wigley et al. 1984), the mean inter-series correlation coefficient between the average of a finite number of time series and the population average (Tables 3 and 5). The useable portion (EPS > 0.85) of each chronology was calculated in order to ensure reliability for future climate studies (Table 5). Mean sensitivity was determined for each chronology (Table 3) by

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[4] The Baillie-Pilcher *t* (t_{BP}) is a measure of significance between a "sample" and a "master" chronology, taken across all years in common. It is strongly dependent on sample size. The statistic is:

$$t_{BP} = \frac{r_{(BP)}\sqrt{(N-2)}}{\sqrt{(1-r_{(BP)}{}^2)}}.$$

where t_{BP} is the Baillie-Pilcher *t*, r_{BP} is the Baillie-Pilcher *r*, and *N* is the combined sample size. Each chronology was compared with the master once only, so no adjustments to critical values were needed. When used in cross-dating, multiple tests are conducted simultaneously, so an arbitrary value of 3.5, approximating a 100-series chronology, is used as the critical value. This works well in practice, but occasionally produces ambiguous dates. To correct this problem, Scheffé's Method may be applied (Wigley et al. 1987).

[5] The Baillie-Pilcher *r* (r_{BP}) is a measure of correlation between a "sample" and a "master" chronology, taken across all years in common. The formula is:

$$r_{BP} = \frac{\sum_{i=1}^{n} x_i y_i - N\bar{x}\bar{y}}{\sqrt{(\sum_{i=1}^{n} x_i^2 - N\bar{x}^2)(\sum_{i=1}^{n} y_i^2 - N\bar{y}^2)}}$$

Both t_{BP} and r_{BP} are used on detrended series because the method assumes a linear relationship between *x* and *y* (Baillie and Pilcher 1973).

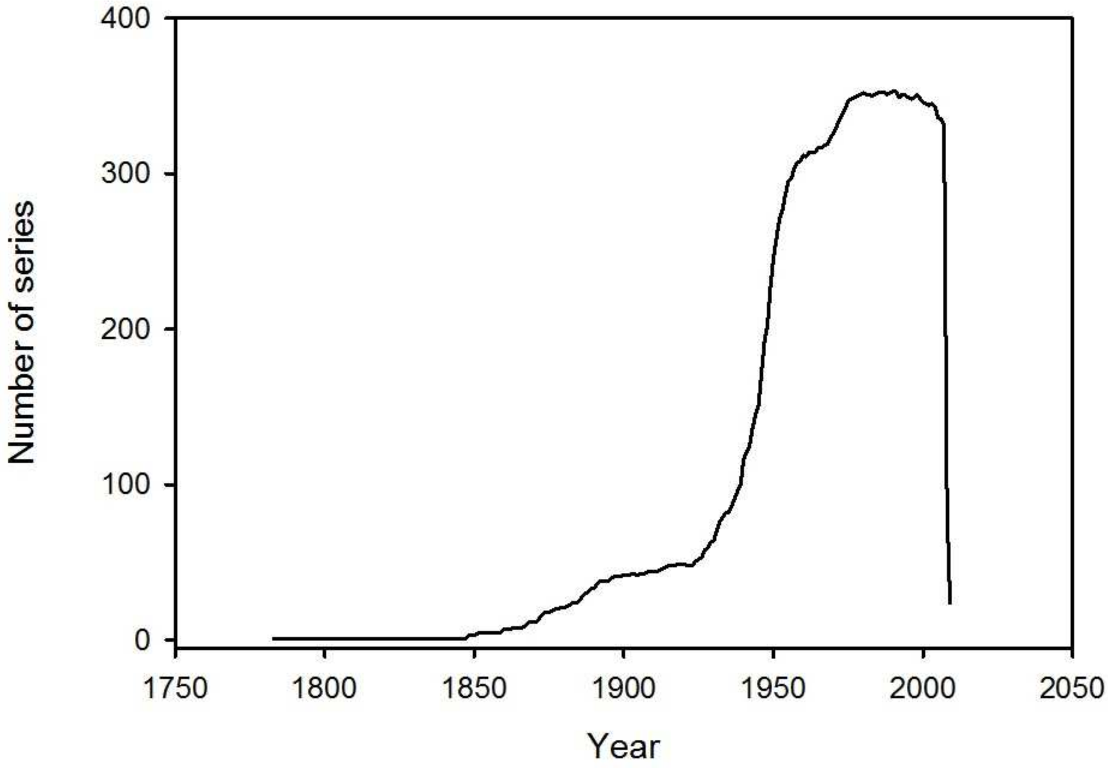

Figure 5. Sample Depth. Sample depth is the number of series with ring measurements in the given year. The sharp drop off in sample depth after 2007 is the result of sampling being spread over three years.

taking the absolute difference in the width of two consecutive rings and dividing it by their average. This was averaged for the entire chronology (Fritts et al. 1965).

Pointer years are determined by calculating the ratio of the current year's growth to the previous year's growth, then calculating the mean and standard deviation of that ratio for the series or chronology. A year is a PY if a minimum of 80% of a minimum of 13 trees have ratios that differ from the yearly mean by more than one standard deviation. (Schweingruber et al. 1990). Pointer years were identified for each site and for the master chronology. The smallest site chronology (Pigeon Creek) had 22 component series; the largest (Babylon Bluff) had 48.

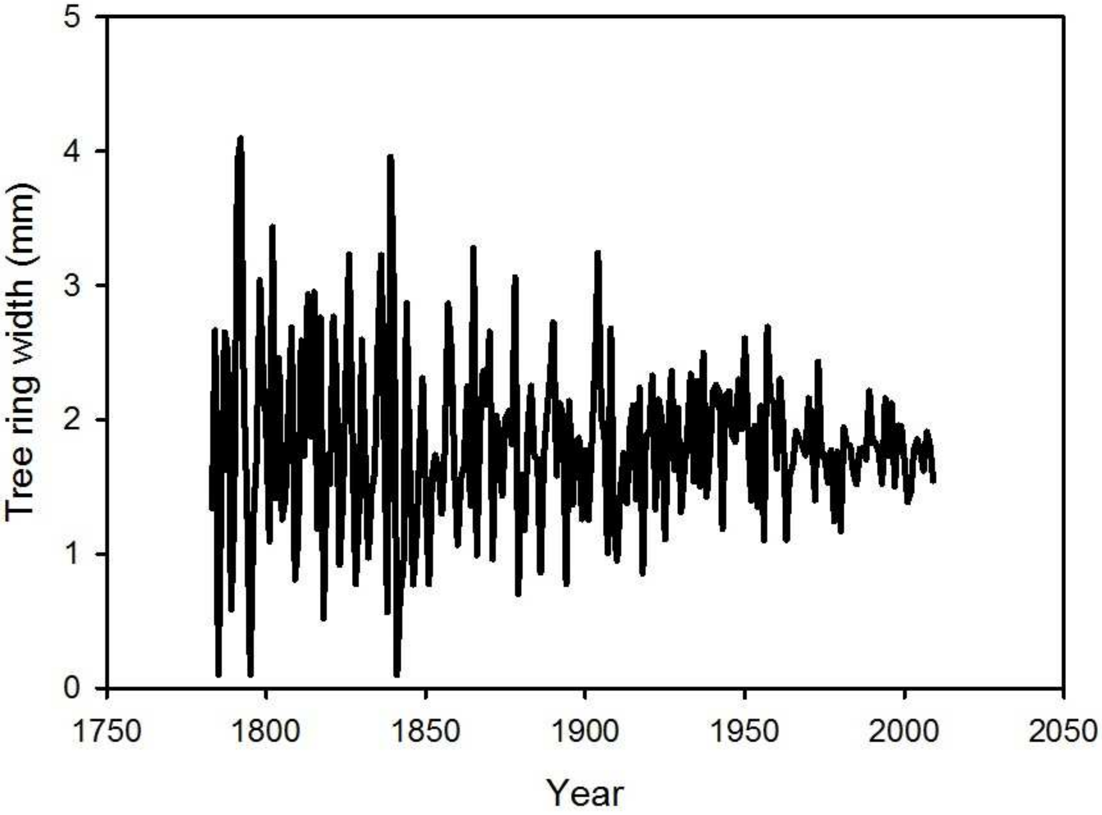

Figure 6. Detrended Tree Ring Width (mm). The detrending process sometimes produces negative estimates of tree ring width. Decreasing variability is probably due to increasing sample depth.

RESULTS/DISCUSSION

Baillie-Pilcher t-values (t_{BP}) ranged between 1.34 (Irons Fork) to 34.02 (Babylon Bluff) (Table 4). Camp Tom Hale had the second-lowest value of t_{BP} (2.62). Excluding Irons Fork, all t_{BP} values exceeded the critical value which varied due to sample size (α=0.05) (Table 4). If the value of t_{BP} is less than the critical value (≈1.7), ring width values do not differ significantly from the yearly means and the site chronology's cross-dating accuracy is considered insufficient. Babylon Bluff, Knoppers Ford, Caddo Gap and Greenbrier produced the highest r_{BP} values when compared to the master chronology (0.92, 0.76, 0.75 and 0.72, respectively). r_{BP} is a measure of the strength and direction of the linear relationship

Table 4. Comparison of site chronologies. Overlap is the number of years in common with the Ouachita Chronology; t_{BP} and r_{BP} are the Baillie-Pilcher *t* and *r* values, respectively. Critical t_{BP} values are for $\alpha=0.050$. Only Irons Fork is not significant.

Site chronology	Start Year	End Year	Overlap (yrs)	t_{BP}	Critical t_{BP}	r_{BP}
Babylon Bluff	1781	2009	229	34.02	1.69	0.92
Caddo Gap	1915	2009	95	10.86	1.71	0.75
Camp Tom Hale	1967	2009	43	2.62	1.70	0.38
Cold Springs	1941	2008	68	3.76	1.68	0.42
Greenbrier	1946	2007	62	7.96	1.69	0.72
Irons Fork	1932	2007	76	1.34	1.70	0.15
Knoppers Ford	1924	2007	84	10.68	1.71	0.76
Pigeon Creek	1943	2009	67	4.90	1.72	0.52
Pilot Knob	1940	2007	68	6.15	1.71	0.60
Sand Lick	1929	2007	79	6.59	1.70	0.60
Story	1888	2007	120	9.35	1.68	0.65

Table 5. Comparison of Baillie-Pilcher r-values (upper triangle) and Baillie-Pilcher t-values (lower triangle) between site chronologies. Cold Springs and Greenbrier (opposite ends of the same stand) are the most similar. Babylon Bluff and Irons Fork are the least similar. Greenbrier (lower hill) and Pilot Knob (hilltop) are adjacent, but on different ecological sites.

Site	Babylon	Caddo	Tom Hale	ColdSp	Grnbrier	Irons	Knoppers	Pigeon	Pilot	Sand	Story
Babylon	*	0.40	0.09	0.24	0.35	-0.02	0.36	0.26	0.33	0.31	0.38
Caddo	4.16	*	0.21	0.17	0.50	0.26	0.41	0.42	0.37	0.60	0.68
Tom Hale	0.56	1.40	*	0.33	0.31	0.04	0.36	0.49	0.34	0.17	0.13
ColdSp	2.06	1.39	2.20	*	0.91	0.33	0.39	0.75	0.48	0.13	0.29
Grnbrier	2.89	4.38	2.03	16.99	*	0.37	0.55	0.54	0.86	0.34	0.40
Irons	-0.18	2.33	0.27	2.85	3.12	*	0.24	0.37	0.28	0.50	0.52
Knoppers	3.45	4.02	2.38	3.39	5.10	2.08	*	0.47	0.52	0.38	0.64
Pigeon	2.14	3.79	3.58	9.05	4.93	3.19	4.24	*	0.41	0.21	0.35
Pilot	2.79	3.24	2.27	4.43	13.29	2.33	4.91	3.56	*	0.31	0.32
Sand	2.87	6.61	1.10	1.08	2.75	5.02	3.64	1.74	2.66	*	0.62
Story	4.43	8.96	0.80	2.48	3.35	5.31	7.60	3.00	2.72	6.96	*

between a site chronology and its component series with values near 1 indicating near-perfect correlation, those near 0 indicating no correlation and negative values indicating a negative correlation – growth increased when it should have decreased and vice versa. The master chronology sample depth, the number of trees used in calculating an average TRW for a given year, exceeded thirteen trees beginning in

1872. It reached twenty trees in 1877, fifty trees in 1924 and 100 trees in 1939. From 1957 to 2007, sample depth exceeded 300 trees. It dropped to 85 in 2008 and 24 in 2009.

There were 170 positive PYs and 166 negative PYs in the eleven chronologies. One positive (1957) and three negative PYs (1938, 1943, 1956) appeared at all study sites. Regional PYs, those that appear on at least three of at least half of applicable site chronologies (Poljanšek et al. 2012), were identified. On the positive side, these were: 1923, 1926, 1935, 1940, 1944, 1955, 1957, 1961, 1964, 1973, 1979, 1981, 1989, 1994, 1996, 1998 and 2003. On the negative side, regional PYs were: 1925, 1938, 1943, 1951, 1954, 1956, 1958, 1963, 1974, 1978, 1980 and 1997.

To establish its validity, the Ouachita chronology was compared to three previously-published local chronologies (McCurtain County – Stahle et al. 1982a; Lake Winona – Stahle 1980; Hot Springs – Stahle et al. 1982b); the McCurtain County Chronology, just north of Broken Bow, Oklahoma and about 75km south-southwest of the Pigeon Creek site, was the best fit (t_{BP} = 6.11; r_{BP} = 0.40; Critical t_{BP} = 1.677) (Table 6). Cross-dating within each chronology is strong, but the two chronologies have moderately-different signals. The Lake Winona Chronology had a t_{BP}-value of 2.47 and r_{BP}-value of 0.17. Hot Springs had a t_{BP}-value of 2.81 and r_{BP}-value of 0.20. Both chronologies had adequate cross-dating compared to the Ouachita Chronology, but the signals were not well correlated. Trees at the Lake Winona site had extremely narrow rings and low sensitivity, possibly as a result of extremely rocky site conditions. A comparison with the Drury House Chronology (Stahle 1979), taken from an old house in the southern Ozarks, showed no correlations.

Table 6. Comparison of the Ouachita Chronology (this study) with nearby chronologies

Chronology	Start Year	End Year	Overlap	t_{BP}	r_{BP}
McCurtain County (Stahle et al. 1982a)	1688	1982	200	6.11	0.40
Lake Winona (Stahle 1980)	1669	1980	198	2.47	0.17
Hot Springs (Stahle et al. 1982b)	1737	1982	200	2.81	0.20
Ouachita Chronologies	1781	2009	201	[1]	[1]

[1] Baillie-Pilcher t- and r-values are computed in comparison with the Ouachita Chronologies. A chronology does not compare with itself.

CHAPTER II

(MANUSCRIPT II)

TREE RING RECONSTRUCTION OF WINTER STORM DISTURBANCES IN *Pinus echinata* MILL. IN THE OUACHITA MOUNTAINS OF OKLAHOMA AND ARKANSAS

INTRODUCTION

Severe winter storms, including both snow and ice storms, are one of the most important causes of forest disturbance (Seischab et al. 1993; Lott et al. 1998; Bragg et al. 2003; Bragg et al. 2004). They interfere with transportation, power systems and cause other economic losses, affecting portions of the South every year (Fountain and Burnett 1979; Halverson and Guldin 1995). The December 2000 ice storms in Arkansas damaged or destroyed 82,100 hectares of *Pinus echinata* (Burner and Ares 2003) and heavily damaged stands in LeFlore and McCurtain Counties in Oklahoma.

Globally, ice storms occur most frequently in eastern North America where warm, moist air masses from the Gulf of Mexico ride up over frigid air masses from Canada, setting up inversion layers (Bennett 1959; Stewart and King 1987; Gay and Davis 1993; Rauber et al. 1994). When snow forms at the top of the warm layer it falls into the warmer air below then melts. The resulting raindrop becomes super-chilled when it falls into the cold layer near the ground, freezing in a phase-change reaction when it strikes an object, such as a power line or twig (Michaels 1991) to form glaze.

Glaze icing events in relatively-flat terrain tend to be oriented southwest-to-northeast (LeCompte et al. 1998). They can be as narrow as 15km and as wide as 250km (Lemon 1961). Glazing conditions can be widespread over flat terrain, but tend to be quite patchy in rugged topography (Millward et al. 2009). The December 2000 ice storms broke 48 trees on 0.16ha at OSU's growth-and-yield study site at Camp Tom Hale near Talihina, Oklahoma and two on a similar-sized area at another study site, Bohannon Creek, 7km away. A storm reconstruction for Camp Tom Hale is part of this study.

Severe winter storms affect the width of tree rings (Travis et al. 1989; Travis et al. 1990; Travis and Meetemeyer 1991; Lafon and Speer 2002), presumably through loss of photosynthetic capacity and the need to use stored carbohydrate to repair damage. Until now lack of a well-defined storm signal made reconstruction of storm chronologies difficult. Lafon and Speer (2002) noted a two-year reduction in total ring width (TRW) following ice storms and speculated that it might be diagnostic. "Total ring width" refers to wood formed within a single calendar year. Unless otherwise specified, ring widths in this paper refer to TRW. Lafon and Speer (2002) defined a "significant decrease" in TRW as a 40% reduction from the average of the previous five years and a "significant increase" as a 50% increase in TRW over the same time period. Further, they required that a minimum of 10% of trees show the reduction in growth before considering the ring in question to indicate an ice storm.

There is no clear divide between "ice storms" and other storms and no clear divide between "large" and "small" storms. Consequently, there is no way to say with certainty that a given storm was or was not an "ice storm." In this paper the term "ice storm" means specifically a storm that produced glaze icing. "Severe winter storm" includes ice storms, but may also include snow, graupel, freezing rain, and sleet and frequently includes all of them. Several severe winter storms that produced heavy snow and severe cold and left their mark in the tree ring record, almost certainly did not produce glaze icing.

This study intends to (1) determine if there is a pattern in tree rings that could be associated with winter storms; (2) describe such a pattern if one is found and (3) use that pattern to construct a history of winter storms in the Ouachita Mountains of Oklahoma and Arkansas. If found, such a signal will allow researchers “to characterize land-form scale spatial variations in ice storm climatology (Lafon and Speer 2002).” Tree ring analysis matches ring-width patterns to things that affect radial growth. This permits climate to be studied at finer scales than other records allow (Phipps 1982). Winter storm damage might be distinguished from ring-width variations caused by rainfall, temperature, droughts and insect defoliation (Stahle et al. 1985; Swetnam and Betancourt 1990; Graumlich 1993). Studies in Georgia and South Carolina (Travis et al. 1989) found that ice damage accounted for 10-19% of ring width variance in *Pinus taeda* beyond the 25-39% explained by temperature and precipitation. Travis and Meetemeyer (1991) found that ice damage affected radial growth of *P. taeda* only during the season following the storm, possibly because they included only trees with no structural damage. *P. taeda* damaged in an ice storm had a reduced ring thickness five years after the storm (Belanger et al. 1996).

METHODS

In 1985 Oklahoma State University installed a growth-and-yield study of *P. echinata* on the Ouachita National Forest in eastern Oklahoma and western Arkansas. One hundred eighty-two plots were installed and another 18 plots from a previous study were included and updated. Plots were measured in 1987 and re-measured at approximately five-year intervals. In 2000, 87 plots were already measured for an update when the Christmas 2000 ice storm struck. The measurement protocols were re-designed to include ice damage data and the remaining plots measured, creating two groups of plots for the 2000/2001 update: those measured before the storm and those measured after it. In 2006 a study of ice-caused damage was implemented.

Tree ring data was obtained from the Babylon Bluff, Cold Springs, Sand Lick and Story site chronologies of the Ouachita Chronologies (Figure 7) (Stevenson 2013). Cold Springs contained 44 series, Sand Lick 39 and Story 26. Babylon Bluff (6 series) and Shortleaf Canyon (40 series) (Cerny 2009) were combined under the name of Babylon Bluff, resulting in a site chronology with 46 series. Babylon Bluff and Shortleaf Canyon are on opposite sides of the Canadian River and may be considered a single stand. This produced a set of four site chronologies which were truncated to include only years with at least eight observations. At Babylon Bluff, the result was a chronology dating from 1862 to 2008, even though one tree dated to 1781. Cold Springs dates are 1945 to 2008 with two trees dating to 1942. Sand Lick dates are 1944 to 2007 with one tree dating to 1930, and Story dates are from 1923 to 2007 with one tree dating to 1887. Sinco Branch was used for data on the 1963 storm, but was too small for use in modeling.

Three published site chronologies were chosen for winter storm reconstructions. They were McCurtain County (51 series) (Stahle et al. 1982a) dating to 1688, Lake Winona (48 series) (Stahle 1980) dating to 1667, and Hot Springs (16 series) (Stahle et al. 1982b) dating to 1737. After truncation, the time spans were: 1745 to 1982 (McCurtain County), 1749 to 1980 (Lake Winona) and 1777 to 1982 (Hot Springs).

Descriptions of storms in back issues of *Storm Data and Unusual Weather Phenomena* (*Storm Data*) were downloaded from the National Climatic Data Center (NCDC 2011b). There were no direct measurements of glaze ice listed in Weather Bureau/National Weather Service publications. Nevertheless, one could assemble a list of probable ice storms and determine whether they might have hit a subject location (Table 7). From 1949, when *Storm Data* began storm reports, resulting in poor quality or non-existent data. In the event of a missing report in one state or division, reports from the adjacent state or division were used to get an idea of what should have been in the missing report.

Climatological Data (NCDC 2011a) records are lists of daily and monthly temperatures and precipitation with occasional notes on ice accumulation, sleet and snow. *Storm Data* began publishing in

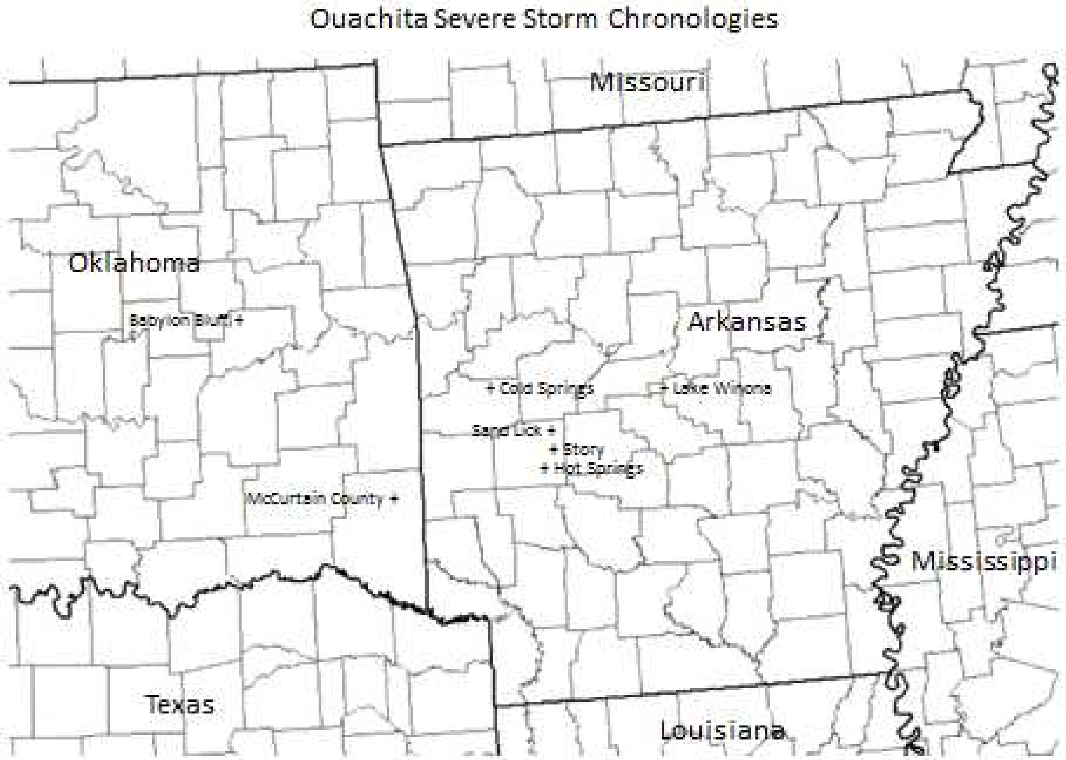

Figure 7. Severe storm signal study sites. Map includes Ouachita Site Chronologies as well as three site published chronologies. Map data from National Atlas of the United States, United State Department of the Interior, 2013.

January 1949. There were 31 stations on or within 50km of the Ouachita National Forest, most of which were not operating at any given time.

Before 1891, back to the Civil War, there were only newspaper accounts (Colson 1886; Anonymous 1894a; Anonymous 1894b) to provide dates and descriptions of major storms (1881, 1886 and 1894). These only included larger storms as small storms weren’t considered newsworthy. Before 1855 there was nothing.

Legends (Black Hawk 1890; Stahle 1979; Wilder 2007) tell of two weather events – the “Resting Summer” of 1855 (a drought), and the “Snow Winter” of 1881. Though the book, *The First Four Years*, is a fictionalized account, descriptions of the “Snow Winter” given by Wilder (2007) are accurate.

Table 7. Record of storms that affected study plots from 1862 to 2009. The year is the first growing season after the storm. Sources of information are: CD = Profile developed from *Climatological Data*, OC = Profile developed from *Ouachita Site Chronologies* and SD = *Storm Data and Unusual Weather Phenomena*.

Year	Remarks
2009	*Ice Storm* Jan 26 - 28. Freezing rain and sleet over most of AR. Heaviest icing along MO border tapering off farther south. Severe tree damage in Ft. Smith (SD).
2006	*Winter Storm* Feb 17 - 18. One inch sleet in portions of McIntosh County, OK (SD).
2005	*Ice Storm* Feb 26. Up to 2cm freezing rain in isolated areas. 5000-6000 people without power (SD).
2002	*Winter Storm* (AR), *Heavy Snow* (OK) Feb 5 - 6. 15cm snow in Poteau; 5cm in McAlester. Snow and sleet in western AR. Power outages due to tree breakage (SD).
2001	*Ice Storm* Dec 12 - 13 and Dec 25, 2000. Heavy damage to trees and powerlines throughout AR and eastern OK (SD).
1997	*Winter Storm* Jan 8-9. Snow, sleet and freezing rain in western AR. Accumulation on trees and grassy areas (SD).
1995	*Ice Storm* (AR), *Freezing Rain* (OK) Jan 5 - 7. Freezing rain and drizzle. A few trees and power lines downed. 5000 people without power (AR). Freezing rain (OK). (SD).
1993	*Snow and Ice* (OK) *Ice Storm* (AR). Jan 17 - 19. Sleet and freezing rain in OK; freezing rain, about 8000 people without power (AR) (SD).
1992	*Heavy Snow* (AR), *Snow Storm* (OK) Jan 17 - 18. Up to 7 inches of snow broke tree limbs and power lines (AR). Six to eight inches of snow in McCurtain and LeFlore (OK) (SD).
1990	*Freezing rain, sleet snow* (OK), *Flash Flood* (AR) Feb 14 - 15. Freezing rain and sleet in OK. Heavy rains and flooding in AR. (SD).
1988	*Snow Storm* (AR), *Heavy Snow* (OK). Jan 5 - 7. “Largest snow storm of the century” and “coating of sleet and freezing rain” in AR. Over 10 inches of snow with four-foot drifts in OK (SD).
1987	*Heavy Snow/Ice Storm* (OK) Jan 16 - 17. Freezing rain and sleet; coating of ice up to 1 inch thick on trees and power lines; 100,000 people without power. No report for AR (SD).
1985	*Low Temperature* (AR), *Winter Storm* (OK) Feb 2 - 4. Up to 8 inches of snow in northeast OK.
1984	*Ice Storm* (AR), *Winter Storm* (OK) Dec 20 - 21, 1983. Mainly freezing rain and drizzle; trees and power lines down; timber damage extensive (AR). Average monthly temperature coldest on record; freezing rain, freezing drizzle and snow, depths less than three inches (OK) (SD).
1982	*Unusual Cold* (AR), *Freezing Temps* (OK) Jan 10 - 12. Arctic outbreak; record low temperatures (AR). Temperature near 10 below (OK) (SD).
1981	*Wind, Ice Storm* (OK), No report for AR. Feb 10. Freezing rain; high winds (SD).
1980	Storms on Feb 1 and 17. No reports in SD. Extreme cold (<-12 degrees C.) and storms inferred from station logs (CD).
1979	*Ice Storm* (AR), No report (OK). Jan 1. Mostly northern AR; freezing rain, ice accumulations up to one inch, trees and electrical lines toppled; 15,000 people without power; worst ice storm since 1949 (SD).
1978	*Winter Storms* (AR), No report (OK). Jan 11 - 29. Freezing rain, sleet, 4 inches of ice, freezing drizzle; 26 counties declared disaster areas (SD).
1976	*Snow* (AR), *Heavy Snow* (OK). Dec 24 - 25, 1975. No reports for January. Ten to 20 inches of heavy wet snow. Numerous trees and electric lines were downed (SD).
1974	*Freezing Rain and Sleet* (AR), *Sleet and Freezing Rain* (OK). Jan 2. Freezing rain and sleet; ice broke trees; timber severely damaged; 36,000 homes without power (AR). Sleet and freezing rain; no significant utility outages (OK) (SD).

Table 7 (continued):

1972	*Snow and Ice* (OK), No report (AR). Feb 2 - 3. Snow mixed with ice; 600-700 people without power; snow and ice accumulations one to three3 inches (SD).
1970	*Snow and Ice* (OK), No report (AR). Dec 28 - 30, 1969. No reports for Feb. Freezing rain produced heavy coat of ice in southern and eastern sections; damage to trees, utility lines; worst storm in 30 years (SD).
1969	*Fog and Glaze* (OK), No report (AR). Jan 28 - 31. Freezing rain (SD).
1965	*Wind, sleet, freezing rain, snow and dust* (OK). Feb 23 - 24. 50-mile wide band of sleet and freezing rain; freezing rain and drizzle and blowing snow; 405 broken poles and 135 damaged cross-arms (SD).
	Storm and Wind (AR), *Snow, sleet and freezing rain* (OK). Jan 9. Rain changed to ice; wind caused considerable damage to trees (AR); freezing rain and sleet; many power lines and poles were downed; glazing and snowfall (OK) (SD).
	Ice storm (OK), No report (AR). Dec 2 - 3, 1964. Sleet, freezing rain and light snow; glazed entire state; ice and sleet up to 0.3 inches (OK) (SD).
1963	*Glaze* (OK), No report (AR). Jan 25 - 26. Freezing drizzle; glazed highways (SD).
1959	*Storm Data and Unusual Weather Phenomena* begins publication Jan 1.
1956	Storm on Dec 16, 1955 (CD).
1955	Storms on Jan 29 and Feb 11 (CD).
1954	Storm on Jan 11 (CD).
1952	Storm on Dec 16, 1951 (CD).
1949	Storm on Feb 1 (CD).
1947	Storms on Jan 4, Feb 10 and Feb 18. Sleet reported on 18th (CD).
1946	Beginning of Cold Springs chronology.
1944	Beginning of Sand Lick chronology.
1943	Storms on Jan 20 and Mar 5 - 7 (CD).
1936	Storms Feb 1 - 4 (CD).
1934	Storm Feb 24 (CD).
1930	Major ice storm in Dec 1929. Smaller storms Jan 16 and Jan 20.
1925	Major storm Dec 22 - 25, 1924.
1924	Beginning of Story chronology.
1920	Storms on Dec 10, 1919, Jan 5 and Feb 16 (CD).
1918	Major storm on Jan 10 - 11 (CD).
1911	Storm on Jan 3 (CD).
1910	Storms on Jan 7 and Feb 18 (CD).
1902	Storm on Dec 14, 1901.
1901	Storm on Feb 6. Sleet (CD).
1899	Storm, severe cold (-27 degrees C.) on Feb 11 (CD).
1895	Beginning of Palmer Drought Severity Index.
1894	Severe storm. Mar 11 - 16 (*Rocky Mountain News*, March 16, 1894 and *Wichita Daily Eagle*, Mar 18, 1894).
1891	Beginning of *Climatological Data*.
1886	Severe storm. Jan 9 - 19 and Jan 29 - Feb 4 (*Wichita Daily Eagle*, Jan 19 and Feb 5, 1886).
1881	“Snow Winter.”
1862	“Noachian” storm; Beginning of Babylon Bluff Chronology.
1855	“Resting Summer.”

Prior to 1959, and to fill in missing information, profiles were developed from *Climatological Data* by listing daily high and low temperatures and precipitation at the weather station closest to each study site. When available, number of stations reporting glaze icing or freezing rain, for the months of November through March of each year was also included. For the Babylon Bluff site weather records from Eufaula, Oklahoma were used. For Cold Springs weather records came Booneville, Arkansas (temperatures) and Cold Springs, Arkansas (precipitation). For Story and Sand Lick, records came from Mount Ida, Arkansas (1923 to 1938 and November 1943 to 2007) and Story, Arkansas (1939 to March 1943) (Figure 7).

Temperature and precipitation amounts were used to create storm profiles. Glaze icing occurs between -3^o and 1^o C. To create icing conditions temperature must be in this range. Glaze icing was reported at several stations when only 0.635cm of precipitation was reported (NCDC 2011a); thus, 0.635cm of precipitation was assumed to be sufficient for ice accumulation.

From records and profiles a list of all known storms that struck eastern Oklahoma and/or western Arkansas was compiled as far back as weather records go (Table 7). Descriptions in *Storm Data* (NCDC 2011b) that included the terms “ice storm,” “glaze,” “freezing rain,” “sleet,” “winter storm,” “snowstorm” or “heavy snow” were used as indicators of a storm. A storm was considered “large” (“severe”) if it occurred in multiple climate divisions (NCDC 2011a) and caused damage such as loss of electrical service, tree breakage or damage to power lines and cross-arms; otherwise, it was considered a “small” storm.

A monthly listing of the PDSI going back to January 1895 was obtained from the National Oceanic and Atmospheric Administration (NOAA) (2012). Babylon Bluff is located in Oklahoma Division 6, Cold Springs is in Arkansas Division 4 and Sand Lick and Story are in Arkansas Division 7. Monthly records are continuous within each division.

There were three important storms worthy of special mention: trees affected by the 1963 storm had missing tops which had completely decayed and were no longer lying on the ground. They also had the pronounced double narrow ring which Lafon and Speer (2002) reported in association with ice storms. Most wood laid down prior to 1964 either had incipient decay or was rotted away, consistent with the patterns produced by decay-causing fungi (Shigo 1986) attacking a wound made in 1963. This leads to the conclusion that the 1963 storm was an ice storm.

The storm of January 17, 1992 consisted more of snow than of ice. *Storm Data* (NCDC 2011b) characterized this storm as “heavy snow (Arkansas)” and “snow storm (Oklahoma)” and reported broken tree limbs and damaged power lines, thus qualifying as a “large” or severe storm. Inventory crews updating plot data after the 1992 storm reported no trunk breakage; however, there were some missing rings and a very noticeable two-year decline in ring thickness, consistent with findings of Lafon and Speer (2002). Tree height measurements from 1992 show no reductions from 1987, indicating no breakage, consistent with bending stress and/or compression injuries (Lutz 1936; Forest Products Research Laboratory 1941).

Severe breakage caused by the storms of December 2000 was personally observed by the author in June of 2001. This was a major ice storm. Descriptions in *Storm Data* describe this storm as patchy with many skips and gaps in damage patterns. Subsequent investigation showed no breakage at the Babylon Bluff or Sand Lick sites, but extensive damage at Cold Springs and Story.

I hypothesized that damage caused by winter storms in general would slow growth for a period of time in affected trees. The length of the recovery period and growth ring response to ice and snow damage might form a diagnostic pattern. It was hoped that data from this study, supplemented by increment core data, could be used for this study of ice storms.

The next step was to see if drought was associated with winter storms. I used Cohen’s Kappa (Cohen 1960; Landis and Koch 1977), a measure of agreement between two sets of categorical observations, both of which may contain error. It could be used to assess the level of concordance between two categorical assessments of the same phenomenon. In this case, one categorization was the list of storms developed from *Storm Data* and *Climatological Data* while the other was the list of storms produced by examining tree ring widths. Values of Kappa could range between -1 and 1, with values near 1 indicating strong positive agreement and values near zero indicating no agreement or random agreement, as happens when two unrelated variables produce the same result by chance. Values of Kappa near -1 would indicate a strong inverse relationship. I used Cohen's Kappa (Cohen 1960; Landis and Koch 1977) to determine whether drought and severe storm occurrence were coincident, defining "drought" as $Y = 1$ when JAS PDSI < -1.50 (-1.60 at Babylon Bluff) (else: Y=0) and obtaining "storm" from the historical record (Tables 7 and 8).

Because of the fair to moderate association between droughts and storms the drought signal was not removed from the data (Tables 9 to 11). This was done to avoid removal of the storm signal. There is no consensus as to whether severe winter storms and droughts are associated and it would be inappropriate to speculate on the causes.

To see if a correlation between drought and ring width might be related to visible limb or trunk breakage, I extended Stevenson's (2010) findings by comparing TRW of trees whose trunks were broken in the 2001 storm, those with broken branches only and those with no visible damage (Table 12). This was done by comparing ring widths of the five years before the storm with those of the five years following the storm and by comparing ring widths from broken, damaged and undamaged trees.

Ice Storm Detection

Lafon and Speer (2002) presented an approach to identifying probable ice storms using oaks in Virginia. This approach might work with *P. echinata.* They divided the width of the current ring by the average width of the previous five rings:

$$R_i = \frac{5Y_i}{(Y_{i-5} + Y_{i-4} + Y_{i-3} + Y_{i-2} + Y_{i-1})} \qquad 1$$

where:

R_i is the growth ratio for Year i,

Table 8. Cohen's Kappa (K): Concordance between severe winter storms and averaged PDSI values for July, August and September. s = standard error; Conc. = concordance using Landis and Koch (1977) strength of agreement term (Fair: $0.21 < K \le 0.40$; Moderate: $0.41 < K < 0.60$). A = correctly predicted winter storm years; B = false positives; C = false negatives; D = correctly predicted normal years. Z = K/s. K and s were determined with an online calculator (Lowry 2013a), as was the p-value for the null hypothesis Kappa = 0 (Lowry 2013b).

Site	PDSI	Correct	est. K	s	Conc.	A	B	C	D
Babylon Bluff	-1.60	80.0%	0.496	0.152	Moderate	7	1	8	29
Cold Springs	-1.50	68.9%	0.271	0.162	Fair	6	3	11	25
Sand Lick	-1.50	71.1%	0.258	0.183	Fair	4	10	2	28
Story	-1.50	68.9%	0.231	0.179	Fair	4	11	2	27

	Z	p-value
Babylon Bluff	3.263	0.00213
Cold Springs	1.673	0.101
Sand Lick	1.410	0.166
Story	1.291	0.204

Table 9. Cohen's Kappa (K): Concordance between Lafon and Speer's (2002) method using optimized indices and occurrence of winter storms in the Ouachita Mountains. s = standard error; Conc. = concordance using Landis and Koch (1977) strength of agreement terms (Moderate: $0.41 < K \le 0.60$; Substantial: $0.61 < K \le 0.80$). A = correctly predicted storm years; B = false positives; C = false negatives; D = correctly predicted normal years. Z = K/s. K and s were determined with an online calculator (Lowry 2013a), as was the p-value for the null hypothesis Kappa = 0 (Lowry 2013b).

Site	IndexA	IndexB	Correct	est K	s	Conc.	A	B	C	D
Babylon Bluff	0.55	0.03	80.0%	0.612	0.116	Substantial	16	9	0	20
Cold Springs	0.84	0.10	79.5%	0.607	0.117	Substantial	17	9	0	18
Sand Lick	0.85	0.45	86.0%	0.620	0.144	Substantial	7	6	0	30
Story	0.72	0.15	76.7%	0.472	0.146	Moderate	9	4	6	24

	Z	p-value
Babylon Bluff	5.276	3.86E-06
Cold Springs	5.188	5.46E-06
Sand Lick	4.306	9.78E-06
Story	3.233	0.00239

Table 10. Cohen's Kappa (K), single index: Concordance between current TRW divided by average of previous five years and severe storm occurrence in the Ouachita Mountains. s = standard error; Conc. = concordance using Landis and Koch (1977) strength of agreement (Fair: $0.21 < K \leq 4.00$; Moderate: $0.41 < K \leq 0.60$). A = correctly predicted ice storm years; B = false positives; C = false negatives; D = correctly predicted normal years. Z = K/s. K and s were determined with an online calculator (Lowry 2013a), as was the p-value for the null hypothesis K=0 (Lowry 2013b).

Site	Index	Correct	est K	s	Conc.	A	B	C	D
Babylon Bluff	0.80	80.0%	0.491	0.152	Moderate	7	1	8	29
Cold Springs	0.40	61.4%	0.305	0.132	Fair	15	16	1	12
Sand Lick	0.87	77.3%	0.428	0.158	Moderate	7	7	3	26
Story	0.78	74.4%	0.358	0.167	Fair	6	8	3	26

	Z	p-value
Babylon Bluff	3.230	0.00234
Cold Springs	2.311	0.0257
Sand Lick	2.709	0.00973
Story	2.144	0.0379

Table 11. Cohen's Kappa (K): Concordance between current TRW divided by average of succeeding five years and severe storm occurrence in the Ouachita Mountains. Index B = minimum proportion of series with growth less than Index A. s = standard error; Conc. = concordance using Landis and Koch (1977) strength of agreement terms (Moderate: $0.41 < K \leq 0.60$; Substantial: $0.61 < K \leq 0.80$). A = correctly predicted ice storm years; B = false positives; C = false negatives; D = correctly predicted normal years. Z = K/s. K and s were determined with an online calculator (Lowry 2013a), as was the p-value for the null hypothesis Kappa = 0 (Lowry 2013b).

Site	IndexA	IndexB	Correct	est K	s	Conc.	A	B	C	D
Babylon Bluff	0.70	0.10	88.9%	0.747	0.107	Substantial	12	4	1	28
Cold Springs	0.90	0.20	82.5%	0.660	0.117	Substantial	17	1	9	19
Sand Lick	0.80	0.30	85.0%	0.634	0.138	Substantial	8	6	0	26
Story	0.82	0.15	76.9%	0.552	0.129	Moderate	14	1	8	16

	Z	p-value
Babylon Bluff	6.981	1.22E-08
Cold Springs	5.641	1.21E-06
Sand Lick	4.594	4.46E-05
Story	4.279	0.000122

Y_i is the average TRW for the chronology in Year *i*, and

Y_{i-5}, Y_{i-4}, Y_{i-3}, Y_{i-2} and Y_{i-1} are average TRWs for the chronology in the five preceding years.

If more than 10% of intercorrelated series suffered more than 40% reduction in growth, an ice storm was indicated. To make this system work two index values were needed – a threshold value (40%) and a proportion (10%(. To see if this was so for *P. echinata,* I tried

various combinations of threshold values (Index A) and proportions (Index B) on the four sites.

This was done by assigning arbitrary values to each index, testing the result as described below, then adjusting each index until the proportion of correct predictions was maximized (Table 9). A possible indicator of severe storms is a sudden decrease in growth (Travis et al. 1989; Travis et al. 1990; Travis and Meetemeyer 1991; Lafon and Speer 2002). Values of Index A in the Lafon and Speer (2002) example could be used by themselves, without calculating an R_i value. Low values should reflect the increased probability of a storm. To test this, Cohen's Kappa was used to compare severe storm occurrence with predictions based on the ratio of the width of the current ring to the average width of the previous five rings (Table 10).

To see if Lafon and Speer's (2002) method might be used to detect severe storms by using ring widths laid down after the storm, rather than before, I used Cohen's Kappa to test concordance concordance between severe storm occurrence and the sum of the two years after the storm year divided by the sum of the two succeeding years (Table 6):

$$R_i = \frac{(Y_i + Y_{i+1})}{(Y_{i+2} + Y_{i+3})} \qquad 2$$

where:

R_i is the growth ratio for Year *i*,

Y_i is the average TRW for the chronology in Year *i*, and

Y_{i+1}, Y_{i+2} and Y_{i+3} are average TRWs for succeeding years.

Table 12. Comparison of broken and unbroken *Pinus echinata* from the Christmas 2000 ice storm (Cold Springs and Story). TRW = Average Total Ring Width in microns; STD = Standard Deviation in microns; Pool = Pooled Standard Deviation. Critical value of t with α = 0.05 and 95 degrees of freedom = 1.661.

Unbroken: (n = 35).

Year	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
TRW	2584	1733	2308	2090	1966	1677	1498	1783	1879	1946	1907	2122
STD	839	673	724	764	751	641	634	676	671	720	668	801

Broken: (n = 62).

Year	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
TRW	2752	1925	2324	2395	2141	1620	1616	1803	2070	2008	2067	2221
STD	1200	643	803	815	658	837	809	777	903	693	727	817

t-test for difference in total ring width between broken and unbroken trees.

Year	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Pool	1.176	0.427	0.601	0.636	0.480	0.597	0.564	0.551	0.684	0.494	0.499	0.658
t	0.733	1.388	0.097	1.806	1.195	0.345	0.744	0.126	1.087	0.423	1.070	0.567

Ratio of ring widths from broken trees to those from unbroken ones.

Year	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Ratio	1.065	1.111	1.007	1.146	1.089	0.966	1.079	1.011	1.101	1.032	1.084	1.046

Only the ice storm year (2001) shows broken trees with narrower rings than unbroken trees.

The procedure for using Equation 2 is:

1. Calculate R_i for each TRW for each series.
2. Count the number of series where R_i is less than Index A by year (Year *i*).
3. Divide this result by the number of series that have TRWs for that year (Year *i*).
4. If this number is greater than Index B, a storm is predicted for Year *i*.
5. For each TRW for each series, calculate a seven-year standardized ring width, starting with Year *i*. To calculate the seven-year standardized ring width for ring *i*: from the width of Ring *i* subtract the mean ring width for Years *i* through *i+6* and divide the result by the standard deviation of the same years. When testing for a storm in a specific year, calculate the second year's (*i + 1*) standardized values using the mean and standard error from the first year (*i*).

By comparison with the historical record:

6A. If R_i is greater than Index B, the seven-year standardized ring width for Year *i* is less than -1.000 and the seven-year standardized ring width for Year *i+1* is less than 0.000, a "large" (severe) storm is indicated.

6B. If the seven-year standardized ring width for Year *i* is between -1.000 and -0.300, a "small" storm is indicated. In this case, the value of R_i is irrelevant.

6C. If the seven-year standardized ring width for Year *i* is less than -1.000 and for Year *i+1* is greater than 0.000, a "small" storm is indicated. In this case also, the value of R_i is irrelevant.

Initially, arbitrary values are chosen for Index A and Index B; 0.800 is a good starting point for Index A with 0.400 for Index B. A list of years that produced potential storms is then compared with a list of actual storms from the historical record. Different values of Index A are tested until a maximum proportion of correct results is found. Index B is then adjusted in the same way. Often a change in Index B requires another cycle of testing in Index A. The procedure alternates until the maximum number of correct predictions is obtained. The step can be placed in an interactive spreadsheet so that each change in an index value produces new estimates almost instantly. In developing this procedure, I calculated R_i values and first and second seven-year standardized ring widths for *all* years. Doing so eliminated the risk that a storm year might be missed.

Reconstructions

For winter storm reconstructions, each of the 11 Ouachita Site Chronologies was tested using Baillie-Pilcher r and t values to check cross-dating and series intercorrelation (Baillie and Pilcher 1973). In the Baillie-Pilcher program (originally published as a computer program in FORTRAN IV), Student's t is used to adjust for the size of overlap between the series and the chronology and r is calculated based on difference in the observed (series) ring width and that of the corresponding chronology ring width. The correlation coefficient, r, is parametric in the Baillie-Pilcher system and thus, sensitive to the magnitude of differences in ring width. Because of low Bailie-Pilcher t_{BP} and r_{BP} values, Irons Fork was not used. Ouachita Chronologies were supplemented with the Hot Springs, Lake Winona and McCurtain County chronologies available from the NCDC (Stahle et al. 1982b; Stahle 1980; Stahle et al. 1982a, respectively). Each series was corrected for up to three years of autocorrelation and detrended using a negative logarithmic model. Series were transformed to give each one equal weighting and the results averaged by year.

Reconstructions from this study were visually compared with reconstructions from the other seven sites of the Ouachita Chronologies (Stevenson 2013) and with the McCurtain County (Stahle et al. 1982a), Lake Winona (Stahle 1980) and Hot Springs (Stahle et al. 1982b) site chronologies. Results were as expected with each chronology showing large storms in the same years and small storms in the same years. When there was a discrepancy, it was usually one site showing a small storm while another showed a large one. Also as expected, the greatest differences were between the Babylon Bluff and Hot Springs sites which are also the farthest apart geographically (Figure 7).

The five-year post-storm R_i equation (Equation 2) and indices were used in combination with seven-year post-storm standardization to reconstruct 13 winter storm calendars (Appendix II Tables 1 to 13).

RESULTS

The winter storm signal for Ouachita Mountains *Pinus echinata* consists of two consecutive narrow growth rings, the first formed during the growing season following the storm. Canopy damage results in loss of photosynthetic capacity, producing reduced radial growth while the tree regrows its crown (Belanger et al. 1996). Radial growth is sensitive to injury-induced stress because stem growth has low priority for resource allocation within the tree (Pedersen 1998). The second year's ring is usually narrow, but wider than the first. Rarely, the third year's growth ring may also be narrow. The exact definition of "narrow" is variable and depends on the rate of recovery from injury, but usually is represented by ring width of the first two years that is 10 to 30% less than that of the third and fourth years. The proportion of trees showing this growth reduction (10 to 30% of the stand) is the storm indicator.

Tree ring width was positively correlated with JAS PDSI at all four sites (Table 8). Adjusted r^2 ranged between 0.092 and 0.336 and standard deviations of the models ranged between 0.328mm and 0.779mm. For Babylon Bluff, Cold Springs, Sand Lick and Story, $p \leq 0.01$, $p \leq 0.01$, $p=0.04$ and $p \leq 0.01$, respectively. JAS PDSI predicts tree ring width; they are correlated. Tree ring width is controlled by water (drought), but this was less so at Sand Lick than elsewhere.

When Cohen's Kappa was used to test concordance between severe storm occurrence and JAS PDSI, optimum results were obtained when JAS PDSI < -1.60 at Babylon Bluff and JAS PDSI < -1.50 at the other sites. The Cold Springs, Sand Lick and Story Kappas significantly differed from zero at the 0.05 significance level for the null hypothesis H_0: Kappa = 0 (Table 2). The Kappa value of 0.496 obtained for Babylon Bluff is significant ($p<0.01$), but indicates only a moderate level of agreement, while lower p-values at the other three sites indicate fair concordance, but are not significant ($p=0.10$, $p=0.17$ and $p=0.20$ for Cold Springs, Sand Lick and Story, respectively). On three out of four sites the degree of association was inadequate to consider drought determined by JAS PDSI to be associated with severe winter storms.

Except for the year of the ice storm, rings of broken trees were *wider* than those of unbroken ones throughout the twelve years tested (1996 to 2007) (Table 3). In 2001, TRW decreased from the average of the previous five years by 15% in unbroken trees and 24% in broken trees, but the difference was not statistically significant (pooled $p=0.12$); in the second year (2002) it decreased another 6% in each before recovering to pre-ice storm widths (pooled $p=0.36$). Trees that broke in the December 2000 storms grew faster than trees that didn't break, both before and after the storms.

Lafon and Speer's (2002) (double index; previous five years) method produced significant values of Kappa (Table 4). P-values were less than 0.01 at all four sites. Kappa values for Babylon Bluff, Cold Springs and Sand Lick were between 0.600 and 0.700 which is considered substantial agreement (Landis and Koch 1977). At Story, Kappa was somewhat less at 0.472 (moderate agreement). Lafon and Speer's method successfully predicted association between growth reduction from pre-storm levels and the occurrence of severe winter storms.

Values of Cohen's Kappa for the single index method (Table 5) were significant at all sites ($p<0.01$, $p=0.03$, $p=0.01$ and $p=0.04$ at Babylon Bluff, Cold Springs, Sand Lick and Story, respectively). Results were not quite as good as with the Lafon and Speer (2002) double index method. Kappas were 0.305 (fair, Cold Springs), 0.358 (fair, Story), 0.428 (moderate, Sand Lick) and 0.491 (moderate, Babylon Bluff). The single index method worked, establishing an association between reduced growth and severe winter storms, but Lafon and Speer's (2002) double index method worked better.

When the double-index method was applied to the ratio of current ring width to that of the five years *after* the storm, Kappas were the largest of any of the four methods (Table 6) with values of 0.552 (moderate, Story), 0.634 (substantial, Sand Lick), 0.660 (substantial, Cold Springs) and 0.747 (substantial, Babylon Bluff). P-values were *all* less than 0.00012. At three out of four sites there was substantial association between ring widths after the storm and the occurrence of the storm; at the fourth site agreement was moderate. This method worked better than any of the others.

When the Babylon Bluff indices were used to predict the Cold Springs storm calendar (Table 7), the result was a p-value of 0.075 (not significant at $\alpha = 0.05$, where α is the probability of rejecting the null hypothesis H_0: Kappa = 0 when it is true). Otherwise, all sets of indices predicted all storm calendars from the other three sites satisfactorily, even though indices were not optimized for the other sites. Except for Babylon Bluff/Cold Springs, all p-values were less than 0.0064. The system was quite robust in detecting severe storms, even when index values were not optimized.

Using Equation 2, storm histories of four of the site chronologies from the Ouachita Chronologies were constructed and compared with the historical record (Tables 9 and 10). A few comments: Babylon Bluff (1862 to 2008): The storms of 1866, 1871 and 1879 occurred before weather record-keeping began in the area. Weather records at Eufaula indicate a storm on February 16 and 17, 1938; likewise, on February 20 and 21, 1952. Even though these years do not appear on the historical record as severe storm years, storms did occur. As far as can be understood from the historical record, the process is accurate.

Cold Springs (1945 to 2008): Except where historical data was missing, the process exactly duplicated the historical record. Sand Lick (1944 to 2007): The seven-year standardized ring widths for 1946 and 1947 show two consecutive years with values below -1.000, ordinarily reason to suspect a "large" storm in 1946. But the proportion of R_i values less than Index A is extremely low (1946: 0.071; 1947: 0.000). The historical record does not show a winter storm in 1946. The low temperature for February 1946 was -11° C. in Mount Ida, low enough to disturb growth if temperature at the site was as low as it was in Mount Ida, something I can't be sure of. I have no way of knowing if 1946 belongs on the list. Likewise, there was a storm on February 16, 1967 that produced a low temperature of -12° C. at Mount Ida and snow with ice glazing at Eufala. It produced all the same problems in interpretation as 1946. *Storm Data* records for Montgomery County, Arkansas for February 1967 were missing. A small late-season storm evidently hit Sand Lick on February 16, 1967.

It appears this particular pattern is the result of two consecutive winters with "small" storms, rather than one winter with one "large" storm. The process probably produced a correct result, but the records aren't good enough to be sure.

Story (1924 to 2007): The storm in 1938 is not in Story's historical record; however, the same storm that struck Eufaula on February 16 and 17, 1938 probably struck Story, too. The low temperature at Story on February 16 was -12° C. – low enough to produce a growth anomaly – maybe.

DISCUSSION

The severe winter storm signal consists of a two-year decline in ring width followed by an increase to almost-normal in the third year and resumption of normal growth in the fourth year; although, if the tree was severely damaged, that may be a new normal. The difference between this method and previous ones is that the width of the storm ring is compared to the width of rings that come *after* the storm ring. The tree's response to injury is the diagnostic. In this study that was *always* a growth rate in the first and second years that was between 70% and 90% of the growth rate in the third and fourth years in 10% to 30% of the trees.

The process detected every known large storm, but also indicated some that were previously unknown and whose existence was uncertain. There were several years with missing or inconclusive evidence and it was often debatable whether a given storm belonged in the "large" or the "small" category.

Though more research is needed, the reconstructions show that on average, severe winter storms occur at about 17-year intervals at Babylon Bluff, 16-year intervals at Cold Springs and Sand Lick and 20-year intervals at Story. One such storm (1992) produced no evidence of breakage; two others (1963 and 2001) did. The probability of a severe winter storm in the Ouachita Mountains is about 0.058 (obtained by averaging the reciprocals of the four average storm intervals) in any given year with a probability of about 0.039 (=storm probability times two damaging years divided by three storm years) of tree breakage resulting in damage to commercial-sized trees.

Although there is no danger of mistaking a one-year growth reduction caused by extreme cold for a two-year one caused by a severe storm, there is a risk that an extreme cold event might produce a ring narrow enough to produce a seven-year standardized ring width between -1.000 and -0.300 that would be interpreted as a "small" storm. This was not observed in the course of this study, but it might happen.

The instances of extreme cold that were observed in the historical record produced seven-year standardized ring widths between -0.300 and 0.000.

The two-year decline in TRW can be observed directly by examining the tree's rings. This can be enhanced by standardizing ring widths in the years following a possible storm. Ice storm years show a sharp drop in ring thickness, producing a standardized value less than -1.000. That value increases in the second year and approaches zero, or even goes above zero, in the third year.

Because each stand has a different history, index values vary between stands. In the case of Cold Springs, opposite ends of the same stand have different indices. Index values are assumed to apply to earlier times in the chronology, but they do not apply to other chronologies. Values for Index A and Index B are set based solely on the relationship between ring thicknesses. There are no statistics involved – the values are chosen arbitrarily, then adjusted to produce an optimum fit.

When drought is the cause of a single narrow ring, recovery after the event is rapid, so the seven-year standardized ring width of the second year is positive, thus distinguishing droughts from storms. Drought affects every tree in the stand, so values of R_i for drought years tend to be higher than for storm years. In one instance (2005 and 2006 at Babylon Bluff), two consecutive drought years mimicked the severe storm signal, producing a false positive. Between 1886 and 2006, the period for which reliable historical data is available for Babylon Bluff, the severe storm configuration occurred eight times, one of which was the 2005/2006 false positive. The method works, but is not perfect.

Historical Records vs. Tree Rings

There are serious problems with the historical records. *Storm Data* only goes back to 1949 and there are numerous gaps. *Climatological Data* goes back to 1905 locally, with one low-quality record (Dallas, Arkansas) going back to September 1896. Before that there are only a few newspapers and scattered other records. Though 31 weather stations operated intermittently on or near the Ouachita National Forest, only Booneville, DeQueen, Hot Springs, Mena, Mount Ida, Smithville, Subiaco and

Waldron have operated more-or-less continuously for the decades needed to calibrate tree ring series and Smithville was shut down in 2006.

A Peculiarity of R_i can result in false positive storm indications. Because of the way R_i is calculated, it sometimes acquires a large value in the year before the storm. When two consecutive "storm" years occur, such a situation should be suspected. Check the TRW for the two years: the narrow one indicates the storm year and the one before it is a false positive. As the problem cannot be prevented, it must be disregarded when it occurs.

Winter Storm Signals

Rings associated with storm signals are the narrowest ones in each chronology (Babylon Bluff: 1963; Cold Springs: 1976; Hot Springs: 1822; Lake Winona: 1782; McCurtain County: 1879; Sand Lick: 1956; Story: 1931). In each case, the storm signal is the strongest one in the chronology, permitting the creation of thresholds for storm detection.

"Severe" or "large" storms may be distinguished from "small" ones by referring to the post-storm seven-year standardized ring width of the first and second rings following the storm. If the first year's standardized width is less than -1.000 and the second year's was less than 0.000, then the year in question had a "large" storm, probably an ice storm. If the first year's standardized value was less than -0.300, but larger than -1.000, the storm would be considered "small." Though I did not vary these two thresholds in this study, it is likely that better fits could be obtained by allowing different values on different sites. Further research is indicated.

Distances between research sites and weather stations could be an issue. They are: Babylon Bluff to Eufaula: 26km; Cold Springs to Booneville: 11km; Cold Springs to Cold Springs: 2km; Sand Lick to Mount Ida: 26km; Sand Lick to Story: 8km; Story to Mount Ida: 20km and Story to Story: 5km. As a rough check on the uniformity of weather, monthly average temperature and precipitation at Mena, Arkansas were used to estimate those at Booneville, Arkansas (67km away), using a linear regression model. For average monthly temperature, $r^2 = 0.991$; for average monthly precipitation, $r^2 = 0.547$. Standard deviation (STD) was 0.798° C. for temperature and 4.525cm for precipitation. There is remarkable uniformity between these stations.

Winter storm reconstructions were in remarkable agreement with each other and with the historical record. In a few cases, differences in storm intensity and even in the route of a particular storm could be traced across the forest.

Future Research

Most trunk breakage occurs above commercial height and so has little immediate effect on timber volume. If enough canopy is left, broken trees continue to grow and produce timber above the storm-caused break. However, storm damage creates entry-routes for fungi; decay progression over the ensuing decades can hollow out a tree, rendering it cull. More work is needed on the rate of progression of decay-causing fungi through the tree and their effects on net volume. With ice storm models (Travis et al. 1989; Stevenson et al. 2010) the loss of radial growth caused by severe storms can be quantified. This should be done by incorporating ice storm models into growth-and-yield simulators, such as that developed by Lynch et al. (1999).

Lafon and Speer (2002) applied the method above to *Quercus prinus* L. and *Q. velutina* Lam. The author has observed a double narrow ring pattern in *Pinus taeda* L. from southeast Oklahoma, apparently resulting from the same December 2000 storm. This method of detecting winter storms in tree ring data needs to be tested in other species before the technique can be applied to tree species generally.

It is likely that criteria could be developed to distinguish winter storms from other, possibly confounding events. Drought reduces the growth of *all* trees and lacks the prolonged recovery period of winter storms. Wind storms may trigger release but not suppression (Lafon and Speer 2002; Frelich and Ostuno 2012) and except in extreme cases like hurricanes and tornados, affect a relatively small number of trees (Reilly 1991); wind does not usually produce widespread canopy damage (Lafon and Speer 2002). Amount of snow/ice in a damaging storm might correlate with values of the seven-year standardized ring widths. It should be possible to develop better methods of separating these signals.

In some hardwood species, a two-part signal may indicate ice-caused breakage. By combining signals from multiple species, like pines and oaks, it should be possible to distinguish between ice storms, severe snow storms, and smaller snow storms. By fitting low-temperature and snowfall/precipitation data to the seven-year standardized ring width values, it may be possible to estimate temperatures and precipitation. In North America, radial growth is greatest during the spring when water is abundant. The amount of water affects the amount of foliage and the thickness of the following year’s growth ring, even more than the current year (Raison et al. 1992). This might be used to estimate precipitation on a quarterly basis.

It should be possible with a minimum of additional research to use tree rings to predict the occurrence of ice storms, other severe winter storms, a continuum of lesser winter storms with temperature and precipitation ranges, wind storms and precipitation for the spring and summer seasons (maybe seasonally for the entire year), and do all this at a scale far finer than that achievable with instrumental records.

CHAPTER III

(MANUSCRIPT III)

TRUNK BREAKAGE IN *Pinus echinata* Mill. CAUSED BY THE DECEMBER 2000 ICE STORMS IN THE OUACHITA MOUNTAINS OF OKLAHOMA AND ARKANSAS

INTRODUCTION

Glaze-producing storms occur somewhere every year in the southern United States (Fountain and Burnett 1979; Halverson and Guldin 1995) and average about once every 17 years in the Ouachita Mountains (Stevenson 2013a) , causing trunk and limb breakage, bending and uprooting (Seischab et al. 1993). Ice-caused disturbances are among the most-disruptive influences on southern pines (Bragg et al. 2003; Bragg et al. 2004). Losses in the millions of dollars occur each year from timber damage, power pole breakage, damage to cross arms and wiring and traffic disruption (Lott et al. 1998). The ice storms of December 12-13 and 25-27, 2000 in Arkansas and Oklahoma completely destroyed an estimated 27,500ha of *Pinus echinata* (shortleaf pine) forest and damaged another 54,600ha, posing a significant loss to growers of shortleaf pine (Burner and Ares 2003).

To better understand the phenomenon this study attempted to determine (1) a relationship between breakage probability and total tree height (THt) and diameter at breast height (DBH); and (2) the probable location of the break. The breakage probability and location functions could then be written into growth and yield computer program to simulate the effect of ice storms.

The ability of trees to withstand ice loading is affected by the maximum bending load to failure, which in turn is related to specific gravity and moisture content (Panshin and de Zeeuw 1970). Specific gravity varies within a species and even within a single tree. The proportion of juvenile wood produced in the tree's crown, vs. mature wood produced below the crown, varies with height and within an individual increment core.

The major factor in determining which trees are damaged is exposure. Many factors affect probability and location of breaks – wind direction and strength, site slope, aspect, canopy gaps, crown density, average wind speed, weak points, decay, knots, crooks, forks and irregular loading to name a few (Petty and Worrell 1981; Peltola et al. 1999). Factors related to tree exposure and wood quality are important, but not easily measured or modeled.

Previous authors have noted inexplicable reductions in radial growth rates and attributed them to "bending stress (Lutz 1936; Forest Products Research Laboratory 1941; Lafon and Speer 2002)." Lutz (1936) found external callous lesions on smooth-barked hardwoods, apparently resulting from over-stretching of bark of ice-laden trees. The Forest Products Research Laboratory (1941) reported compression injuries in seemingly undamaged trees as a result of ice loading. Even when a tree appears to have escaped injury, it can still suffer reduced growth.

Van Dyke (1999) found that both dense stands and open grown trees were more vulnerable to glaze ice than moderately-stocked stands, summing up what is known about the effects of stocking on ice damage. Rebertus et al. (1997) found a set of logistic equations that predict the probability of damage in various hardwoods in northern Missouri based on diameter. Hennessey et al. (2012), working with *Pinus taeda*, found THt to be a significant predictor of crown loss; DBH accounted for an additional 2.4% of variation in the data and LCR was a significant predictor and improved the fit by 4.7%.

Winter storms are an environmental fact for most North American trees. Before the ice storms of December 2000, previous winter storms that affected stands used in this study, occurred in 1938, 1943, 1947, 1963, 1976, 1984, 1992 and 1993 (National Climatic Data Center 2011; Stevenson 2013a). While a number of trees broke in the storm of 1963, there was no apparent evidence of breakage from the storms of 1976, 1984, 1992 or 1993. Neither was there any apparent evidence of breakage from the storms of 1943 and 1947, but after 50 years, evidence might no longer exist. Selective thinning in 1987 and 1997 might have removed evidence of breakage at some sites. The storm of 1938 was an enigma; it was very large and probably produced damage at two sites (Knoppers Ford and Story), but this was uncertain; other stands were too young to have been affected.

METHODS

Data for this study came from OSU's ongoing shortleaf pine growth and yield study on the Ouachita National Forest (Figure 8). The study was established in 1985 to 1987 with 0.081ha plots which were re-measured at approximately five-year intervals thereafter. All tree diameters were measured in inches at DBH (1.37m). In addition, total tree height (THt) and height to the lowest live limb (CHt) were measured for the first two trees on each plot in each 2.54cm diameter class, starting at north and proceeding clockwise. In subsequent re-measurements additional heights were measured to maintain the two trees per diameter class standard.

At the time of the December 2000 ice storms, the growth and yield study was in the process of being updated; 74 plots were already measured with 126 more yet to complete. After the storm, the remaining plots were re-measured, but no additional data were collected from those already updated. This resulted in some plots with pre-ice storm data and some plots with post-ice storm data. Plot data was updated again in 2006.

In 2006 through 2009, ice damage data and cores were collected from 90 of OSU's growth and yield plots located on 23 separate sites. The 90 plots originally contained 4456 trees. At the time of the December 2000 ice storms, 2485 trees were still alive. Of these, 584 had broken trunks as a result of the storms. A tree was considered "broken" when the main stem broke. That could be anywhere between

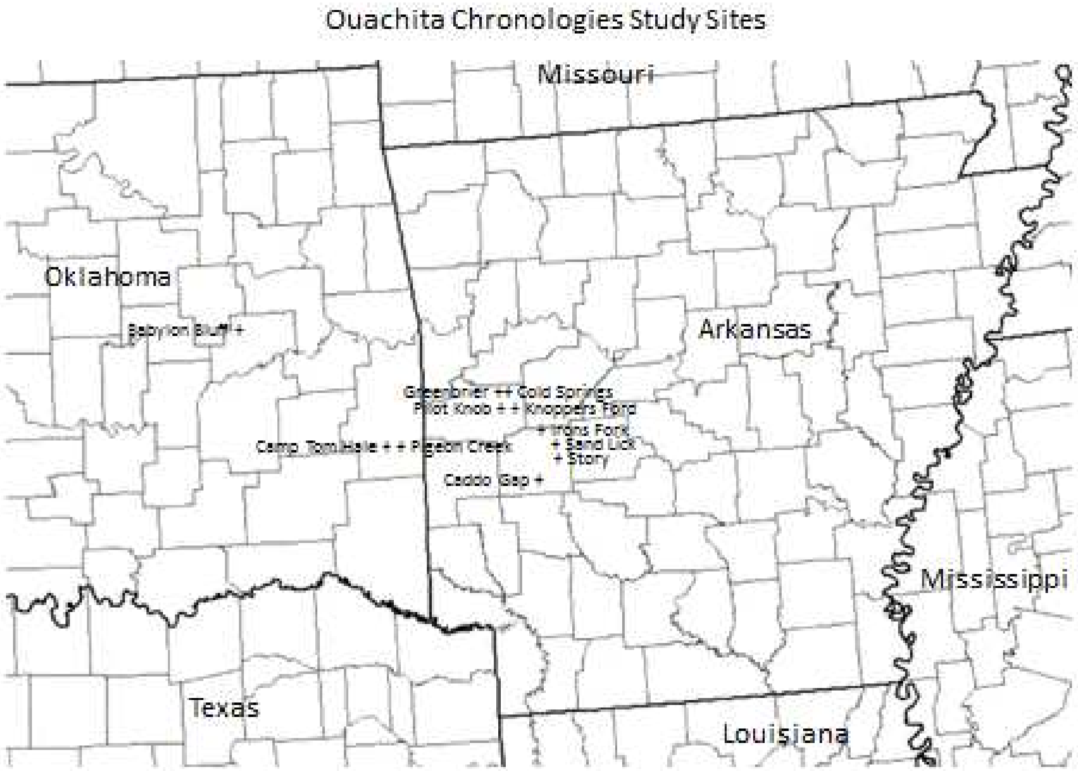

Figure 8. Research study sites. Babylon Bluff was included because it was not affected by glaze icing in December 2000 and could serve as a control. Map data from National Atlas of the United States, United States Department of the Interior, 2013.

the ground and the terminal bud. In the case of forks, the taller fork was considered to be the main stem. There was no minimum diameter and no minimum length; although the shortest top measured was 0.12m long. A year later in 2001, thirteen additional trees were dead, victims of the ice. Although these were broken trees, suppression was probably a contributing factor. There was no evidence of other causes of mortality, like insect attack or lightning. This left 2472 living trees, of which 571 (23.1%) had broken trunks. By 2006, an additional 138 were dead, some as a result of ice damage and some from undetermined causes, leaving 2334 trees.

On each plot, heights (THt and CHt), diameters and break heights were measured from two broken and two unbroken trees, if available. When this sample proved inadequate for a comparison study due to a shortage of unbroken trees, additional data were collected from all trees on each of eleven of the 23 sites, a total of 42 plots.

In the original growth and yield study, it was intended to estimate missing heights using diameter-height regression models. After the ice storm there were often too few survivors to allow this on a plot-by-plot basis. To solve this problem, a subset of the 2485-tree sample was selected. To be included, trees had to have four measured heights, two before the ice storm, no earlier than 1992, and two afterward. At least one of these had to be in either 2000 or 2001. These criteria were met by 850 trees, some broken, some not.

For unbroken trees, height was interpolated between the closest measurements before and after the storm. Thus, heights used for the 2000 season were either direct measurements made in the fall and winter of 2000 (106 trees), or interpolated from data recorded in 1996/1997 and 2001 or 2006 (525 trees). Fifteen of the 106 direct measurement trees were measured both before and after the storm. For broken trees, the first two measured heights prior to the storm were used to calculate a straight-line equation (point-slope method) which was then used to estimate the height just before the storm. For example, the 1992 and 1996/1997 height measurements were used to estimate the height in December 2000 (106 trees). Direct height measurements of the break point made in the winter of 2000 were available on 113 trees, of which 14 trees had direct measurements both before and after the storm. Total height after break was estimated in the same way from measurements made in 2001 and 2006 (471 trees). As a rough check on accuracy, before-storm height and break height were estimated for the 14 trees with before-and-after-storm measurements. Average error was 0.52m (range: -0.90m to 9.26m) with two trees producing estimated pre-break total heights that were less than the measured break height (BHt).

A variety of variables were tested using linear and multiple regression models in an effort to predict crown loss (THt minus BHt). These included THt, DBH, average crown height (ACH) of the plot, THt divided by ACH, THt divided by DBH, THt divided by DBH squared, THt in 1987 divided by DBH in 1987 and THt in 1987 divided by DBH squared in 1987. Those that were significant (THt, DBH and LCR) were further tested using multiple linear regression. Live crown ratio (LCR) is the difference between the total live height (THt) of the tree and the height of the lowest live limb (CHt), divided by the total live height (THt). Partial analysis of variance was used to separate variation into its components and determine significance of the contribution for each variable in the context of a Stepwise variable selection procedure (Tables 13 to 15).

A model for estimation of the probability of trunk breakage was developed using a binomial dependent variable (broken = 1; unbroken = 0). A logistic model (SAS Institute 1988; Rebertus et al. 1997; Newson 2002; SAS Institute 2008) to predict which trees would break was tested using THt, DBH and LCR as variables (Tables 16A and 16B).

Trees uprooted or bent over were counted and their survival determined from growth and yield study records. As there were only two survivors after six years, statistical analysis was unneeded.

RESULTS

Of the 584 broken trees, 337 trees (58%) lost less than one-quarter of their LCR, 174 (29%) lost between one-quarter and one-third of their LCR, 117 (20%) lost between one-third and half of their LCR, 24 (4%) lost between half and two-thirds of their LCR, and 23 (4%) lost between two-thirds and three-quarters of their LCR. Eleven trees (2%) lost more than three-quarters of their crown, yet survived for at least six years. Loss of the entire crown was a rare event; it happened to only nine trees, seven of which died before the next update. There were two trees that lost almost their entire crown and survived - one tree lost all of its crown except for a one meter long twig; another tree lost its entire crown, but six years later both trees were still alive and had produced epicormic branches.

Table 13. Partial Analysis of Variance for height loss of *Pinus echinata* vs. tree height (m) and diameter (cm) during the December 2000 ice storms in Oklahoma and Arkansas.

pANOVA	df	SS	MS	F
Model	2	190.50	95.23	30.19
THt	1	109.5	109.5	34.71
DBH|THt	1	81.0	81.0	25.68
Error	546	1722.3	1.78	
Sum	548	1912.8		

$r^2 = 0.100$ $r^2_{THt} = 0.057$ $r^2_{DBH|THt} = 0.042$

$s = 1.78$ $F(0.95,1,546) = 3.86$ $F(0.95,2,546) = 3.01$

Model: $Y = 1.1640 + 0.1704X_1 - 0.0719X_2$

where:

Y = Height loss in meters,

X_1 = Total tree height (THt) in meters,

X_2 = Diameter (DBH) in centimeters.

Table 14. Partial Analysis of Variance for height loss of *Pinus echinata* vs. tree height (m), diameter (cm) and live crown ratio in the December 2000 ice storms in Oklahoma and Arkansas.

pANOVA	df	SS	MS	F
Model	3	297.50	99.15	33.42
THt	1	109.5	109.5	33.22
DBH|THt	1	81.0	81.0	27.64
LCR|THt,DBH	1	107.0	107.0	36.31
Error	544	1614.2	2.967	
Sum	547	1911.6		

$r^2 = 0.156$ $r^2_{THt} = 0.057$ $r^2_{DBH|THt} = 0.042$ $r^2_{LCR|THt,DBH} = 0.056$

$s = 1.723$ $F(0.95,1,544) = 3.86$ $F(0.95,3,544) = 2.62$

Full Model: $Y = -1.7632 + 0.2701X_1 - 0.1206X_2 + 6.2969X_3$

where:

Y = Height loss in meters,

X_1 = Total tree height (THt) in meters,

X_2 = Diameter (DBH) in centimeters.

X_3 = Live Crown Ratio (LCR).

Table 15. Analysis of Variance for height loss of *Pinus echinata* vs. tree height (m) in the December 2000 ice storms in Oklahoma and Arkansas.

ANOVA	df	SS	MS	F
$\text{Model}_{\text{THt}}$	1	109.5	109.5	33.22
Error	547	1803.3	3.2967	
Sum	548	1912.8		

$r^2 = 0.057$ $s = 1.816$ F(0.95,1,547) = 3.859

Model: $Y = 0.9261 + 0.0788X_1$

where:
Y = Height loss in meters, and
X_1 = Total tree height (THt) in meters.

Table 16A. Logistic Model (Total Tree Height) for probability of trunk breakage during the Christmas 2000 ice storm in Oklahoma and Arkansas.

	Total Tree Height Before Storm
Broken (Y=1)	267
Unbroken (Y=0)	916
AIC (Intercept and covariates)	1252.931
SC (Intercept and covariates)	1263.083
-2 Log L (Intercept and convariates)	1248.931

	Chi-Square	Probability of Greater Chi-Square
Likelihood Ratio (DF=1)	14.572	0.0001
Score (DF=1)	14.6468	0.0001
Wald (DF=1)	14.4668	0.0001

Parameter	DF	Estimate	Standard Error	Wald Chi-Square	Pr>ChiSq
Intercept	1	2.1801	0.2634	68.4805	<0.0001
Total Tree Height	1	-0.0444	0.0117	14.4668	0.0001

Percent Concordant:	57.0	Somer's D:	0.154
Percent Discordant:	41.7	Gamma:	0.156
Percent Tied:	1.3	Tau-a:	0.054
Pairs:	244,572	c:	0.577

Table 16B. Logistic Model (Diameter; DBH) for probability of trunk breakage during the Christmas 2000 ice storm in Oklahoma and Arkansas.

	Total Tree Height Before Storm
Broken (*Y*=1)	267
Unbroken (*Y*=0)	916
AIC (Intercept and covariates)	1262.653
SC (Intercept and covariates)	1272.805
-2 Log L (Intercept and convariates)	1258.653

	Chi-Square	Probability of Greater Chi-Square
Likelihood Ratio (DF=1)	4.850	0.0276
Score (DF=1)	4.869	0.0273
Wald (DF=1)	4.848	0.0277

Parameter	DF	Estimate	Standard Error	Wald Chi-Square	Pr>ChiSq
Intercept	1	1.7062	0.2288	55.6313	<0.0001
Diameter (DBH)	1	-0.0150	0.00683	4.8482	0.0277

Percent Concordant:	52.7	Somer's D:	0.075
Percent Discordant:	45.2	Gamma:	0.076
Percent Tied:	2.1	Tau-a:	0.026
Pairs:	244,572	c:	0.537

Variables tested and not found to be significant predictors of BHt included THt, DBH, average crown height (ACH) of the plot, THt divided by ACH, THt divided by DBH, THt divided by DBH squared, THt in 1987 divided by DBH in 1987 and THt in 1987 divided by DBH squared in 1987. THt, DBH and LCR were further tested using STEPWISE multiple linear regression (SAS Institute 2008).

The full model for length of the broken top was:

$$Y = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + \varepsilon \qquad 1$$

where:

Y = Height loss in meters,

X_1 = Total Tree Height (THt) in meters,

X_2 = Diameter (DBH) in centimeters,

X_3 = Live Crown Ratio (LCR),

b_0, b_1, b_2, b_3 = coefficients to be estimated,

b_0 = -1.7632; standard error: 0.5557,

b_1 = 0.2701; standard error: 0.0274,

b_2 = -0.1206; standard error: 0.0160,

b_3 = 6.2969; standard error: 1.0460, and

ε is an error term with zero mean and constant variance.

In an attempt to create a model that could be used in the field, height loss was regressed onto diameter and height. Again, Y is the length of the broken top:

$$Y = b_0 + b_1X_1 + b_2X_2 + \varepsilon \qquad 2$$

where:

Y = Height loss in meters,

X_1 = Total tree height (THt) in meters,

X_2 = Diameter (DBH) in centimeters,

b_0, b_1, b_2 = coefficients to be estimated,

b_0 = 1.1640; standard error: 0.2769,

b_1 = 0.1704; standard error: 0.0255, and

b_2 = -0.0719; standard error: 0.0142.

ε is an error term with zero mean and constant variance. The Analysis of Variance table from the final SAS STEPWISE procedure is presented in Table 1.

Because diameter, though significant, did not account for very much variation, a simpler model was tested:

$$Y = b_0 + b_1X + \varepsilon \qquad 3$$

where:

Y = Height loss in meters,

X = Total Tree Height (THt) in meters,

b_0, b_1 = coefficients to be estimated,

b_0 = 0.9261; standard error: 0.2790, and

b_1 = 0.0788; standard error: 0.0137.

ε is an error term with zero mean and constant variance.

A partial Analysis of Variance from the SAS STEPWISE procedure (SAS Institute 2008) (Table 2) showed that THt accounted for the largest amount of variation (15.4%) in Equation 1. DBH accounted for an additional 2.1% and live crown ratio, another 4.8%. LCR was not significant if DBH was not in the model. In Equation 2, DBH “explained” only 10.0% of the variation while THt by itself accounted for 15.6% (Table 3).

Probability of Breakage Model

A Bernoulli random variable with $Y = 1$ for trunk breakage, otherwise $Y = 0$, was used as a dependent variable to develop a model of probability of stem breakage in the presense of a severe storm. The use of a Bernoulli random variable (one that is constrained between 0 and 1) as a dependent variable in a linear model was problematic because predictions from a linear model cannot be constrained to be greater than 0 or less than 1. Thus, a logistic model (SAS Institute 1988; Rebertus et al. 1997; Newson 2002; SAS Institue 2008) for breakage probability was tested:

$$p(Y = 1) = \frac{1}{1 + \exp(a + bX)} \qquad 4$$

where:

$p(Y{=}1)$ = probability of trunk breakage,

X = independent variable; THt or DBH,

a,b = coefficients to be estimated:

a_{THt} = 2.1801; standard error: 0.2634, to be used with independent variable THt,

b_{THt} = -0.0444; standard error: 0.0117, to be used with independent variable THt,

a_{DBH} = 1.7062; standard error: 0.2288, to be used with independent variable DBH, and

b_{DBH} = -0.0150; standard error: 0.00683, to be used with independent variable DBH.

Live crown ratio was tested and found to be insignificant.

The fit of the model is determined using the maximum likelihood function for a binomial variable (SAS Institute 1988; Newson 2002). I used SAS' PROC LOGISTIC; the Analysis of Maximum Likelihood (SAS Institute 2008).

The logistic models were significant ($p \leq 0.01$ for THt and p-value=0.03 for DBH) (Tables 4A and 4B). THt had a range of $p(Y{=}1)$ values from a low of 0.122 (4.57m for a suppressed tree) to a high of 0.364 (36.58m); AIC was 1252.931. The concordance/discordance ratio was 57.0/41.7 = 1.367, slightly lower than the range of Rebertus' (1977) hardwoods. For DBH, the range of $p(Y{=}1)$ was from 0.165 (5.74cm DBH) to 0.339 (69.19cm), slightly narrower than for THt. When the STEPWISE procedure was tried in PROC LOGISTIC for breakage with independent variables THt, DBH and LCR, only THt was retained in the model. LCR was not significant in the logistic model since it had a p-value greater than 0.05.

Trees that broke in the December 2000 ice storms averaged 20.40m tall before the storm (Table 5). Trees that did not break in that storm averaged 18.87m, a difference of 1.54m. Standard deviations were 0.12m and 0.23m, respectively. The difference (1.54m) between pre-break height of broken trees (20.40m) and post-break height of broken trees (17.19m) is significant (difference = 2.21m) (p-value=0.03).

Almost all (97.5%) of 80 bent or up-rooted trees died within five years of the storm. In 2006 only two trees (2.5%), both on Plot 120 of the Camp Tom Hale site, remained alive. At the time of the 2006 update one had straightened up and was suppressed but appeared untouched. The other was horizontal and covered by debris, but still alive. In 2009 both were still alive.

DISCUSSION

Height loss and breakage probability models are needed to predict how many and which trees will break in an ice storm and how extensive the damage to the trunk will be. They are useful in growth and yield simulators to estimate losses from the pre-storm stand and survivorship in the post-storm stand.

Total tree height was the most-accurate predictor of height loss detected, accounting for 15.6% of total variation. DBH accounted for an additional 2.4% of variation in the data. LCR was a significant predictor and improved the fit by 4.7%, but is not easy to use in the field. These numbers clearly showed THt to be the most important variable of all those examined. Hennessey et al. (2012), working with *P. taeda*, found THt to be a significant predictor of crown loss, but also found DBH and LCR to be much more important than I did with *P. echinata*.

The same variables were tested using a logistic model to predict probability of breakage. To be useable, a probability model must produce a reasonably wide range of probability estimates. When the lowest estimate is almost the same as the highest one, the result has little more utility than a simple average. The logistic model for the probability of stem breakage using THt produced a 0.242 range of probability estimates, not as good as it might be, but still useable.

For diameter, the range of $p(Y=1)$ in the logistic model was slightly narrower (0.174) than for THt (total height). Even though DBH was not as good a predictor as THt, it was easier to use in the field and because results were very similar for both, DBH might be the preferred choice in field applications. LCR was not significant in a model to predict breakage probability.

Taken together, these results suggest that larger trees were sheltering smaller ones from ice accumulation. The study did not include enough short trees in dominant or codominant crown positions to determine whether height or crown position is more important in predicting breakage of short trees. The study included only even-aged plots. Uneven-aged plots might show a different result.

In Equations 1 and 4, the DBH coefficient is negative, while the THt coefficient was positive. This suggested that taller trees with narrower trunks were more-likely to break, and lose more of their height when they did. On the other hand, the situation was reversed in Equation 2 and THt/DBH and THt/DBH^2 were insignificant when tested. Trunk shape seemed to have an effect on breakage probability, but the nature of that effect was unclear.

Some variables that might be tried to increase accuracy are the cube of the DBH and the cube of the stem diameter at the break point (Petty and Worrell 1981). Stem diameters measured at intervals through the crown might point to sudden changes in diameter that pre-dispose a trunk to breakage. Also, a tree's position on the edge of a stand, site slope, aspect, canopy gaps, crown density, the area of the crown presented to the wind (adjusted for streamlining and ice accumulation), the weight of the crown and accumulated ice above the break point have been proposed as contributing to probability and location of breaks. Weak points caused by decay, knots, crooks, forks, inconsistent wood quality, and irregular loading caused by branch damage or ice accumulation on the windward side of the tree might also contribute to probability and location of breaks (Petty and Worrell 1981). Distance and direction to the next tallest or taller trees may also affect breakage. Ways need to be devised to measure these variables and their effects modeled.

For most trees in this study, height loss was minor. Breakage was heavily skewed toward the top of the tree. Juvenile wood, which grows in the area of the live crown, has a lower specific gravity than mature wood (Megraw 1985). This may have been part of the reason that most stem failures occured high in the crown. For the vast majority of trees, breakage occurred well above commercial height (defined as occurring at a top inside-bark diameter of 12.7cm), produced no immediate loss of commercial timber volume and very little loss of pulpwood volume. If a stand was salvaged soon after an ice storm, there would be very little economic loss, even in heavily damaged stands.

The real damage done by ice storms is to future net growth. The two years following the storm produce narrow rings, resulting in lower volume production (Rebertus et al. 1997; Lafon and Speer 2002; Smith and Shortle 2003; Smolnik et al. 2006; Stevenson 2013b). My results agreed with this. Whether subsequent accelerated growth due to stand density (release) could make up this loss over time has not been determined..

Forty-five years after the 1963 storm, trees broken in that storm were almost all culls, as determined from increment cores. I was unable to check the progress of decay in trees broken in the 2001 storm, but it seemed just a question of time before they too, were further damaged by decay. This agreed with Shigo (1986) who found that following major injury, decay fungi eventually consumed all wood that existed at the time of the injury. Decay progression should be examined in more detail so it can be included in future growth simulators. A study of the commercial aspects of tree breakage could enhance future management of storm-damaged southern pines.

Lynch et al. (1999) published a model for *P. echinata* growth and yield prediction in even-aged stands. My model was developed from the same stands using much of the same data.[6] When I collected

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[6] Lynch's model citation used data through 1996; mine used the same plots with one additional update done in 2000/2001.

data for my study, the plots were five years older, had a few fewer trees and except for storm-damaged plots, had slightly higher stocking (measured by basal area). Nevertheless, as the plots weren't identical, caution should be exercised.

The logistic ice storm model predicting the probability of breakage could be used in a Monte Carlo simulation to estimate damage expected from future ice storms and an algorithm added to the Lynch model. The 0.058 probability of an ice storm in any given year with a 0.667 chance of tree breakage in the event of a storm (Stevenson 2013b) and the breakage probability and height loss equations make this possible, but they should be further refined before actually being used. It may be possible to find periods in the data, such as the nine-year sine curve and the sixteen-year sine curve (cause unknown) found by Stambaugh and Guyette (2004) in *P. echinata* ring widths, that allow better estimates to be made of when damage is likely to occur. That THt is a significant predictor of breakage agrees with other research (Bragg et al. 2004; Hennessey et al. 2012). Variables such as diameter (DBH), form (various height/diameter variables) and stocking (Bragg et al. 2004), show inconsistent results and may depend on variables such as species (Rebertus et al. 1997; Smith and Shortle 2003; Smolnik et al. 2006) and management history (Rebertus et al. 1997). Few trees even survived serious bending or uprooting and those that did had very little commercial value or potential for future growth.

It is important to remember that these findings are for even-aged stands of *P. echinata* between 30 and 105 years old, stocking between about 9.5 and 35m^2 ha^{-1} and diameters between 0.20 and 0.50m. Using the models for smaller, younger stands would be especially risky. They offer a starting point for research into the simulation of ice storms in computer simulations of future growth and effects on the economics of silviculture and timber management.

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APPENDIX I

OUACHITA CHRONOLOGIES

The Ouachita Chronologies dataset is presented in Tucson Format. The heading for each site chronology gives name, state, location in geographic coordinates, elevation in meters, beginning year and ending year. The “PIEC” abbreviation is a contraction of the scientific name for *Pinus echinata* Mill. All site chronologies are based on Total Ring Width. The species name in English is included in each heading. The people who contributed to each chronology are listed on the third line of the heading and differ between site chronologies.

The first data column indicates the decade. Thereafter, columns alternate with the next (second) column in the table indicating total ring width in microns and the next (third) column showing the sample depth. Years count up from left to right with the second and third columns representing years ending in “0,” the fourth and fifth columns representing years ending in “1,” the sixth and seventh columns representing years ending in “2,” and so on. The number “9990” indicates “no data” for that year.

Ouachita Chronologies

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Ouachita Chronology                    Total Ring Width                                   PIEC
Oklahoma & Arkansas        Shortleaf Pine        Ouachita National Forest        1783  2009
D. Stevenson     K. Cerny     T. Lynch     J. Guldin      P. Murphy
1780 9990   0 9990   0 9990   0 1338   1 2687   1    0   1 1557   1 2650   1 2490   1  589   1
1790 1329   1 3918   1 4094   1 2173   1 1391   1    0   1 1256   1 1723   1 3037   1 2353   1
1800 1949   1 1093   1 3435   1 1415   1 2457   1 1258   1 1406   1 2109   1 2683   1  810   1
1810 1104   1 2587   1 1732   1 2935   1 1872   1 2952   1 1189   1 2760   1  520   1 1730   1
1820 1522   1 2767   1 2302   1  917   1 1404   1 2385   1 3229   1 1896   1  774   1 1271   1
1830 2595   1 1708   1  972   1 1454   1 1616   1 2530   1 3227   1 1856   1  566   1 3958   1
1840 2879   1    0   1  708   1  899   1 2867   1 1662   1  773   1 1077   1 1711   3 2309   3
1850 1466   3  776   4 1584   5 1738   5 1623   5 1300   5 1796   5 2865   5 2515   5 1610   5
1860 1068   7 1560   7 1658   7 2247   8 1360   8 3279   8  992   8 1953   9 2359  11 2114  12
1870 2654  12  963  12 2031  15 1902  17 1435  18 2015  18 2063  19 1819  20 3060  20  701  21
1880 1589  21 1179  22 1940  23 2253  24 1723  24 1710  25  863  28 1722  30 2057  31 2330  33
1890 2724  33 1584  36 2122  38 2027  38  777  38 2137  38 1368  40 1837  41 1861  41 1260  41
1900 1773  42 1255  42 1816  42 2393  43 3243  42 2017  42 1880  43 1008  43 2678  44 1182  44
1910  951  44 1457  44 1750  45 1380  46 1942  47 2108  48 1406  48 2236  48  854  49 1885  49
1920 1895  49 2328  48 1332  48 2149  48 1988  51 1111  52 1931  53 2362  58 1628  59 2086  63
1930 1311  64 1618  70 1902  76 2339  79 1536  82 2287  82 1502  86 2496  91 1428  96 1743 100
1940 2209 116 2259 121 2206 125 1187 136 2180 145 2212 151 1881 172 1833 192 2300 203 1928 227
1950 2607 246 1887 259 1399 271 1954 277 1346 287 2102 295 1101 297 2691 304 2165 307 2125 308
1960 1638 312 2304 311 1931 314 1106 314 1575 314 1655 317 1912 317 1852 318 1808 319 1733 323
1970 2160 326 1872 330 1400 335 2431 338 1726 342 1742 347 1529 348 1772 349 1242 350 1759 351
1980 1169 352 1943 351 1806 351 1807 350 1598 351 1518 352 1781 352 1790 352 1704 351 2215 352
1990 1824 353 1825 353 1753 349 1524 351 2157 351 1732 349 2121 348 1501 349 1956 351 1956 351
2000 1700 346 1385 345 1467 344 1775 345 1854 343 1759 336 1619 335 1909 331 1808  85 1546  24
2010 -9999
```

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Babylon Bluff/Shortleaf Canyon               Ouachita Chronologies                        PIEC
Oklahoma         Shortleaf Pine         Total Ring Width       187m 3525-9550       1783  2009
D. Stevenson     K. Cerny     T. Lynch
1780 9990   0 9990   0 9990   0 1109   1 2210   1    0   1 1290   1 2197   1 2064   1  488   1
1790 1102   1 3247   1 3394   1 1804   1 1153   1    0   1 1041   1 1428   1 2518   1 1951   1
1800 1615   1  906   1 2847   1 1173   1 2037   1 1043   1 1166   1 1748   1 2224   1  672   1
1810  915   1 2145   1 1436   1 2433   1 1552   1 2447   1  986   1 2288   1  431   1 1434   1
1820 1261   1 2294   1 1908   1  760   1 1164   1 1977   1 2676   1 1572   1  642   1 1054   1
1830 2151   1 1416   1  806   1 1205   1 1339   1 2098   1 2675   1 1539   1  469   1 3281   1
1840 2386   1    0   1  587   1  745   1 2377   1 1378   1  641   1  893   1 1418   3 1914   3
1850 1215   3  643   4 1313   5 1441   5 1345   5 1078   5 1488   5 2375   5 2085   5 1334   5
1860  885   7 1293   7 1374   7 1863   8 1127   8 2718   8  822   8 1619   9 1955  11 1752  11
1870 2200  12  798  12 1683  15 1577  17 1190  18 1670  18 1710  19 1508  20 2536  20  581  21
1880 1317  21  977  22 1608  23 1867  24 1428  24 1417  25  716  28 1427  30 1729  30 1915  32
1890 2286  32 1311  35 1802  37 1673  37  637  37 1790  37 1150  39 1517  40 1508  40 1064  40
1900 1468  41 1032  41 1497  41 1983  42 2712  41 1672  41 1576  41  792  41 2263  41  964  41
1910  756  41 1154  41 1505  41 1119  41 1569  41 1685  41 1167  41 1906  41  666  41 1552  41
1920 1524  41 1969  40 1145  40 1717  40 1669  40  901  40 1721  40 1964  40 1362  40 1635  40
1930 1249  40 1357  40 1307  40 1819  40  976  40 1587  40 1123  40 1246  40 1361  40 1418  40
1940 1658  41 1539  41 1807  42 1156  42 1603  42 1584  42 1743  42 1937  42 1742  42 1019  42
1950 2371  43 1028  45 1046  45 1545  45 1066  45 1266  45  949  45 1553  45 2212  45 2084  45
1960 1688  45 2184  44 1905  44  557  44 1291  44 1280  44 1687  44 1416  44 1506  44 1426  44
1970 1646  44 1684  44 1093  44 2208  44 1440  44 1388  44 1418  44 1890  44  785  44 1276  45
1980 1228  45 1754  45 1793  45 1334  45 1370  45 1361  45 1593  45 1439  45 1090  45 1878  45
1990 1418  45 1840  45 1957  45 1140  45 1686  45 1454  45 1712  45 2182  45 1198  45 1760  44
2000 1636  44 1499  44 1037  44 1350  44 1477  44 1547  44  942  43 1774  42 1546  42 1177   6
2010 -9999
```

```
Caddo Gap                              Ouachita Chronologies                              PIEC
Arkansas       Shortleaf Pine       Total Ring Width         248m  3427-9330        1913  2009
D. Stevenson     T. Lynch     J. Guldin
1910 9990   0 9990   0 9990   0 9990   0 9990   0 1225   1  319   1  200   1    0   1  608   1
1920  595   1  694   1  219   1  712   1  562   1  263   1  499   1  938   1  451   1 1092   1
1930    0   1   50   1 1991   3 2050   4 1056   5 2378   5 1018   6 1220   6 2087   6 1491   6
1940 1918   8 1625   9 1753  10  924  13 1868  13 2403  13 1297  14 1227  14 1296  14 1895  15
1950 1976  17 1603  17 1232  17 1775  18 1279  19 2478  20 1381  21 3641  21 2679  21 2359  22
1960 1933  23 2572  23 2546  23 1841  23 2262  23 1653  23 1838  23 1900  23 2010  23 2053  23
1970 2395  23 1914  23 1767  23 2945  23 2354  23 2223  23 1904  23 2154  23 1291  23 1615  23
1980 1139  23 2071  23 2351  23 2063  23 2242  23 1781  23 1781  23 1709  23 2203  23 2435  23
1990 2104  23 1817  23 1981  23 1612  23 2441  23 1673  23 2202  23 1764  23 2709  23 1940  23
2000 2032  23 1214  23 1600  23 2416  23 2265  23 1688  22 2018  22 2309  22 1492   7 1761   6
2010 -9999
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Camp Tom Hale                             Ouachita Chronologies                            PIEC
Oklahoma       Shortleaf Pine        Total Ring Width        225m  3444-9455         1967  2009
D. Stevenson     T. Lynch     J. Guldin
1960 9990   0 9990   0 9990   0 9990   0 9990   0 9990   0 9990   0 3288   1 5971   1  3727   3
1970 3827   6 4048  10 3317  13 3325  16 2523  21 2549  24 2588  25 2003  25 1785  26  2902  26
1980 1770  27 2626  27 2414  27 1958  26 1639  26 1863  27 2403  27 2418  27 1805  27  2538  28
1990 3508  29 2205  29 3374  28 1690  29 2054  29 2295  29 2447  29 1115  29 2054  29  2068  28
2000 1728  28 1347  28 1488  28 1859  28 2126  27 1795  26 1656  27 2235  27 2076  19  1627   8
2010 -9999
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Cold Springs                            Ouachita Chronologies                             PIEC
Arkansas       Shortleaf Pine       Total Ring Width         154m  3503-9353        1941  2008
D. Stevenson     T. Lynch     J. Guldin
1940 9990   0 4281   1 6527   3 5570   3 5210   4 5105   7 3891  14 2799  23 4822  23 2987  32
1950 3903  37 2670  40 1908  42 2596  44 1713  44 2601  45 1371  45 3659  45 2616  46 2251  46
1960 1933  46 2943  46 2424  46 1209  46 1696  45 1968  45 2552  45 2405  45 2370  46 2238  46
1970 1863  46 2144  46 1703  46 3105  46 2221  46 2251  46 1046  46 1666  46 1637  46 2666  46
1980 1280  46 2321  46 2179  46 2390  46 1888  46 2043  46 2223  46 2294  46 2041  46 2548  46
1990 2000  46 1957  46 1889  46 1824  46 2794  46 2018  46 2492  46 1595  46 2034  46 2366  45
2000 1786  45 1538  45 1966  45 1922  45 2262  45 2112  45 2030  44 2200  44 2398  13 -9999
```

```
Greenbrier                             Ouachita Chronologies                              PIEC
Arkansas       Shortleaf Pine       Total Ring Width          147m  3501-9403       1946  2007
D. Stevenson     T. Lynch     J. Guldin
1940 9990   0 9990   0 9990   0 9990   0 9990   0 9990   0 4211   5 2914  10 4175  15 3565  20
1950 3508  22 3706  27 1576  28 2754  27 1891  29 2793  31 1513  31 3780  32 2904  32 2415  32
1960 2006  32 2785  32 2563  32 1198  32 2181  32 1849  32 2353  32 2663  32 2422  32 2067  32
1970 2180  32 2115  32 1906  32 3115  32 1679  32 2335  32 1451  32 1825  32 1664  32 2583  32
1980 1364  32 2636  32 2482  32 2592  32 2243  32 2018  32 2238  32 2516  32 2122  32 3029  32
1990 2332  32 2242  32 2157  32 1940  32 2724  32 2252  32 2655  32 1745  32 2611  32 2736  32
2000 2052  32 1852  32 2163  32 2195  32 2470  32 2449  30 2152  29 1962  28 -9999
```

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Irons Fork                                    Ouachita Chronologies                          PIEC
Arkansas       Shortleaf Pine       Total Ring Width          206m  3445-9328       1932  2007
D. Stevenson     T. Lynch     J. Guldin
1930 9990   0 9990   0 9223   1 4848   2 5250   2 5209   2 3092   4 3678   5 1843   7 1859   8
1940 2706  11 2759  12 2076  12 1170  13 2035  14 2118  15 1662  16 1593  16 2002  18 1833  18
1950 1841  20 1474  20 1596  21 1947  21 1226  22 2210  22 1098  22 2437  23 1610  23 2180  23
1960 1642  23 2006  23 1488  23 1436  23 1366  23 1892  25 1641  25 1570  25 1404  25 1340  25
1970 2373  25 1847  25 1203  26 2172  26 1737  26 1437  26 1672  26 2006  27 1213  27 1546  27
1980  952  27 1786  27 1515  27 1618  27 1561  27 1524  27 1606  27 1539  27 2010  27 2197  27
1990 1378  27 1657  27 1391  27 1458  27 1866  27 1543  27 2123  26 1331  26 2302  26 2002  26
2000 1571  26 1221  26 1392  26 1871  26 1678  26 1660  24 1665  25 2076  25 -9999
```

```
Knoppers Ford                                   Ouachita Chronologies                        PIEC
Arkansas       Shortleaf Pine       Total Ring Width         231m  3500-9351        1924  2007
D. Stevenson     T. Lynch     J. Guldin
1920 9990   0 9990   0 9990   0 9990   0 1719   1 1396   2 1478   3 2297   7 1805   7 1965  10
1930 1416  11 1885  17 1592  19 1933  19 1582  20 2146  20 1119  20 3774  21  896  21 1243  22
1940 2072  23 1769  23 2065  23  977  23 2105  23 2141  22 1445  22 1367  22 1715  23 1335  23
1950 2335  23 2321  23 1699  24 2191  24 1525  24 2263  24  918  24 2899  24 2224  24 1963  24
1960 1378  24 2103  24 1949  24 1179  24 1484  24 1407  24 2395  24 2170  24 1890  24 2103  24
1970 2083  24 1824  24 1235  24 2325  24 1733  24 1928  24 1207  24 1371  24 1252  24 1759  24
1980 1502  24 1960  24 1619  24 1953  24 1446  24 1465  24 1853  24 2257  24 1798  24 2496  24
1990 1944  24 1889  24 1526  24 1255  24 2289  24 1698  24 2082  24 1412  24 1742  24 1944  24
2000 1690  23 1471  23 1597  23 1594  23 1904  22 1955  22 1520  22 1660  22 -9999
```

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Pigeon Creek                                    Ouachita Chronologies                        PIEC
Arkansas       Shortleaf Pine       Total Ring Width           334m  3438-9432      1943  2009
D. Stevenson     T. Lynch     J. Guldin
1940 9990   0 9990   0 9990   0 3307   2 2944   2 4029   2 1685   3  625   5 2787   5 3040   6
1950 2650   8 2238   8 1428  11 2204  11 1904  15 1927  19 1282  19 3078  20 2603  20 2474  20
1960 2437  22 2516  22 1834  22 1430  22 1561  22 1868  22 2164  22 2259  22 2110  22 2310  22
1970 2406  22 2508  22 1622  22 3012  22 2068  22 2353  22 1899  22 1829  22 1714  22 1779  22
1980 1211  22 2198  21 2020  22 1973  22 1920  22 1744  22 1811  22 2529  22 1850  22 2263  22
1990 2177  21 2164  21 2365  20 1576  20 2384  19 1739  19 2185  19 1700  20 1924  21 2284  21
2000 1824  21 1743  20 1814  19 2135  19 2101  19 1700  19 1803  19 2083  19 2065   4 2182   4
2010 -9999
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Pilot Knob                                     Ouachita Chronologies                         PIEC
Arkansas       Shortleaf Pine       Total Ring Width           244m  3500-9403     1940  2007
D. Stevenson     T. Lynch     J. Guldin
1940 2334   1    0   1 1952   1 1199   2 4507   2 1259   4 2252   5 2642   8 3381   8 2996  11
1950 3859  14 2403  16  974  19 1904  21 1447  22 2449  22 1115  23 3484  24 2406  24 1938  24
1960  987  24 2454  24 2198  24  983  24 1540  24 1524  24 2199  24 2142  24 1966  24 1999  24
1970 1876  24 1447  24 1452  24 2307  24 1561  23 2001  24 1144  24 1596  24 1227  24 1812  24
1980 1050  24 1865  24 1679  23 1912  23 1734  24 1392  24 1688  24 1889  24 1636  23 2224  23
1990 1953  24 1841  24 1637  22 1639  23 2260  24 1693  23 1939  23 1378  22 1997  23 2052  23
2000 1604  22 1355  22 1595  22 1780  23 1954  23 1666  22 1637  22 1691  22 -9999
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Sand Lick                             Ouachita Chronologies                          PIEC
Arkansas       Shortleaf Pine       Total Ring Width          260m  3444-9327       1928  2007
D. Stevenson     T. Lynch     J. Guldin     P. Murphy
1920 9990   0 9990   0 9990   0 9990   0 9990   0 9990   0 9990   0 9990   0 9990   0 1885   1
1930    0   1 3226   1 3441   1 2523   1 1819   1 3012   1  943   1 1665   1 1362   1 1748   1
1940 2101   4 2697   4 2073   4  788   6 2271   9 1521  10 1357  14 1644  14 1992  16 2043  20
1950 2051  21 1913  22 1543  23 1778  26 1023  26 2255  26  805  26 2402  28 1885  29 2352  29
1960 1489  30 2239  30 1796  33 1070  33 1796  34 2084  35 1686  35 1670  35 1755  35 1318  37
1970 3048  37 1883  37 1391  38 2173  38 1447  38 1509  39 1638  39 2087  39 1199  39 1638  39
1980  963  39 1930  39 1448  39 1701  39 1506  39 1266  39 1851  39 1482  39 1699  39 1922  39
1990 1581  39 1806  39 1326  39 1747  39 2287  39 1947  38 2359  38 1257  39 2087  39 1947  39
2000 1755  39 1396  39 1416  39 1946  39 1818  39 1945  39 1864  39 2156  39 -9999
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Story                                 Ouachita Chronologies                          PIEC
Arkansas       Shortleaf Pine       Total Ring Width          218m  3440-9328       1888  2007
D. Stevenson     T. Lynch     J. Guldin
1880 9990   0 9990   0 9990   0 9990   0 9990   0 9990   0 9990   0 9990   0 1054   1 2628   1
1890 1425   1 1453   1  151   1 2039   1  930   1 1160   1  531   1 1864   1 3103   1  268   1
1900 1630   1 1475   1 1989   1 2139   1 1783   1 1796   1 1259   2 1847   2 1724   3 1268   3
1910 1310   3 2049   3  954   4 1430   5 1996   6 1997   6 1270   6 1809   6 1243   7 1692   7
1920 1933   7 1800   7  997   7 2239   7 1676   9 1031   9 1279   9 2005  10 1283  11 2162  11
1930  889  11  964  11 2240  12 2505  13 1761  14 2510  14 1850  15 2804  18 1026  21 1905  23
1940 2065  28 2606  30 1855  30  699  32 1872  36 1923  36 1458  37 1341  38 1640  39 1479  39
1950 2051  40 1310  40 1282  40 1538  40 1176  41 1897  41 1038  41 2194  42 1567  43 1919  43
1960 1467  43 1995  43 1474  43 1182  43 1375  43 1527  43 1497  43 1497  43 1456  43 1450  43
1970 2156  43 1634  43 1010  43 2005  43 1634  43 1214  43 1761  43 1637  43 1114  43 1251  43
1980  994  43 1498  43 1539  43 1660  43 1317  43 1310  43 1491  43 1313  43 1700  43 2155  43
1990 1484  43 1572  43 1182  43 1555  43 2084  43 1552  43 2061  43 1179  43 2140  43 1583  43
2000 1653  43 1180  43 1218  43 1652  43 1627  43 1536  43 1576  43 1633  42 -9999
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APPENDIX II

WINTER STORM RECONSTRUCTIONS
IN THE
WESTERN OUACHITA MOUNTSINS

Table 1. Babylon Bluff (Lat = 35° 25’ N., Long = 95° 50’ W.) Winter Storm Reconstruction. Henryetta, Oklahoma. Index A = 0.960. Index B = 0.710. Drought: JAS PDSI < -1.40. A “1” in the “Small” or “Large” column indicates a storm of that type. A “0” indicates no storm of that type and a “.” indicates no data.

Year	R_i Ratio	TRW	Standard	PDSI	Hist	Small	Large	Pointers	Color Key
2009	.	1.177	.	0.20	26-Jan	.	.	0	Small
2008	.	1.546	.	2.67	.	.	.	0	Large
2007	.	1.774	.	2.32	.	.	.	0	Drought
2006	.	0.942	.	-2.85	17-Feb	.	.	1	Pointers
2005	0.881	1.547	.	-1.92	26-Feb	.	.	0	Profiles
2004	0.167	1.477	.	1.83	.	.	.	0	Newspapers
2003	0.186	1.350	-0.188	-1.24	.	0	0	0	Legends
2002	0.884	1.037	-1.159	-0.40	5-Feb	1	1	1	
2001	0.651	1.499	0.423	-0.29	.	0	0	0	
2000	0.091	1.636	1.055	-0.13	.	0	0	0	
1999	0.045	1.760	1.245	-0.57	.	0	0	0	
1998	0.568	1.198	-0.901	-1.09	5-Jan	1	0	1	
1997	0.432	2.182	1.726	2.52	.	0	0	0	
1996	0.114	1.712	0.361	2.28	.	0	0	0	
1995	0.591	1.454	-0.588	0.57	5-Jan	1	0	0	
1994	0.886	1.686	0.084	0.44	.	0	0	0	
1993	0.711	1.140	-1.251	3.00	17-Jan	1	0	1	
1992	0.422	1.957	0.885	3.91	.	0	0	0	
1991	0.111	1.840	0.381	-0.64	.	0	0	0	
1990	0.311	1.418	-0.654	-0.59	14-Feb	1	0	0	
1989	0.711	1.878	0.851	1.73	.	0	0	0	
1988	0.600	1.090	-1.347	-1.90	5-Jan	1	0	0	
1987	0.867	1.439	-0.275	0.64	16-Jan	0	0	0	
1986	0.356	1.593	-0.030	0.15	.	0	0	0	
1985	0.267	1.361	-0.562	0.95	2-Feb	1	0	0	
1984	0.556	1.370	-0.333	-1.14	20-Dec	1	0	0	
1983	0.578	1.334	-0.423	-1.39	.	1	0	0	

Babylon Bluff (continued):

Year	R_i Ratio	TRW	Standard	PDSI	Hist	Small	Large	Pointers
1982	0.222	1.793	1.667	0.01	.	0	0	0
1981	0.089	1.754	1.210	1.08	.	0	0	0
1980	0.600	1.228	-1.182	-2.99	17-Feb	1	0	0
1979	0.978	1.276	-0.734	0.49	1-Jan	1	0	0
1978	0.977	0.785	-1.694	-1.83	11-Jan	1	1	1
1977	0.273	1.890	1.146	-1.22	.	0	0	0
1976	0.023	1.418	-0.080	0.31	.	0	0	0
1975	0.341	1.388	-0.009	2.86	.	0	0	0
1974	0.705	1.440	0.285	1.96	.	0	0	1
1973	0.159	2.208	1.590	3.82	.	0	0	0
1972	0.273	1.093	-0.776	-2.41	2-Feb	1	0	0
1971	0.841	1.684	0.258	1.03	.	0	0	0
1970	0.523	1.646	0.265	-0.53	.	0	0	0
1969	0.273	1.426	-0.372	-1.11	28-Jan	1	0	0
1968	0.568	1.506	-0.192	2.22	.	0	0	0
1967	0.568	1.416	-0.446	0.50	.	1	0	0
1966	0.455	1.687	0.913	-1.56	.	0	0	0
1965	0.409	1.280	-1.532	-1.60	23-Feb	1	0	0
1964	0.773	1.291	-1.091	-2.92	.	1	0	0
1963	0.909	0.557	-2.094	-3.51	25-Jan	1	1	1
1962	0.545	1.905	1.242	-1.39	.	0	0	0
1961	0.000	2.184	1.353	2.10	.	0	0	0
1960	0.068	1.688	0.331	1.87	.	0	0	0
1959	0.636	2.084	0.901	2.52	.	0	0	0
1958	0.409	2.212	0.849	3.69	---------	0	0	0
1957	0.489	1.553	-0.324	2.99	---------	0	0	0
1956	1.000	0.949	-1.890	-4.03	16-Dec	1	1	1
1955	1.000	1.266	-0.904	-2.34	11-Feb	1	0	0
1954	0.533	1.066	-0.987	-3.89	11--Jan	1	0	0
1953	0.133	1.545	0.042	-1.64	---------	0	0	0
1952	0.267	1.046	-0.752	-1.91	16-Dec	1	0	0
1951	0.822	1.028	-0.711	1.19	---------	1	0	1
1950	0.163	2.371	2.079	2.73	---------	0	0	0
1949	0.048	1.019	-0.637	1.64	1—Feb	1	0	1
1948	0.690	1.742	0.658	1.22	---------	0	0	0
1947	0.262	1.937	0.778	-0.58	---------	0	0	0
1946	0.095	1.743	0.352	-1.06	---------	0	0	0
1945	0.667	1.584	-0.100	5.66	---------	0	0	0
1944	0.619	1.603	-0.272	0.24	---------	0	0	0
1943	0.762	1.156	-1.155	-1.56	5—Mar	1	1	1
1942	0.571	1.807	0.615	1.83	---------	0	0	0
1941	0.195	1.539	-0.340	-0.37	---------	1	0	0
1940	0.195	1.658	0.350	1.21	---------	0	0	0
1939	0.575	1.418	-0.584	-1.78	---------	1	0	0
1938	0.725	1.361	-0.676	-0.19	---------	1	0	0

Babylon Bluff (continued):

Year	R_i Ratio	TRW	Standard	PDSI	Hist	Small	Large	Pointers
1937	0.600	1.246	-0.912	-1.10	---------	1	0	0
1936	0.600	1.123	-1.383	-3.52	1---Feb	1	0	0
1935	0.475	1.587	0.877	0.78	---------	0	0	0
1934	0.425	0.976	-1.485	-1.94	24-Feb	1	0	1
1933	0.375	1.819	1.614	0.22	---------	0	0	0
1932	0.200	1.307	-0.137	-1.45	---------	0	0	0
1931	0.475	1.357	0.042	-1.31	---------	0	0	0
1930	0.750	1.249	-0.342	-1.94	----Dec	1	0	0
1929	0.300	1.635	0.769	0.42	---------	0	0	0
1928	0.400	1.362	-0.089	3.05	---------	0	0	1
1927	0.300	1.964	1.559	4.61	---------	0	0	0
1926	0.175	1.721	0.784	1.53	---------	0	0	0
1925	0.800	0.901	-1.590	-1.43	22-Dec	1	0	1
1924	0.925	1.669	0.477	0.65	---------	0	0	0
1923	0.175	1.717	0.438	-0.17	---------	0	0	0
1922	0.325	1.145	-0.939	-1.14	---------	1	0	1
1921	0.525	1.969	0.946	-0.24	---------	0	0	0
1920	0.225	1.524	0.010	0.67	10-Dec	0	0	0
1919	0.475	1.552	0.154	-0.64	---------	0	0	0
1918	0.850	0.666	-1.853	-1.42	10--Jan	1	0	1
1917	0.732	1.906	0.894	0.48	---------	0	0	0
1916	0.098	1.167	-0.546	-1.48	---------	1	0	1
1915	0.341	1.685	0.418	3.25	---------	0	0	0
1914	0.317	1.569	0.322	-2.77	---------	0	0	0
1913	0.561	1.119	-0.623	-0.82	---------	1	0	1
1912	0.732	1.505	0.314	-0.41	---------	0	0	0
1911	0.390	1.154	-0.949	0.26	3---Jan	0	0	0
1910	0.756	0.756	-1.619	-1.78	18-Feb	1	1	0
1909	0.878	0.964	-0.832	-1.90	---------	1	0	1
1908	0.098	2.263	1.862	3.58	---------	0	0	0
1907	0.049	0.792	-0.821	1.44	---------	1	0	1
1906	0.829	1.576	0.538	2.79	---------	0	0	0
1905	0.450	1.672	0.653	2.07	---------	0	0	1
1904	0.025	2.712	1.561	1.32	---------	0	0	0
1903	0.125	1.983	0.401	-0.36	---------	0	0	0
1902	0.725	1.497	-0.470	0.91	14-Dec	1	0	0
1901	0.878	1.032	-0.917	-2.81	6—Feb	1	0	0
1900	0.829	1.468	-0.451	0.77	---------	1	0	0
1899	0.425	1.064	-0.980	2.06	11-Feb	1	0	1
1898	0.350	1.508	-0.173	3.42	---------	0	0	0
1897	0.150	1.517	0.244	-0.32	---------	0	0	0
1896	0.282	1.150	-0.751	-2.34	---------	1	0	0
1895	0.459	1.790	1.512	2.38	---------	0	0	0
1894	0.595	0.637	-1.747	.	16-Mar	1	0	1
1893	0.622	1.673	0.840	.	---------	0	0	0

Babylon Bluff (continued):

Year	R_i Ratio	TRW	Standard	PDSI	Hist	Small	Large	Pointers
1892	0.054	1.802	0.868	.	---------	0	0	0
1891	0.143	1.311	-0.239	.	---------	0	0	1
1890	0.375	2.286	1.427	.	---------	0	0	0
1889	0.094	1.915	0.540	.	---------	0	0	0
1888	0.500	1.729	0.205	.	---------	0	0	0
1887	0.800	1.427	-0.958	.	---------	1	0	0
1886	0.929	0.716	-1.752	.	29-Jan	1	1	1
1885	0.800	1.417	-0.252	.	--------	0	0	0
1884	0.250	1.428	-0.268	.	--------	0	0	0
1883	0.125	1.867	0.903	.	--------	0	0	0
1882	0.435	1.608	0.412	.	--------	0	0	0
1881	0.682	0.977	-0.963	.	Snow-	1	0	1
1880	0.762	1.317	-0.041	.	--------	1	0	0
1879	0.714	0.581	-1.737	.	--------	1	1	1
1878	0.050	2.536	1.690	.	--------	0	0	0
1877	0.000	1.508	0.036	.	--------	0	0	0
1876	0.474	1.710	0.403	.	--------	0	0	0
1875	0.722	1.670	0.321	.	--------	0	0	0
1874	0.667	1.190	-0.525	.	--------	1	0	0
1873	0.647	1.577	0.064	.	--------	0	0	0
1872	0.533	1.683	-0.032	.	--------	0	0	0
1871	0.667	0.798	-1.927	.	--------	1	0	1
1870	0.500	2.200	1.475	.	--------	0	0	0
1869	0.167	1.752	0.448	.	--------	0	0	0
1868	0.182	1.955	0.769	.	--------	0	0	0
1867	0.556	1.619	-0.082	.	--------	0	0	0
1866	0.875	0.822	-1.345	.	--------	1	1	1
1865	0.375	2.718	1.460	.	--------	0	0	0
1864	0.000	1.127	-0.963	.	--------	1	0	0
1863	0.500	1.863	0.277	.	--------	0	0	0

Table 2. Caddo Gap (Lat = 34° 27’ N., Long = 93° 30’ W.) Winter Storm Reconstruction. Caddo Gap, Arkansas. Index A = 0.640. Index B = 0.220. Drought: JAS PDSI < -1.40. A “1” in the “Small” or “Large” column indicates a storm of that type. A “0” indicates no storm of that type and a “.” indicates no data.

Year	R_i Ratio	TRW	Standard	PDSI	Hist	Small	Large	Pointers	Color Key
2009	.	1.761	.	2.82	26-Jan	.	.	0	Small
2008	.	1.492	.	1.01	.	.	.	0	Large
2007	.	2.309	.	0.16	.	.	.	0	Drought
2006	.	2.018	.	-3.60	17-Feb	.	.	0	Pointers
2005	.	1.688	.	-2.48	26-Feb	.	.	0	Profiles
2004	0.045	2.265	.	-0.03	.	.	.	0	
2003	0.000	2.416	1.198	-1.06	.	0	0	0	
2002	0.091	1.600	-0.984	-1.52	.	0	0	0	
2001	0.636	1.214	-1.614	1.38	25-Dec	1	1	1	
2000	0.136	2.032	0.341	-1.47	.	0	0	0	
1999	0.000	1.940	0.147	-1.30	.	0	0	1	
1998	0.000	2.709	1.356	-0.95	.	0	0	0	
1997	0.000	1.764	-0.379	2.04	8-Jan	1	0	0	
1996	0.087	2.202	0.590	2.40	.	0	0	0	
1995	0.130	1.673	-0.560	-0.86	5-Jan	1	0	1	
1994	0.087	2.202	0.590	2.40	.	0	0	0	
1993	0.043	1.612	-1.050	0.70	17-Jan	1	0	0	
1992	0.000	1.981	-0.177	3.11	17-Jan	0	0	0	
1991	0.174	1.817	-0.367	1.65	.	1	0	0	
1990	0.000	2.104	0.429	1.81	.	0	0	0	
1989	0.000	2.435	1.260	4.17	.	0	0	0	
1988	0.000	2.203	0.384	0.00	5-Jan	0	0	0	
1987	0.130	1.709	-0.933	-1.12	16-Jan	1	0	0	
1986	0.348	1.781	-0.857	-0.18	.	1	0	0	
1985	0.000	1.781	-0.711	-0.92	2-Feb	1	0	1	
1984	0.043	2.242	0.734	0.86	20-Dec	0	0	0	
1983	0.000	2.063	0.119	-0.01	.	0	0	0	
1982	0.000	2.351	1.279	-1.25	.	0	0	0	
1981	0.043	2.071	0.285	1.51	.	0	0	0	
1980	0.174	1.139	-1.927	-1.61	17-Feb	1	0	1	
1979	0.522	1.615	-0.669	2.96	1-Jan	1	0	0	
1978	0.217	1.291	-1.118	-3.48	11-Jan	1	0	1	
1977	0.043	2.154	0.735	-1.05	.	0	0	0	
1976	0.000	1.904	0.253	0.65	.	0	0	0	
1975	0.000	2.223	1.029	2.31	.	0	0	0	
1974	0.000	2.354	1.143	3.87	.	0	0	0	
1973	0.000	2.945	1.636	3.79	.	0	0	0	
1972	0.000	1.767	-0.627	-1.64	2-Feb	1	0	0	
1971	0.304	1.914	-0.675	-1.07	.	1	0	1	
1970	0.000	2.395	0.448	0.77	.	0	0	0	

Caddo Gap (continued):

Year	R_i Ratio	TRW	Standard	PDSI	Hist	Small	Large	Pointers
1969	0.000	2.053	-0.472	-1.07	.	1	0	0
1968	0.000	2.010	-0.492	2.76	.	1	0	0
1967	0.130	1.900	-0.594	-0.10	.	1	0	0
1966	0.043	1.838	-0.702	1.31	.	1	0	0
1965	0.087	1.653	-1.366	-1.53	23-Feb	1	0	1
1964	0.000	2.262	0.976	-2.16	.	0	0	0
1963	0.000	1.841	-0.496	-1.93	.	1	0	1
1962	0.043	2.546	1.782	-0.75	.	0	0	0
1961	0.000	2.572	1.310	1.85	.	0	0	0
1960	0.000	1.933	-0.432	-0.20	.	1	0	0
1959	0.045	2.359	0.534	1.09	.	0	0	0
1958	0.000	2.679	1.131	3.38	---------	0	0	0
1957	0.000	3.641	1.904	2.47	---------	0	0	0
1956	0.000	1.381	-1.527	-3.16	16-Dec	1	0	1
1955	0.300	2.478	0.062	-1.39	11-Feb	1	0	0
1954	0.105	1.279	-1.192	-3.82	11-Jan	1	0	1
1953	0.167	1.775	-0.547	-0.10	--------	1	0	0
1952	0.118	1.232	-0.924	-2.14	16-Dec	1	0	0
1951	0.059	1.603	-0.355	1.42	--------	1	0	0
1950	0.000	1.976	0.677	3.15	--------	0	0	0
1949	0.000	1.895	0.341	0.53	--------	0	0	0
1948	0.143	1.296	-0.907	-1.46	--------	0	0	0
1947	0.357	1.227	-1.073	-0.53	18-Feb	1	1	0
1946	0.214	1.297	-0.641	-0.93	--------	0	0	1
1945	0.000	2.403	1.663	4.56	--------	0	0	0
1944	0.000	1.868	0.359	-0.88	--------	0	0	0
1943	0.231	0.924	-1.240	-2.99	5-Mar	1	0	1
1942	0.700	1.753	0.431	0.52	--------	0	0	0
1941	0.111	1.625	0.081	1.03	--------	0	0	0
1940	0.000	1.918	0.495	1.35	--------	0	0	0

Table 3. Camp Tom Hale (Lat = 34° 45’ N., Long = 94° 53’ W.) Winter Storm Reconstruction. Talihina, Oklahoma. Index A = 0.890. Index B = 0.440. Drought: JAS PDSI < -1.40. A “1” in the “Small” or “Large” column indicates a storm of that type. A “0” indicates no storm of that type and a “.” indicates no data.

Year	R_i Ratio	TRW	Standard	PDSI	Hist	Small	Large	Pointers	Color Key
2009	.	1.627	.	3.25	26-Jan	.	.	0	Small
2008	.	2.076	.	4.22	.	.	.	0	Large
2007	.	2.235	.	0.43	.	.	.	0	Drought
2006	0.250	1.656	.	-0.81	17-Feb	.	.	0	Pointers
2005	0.500	1.795	.	-1.46	26-Feb	1	0	1	
2004	0.192	2.126	.	0.68	.	0	0	0	
2003	0.077	1.859	-0.218	-1.78	.	0	0	0	
2002	0.615	1.488	-1.494	-0.34	5-Feb	1	1	0	
2001	0.815	1.347	-1.367	-1.35	25-Dec	1	1	0	
2000	0.500	1.728	0.054	-1.70	.	0	0	0	
1999	0.071	2.068	1.038	-0.79	.	0	0	0	
1998	0.071	2.054	0.805	-1.25	.	0	0	0	
1997	0.536	1.115	-1.517	-0.96	8-Jan	1	0	1	
1996	0.571	2.447	1.491	1.50	.	0	0	0	
1995	0.000	2.295	0.875	-0.14	.	0	0	0	
1994	0.034	2.054	0.201	1.72	.	0	0	0	
1993	0.724	1.690	-0.613	1.12	17-Jan	1	0	1	
1992	0.071	3.374	1.762	1.42	.	0	0	0	
1991	0.000	2.205	0.053	-0.22	.	0	0	1	
1990	0.000	3.508	1.470	-1.03	.	0	0	0	
1989	0.074	2.538	0.021	0.66	.	0	0	0	
1988	0.741	1.805	-0.890	-1.90	5-Jan	1	0	1	
1987	0.926	2.418	-0.124	-1.31	16-Jan	0	0	0	
1986	0.074	2.403	-0.331	-0.39	.	1	0	0	
1985	0.259	1.863	-0.932	-1.41	2-Feb	1	0	0	
1984	0.769	1.639	-1.059	-0.65	20-Dec	1	1	0	
1983	0.577	1.958	-0.368	-0.66	.	1	0	1	
1982	0.038	2.414	1.032	-0.48	.	0	0	0	
1981	0.000	2.626	1.197	1.44	.	0	0	0	
1980	0.308	1.770	-0.859	-3.20	27-Feb	1	0	1	
1979	0.462	2.902	1.530	2.03	.	0	0	0	
1978	0.154	1.785	-0.758	-2.20	11-Jan	1	0	0	
1977	0.560	2.003	-0.465	-1.60	.	1	0	0	
1976	0.280	2.588	0.648	-2.01	.	0	0	0	
1975	0.000	2.549	0.508	2.23	.	0	0	0	
1974	0.238	2.523	0.493	1.62	.	0	0	0	
1973	0.000	3.325	1.545	2.90	.	0	0	0	
1972	0.154	3.317	1.248	-1.56	2-Feb	0	0	1	

Table 4. Cold Springs (Lat = 35° 03’ N., Long = 93° 53’ W.) Winter Storm Reconstruction. Booneville, Arkansas. Index A = 0.760. Index B = 0.310. Drought: JAS PDSI < -1.40. A “1” in the “Small” or “Large” column indicates a storm of that type. A “0” indicates no storm of that type and a “.” indicates no data.

Year	R_i Ratio	TRW	Standard	PDSI	Hist	Small	Large	Pointers	Color Key
2008	.	2.398	.	4.22	.	.	.	0	Small
2007	.	2.200	.	0.43	.	.	.	0	Large
2006	.	2.030	.	-0.81	17-Feb	.	.	0	Drought
2005	0.077	2.112	.	-1.46	26-Feb	.	.	0	Pointers
2004	0.023	2.262	.	0.68	.	.	.	0	Profiles
2003	0.091	2.922	.	-1.78	.	.	.	0	
2002	0.178	1.966	-0.946	-0.34	.	0	0	0	
2001	0.356	1.538	-1.952	-1.35	25-Dec	1	1	0	
2000	0.289	1.786	-0.681	-1.70	.	1	0	1	
1999	0.022	2.366	1.316	-0.79	.	0	0	0	
1998	0.022	2.034	0.187	-1.25	.	0	0	0	
1997	0.222	1.595	-1.034	-0.96	8-Jan	1	0	1	
1996	0.000	2.492	1.440	1.50	.	0	0	0	
1995	0.000	2.018	0.117	-0.14	5-Feb	0	0	1	
1994	0.022	2.794	1.528	1.72	.	0	0	0	
1993	0.043	1.824	-0.815	1.12	17-Jan	1	0	0	
1992	0.543	1.889	-0.493	1.42	17-Jan	1	0	0	
1991	0.304	1.957	-0.299	-0.22	.	0	0	0	
1990	0.043	2.000	-0.385	-1.03	.	1	0	0	
1989	0.022	2.548	1.082	0.66	.	0	0	0	
1988	0.022	2.041	-0.295	-1.90	5-Jan	0	0	0	
1987	0.065	2.294	0.842	-1.31	.	0	0	0	
1986	0.043	2.223	0.377	-0.39	.	0	0	0	
1985	0.065	2.043	-0.546	-1.41	.	1	0	0	
1984	0.217	1.888	-1.165	-0.65	20-Dec	1	0	0	
1983	0.065	2.390	0.814	-0.66	.	0	0	0	
1982	0.043	2.179	0.161	-0.48	10-Jan	0	0	0	
1981	0.065	2.321	0.747	1.44	.	0	0	0	
1980	0.391	1.280	-2.031	-3.20	17-Feb	1	0	1	
1979	0.087	2.666	1.255	2.03	.	0	0	0	
1978	0.043	1.637	-0.865	-2.20	11-Jan	1	0	0	
1977	0.304	1.666	-0.711	-1.60	.	1	0	0	
1976	0.717	1.046	-1.339	-2.01	24-Dec	1	1	1	
1975	0.152	2.251	0.698	2.23	.	0	0	0	
1974	0.000	2.221	0.686	1.62	.	0	0	0	
1973	0.022	3.105	1.473	2.90	.	0	0	0	
1972	0.065	1.703	-0.373	-1.56	2-Feb	1	0	1	
1971	0.609	2.144	0.194	-1.45	.	0	0	0	
1970	0.283	1.863	-0.295	-0.47	28-Dec	0	0	1	
1969	0.022	2.238	0.046	-0.62	.	0	0	0	
1968	0.022	2.370	0.301	2.06	.	0	0	0	

Cold Springs (continued):

Year	R_i Ratio	TRW	Standard	PDSI	Hist	Small	Large	Pointers
1967	0.000	2.405	0.318	1.08	.	0	0	0
1966	0.022	2.552	1.212	-1.98	.	0	0	0
1965	0.111	1.968	-1.022	0.35	2-Dec	0	0	0
1964	0.422	1.696	-1.451	-0.56	.	1	1	0
1963	0.756	1.209	-1.797	-3.05	25-Jan	1	1	1
1962	0.244	2.424	0.681	0.47	.	0	0	0
1961	0.022	2.943	1.320	2.77	.	0	0	0
1960	0.000	1.933	-0.294	0.27	.	0	0	0
1959	0.478	2.251	0.345	2.10	.	0	0	0
1958	0.109	2.616	0.788	3.77	---------	0	0	1
1957	0.022	3.659	1.587	4.02	---------	0	0	0
1956	0.044	1.371	-1.486	-3.13	16-Dec	1	0	1
1955	0.864	2.601	0.162	-1.96	---------	0	0	0
1954	0.279	1.713	-0.790	-4.35	11--Jan	1	0	1
1953	0.070	2.596	0.265	-1.69	---------	0	0	0
1952	0.190	1.908	-0.584	-2.16	16-Dec	1	0	1
1951	0.175	2.670	0.406	1.73	---------	0	0	1
1950	0.027	3.903	1.807	4.56	---------	0	0	0
1949	0.063	2.987	0.502	1.42	1—Feb	0	0	1

Table 5. Greenbrier (Lat = 35° 01' N., 94° 03' W.) Winter Storm Reconstruction. Booneville, Arkansas. Index A = 0.780. Index B = 0.320. Drought : JAS PDSI < -1.40. A "1" in the "Small" or "Large" column indicates a storm of that type. A "0" indicates no storm of that type and a "." indicates no data.

Year	R_i Ratio	TRW	Standard	PDSI	Hist	Small	Large	Pointers	Color Key
2007	.	1.962	.	0.43	.	.	.	0	Small
2006	.	2.152	.	-0.81	17-Feb	.	.	0	Large
2005	.	2.449	.	-1.46	26-Feb	.	.	0	Drought
2004	0.000	2.470	.	0.68	.	.	.	0	Pointers
2003	0.034	2.195	.	-1.78	.	.	.	0	Profiles
2002	0.133	2.163	.	-0.34	.	.	.	0	
2001	0.344	1.852	-1.425	-1.35	25-Dec	1	1	0	
2000	0.156	2.052	-0.640	-1.70	.	0	0	1	
1999	0.000	2.736	1.558	-0.79	.	0	0	0	
1998	0.000	2.611	0.988	-1.25	.	0	0	0	
1997	0.250	1.745	-1.224	-0.96	8-Jan	1	0	1	
1996	0.344	2.655	0.975	1.50	.	0	0	0	
1995	0.000	2.252	-0.049	-0.14	5-Feb	0	0	0	
1994	0.000	2.724	0.846	1.72	.	0	0	0	
1993	0.219	1.940	-1.086	1.12	17-Jan	1	0	0	
1992	0.375	2.157	-0.372	1.42	17-Jan	1	0	0	
1991	0.094	2.242	-0.009	-0.22	.	0	0	0	
1990	0.031	2.332	0.011	-1.03	.	0	0	1	
1989	0.000	3.029	1.748	0.66	.	0	0	0	
1988	0.000	2.122	-0.634	-1.90	5-Jan	0	0	0	
1987	0.250	2.516	0.514	-1.31	.	0	0	0	
1986	0.156	2.238	-0.440	-0.39	.	1	0	0	
1985	0.250	2.018	-1.010	-1.41	.	1	0	0	
1984	0.250	2.243	-0.339	-0.65	20-Dec	1	0	0	
1983	0.031	2.592	0.572	-0.66	.	0	0	0	
1982	0.000	2.482	0.767	-0.48	10-Jan	0	0	0	
1981	0.094	2.636	1.087	1.44	.	0	0	0	
1980	0.469	1.364	-1.962	-3.20	17-Feb	1	0	1	
1979	0.563	2.583	0.673	2.03	.	0	0	0	
1978	0.063	1.664	-1.100	-2.20	11-Jan	1	0	0	
1977	0.188	1.825	-0.639	-1.60	.	0	0	0	
1976	0.531	1.451	-0.996	-2.01	24-Dec	1	0	1	
1975	0.000	2.335	0.667	2.23	.	0	0	0	
1974	0.000	1.679	-0.361	1.62	.	1	0	0	
1973	0.000	3.115	1.694	2.90	.	0	0	0	
1972	0.031	1.906	-0.161	-1.56	2-Feb	0	0	0	
1971	0.313	2.115	0.100	-1.45	.	0	0	0	
1970	0.313	2.180	0.128	-0.47	28-Dec	0	0	0	
1969	0.000	2.067	-0.293	-0.62	.	0	0	0	
1968	0.031	2.422	0.457	2.06	.	0	0	0	
1967	0.000	2.663	0.742	1.08	.	0	0	0	
1966	0.031	2.353	0.432	-1.98	.	0	0	0	

Greenbrier (continued):

Year	R_i Ratio	TRW	Standard	PDSI	Hist	Small	Large	Pointers
1965	0.344	1.849	-1.450	0.35	2-Dec	1	0	0
1964	0.313	2.181	-0.244	-0.56	.	0	0	0
1963	0.406	1.198	-1.899	-3.05	25-Jan	1	1	1
1962	0.156	2.563	0.764	0.47	.	0	0	0
1961	0.000	2.785	1.009	2.77	.	0	0	0
1960	0.000	2.006	-0.245	0.27	.	0	0	0
1959	0.438	2.415	0.517	2.10	.	0	0	0
1958	0.031	2.904	1.058	3.77	---------	0	0	1
1957	0.000	3.780	1.575	4.02	---------	0	0	0
1956	0.097	1.513	-1.470	-3.13	16-Dec	1	0	1
1955	0.968	2.793	0.269	-1.96	---------	0	0	0
1954	0.310	1.891	-0.762	-4.35	11--Jan	1	0	1
1953	0.037	2.754	0.238	-1.69	---------	0	0	0
1952	0.333	1.576	-1.062	-2.16	16-Dec	1	0	1
1951	0.154	3.706	1.194	1.73	---------	0	0	0
1950	0.048	3.508	1.087	4.56	---------	0	0	0
1949	0.100	3.565	0.878	1.42	1---Feb	0	0	0
1948	0.067	4.175	1.173	0.41	---------	0	0	0
1947	0.400	2.914	-0.302	-1.65	18-Feb	1	0	0
1946	0.600	4.211	.	-0.80	---------	0	0	0

Table 6. Hot Springs Winter Storm Reconstruction. Hot Springs National Park, Arkansas. Index A = 0.880. Index B = 0.500. Drought: JAS PDSI < -1.40. A “1” in the “Small” of “Large” column indicates a storm of that type. A “0” indicates no storm and a “.” indicates no data.

Year	R_i Ratio	TRW	Standard	PDSI	Hist	Small	Large	Pointers	Color Key
1982	.	1.302	.	-1.25	.	.	.	0	Small
1981	.	1.216	.	1.51	.	.	.	0	Large
1980	.	0.866	.	-1.61	17-Feb	.	.	0	Drought
1979	0.893	1.013	.	2.96	1-Jan	.	.	0	Pointers
1978	0.357	0.882	.	-3.48	.	.	.	1	Profiles
1977	0.071	1.280	.	-1.05	.	.	.	0	Newspapers
1976	0.036	1.191	0.452	0.65	.	0	0	0	Legends
1975	0.107	1.266	0.918	2.31	.	0	0	0	
1974	0.214	1.139	0.279	3.87	.	0	0	0	
1973	0.179	1.374	1.245	3.79	.	0	0	0	
1972	0.536	0.687	-1.753	-1.64	2-Feb	1	0	1	
1971	0.786	1.260	0.395	-1.07	.	0	0	0	
1970	0.107	1.176	0.090	0.77	.	0	0	0	
1969	0.036	1.218	0.262	-1.07	.	0	0	0	
1968	0.143	1.327	0.694	2.76	.	0	0	0	
1967	0.179	1.284	0.409	-0.10	.	0	0	0	
1966	0.321	1.278	0.462	1.31	.	0	0	0	
1965	0.321	1.100	-1.757	-1.53	2-Dec	1	1	0	
1964	0.679	0.774	-2.076	-2.16	.	1	1	1	
1963	0.643	1.087	-0.345	-1.93	25-Jan	1	0	0	
1962	0.143	1.141	-0.003	-0.75	.	0	0	1	
1961	0.000	1.466	1.408	1.85	.	0	0	0	
1960	0.107	1.050	-0.366	-0.20	.	1	0	0	
1959	0.357	1.378	1.038	1.09	.	0	0	0	
1958	0.107	1.253	0.386	3.38	---------	0	0	0	
1957	0.214	1.099	-0.700	2.47	---------	0	0	0	
1956	0.821	0.757	-1.737	-3.16	16-Dec	1	1	1	
1955	0.143	1.518	1.120	-1.39	---------	0	0	0	
1954	0.000	0.998	-0.600	-3.82	11--Jan	1	0	1	
1953	0.179	1.268	0.342	-0.10	---------	0	0	0	
1952	0.321	1.100	-0.175	-2.14	16-Dec	0	0	0	
1951	0.179	1.268	0.342	1.42	---------	0	0	0	
1950	0.107	1.399	0.908	3.15	---------	0	0	0	
1949	0.036	1.356	0.553	0.53	---------	0	0	0	
1948	0.321	1.149	-0.357	-1.46	---------	0	0	0	
1947	0.750	1.027	-1.284	-0.53	18-Feb	1	1	0	
1946	0.571	1.094	-0.610	-0.93	---------	1	0	0	
1945	0.107	1.248	0.340	4.56	---------	0	0	0	
1944	0.071	1.184	-0.180	-0.88	---------	0	0	0	
1943	0.536	0.797	-1.823	-2.99	5—Mar	1	1	1	
1942	0.536	1.313	1.163	0.52	---------	0	0	0	
1941	0.000	1.323	0.976	1.03	---------	0	0	0	

Hot Springs (continued):

Year	R_i Ratio	TRW	Standard	PDSI	Hist	Small	Large	Pointers
1940	0.000	1.293	0.612	1.35	---------	0	0	0
1939	0.357	1.103	-0.413	-1.16	---------	0	0	0
1938	0.750	0.918	-1.042	0.19	---------	1	1	1
1937	0.321	1.315	0.748	-0.01	---------	0	0	0
1936	0.000	1.289	0.431	-4.19	1---Feb	0	0	0
1935	0.107	1.287	0.452	-0.92	---------	0	0	0
1934	0.393	0.984	-1.116	-4.11	24-Feb	1	0	0
1933	0.821	0.981	-0.850	-2.15	---------	1	1	0
1932	0.571	0.966	-0.772	-1.09	---------	1	0	0
1931	0.071	1.515	1.510	0.46	---------	0	0	0
1930	0.071	1.036	-0.540	-2.32	----Dec	1	0	0
1929	0.500	1.165	0.156	-1.41	---------	0	0	0
1928	0.393	1.181	0.321	1.10	---------	0	0	0
1927	0.143	1.373	0.963	2.28	---------	0	0	0
1926	0.250	1.079	-0.563	-0.10	---------	0	0	0
1925	0.750	0.817	-1.535	-3.16	22-Dec	1	1	1
1924	0.536	1.253	0.699	-1.85	---------	0	0	0
1923	0.036	1.343	0.906	1.59	---------	0	0	0
1922	0.036	0.940	-0.969	-0.53	---------	1	0	0
1921	0.643	1.074	-0.247	-0.82	---------	1	0	0
1920	0.214	1.159	0.357	2.28	---------	0	0	0
1919	0.250	0.972	-0.579	0.21	---------	1	0	1
1918	0.321	1.204	0.466	-3.40	-10-Jan	0	0	0
1917	0.143	1.019	-0.579	-1.16	---------	1	0	0
1916	0.429	1.076	0.129	-1.81	---------	0	0	0
1915	0.179	1.023	-0.640	0.18	---------	1	0	0
1914	0.250	1.071	-0.050	-0.29	---------	0	0	0
1913	0.143	1.219	1.443	0.23	---------	0	0	0
1912	0.071	0.965	-1.222	-0.58	---------	0	0	0
1911	0.536	0.894	-1.418	0.37	3---Jan	1	1	1
1910	0.321	1.235	1.330	0.55	---------	0	0	0
1909	0.107	0.975	-0.615	-2.15	---------	1	0	0
1908	0.250	1.307	1.330	0.63	---------	0	0	0
1907	0.321	0.985	-0.594	-0.97	---------	1	0	1
1906	0.250	1.222	0.839	2.95	---------	0	0	0
1905	0.250	1.141	0.205	3.50	---------	0	0	0
1904	0.286	1.066	-0.517	0.77	---------	1	0	0
1903	0.607	0.967	-0.958	-0.24	---------	1	0	0
1902	0.464	1.140	0.180	-1.13	---------	0	0	0
1901	0.000	1.239	1.214	-2.48	---------	0	0	0
1900	0.036	1.187	0.521	-0.15	---------	0	0	0
1899	0.321	1.024	-0.894	-0.15	---------	1	0	0
1898	0.500	1.058	-0.411	1.15	---------	1	0	0
1897	0.214	1.115	0.115	-2.37	---------	0	0	0
1896	0.429	0.807	-1.943	-3.92	---------	1	0	1

Hot Springs (continued):

Year	R_i Ratio	TRW	Standard	PDSI	Hist	Small	Large	Pointers
1895	0.500	1.412	1.541	0.83	---------	0	0	0
1894	0.179	0.842	-1.073	.	16-Mar	1	0	1
1893	0.036	1.471	1.430	.	---------	0	0	0
1892	0.036	1.351	0.744	.	---------	0	0	0
1891	0.393	0.905	-0.790	.	---------	1	0	0
1890	0.786	1.164	0.098	.	---------	0	0	1
1889	0.250	1.487	0.946	.	---------	0	0	0
1888	0.000	1.387	0.593	.	---------	0	0	0
1887	0.393	1.092	-0.797	.	---------	1	0	0
1886	0.821	1.051	-0.739	.	29-Jan	1	0	0
1885	0.643	1.025	-0.605	.	---------	1	0	0
1884	0.321	1.095	-0.519	.	---------	1	0	0
1883	0.393	0.799	-1.455	.	---------	1	0	1
1882	0.179	1.489	1.525	.	---------	0	0	0
1881	0.071	0.979	-0.471	.	-Snow-	1	0	0
1880	0.571	0.997	-0.315	.	---------	1	0	0
1879	0.643	1.004	-0.252	.	---------	1	0	0
1878	0.107	1.396	1.168	.	---------	0	0	0
1877	0.036	1.490	1.142	.	---------	0	0	0
1876	0.179	1.031	-0.679	.	---------	1	0	0
1875	0.750	1.033	-0.466	.	---------	1	0	0
1874	0.679	0.863	-1.090	.	---------	1	1	0
1873	0.357	1.222	0.324	.	---------	0	0	0
1872	0.071	1.547	1.230	.	---------	0	0	0
1871	0.071	1.265	0.227	.	---------	0	0	0
1870	0.250	1.531	1.227	.	---------	0	0	0
1869	0.464	0.925	-0.995	.	---------	0	0	0
1868	0.964	0.762	-1.253	.	---------	1	1	0
1867	0.857	0.900	-0.848	.	---------	1	0	0
1866	0.107	1.133	-0.061	.	---------	0	0	0
1865	0.143	1.080	-0.019	.	---------	0	0	1
1864	0.071	1.423	1.119	.	---------	0	0	0
1863	0.071	1.219	0.702	.	---------	0	0	0
1862	0.500	1.005	-0.324	.	---------	1	0	0
1861	0.607	1.268	0.696	.	---------	0	0	0
1860	0.571	0.536	-1.986	.	---------	1	0	1
1859	0.444	1.598	1.281	.	---------	0	0	0
1858	0.037	1.357	0.452	.	---------	0	0	0
1857	0.074	1.327	0.416	.	---------	0	0	0
1856	0.889	0.748	-0.993	.	---------	1	0	0
1855	0.885	1.014	-0.287	.	Resting	0	0	0
1854	0.308	1.002	-0.218	.	.	0	0	0
1853	0.077	1.086	-0.268	.	.	0	0	0
1852	0.154	1.382	1.067	.	.	0	0	0
1851	0.269	0.908	-0.706	.	.	0	0	0

Hot Springs (continued):

Year	R_i Ratio	TRW	Standard	PDSI	Hist	Small	Large	Pointers
1850	0.692	0.624	-1.400	.	.	1	1	0
1849	0.577	1.176	0.634	.	.	0	0	0
1848	0.080	1.364	1.078	.	.	0	0	0
1847	0.120	1.595	1.330	.	.	0	0	0
1846	0.200	1.255	0.210	.	.	0	0	1
1845	0.400	1.783	1.370	.	.	0	0	0
1844	0.125	1.964	1.285	.	.	0	0	0
1843	0.542	0.595	-1.762	.	.	1	0	0
1842	0.958	1.401	-0.048	.	.	0	0	0
1841	0.435	1.124	-0.580	.	.	1	0	0
1840	0.273	0.777	-0.994	.	.	1	0	0
1839	0.773	0.966	-0.517	.	.	1	0	0
1838	0.273	1.054	-0.160	.	.	0	0	0
1837	0.273	0.740	-0.774	.	.	1	0	1
1836	0.364	1.172	0.601	.	.	0	0	1
1835	0.000	1.523	1.782	.	.	0	0	0
1834	0.000	1.174	0.432	.	.	0	0	0
1833	0.571	1.058	-0.170	.	.	1	0	0
1832	0.619	1.113	-0.028	.	.	0	0	0
1831	0.571	0.585	-1.516	.	.	1	1	1
1830	0.571	1.180	0.234	.	.	0	0	1
1829	0.190	1.348	0.713	.	.	0	0	0
1828	0.048	1.337	0.870	.	.	0	0	0
1827	0.524	0.809	-0.904	.	.	1	0	0
1826	0.857	0.902	-0.482	.	.	1	0	0
1825	0.476	1.111	0.253	.	.	0	0	0
1824	0.050	1.093	-0.092	.	.	0	0	0
1823	0.200	1.114	0.062	.	.	0	0	0
1822	0.700	0.362	-1.911	.	.	1	0	1
1821	0.850	1.194	0.878	.	.	0	0	0
1820	0.100	0.830	-0.396	.	.	1	0	1
1819	0.000	1.462	1.268	.	.	0	0	0
1818	0.400	0.548	-1.027	.	.	1	0	1
1817	0.450	1.619	1.297	.	.	0	0	0
1816	0.150	1.202	0.366	.	.	0	0	0
1815	0.050	1.647	1.057	.	.	0	0	0
1814	0.450	0.973	-0.500	.	.	1	0	1
1813	0.400	1.594	0.735	.	.	0	0	0
1812	0.250	0.965	-0.609	.	.	1	0	0
1811	0.450	1.321	-0.037	.	.	0	0	0
1810	0.350	1.285	0.004	.	.	0	0	0
1809	0.450	0.800	-1.308	.	.	1	0	1
1808	0.250	1.647	1.289	.	.	0	0	0
1807	0.158	1.072	-0.534	.	.	0	0	0
1806	0.842	0.669	-1.308	.	.	1	1	1

Hot Springs (continued):

Year	R_i Ratio	TRW	Standard	PDSI	Hist	Small	Large	Pointers
1805	0.722	1.397	0.658	.	.	0	0	0
1804	0.000	1.524	0.884	.	.	0	0	0
1803	0.000	1.351	0.384	.	.	0	0	0
1802	0.500	1.254	-0.061	.	.	1	0	0
1801	0.824	0.740	-1.220	.	.	1	1	0
1800	0.647	0.790	-0.879	.	.	1	0	0
1799	0.588	0.723	-1.120	.	.	1	1	0
1798	0.471	0.954	-0.288	.	.	0	0	0
1797	0.313	1.344	1.122	.	.	0	0	0
1796	0.250	0.766	-0.668	.	.	1	0	1
1795	0.200	1.812	1.924	.	.	0	0	0
1794	0.133	1.360	0.619	.	.	0	0	0
1793	0.000	1.562	0.834	.	.	0	0	0
1792	0.667	0.959	-0.780	.	.	1	0	1
1791	0.357	1.605	0.707	.	.	0	0	0
1790	0.214	1.165	-0.409	.	.	0	0	0
1789	0.571	1.039	-1.001	.	.	1	1	0
1788	0.857	0.865	-1.219	.	.	1	1	0
1787	0.214	1.843	1.468	.	.	0	0	0
1786	0.214	1.138	-0.257	.	.	0	0	0
1785	0.571	1.071	-0.506	.	.	1	0	0
1784	1.000	0.400	-1.573	.	.	1	1	1
1783	0.500	1.664	1.071	.	.	0	0	0
1782	0.000	0.687	-0.794	.	.	1	0	1
1781	0.143	1.890	2.228	.	.	0	0	0
1780	0.231	0.948	-0.319	.	.	1	0	0

Table 7. Knoppers Ford (Lat = 35° 00’ N., 93° 51’ W.) Winter Storm Reconstruction. Booneville, Arkansas. Index A = 0.880. Index B = 0.420. Drought: JAS PDSI < -1.40. A “1” in the “Small” or “Large” column indicates a storm of that type. A “0” indicates no storm of that type and a “.” indicates no data.

Year	R_i Ratio	TRW	Standard	PDSI	Hist	Small	Large	Pointers	Color Key
2007	.	1.660	.	0.43	.	.	.	0	Small
2006	.	1.520	.	-0.81	.	.	.	1	Large
2005	.	1.955	.	-1.46	.	.	.	0	Drought
2004	0.045	1.904	.	0.68	.	.	.	0	Pointers
2003	0.136	1.594	.	-1.78	.	.	.	0	Profiles
2002	0.773	1.597	.	-0.34	5-Feb	1	0	0	
2001	0.455	1.471	-1.072	-1.35	25-Dec	1	1	0	
2000	0.174	1.690	0.074	-1.70	.	0	0	0	
1999	0.043	1.944	1.058	-0.79	.	0	0	0	
1998	0.087	1.742	0.208	-1.25	.	0	0	0	
1997	0.478	1.412	-1.257	-0.96	8-Jan	1	0	1	
1996	0.292	2.082	1.552	1.50	.	0	0	0	
1995	0.083	1.698	-0.093	-0.14	5-Jan	0	0	0	
1994	0.042	2.289	1.558	1.72	.	0	0	0	
1993	0.417	1.255	-1.426	1.12	17-Jan	1	0	0	
1992	0.750	1.526	-0.517	1.42	17-Jan	1	0	0	
1991	0.375	1.889	0.412	-0.22	.	0	0	0	
1990	0.042	1.944	0.379	-1.03	14-Feb	0	0	0	
1989	0.083	2.496	1.460	0.66	.	0	0	0	
1988	0.250	1.798	-0.207	-1.90	5-Jan	0	0	0	
1987	0.500	2.257	0.900	-1.31	.	0	0	0	
1986	0.250	1.853	-0.354	-0.39	.	1	0	0	
1985	0.625	1.465	-1.481	-1.41	2-Feb	1	1	0	
1984	0.917	1.446	-1.161	-0.65	20-Dec	1	1	1	
1983	0.250	1.953	0.149	-0.66	.	0	0	0	
1982	0.042	1.619	-0.525	-0.48	10-Jan	1	0	0	
1981	0.208	1.960	0.560	1.44	.	0	0	0	
1980	0.333	1.502	-0.795	-3.20	17-Jan	1	0	0	
1979	0.458	1.759	0.393	2.03	.	0	0	0	
1978	0.625	1.252	-1.469	-2.20	11-Jan	1	0	0	
1977	0.708	1.371	-0.944	-1.60	.	1	0	0	
1976	0.458	1.207	-1.155	-2.01	24-Dec	1	1	1	
1975	0.083	1.928	1.143	2.23	.	0	0	0	
1974	0.000	1.733	0.713	1.62	.	0	0	0	
1973	0.000	2.325	1.657	2.90	.	0	0	0	
1972	0.292	1.235	-0.800	-1.56	2-Feb	1	0	1	
1971	0.792	1.824	0.398	-1.45	.	0	0	0	
1970	0.125	2.083	0.772	-0.47	28-Dec	0	0	0	
1969	0.000	2.103	0.610	-0.62	.	0	0	0	
1968	0.208	1.890	0.015	2.06	.	0	0	0	
1967	0.375	2.170	0.626	1.08	.	0	0	0	
1966	0.083	2.395	1.186	-1.98	.	0	0	0	

Knoppers Ford (continued):

Year	R_i Ratio	TRW	Standard	PDSI	Hist	Small	Large	Pointers
1965	0.375	1.407	-1.825	0.35	2-Dec	0	0	0
1964	0.917	1.484	-1.230	-0.56	.	1	1	0
1963	0.750	1.179	-1.380	-3.05	25-Jan	1	1	1
1962	0.208	1.949	0.380	0.47	.	0	0	0
1961	0.042	2.103	0.638	2.77	.	0	0	0
1960	0.167	1.378	-0.714	0.27	.	1	0	0
1959	0.583	1.963	0.906	2.10	.	0	0	0
1958	0.042	2.224	1.168	3.77	---------	0	0	1
1957	0.042	2.899	1.666	4.02	---------	0	0	0
1956	0.417	0.918	-1.588	-3.13	16-Dec	1	0	1
1955	0.917	2.263	0.464	-1.96	---------	0	0	0
1954	0.417	1.525	-0.540	-4.35	11--Jan	1	0	1
1953	0.125	2.191	0.309	-1.69	---------	0	0	0
1952	0.250	1.699	-0.410	-2.16	16-Dec	1	0	0
1951	0.087	2.321	0.538	1.73	---------	0	0	0
1950	0.130	2.335	0.824	4.56	---------	0	0	0
1949	0.478	1.335	-1.467	1.42	1---Feb	1	0	1
1948	0.870	1.715	-0.394	0.41	---------	0	0	0
1947	0.500	1.367	-1.126	-1.65	18-Feb	1	1	0
1946	0.318	1.445	-0.705	-0.80	---------	1	0	1
1945	0.045	2.141	0.740	4.52	---------	0	0	0
1944	0.000	2.105	0.790	1.99	---------	0	0	0
1943	0.500	0.977	-1.419	-1.69	5—Mar	1	0	1
1942	0.818	2.065	0.848	0.22	---------	0	0	0
1941	0.043	1.769	0.164	1.19	---------	0	0	0
1940	0.130	2.072	0.628	1.50	---------	0	0	0
1939	0.455	1.243	-1.112	-0.47	---------	1	0	0
1938	0.714	0.896	-1.290	0.24	---------	1	1	1
1937	0.143	3.774	1.972	0.19	---------	0	0	0
1936	0.150	1.119	-0.754	-2.52	1---Feb	1	0	1
1935	0.700	2.146	0.295	-0.77	---------	0	0	0
1934	0.500	1.582	-0.257	-1.92	24-Feb	1	0	0
1933	0.105	1.933	0.123	-0.08	---------	0	0	0
1932	0.368	1.592	-0.286	-0.32	---------	0	0	0
1931	0.176	1.885	-0.141	0.17	---------	0	0	0
1930	0.364	1.416	-0.726	-1.77	29-Dec	1	0	0
1929	0.400	1.965	0.675	-0.36	---------	0	0	0
1928	0.000	1.805	.	2.85	---------	0	0	0

Table 8. Lake Winona Winter Storm Reconstruction. Mount Ida, Arkansas. Index A = 0.710. Index B = 0.200. Drought : JAS PDSI < -1.40. A “1” in the “Small” or “Large” column indicates a storm of that size. A “0” indicates no storm of that type and a “.” indicates no data.

Year	R_i Ratio	TRW	Standard	PDSI	Hist	Small	Large	Pointers	Color Key .
1980	.	0.097	.	-1.61	17-Jan	.	.	1	Small
1979	.	0.121	.	2.96	.	.	.	0	Large
1978	.	0.099	.	-3.48	11-Jan	.	.	0	Drought
1977	0.043	0.109	.	-1.05	.	.	.	1	Pointers
1976	0.043	0.124	.	0.65	24-Dec	.	.	0	Profiles
1975	0.000	0.129	.	2.31	.	.	.	0	Newspapers
1974	0.021	0.098	-0.992	3.87	2-Jan	0	0	1	Legends
1973	0.000	0.154	1.783	3.79	.	0	0	0	
1972	0.021	0.128	0.371	-1.64	.	0	0	0	
1971	0.043	0.096	-1.162	-1.07	.	1	0	1	
1970	0.319	0.125	0.168	0.77	.	0	0	0	
1969	0.000	0.112	-0.415	-1.07	28-Jan	1	0	1	
1968	0.021	0.128	0.405	2.76	.	0	0	0	
1967	0.000	0.134	0.467	-0.10	.	0	0	0	
1966	0.000	0.124	0.261	1.31	.	0	0	0	
1965	0.043	0.133	0.824	-1.53	.	0	0	0	
1964	0.021	0.111	-1.415	-2.16	.	1	0	0	
1963	0.128	0.109	-1.128	-1.93	25-Jan	1	0	0	
1962	0.021	0.129	0.482	-0.75	.	0	0	0	
1961	0.000	0.128	0.380	1.85	.	0	0	0	
1960	0.021	0.108	-1.191	-0.20	.	1	0	0	
1959	0.043	0.131	0.847	1.09	.	0	0	0	
1958	0.043	0.115	-0.341	3.38	---------	1	0	1	
1957	0.000	0.159	1.908	2.47	---------	0	0	0	
1956	0.000	0.120	-0.420	-3.16	16-Dec	0	0	0	
1955	0.021	0.131	0.220	-1.39	---------	0	0	0	
1954	0.128	0.108	-0.924	-3.82	11--Jan	1	0	0	
1953	0.043	0.107	-0.958	-0.10	---------	1	0	0	
1952	0.085	0.105	-0.807	-2.14	16-Dec	0	0	0	
1951	0.000	0.105	-0.729	1.42	---------	1	0	0	
1950	0.000	0.127	1.111	3.15	---------	0	0	0	
1949	0.000	0.110	-0.282	0.53	1---Feb	0	0	1	
1948	0.000	0.145	1.950	-1.46	---------	0	0	0	
1947	0.000	0.116	-0.007	-0.53	18-Feb	0	0	0	
1946	0.063	0.120	0.140	-0.93	---------	0	0	0	
1945	0.021	0.122	0.069	4.56	---------	0	0	0	
1944	0.000	0.148	1.485	-0.88	---------	0	0	0	
1943	0.021	0.101	-1.297	-2.99	5---Mar	1	0	0	
1942	0.229	0.110	-0.751	0.52	---------	1	0	0	
1941	0.229	0.116	-0.224	1.03	---------	1	0	1	
1940	0.000	0.159	1.627	1.35	---------	0	0	0	
1939	0.000	0.130	0.166	-1.16	---------	0	0	0	

Lake Winona (continued):

Year	R_i Ratio	TRW	Standard	PDSI	Hist	Small	Large	Pointers
1938	0.229	0.088	-1.323	0.19	---------	1	0	1
1937	0.563	0.115	-0.085	-0.01	---------	1	0	0
1936	0.000	0.123	0.144	-4.19	1---Feb	0	0	0
1935	0.000	0.131	0.363	-0.92	---------	0	0	0
1934	0.021	0.104	-0.767	-4.11	24-Feb	1	0	1
1933	0.042	0.123	0.424	-2.15	---------	0	0	0
1932	0.021	0.116	0.110	-1.09	---------	0	0	0
1931	0.000	0.120	0.185	0.46	---------	0	0	0
1930	0.083	0.110	-0.886	-2.32	29-Dec	1	0	0
1929	0.146	0.110	-0.682	-1.41	---------	1	0	0
1928	0.021	0.141	1.911	1.10	---------	0	0	0
1927	0.000	0.155	1.772	2.28	---------	0	0	0
1926	0.021	0.097	-1.238	-0.10	---------	0	0	0
1925	0.875	0.056	-1.782	-3.16	22-Dec	1	1	1
1924	0.375	0.142	0.767	-1.85	---------	0	0	1
1923	0.021	0.175	1.240	1.59	---------	0	0	0
1922	0.000	0.117	-0.228	-0.53	---------	0	0	0
1921	0.500	0.107	-0.354	-0.82	---------	1	0	0
1920	0.292	0.118	0.050	2.28	---------	0	0	0
1919	0.021	0.136	0.406	0.21	---------	0	0	0
1918	0.021	0.108	-0.867	-3.40	10--Jan	1	0	0
1917	0.083	0.119	-0.277	-1.16	---------	0	0	0
1916	0.188	0.104	-1.017	-1.81	---------	1	0	0
1915	0.042	0.142	1.553	0.18	---------	0	0	0
1914	0.042	0.122	0.040	-0.29	---------	0	0	0
1913	0.042	0.132	0.608	0.23	---------	0	0	0
1912	0.313	0.076	-1.804	-0.58	---------	1	0	1
1911	0.313	0.126	0.391	0.37	---------	0	0	0
1910	0.000	0.188	1.767	0.55	---------	0	0	0
1909	0.021	0.127	-0.097	-2.15	---------	0	0	0
1908	0.250	0.133	0.117	0.63	---------	0	0	0
1907	0.417	0.105	-0.639	-0.97	---------	1	0	0
1906	0.125	0.131	0.124	2.95	---------	0	0	0
1905	0.063	0.123	-0.410	3.50	---------	1	0	1
1904	0.000	0.174	1.141	0.77	---------	0	0	0
1903	0.021	0.123	-0.378	-0.24	---------	1	0	0
1902	0.083	0.160	1.033	-1.13	---------	0	0	0
1901	0.146	0.128	-0.280	-2.48	6---Feb	0	0	0
1900	0.104	0.151	0.497	-0.15	---------	0	0	0
1899	0.396	0.071	-1.832	-0.15	---------	1	0	0
1898	0.229	0.164	0.717	1.15	---------	0	0	0
1897	0.000	0.190	1.280	-2.37	---------	0	0	0
1896	0.021	0.093	-1.039	-3.92	---------	1	0	0
1895	0.813	0.104	-0.589	0.83	---------	1	0	0
1894	0.479	0.085	-0.824	.	16-Mar	1	0	1

Lake Winona (continued):

Year	R_i Ratio	TRW	Standard	PDSI	Hist	Small	Large	Pointers
1893	0.042	0.163	0.835	.	---------	0	0	0
1892	0.000	0.169	0.722	.	---------	0	0	0
1891	0.021	0.150	0.318	.	---------	0	0	0
1890	0.292	0.117	-0.262	.	---------	1	0	0
1889	0.313	0.147	0.415	.	---------	0	0	0
1888	0.021	0.162	0.660	.	---------	0	0	0
1887	0.042	0.118	-1.343	.	---------	0	0	0
1886	0.333	0.114	-1.102	.	29--Jan	1	1	0
1885	0.333	0.091	-1.494	.	---------	1	1	1
1884	0.000	0.150	0.854	.	---------	0	0	0
1883	0.021	0.076	-1.459	.	---------	1	0	1
1882	0.021	0.184	1.437	.	---------	0	0	0
1881	0.083	0.066	-1.148	.	“Snow”	1	0	1
1880	0.354	0.132	0.374	.	---------	0	0	0
1879	0.104	0.137	0.405	.	---------	0	0	0
1878	0.000	0.160	0.710	.	---------	0	0	0
1877	0.083	0.149	0.471	.	---------	0	0	0
1876	0.146	0.156	0.416	.	---------	0	0	0
1875	0.417	0.091	-1.027	.	---------	1	0	0
1874	0.854	0.079	-1.560	.	---------	1	1	0
1873	0.362	0.116	-0.329	.	---------	1	0	1
1872	0.000	0.156	0.776	.	---------	0	0	0
1871	0.000	0.124	-0.021	.	---------	0	0	1
1870	0.064	0.186	1.463	.	---------	0	0	0
1869	0.128	0.082	-0.934	.	---------	0	0	0
1868	0.894	0.071	-1.055	.	---------	1	1	1
1867	0.723	0.098	-0.516	.	---------	1	0	0
1866	0.021	0.132	0.263	.	---------	0	0	0
1865	0.000	0.133	0.399	.	---------	0	0	0
1864	0.064	0.150	0.704	.	---------	0	0	0
1863	0.064	0.142	0.849	.	---------	0	0	0
1862	0.234	0.089	-0.912	.	---------	1	0	1
1861	0.234	0.165	1.270	.	---------	0	0	0
1860	0.191	0.060	-1.746	.	---------	1	0	1
1859	0.106	0.211	1.522	.	---------	0	0	0
1858	0.000	0.151	0.263	.	---------	0	0	0
1857	0.064	0.137	0.013	.	---------	0	0	0
1856	0.702	0.093	-0.701	.	---------	1	0	0
1855	0.383	0.127	-0.164	.	Resting	0	0	0
1854	0.043	0.138	0.143	.	.	0	0	0
1853	0.043	0.120	-0.546	.	.	0	0	0
1852	0.106	0.152	1.012	.	.	0	0	0
1851	0.234	0.085	-1.495	.	.	1	0	0
1850	0.702	0.064	-1.509	.	.	1	1	1
1849	0.106	0.214	1.762	.	.	0	0	0

Lake Winona (continued):

Year	R_i Ratio	TRW	Standard	PDSI	Hist	Small	Large	Pointers
1848	0.000	0.130	0.024	.	.	0	0	0
1847	0.085	0.146	0.334	.	.	0	0	0
1846	0.444	0.086	-0.761	.	.	1	0	0
1845	0.556	0.105	-0.267	.	.	0	0	1
1844	0.000	0.205	1.207	.	.	0	0	0
1843	0.000	0.080	-1.078	.	.	1	0	1
1842	0.268	0.188	1.110	.	.	0	0	0
1841	0.125	0.136	0.024	.	.	0	0	0
1840	0.100	0.118	-0.270	.	.	0	0	0
1839	0.375	0.117	-0.407	.	.	1	0	0
1838	0.385	0.071	-1.182	.	.	1	1	0
1837	0.658	0.056	-1.177	.	.	1	1	1
1836	0.189	0.104	-0.206	.	.	0	0	0
1835	0.000	0.132	0.893	.	.	0	0	0
1834	0.000	0.113	0.422	.	.	0	0	0
1833	0.083	0.122	0.711	.	.	0	0	0
1832	0.111	0.103	0.110	.	.	0	0	0
1831	0.382	0.071	-1.082	.	.	1	0	1
1830	0.324	0.117	0.391	.	.	0	0	0
1829	0.029	0.108	-0.057	.	.	0	0	0
1828	0.059	0.126	0.928	.	.	0	0	0
1827	0.029	0.140	1.259	.	.	0	0	0
1826	0.118	0.090	-0.785	.	.	0	0	0
1825	0.676	0.075	-1.103	.	.	1	1	0
1824	0.375	0.054	-1.562	.	.	1	1	1
1823	0.265	0.105	0.190	.	.	0	0	0
1822	0.029	0.101	0.080	.	.	0	0	0
1821	0.000	0.127	0.950	.	.	0	0	0
1820	0.088	0.114	0.778	.	.	0	0	0
1819	0.000	0.147	1.398	.	.	0	0	0
1818	0.118	0.098	-0.308	.	.	1	0	1
1817	0.088	0.184	1.902	.	.	0	0	0
1816	0.029	0.165	0.945	.	.	0	0	0
1815	0.000	0.154	0.411	.	.	0	0	0
1814	0.387	0.117	-0.735	.	.	1	0	0
1813	0.161	0.156	0.348	.	.	0	0	0
1812	0.167	0.114	-0.855	.	.	1	0	0
1811	0.100	0.118	-0.937	.	.	0	0	0
1810	0.300	0.080	-1.621	.	.	1	1	0
1809	0.483	0.094	-0.889	.	.	1	0	1
1808	0.034	0.204	1.870	.	.	0	0	0
1807	0.000	0.119	-0.186	.	.	0	0	0
1806	0.310	0.107	-0.312	.	.	1	0	0
1805	0.517	0.109	-0.242	.	.	1	0	1
1804	0.034	0.187	1.230	.	.	0	0	0

Lake Winona (continued):

Year	R_i Ratio	TRW	Standard	PDSI	Hist	Small	Large	Pointers
1803	0.071	0.102	-0.672	.	.	1	0	0
1802	0.107	0.170	0.636	.	.	0	0	0
1801	0.222	0.123	-0.229	.	.	1	0	0
1800	0.231	0.119	-0.363	.	.	1	0	0
1799	0.542	0.065	-1.442	.	.	1	1	1
1798	0.261	0.130	0.040	.	.	0	0	0
1797	0.000	0.156	0.952	.	.	0	0	0
1796	0.043	0.100	-0.664	.	.	1	0	0
1795	0.000	0.179	1.473	.	.	0	0	0
1794	0.000	0.167	0.898	.	.	0	0	0
1793	0.045	0.136	0.076	.	.	0	0	0
1792	0.762	0.070	-1.668	.	.	1	0	1
1791	0.667	0.123	-0.269	.	.	0	0	0
1790	0.095	0.136	0.152	.	.	0	0	0
1789	0.095	0.086	-1.065	.	.	0	0	0
1788	0.762	0.062	-1.265	.	.	1	1	1
1787	0.042	0.147	1.101	.	.	0	0	0
1786	0.050	0.113	0.230	.	.	0	0	0
1785	0.050	0.157	1.163	.	.	0	0	0
1784	0.105	0.089	-0.659	.	.	1	0	1
1783	0.333	0.136	0.654	.	.	0	0	0
1782	0.389	0.049	-1.385	.	.	1	0	1
1781	0.118	0.207	1.547	.	.	0	0	0
1780	0.000	0.113	-0.209	.	.	0	0	0
1779	0.250	0.131	0.091	.	.	0	0	1
1778	0.133	0.150	0.504	.	.	0	0	0
1777	0.067	0.147	0.283	.	.	0	0	0
1776	0.000	0.143	0.190	.	.	0	0	0
1775	0.333	0.083	-1.470	.	.	1	0	1
1774	0.267	0.147	0.686	.	.	0	0	0
1773	0.200	0.114	-0.682	.	.	0	0	0
1772	0.400	0.063	-1.633	.	.	1	1	1
1771	0.533	0.133	0.428	.	.	0	0	0
1770	0.143	0.103	-0.312	.	.	1	0	0
1769	0.143	0.098	-0.262	.	.	0	0	0
1768	0.286	0.120	0.320	.	.	0	0	0
1767	0.357	0.079	-0.951	.	.	1	0	0
1766	0.286	0.114	0.510	.	.	0	0	0
1765	0.357	0.087	-0.950	.	.	1	0	1
1764	0.000	0.141	1.664	.	.	0	0	0
1763	0.000	0.094	-0.493	.	.	1	0	0
1762	0.500	0.095	-0.405	.	.	1	0	0
1761	0.091	0.161	1.677	.	.	0	0	0
1760	0.091	0.099	-0.513	.	.	1	0	0
1759	0.273	0.124	0.340	.	.	0	0	0

Lake Winona (continued):

Year	R_i Ratio	TRW	Standard	PDSI	Hist	Small	Large	Pointers
1758	0.182	0.122	0.097	.	.	0	0	0
1757	0.091	0.135	0.668	.	.	0	0	0
1756	0.091	0.099	-0.835	.	.	1	0	0
1755	0.000	0.166	1.353	.	.	0	0	0
1754	0.091	0.108	-0.595	.	.	0	0	0
1753	0.400	0.070	-1.597	.	.	1	1	1
1752	0.700	0.082	-0.901	.	.	1	0	0
1751	0.500	0.078	-0.806	.	.	1	0	1
1750	0.300	0.085	-0.411	.	.	1	0	0

Table 9. McCurtain County Winter Storm Reconstruction. Broken Bow, Oklahoma. Index A = 0.750. Index B = 0.250. Drought: JAS PDSI < -1.40. A “1” in the “Small” or “Large” column indicates a storm of that type. A “0” indicates no storm of that type and a “.” indicates no data.

Year	R_i Ratio	TRW	Standard	PDSI	Hist	Small	Large	Pointers	Color Key .
1982	.	1.376	.	-0.24	.	.	.	0	Small
1981	.	1.304	.	1.19	.	.	.	0	Large
1980	.	0.999	.	-1.91	17-Feb	.	.	0	Drought
1979	0.292	1.186	.	1.48	1-Jan	.	.	0	Pointers
1978	0.104	0.934	.	-3.17	11-Jan	.	.	0	Profiles
1977	0.063	1.247	.	-1.07	.	.	.	0	Newspapers
1976	0.000	1.340	0.830	0.09	.	0	0	0	Legends
1975	0.000	1.269	0.554	-0.10	.	0	0	0	
1974	0.125	1.113	-0.288	2.61	2-Jan	0	0	0	
1973	0.063	1.300	0.736	4.07	.	0	0	0	
1972	0.146	0.830	-1.613	-2.79	2-Feb	1	0	1	
1971	0.063	1.409	1.003	0.98	.	0	0	0	
1970	0.000	1.349	0.597	-0.22	.	0	0	0	
1969	0.000	1.325	0.491	-0.87	.	0	0	0	
1968	0.146	1.171	-0.214	3.84	.	0	0	0	
1967	0.229	1.113	-0.508	1.26	.	0	0	1	
1966	0.042	1.390	0.786	-1.23	.	0	0	0	
1965	0.042	1.112	-1.189	-1.12	2-Dec	1	0	0	
1964	0.104	1.168	-0.549	-2.55	.	0	0	0	
1963	0.313	0.947	-1.558	-2.64	25-Jan	1	1	1	
1962	0.208	1.141	-0.062	-0.23	.	0	0	1	
1961	0.000	1.559	1.743	2.32	.	0	0	0	
1960	0.021	1.249	0.127	2.46	.	0	0	1	
1959	0.020	1.713	1.642	1.92	.	0	0	0	
1958	0.020	1.373	0.252	3.41	---------	0	0	0	
1957	0.184	1.259	-0.239	2.93	---------	0	0	0	
1956	0.653	0.875	-1.583	-4.86	16-Dec	1	1	1	
1955	0.122	1.426	0.284	-1.90	---------	0	0	0	
1954	0.020	1.054	-0.836	-3.62	11--Jan	1	0	0	
1953	0.061	1.050	-0.707	0.01	---------	1	0	0	
1952	0.245	1.131	-0.185	-1.98	23-Dec	0	0	0	
1951	0.061	1.129	-0.017	1.53	---------	0	0	1	
1950	0.000	1.541	1.593	3.17	---------	0	0	0	
1949	0.000	1.276	0.244	1.30	---------	0	0	0	
1948	0.306	0.922	-1.176	-0.54	---------	1	0	1	
1947	0.388	1.275	0.433	-1.02	---------	0	0	0	
1946	0.041	1.337	0.550	-1.22	---------	0	0	0	
1945	0.020	1.271	0.111	4.34	---------	0	0	0	
1944	0.143	1.147	-0.563	-1.02	---------	0	0	0	
1943	0.286	0.998	-1.115	-2.86	5—Mar	1	1	0	
1942	0.122	1.071	-0.482	-0.02	---------	1	0	0	
1941	0.020	1.135	-0.335	0.84	---------	0	0	1	

McCurtain County (continued):

Year	R_i Ratio	TRW	Standard	PDSI	Hist	Small	Large	Pointers
1940	0.000	1.572	1.827	1.16	---------	0	0	0
1939	0.000	1.227	0.129	-1.67	---------	0	0	0
1938	0.510	0.732	-1.556	-0.62	---------	1	0	1
1937	0.140	1.945	1.759	-1.03	---------	0	0	0
1936	0.000	1.144	-0.301	-2.71	1---Feb	1	0	0
1935	0.140	1.304	0.026	-0.33	---------	0	0	0
1934	0.480	1.008	-0.684	-4.49	24-Feb	1	0	1
1933	0.020	1.390	0.374	-0.49	---------	0	0	0
1932	0.000	1.182	-0.164	-0.61	---------	0	0	0
1931	0.020	1.194	-0.379	-1.59	---------	1	0	0
1930	0.200	1.024	-1.113	-1.94	29-Dec	1	0	1
1929	0.020	1.390	1.119	-0.90	---------	0	0	0
1928	0.020	1.268	0.387	2.64	---------	0	0	0
1927	0.020	1.327	0.560	3.95	---------	0	0	0
1926	0.020	1.381	0.984	0.99	---------	0	0	0
1925	0.240	0.846	-1.769	-2.24	22-Dec	1	0	1
1924	0.440	1.199	-0.030	-0.67	---------	0	0	0
1923	0.020	1.434	0.851	-0.11	---------	0	0	0
1922	0.000	1.259	0.071	-0.73	---------	0	0	0
1921	0.220	1.025	-0.884	-0.56	---------	0	0	0
1920	0.520	0.973	-0.853	1.70	16-Feb	1	0	0
1919	0.180	1.021	-0.436	-0.54	---------	1	0	1
1918	0.040	1.433	1.242	-2.24	---------	0	0	0
1917	0.000	1.376	0.767	0.38	---------	0	0	0
1916	0.235	0.865	-1.240	-2.16	---------	1	0	0
1915	0.451	1.343	0.854	1.92	---------	0	0	0
1914	0.000	1.577	1.294	-1.73	---------	0	0	0
1913	0.000	1.446	0.594	-1.12	---------	0	0	0
1912	0.118	1.150	-0.690	-1.51	---------	1	0	0
1911	0.588	1.023	-0.920	-3.28	3---Jan	1	0	0
1910	0.627	0.824	-1.210	-1.74	18-Feb	1	1	0
1909	0.235	1.149	-0.262	-2.11	---------	0	0	1
1908	0.000	1.959	1.710	2.55	---------	0	0	0
1907	0.020	1.547	0.652	1.47	---------	0	0	0
1906	0.118	1.624	0.753	3.28	---------	0	0	0
1905	0.314	1.438	0.184	2.79	---------	0	0	0
1904	0.314	1.246	-0.415	1.14	---------	1	0	0
1903	0.412	1.081	-1.153	-0.73	---------	1	1	0
1902	0.314	1.236	-0.717	0.30	14-Dec	1	0	0
1901	0.098	1.134	-0.935	-2.59	6—Feb	1	0	0
1900	0.020	1.534	1.001	0.91	---------	0	0	0
1899	0.039	0.988	-1.282	0.27	11-Feb	1	0	0
1898	0.392	1.093	-0.533	2.04	---------	1	0	0
1897	0.196	1.182	0.023	-1.54	---------	0	0	0
1896	0.157	0.870	-1.325	-3.98	---------	1	0	1

McCurtain County (continued):

Year	R_i Ratio	TRW	Standard	PDSI	Hist	Small	Large	Pointers
1895	0.039	1.493	1.246	2.02	---------	0	0	0
1894	0.235	0.582	-1.535	.	16-Mar	1	0	1
1893	0.353	1.484	1.178	.	---------	0	0	1
1892	0.020	2.101	1.711	.	---------	0	0	0
1891	0.020	1.331	0.081	.	---------	0	0	0
1890	0.706	1.045	-0.458	.	---------	1	0	1
1889	0.569	1.443	0.191	.	---------	0	0	0
1888	0.020	1.525	0.356	.	---------	0	0	0
1887	0.039	1.272	-0.569	.	---------	0	0	0
1886	0.627	0.825	-1.333	.	29--Jan	1	1	0
1885	0.804	0.960	-0.919	.	---------	1	0	0
1884	0.078	1.118	-0.202	.	---------	0	0	0
1883	0.098	0.847	-1.047	.	---------	1	0	1
1882	0.039	1.982	1.826	.	---------	0	0	0
1881	0.000	1.099	-0.149	.	“Snow”	0	0	0
1880	0.333	1.254	0.250	.	---------	0	0	0
1879	0.863	0.500	-1.336	.	---------	1	0	1
1878	0.216	1.676	0.939	.	---------	0	0	0
1877	0.020	1.454	0.389	.	---------	0	0	0
1876	0.039	1.343	0.028	.	---------	0	0	0
1875	0.373	1.274	0.125	.	---------	0	0	0
1874	0.333	0.970	-0.632	.	---------	1	0	1
1873	0.157	1.531	0.707	.	---------	0	0	0
1872	0.039	1.239	-0.512	.	---------	0	0	0
1871	0.255	1.005	-1.204	.	---------	1	1	1
1870	0.078	2.087	1.950	.	---------	0	0	0
1869	0.020	1.192	-0.356	.	---------	1	0	0
1868	0.569	0.924	-0.859	.	---------	1	0	0
1867	0.647	1.111	-0.471	.	---------	1	0	0
1866	0.059	1.474	0.466	.	---------	0	0	0
1865	0.000	1.432	0.288	.	---------	0	0	0
1864	0.059	1.512	0.324	.	---------	0	0	0
1863	0.078	1.604	1.137	.	---------	0	0	0
1862	0.118	1.234	-0.379	.	---------	0	0	0
1861	0.549	1.012	-1.474	.	---------	1	1	0
1860	0.784	0.667	-1.825	.	---------	1	1	1
1859	0.275	1.314	0.188	.	---------	0	0	0
1858	0.000	1.498	0.711	.	---------	0	0	0
1857	0.020	1.582	0.909	.	---------	0	0	0
1856	0.157	1.088	-0.358	.	---------	1	0	0
1855	0.804	0.841	-0.894	.	Resting	1	0	1
1854	0.412	1.207	0.106	.	.	0	0	0
1853	0.098	0.981	-0.871	.	.	1	0	1
1852	0.039	1.644	1.211	.	.	0	0	0
1851	0.078	0.908	-0.846	.	.	1	0	0

McCurtain County (continued):

Year	R_i Ratio	TRW	Standard	PDSI	Hist	Small	Large	Pointers
1850	0.373	1.191	0.254	.	.	0	0	0
1849	0.118	1.504	1.063	.	.	0	0	0
1848	0.059	1.184	-0.180	.	.	0	0	0
1847	0.255	1.344	0.349	.	.	0	0	0
1846	0.235	1.229	-0.238	.	.	0	0	0
1845	0.157	1.313	0.405	.	.	0	0	1
1844	0.039	1.714	1.859	.	.	0	0	0
1843	0.118	0.804	-1.750	.	.	1	0	1
1842	0.667	1.283	0.058	.	.	0	0	0
1841	0.176	1.128	-0.482	.	.	1	0	0
1840	0.137	0.887	-1.019	.	.	1	0	0
1839	0.255	1.232	0.125	.	.	0	0	0
1838	0.200	0.765	-1.050	.	.	1	0	0
1837	0.333	0.993	-0.099	.	.	1	0	0
1836	0.229	0.838	-0.894	.	.	1	0	1
1835	0.000	1.462	1.697	.	.	0	0	0
1834	0.021	1.197	0.571	.	.	0	0	0
1833	0.149	1.024	-0.203	.	.	0	0	0
1832	0.370	1.227	0.642	.	.	0	0	0
1831	0.267	0.825	-1.115	.	.	1	0	0
1830	0.295	1.298	0.728	.	.	0	0	0
1829	0.070	1.683	1.565	.	.	0	0	0
1828	0.020	1.109	-0.324	.	.	1	0	0
1827	0.390	1.200	0.018	.	.	0	0	0
1826	0.225	1.367	0.471	.	.	0	0	0
1825	0.000	1.537	0.880	.	.	0	0	0
1824	0.077	0.901	-1.517	.	.	1	0	0
1823	0.641	1.044	-0.782	.	.	1	0	0
1822	0.342	0.952	-0.905	.	.	1	0	1
1821	0.079	1.476	1.036	.	.	0	0	0
1820	0.000	1.051	-0.530	.	.	1	0	0
1819	0.184	1.405	0.786	.	.	0	0	0
1818	0.368	0.763	-1.225	.	.	1	0	1
1817	0.237	1.784	1.613	.	.	0	0	0
1816	0.111	1.066	-0.419	.	.	1	0	0
1815	0.167	1.543	0.696	.	.	0	0	0
1814	0.194	1.148	-0.300	.	.	1	0	0
1813	0.222	1.579	0.618	.	.	0	0	0
1812	0.167	1.576	0.618	.	.	0	0	0
1811	0.086	1.537	0.292	.	.	0	0	0
1810	0.400	1.076	-1.142	.	.	1	0	0
1809	0.758	0.903	-1.520	.	.	1	1	1
1808	0.061	1.809	1.307	.	.	0	0	0
1807	0.031	1.368	-0.124	.	.	0	0	0
1806	0.531	0.552	-1.616	.	.	1	1	0

McCurtain County (continued):

Year	R_i Ratio	TRW	Standard	PDSI	Hist	Small	Large	Pointers
1805	0.875	1.041	-0.339	.	.	1	0	1
1804	0.063	2.328	1.721	.	.	0	0	0
1803	0.000	1.188	-0.211	.	.	0	0	0
1802	0.581	1.398	0.025	.	.	0	0	0
1801	0.645	0.906	-0.627	.	.	1	0	0
1800	0.419	1.158	-0.120	.	.	0	0	0
1799	0.387	0.786	-0.922	.	.	1	0	1
1798	0.133	1.633	0.560	.	.	0	0	0
1797	0.000	1.428	0.716	.	.	0	0	0
1796	0.179	1.055	-0.457	.	.	1	0	1
1795	0.429	1.445	0.783	.	.	0	0	0
1794	0.000	1.364	0.339	.	.	0	0	0
1793	0.077	1.199	-0.261	.	.	0	0	0
1792	0.217	1.291	-0.289	.	.	0	0	0
1791	0.043	1.623	1.520	.	.	0	0	0
1790	0.043	1.348	0.088	.	.	0	0	0
1789	0.261	1.196	-1.047	.	.	1	0	0
1788	0.727	0.738	-1.915	.	.	1	1	1
1787	0.190	1.575	1.001	.	.	0	0	0
1786	0.300	0.577	-1.546	.	.	1	0	1
1785	0.650	1.182	0.013	.	.	0	0	0
1784	0.316	0.903	-0.487	.	.	1	0	1
1783	0.053	1.869	1.571	.	.	0	0	0
1782	0.053	1.158	0.033	.	.	0	0	0
1781	0.263	1.276	0.133	.	.	0	0	0
1780	0.632	0.640	-1.018	.	.	1	0	1
1779	0.421	1.375	0.455	.	.	0	0	0
1778	0.000	1.530	0.694	.	.	0	0	0
1777	0.053	1.613	0.668	.	.	0	0	0
1776	0.000	1.710	1.060	.	.	0	0	0
1775	0.059	1.408	0.124	.	.	0	0	0
1774	0.529	1.119	-0.615	.	.	1	0	1
1773	0.294	1.411	-0.216	.	.	0	0	0
1772	0.588	0.533	-2.001	.	.	1	1	1
1771	0.529	1.359	0.132	.	.	0	0	0
1770	0.000	1.653	0.858	.	.	0	0	0
1769	0.067	1.092	-0.370	.	.	1	0	0
1768	0.467	1.471	0.647	.	.	0	0	0
1767	0.333	0.682	-1.161	.	.	1	0	1
1766	0.533	1.178	0.098	.	.	0	0	0
1765	0.000	1.414	0.473	.	.	0	0	0
1764	0.000	1.407	0.427	.	.	0	0	0
1763	0.077	1.261	0.170	.	.	0	0	0
1762	0.583	0.534	-1.599	.	.	1	0	1
1761	0.273	1.941	1.554	.	.	0	0	0

McCurtain County (continued):

Year	R_i Ratio	TRW	Standard	PDSI	Hist	Small	Large	Pointers
1760	0.000	1.017	-0.545	.	.	1	0	0
1759	0.182	1.489	0.446	.	.	0	0	0
1758	0.091	1.461	0.364	.	.	0	0	0
1757	0.200	1.522	0.458	.	.	0	0	0
1756	0.400	1.035	-0.547	.	.	1	0	0
1755	0.200	1.440	0.081	.	.	0	0	0
1754	0.200	1.210	-0.458	.	.	1	0	0
1753	0.200	0.916	-1.561	.	.	1	0	1
1752	0.500	1.037	-0.796	.	.	1	0	0
1751	0.300	1.343	0.560	.	.	0	0	0
1750	0.000	1.103	-0.278	.	.	0	0	0
1749	0.400	1.071	-0.488	.	.	1	0	0
1748	0.100	1.461	1.584	.	.	0	0	0
1747	0.000	1.415	1.053	.	.	0	0	0
1746	0.250	0.993	-1.073	.	.	1	0	0
1745	0.500	1.052	-0.791	.	.	1	0	0

Table 10. Pigeon Creek (Lat = 34° 38’ N., Long = 94° 32’ W.) Winter Storm Reconstruction. Big Cedar, Oklahoma. Index A = 0.780. Index B = 0.280. Drought: JAS PDSI < -1.40. A “1” in the “Small” or “Large” columns indicates a storm of that type. A “0” indicates no storm of that type and a “.” indicates no data.

Year	R_i Ratio	TRW	Standard	PDSI	Hist	Small	Large	Pointers	Color Key .
2007	.	2.083	.	2.32	.	.	.	0	Small
2006	.	1.803	.	-2.85	17-Feb	.	.	0	Large
2005	.	1.700	.	-1.92	26-Feb	.	.	1	Drought
2004	0.105	2.101	.	1.83	.	.	.	0	Pointers
2003	0.000	2.135	.	-1.24	.	.	.	0	Profiles
2002	0.105	1.814	.	-0.40	5-Feb	.	.	0	
2001	0.316	1.743	-0.899	-0.29	25-Dec	1	0	0	
2000	0.263	1.824	-0.291	-0.13	.	0	0	0	
1999	0.000	2.284	1.506	-0.57	.	0	0	0	
1998	0.050	1.924	-0.255	-1.09	.	0	0	0	
1997	0.150	1.700	-1.010	2.52	8-Jan	1	0	1	
1996	0.158	2.185	1.157	2.28	.	0	0	0	
1995	0.000	1.739	-0.754	0.57	.	1	0	1	
1994	0.000	2.384	1.371	0.44	.	0	0	0	
1993	0.053	1.576	-1.247	3.00	17-Jan	1	0	0	
1992	0.105	2.365	1.159	3.91	.	0	0	0	
1991	0.053	2.164	0.440	-0.64	.	0	0	0	
1990	0.000	2.177	0.302	-0.59	.	0	0	0	
1989	0.000	2.263	0.534	1.73	.	0	0	0	
1988	0.095	1.850	-0.885	-1.90	5-Jan	1	0	1	
1987	0.095	2.529	1.234	0.64	.	0	0	0	
1986	0.000	1.811	-1.362	0.15	.	0	0	0	
1985	0.545	1.744	-1.166	0.95	2-Feb	1	1	0	
1984	0.273	1.920	-0.423	-1.14	20-Dec	1	0	0	
1983	0.045	1.973	-0.142	-1.39	.	0	0	0	
1982	0.045	2.020	0.162	0.01	.	0	0	0	
1981	0.143	2.198	0.643	1.08	.	0	0	0	
1980	0.333	1.211	-2.004	-2.99	17-Feb	1	0	1	
1979	0.714	1.779	-0.179	0.49	.	0	0	0	
1978	0.190	1.714	-0.370	-1.83	11-Jan	1	0	0	
1977	0.045	1.829	0.297	-1.22	.	0	0	0	
1976	0.091	1.899	0.297	0.31	.	0	0	1	
1975	0.000	2.353	1.357	2.86	.	0	0	0	
1974	0.000	2.068	0.664	1.96	.	0	0	0	
1973	0.091	3.012	2.002	3.82	.	0	0	0	
1972	0.045	1.622	-0.935	-2.41	2-Feb	1	0	1	
1971	0.318	2.508	0.681	1.03	.	0	0	0	
1970	0.045	2.406	0.306	-0.53	.	0	0	0	
1969	0.000	2.310	-0.037	-1.11	.	0	0	0	
1968	0.273	2.110	-0.420	2.22	.	1	0	0	
1967	0.091	2.259	-0.142	0.50	.	0	0	0	

Pigeon Creek (continued):

Year	R_i Ratio	TRW	Standard	PDSI	Hist	Small	Large	Pointers
1966	0.182	2.164	-0.116	-1.56	.	0	0	0
1965	0.182	1.868	-1.732	-1.60	23-Feb	1	0	0
1964	0.500	1.561	-1.836	-2.92	.	1	1	0
1963	0.682	1.430	-1.518	-3.51	25-Jan	1	1	0
1962	0.182	1.834	-0.178	-1.39	.	0	0	1
1961	0.000	2.516	1.466	2.10	.	0	0	0
1960	0.000	2.437	1.114	1.87	.	0	0	0
1959	0.000	2.474	1.005	2.52	.	0	0	0
1958	0.050	2.603	0.966	3.69	---------	0	0	0
1957	0.000	3.078	1.367	2.99	---------	0	0	0
1956	0.316	1.282	-1.774	-4.03	16-Dec	1	0	1
1955	0.947	1.927	-0.707	-2.34	11-Feb	1	0	0
1954	0.200	1.904	-0.580	-3.89	11--Jan	1	0	0
1953	0.000	2.204	-0.012	-1.64	---------	0	0	0
1952	0.182	1.428	-1.000	-1.91	16-Dec	1	0	1
1951	.	2.238	0.386	1.19	---------	.	.	0
1950	.	2.650	1.477	2.73	---------	.	.	0
1949	.	3.040	.	1.64	---------	.	.	0
1948	.	2.787	.	1.22	---------	.	.	0
1947	.	0.625	.	-0.58	18-Feb	.	.	1
1946	.	1.685	.	-1.06	---------	.	.	0
1945	.	4.029	.	4.66	---------	.	.	0
1944	.	2.944	.	0.24	---------	.	.	0
1943	.	3.307	.	-1.56	5--Mar	.	.	0

Table 11. Pilot Knob (Lat = 35° 00’ N., Long = 94° 03’ W.) Winter Storm Reconstruction. Booneville, Arkansas. Index A = 0.930. Index B = 0.670. Drought: JAS PDSI < -1.40. A “1” in the “Small” or “Large” column indicates a storm of that type. A “0” indicates no storm of that type and a “.” indicates no data.

Year	R_i Ratio	TRW	Standard	PDSI	Hist	Small	Large	Pointers	Color Key
2007	.	1.691	.	2.32	.	.	.	0	Small
2006	.	1.637	.	-2.85	17-Feb	.	.	0	Large
2005	.	1.666	.	-1.92	26-Feb	.	.	1	Drought
2004	0.091	1.954	.	1.83	.	.	.	0	Pointers
2003	0.091	1.780	.	-1.24	.	.	.	0	Profiles
2002	0.571	1.595	.	-0.40	5-Feb	.	.	0	
2001	0.682	1.355	-1.717	-0.29	25-Dec	1	1	0	
2000	0.636	1.604	-0.284	-0.13	.	0	0	1	
1999	0.045	2.052	1.429	-0.57	.	0	0	0	
1998	0.045	1.997	0.914	-1.09	.	0	0	0	
1997	0.619	1.378	-1.093	2.52	8-Jan	1	0	1	
1996	0.773	1.939	0.808	2.28	.	0	0	0	
1995	0.318	1.693	-0.083	0.57	5-Jan	0	0	1	
1994	0.045	2.260	1.372	0.44	.	0	0	0	
1993	0.182	1.639	-0.713	3.00	.	1	0	0	
1992	0.810	1.637	-0.530	3.91	17-Jan	1	0	0	
1991	0.545	1.841	0.256	-0.64	.	0	0	0	
1990	0.091	1.953	0.451	-0.59	.	0	0	0	
1989	0.095	2.224	1.252	1.73	.	0	0	0	
1988	0.261	1.636	-0.910	-1.90	5-Jan	1	0	0	
1987	0.739	1.889	0.265	0.64	.	0	0	0	
1986	0.478	1.688	-0.711	0.15	.	1	0	0	
1985	0.609	1.392	-1.557	0.95	2-Feb	1	0	0	
1984	0.583	1.734	-0.205	-1.14	20-Dec	0	0	0	
1983	0.217	1.912	0.498	-1.39	.	0	0	0	
1982	0.043	1.679	-0.144	0.01	10-Jan	0	0	0	
1981	0.348	1.865	0.711	1.08	.	0	0	0	
1980	0.696	1.050	-1.885	-2.99	17-Feb	1	0	1	
1979	0.826	1.812	0.572	0.49	.	0	0	0	
1978	0.250	1.227	-1.144	-1.83	11-Jan	1	0	1	
1977	0.250	1.596	0.014	-1.22	.	0	0	0	
1976	0.542	1.144	-1.010	0.31	24-Dec	1	0	1	
1975	0.083	2.001	1.229	2.86	.	0	0	0	
1974	0.130	1.561	0.215	1.96	.	0	0	0	
1973	0.043	2.307	1.555	3.82	.	0	0	0	
1972	0.261	1.452	-0.389	-2.41	2-Feb	0	0	0	
1971	0.870	1.447	-0.508	1.03	.	1	0	1	
1970	0.667	1.876	0.485	-0.53	.	0	0	0	
1969	0.000	1.999	0.589	-1.11	.	0	0	0	
1968	0.083	1.966	0.507	2.22	.	0	0	0	
1967	0.167	2.142	0.788	0.50	.	0	0	0	

Pilot Knob (continued):

Year	R_i Ratio	TRW	Standard	PDSI	Hist	Small	Large	Pointers
1966	0.125	2.199	1.079	-1.56	.	0	0	0
1965	0.583	1.524	-1.222	-1.60	23-Feb	0	0	0
1964	1.000	1.540	-1.311	-2.92	.	1	1	0
1963	0.875	0.983	-1.789	-3.51	25-Jan	1	1	1
1962	0.333	2.198	0.878	-1.39	.	0	0	0
1961	0.000	2.454	1.129	2.10	.	0	0	0
1960	0.292	0.987	-1.189	1.87	.	1	0	1
1959	0.917	1.938	0.487	2.52	.	0	0	0
1958	0.125	2.406	0.987	3.69	---------	0	0	1
1957	0.000	3.484	1.613	2.99	---------	0	0	0
1956	0.348	1.115	-1.134	-4.03	16-Dec	1	0	1
1955	0.955	2.449	0.381	-2.34	---------	0	0	0
1954	0.773	1.447	-0.598	-3.89	11-Jan	1	0	1
1953	0.476	1.904	-0.261	-1.64	---------	0	0	0
1952	0.632	0.974	-1.122	-1.91	16-Dec	1	0	1
1951	0.625	2.403	0.491	1.19	---------	0	0	1
1950	0.000	3.859	1.842	2.73	---------	0	0	0
1949	0.000	2.996	0.731	1.64	---------	0	0	.
1948	.	3.381	0.911	1.22	---------	.	.	.
1947	.	2.642	0.050	-0.58	---------	.	.	.

Table 12. Sand Lick (Lat = 34° 44' N., Long = 93° 27' W.) Winter Storm Reconstruction. Mount Ida, Arkansas. Index A = 0.810. Index B = 0.440. Drought: JAS PDSI < -1.40. A "1" in the "Small" or "Large" column indicates a storm of that type. A "0" indicates no storm of that type and a "." indicates no data.

Year	R_i Ratio	TRW	Standard	PDSI	Hist	Small	Large	Pointers	Color Key
2007	.	2.156	.	0.16	.	.	.	0	Small
2006	.	1.864	.	-3.60	17-Feb	.	.	0	Large
2005	.	1.945	.	-2.48	26-Feb	.	.	0	Drought
2004	0.256	1.818	.	-0.03	.	.	.	0	Pointers
2003	0.256	1.946	.	-1.06	.	.	.	0	Profiles
2002	0.410	1.416	.	-1.52	5-Feb	1	0	0	
2001	0.590	1.396	-1.393	1.38	25-Dec	1	1	0	
2000	0.103	1.755	0.088	-1.47	.	0	0	0	
1999	0.077	1.947	0.824	-1.30	.	0	0	0	
1998	0.026	2.087	1.198	-0.95	.	0	0	0	
1997	0.179	1.257	-1.313	2.04	8-Jan	1	0	1	
1996	0.333	2.359	1.501	2.40	.	0	0	0	
1995	0.026	1.947	0.325	-0.86	5-Jan	0	0	0	
1994	0.051	2.287	0.917	2.54	.	0	0	0	
1993	0.308	1.747	-0.542	0.70	17-Jan	0	0	0	
1992	0.872	1.326	-1.215	3.11	17-Jan	1	1	1	
1991	0.564	1.806	-0.028	1.65	.	0	0	0	
1990	0.154	1.581	-0.768	1.81	14-Feb	1	0	0	
1989	0.051	1.922	0.396	4.17	.	0	0	0	
1988	0.051	1.699	-0.229	0.00	5-Jan	0	0	0	
1987	0.103	1.482	-0.834	-1.12	16-Jan	1	0	1	
1986	0.333	1.851	0.859	-0.18	.	0	0	0	
1985	0.231	1.266	-1.696	-0.92	2-Feb	1	0	0	
1984	0.333	1.506	-0.482	0.86	20-Dec	1	0	0	
1983	0.154	1.701	0.301	-0.01	.	0	0	0	
1982	0.077	1.448	-0.594	-1.25	10-Jan	1	0	1	
1981	0.282	1.930	1.397	1.51	.	0	0	0	
1980	0.385	0.963	-1.653	-1.61	17-Feb	1	0	1	
1979	0.282	1.638	0.462	2.96	.	0	0	0	
1978	0.051	1.199	-0.883	-3.28	11-Jan	1	0	1	
1977	0.000	2.087	1.314	-1.05	.	0	0	0	
1976	0.000	1.638	0.205	0.65	.	0	0	0	
1975	0.231	1.509	-0.145	2.31	.	0	0	0	
1974	0.692	1.447	-0.141	3.87	2-Jan	1	0	1	
1973	0.108	2.173	1.445	3.70	.	0	0	0	
1972	0.054	1.391	-0.669	-1.64	2-Feb	1	0	0	
1971	0.081	1.883	0.475	-1.07	.	0	0	1	
1970	0.027	3.048	2.005	0.77	.	0	0	0	
1969	0.162	1.318	-0.816	-1.07	28-Jan	1	0	1	
1968	0.811	1.755	-0.172	2.76	.	1	0	0	
1967	0.543	1.670	-0.377	-0.10	.	1	0	0	

Sand Lick (continued):

Year	R_i Ratio	TRW	Standard	PDSI	Hist	Small	Large	Pointers
1966	0.057	1.686	-0.235	1.31	.	0	0	0
1965	0.000	2.084	0.298	-1.53	2-Dec	0	0	0
1964	0.118	1.796	-0.203	-2.16	.	0	0	0
1963	0.455	1.070	-1.670	-1.93	25-Jan	1	1	1
1962	0.273	1.796	0.333	-0.75	.	0	0	0
1961	0.000	2.239	1.282	1.85	.	0	0	0
1960	0.100	1.489	-0.645	-0.20	.	1	0	1
1959	0.069	2.352	1.162	1.09	.	0	0	0
1958	0.034	1.885	0.187	3.38	---------	0	0	0
1957	0.483	2.402	1.045	2.47	---------	0	0	0
1956	0.750	0.805	-1.845	-3.16	16-Dec	1	0	1
1955	0.192	2.255	0.575	-1.39	11-Feb	0	0	0
1954	0.077	1.023	-1.107	-3.82	11--Jan	1	0	1
1953	0.154	1.778	-0.012	-0.10	---------	0	0	0
1952	0.000	1.543	-0.214	-2.14	16-Dec	0	0	0
1951	0.000	1.913	0.401	1.42	---------	0	0	0
1950	0.217	2.051	0.795	3.15	---------	0	0	0
1949	0.450	2.043	0.589	0.53	---------	0	0	0
1948	0.211	1.992	0.614	-1.46	---------	0	0	0
1947	0.000	1.644	-1.032	-0.53	18-Feb	1	0	0
1946	0.071	1.357	-1.575	-0.93	---------	1	0	0

Table 13. Story (Lat = 34° 40’ N., Long = 93° 28’ W.) Winter Storm Reconstructions. Story, Arkansas. Index A = 0.910. Index B = 0.420. Drought: JAS PDSI < -1.40. A “1” in the “Small” or “Large” column indicates a storm of that type. A “0” indicates no storm of that type and a “.” indicates no data.

Year	R_i Ratio	TRW	Standard	PDSI	Hist	Small	Large	Pointers	Color Key
2005	.	1.536	.	-1.46	26-Feb	.	.	0	Small
2004	.	1.627	.	0.68	.	.	.	0	Large
2003	0.209	1.652	.	-1.78	.	.	.	0	Drought
2002	0.605	1.218	.	-0.34	5-Feb	1	0	0	Pointers
2001	0.814	1.180	-1.528	-1.35	25-Dec	1	1	0	Profiles
2000	0.302	1.653	0.789	-1.70	.	0	0	0	Newspapers
1999	0.070	1.583	0.440	-0.79	.	0	0	0	Legends
1998	0.000	2.140	1.749	-1.25	.	0	0	0	
1997	0.256	1.179	-0.954	-0.96	8-Jan	1	0	1	
1996	0.558	2.061	1.193	1.50	.	0	0	0	
1995	0.209	1.552	-0.184	-0.14	5-Jan	0	0	1	
1994	0.163	2.084	0.935	1.72	.	0	0	0	
1993	0.326	1.555	-0.499	1.12	.	0	0	0	
1992	0.721	1.182	-1.187	1.42	17-Jan	1	1	0	
1991	0.791	1.572	-0.070	-0.22	.	0	0	0	
1990	0.279	1.484	-0.485	0.66	.	0	0	0	
1989	0.047	2.155	1.450	0.66	.	0	0	0	
1988	0.140	1.700	0.070	-1.90	5-Jan	0	0	0	
1987	0.628	1.313	-0.810	-1.31	16-Jan	1	0	0	
1986	0.814	1.491	-0.210	-0.39	.	0	0	0	
1985	0.442	1.310	-0.912	-1.41	2-Feb	1	0	0	
1984	0.419	1.317	-0.724	-0.65	.	0	0	1	
1983	0.163	1.660	0.310	-0.66	.	0	0	0	
1982	0.070	1.539	0.379	-0.48	.	0	0	0	
1981	0.279	1.498	0.376	1.44	.	0	0	0	
1980	0.837	0.994	-1.870	-3.20	17-Feb	1	0	0	
1979	0.884	1.251	-0.528	2.03	1-Jan	1	0	0	
1978	0.535	1.114	-0.937	-2.20	11-Jan	1	0	1	
1977	0.093	1.637	0.953	-1.60	.	0	0	0	
1976	0.047	1.761	1.274	-2.01	24-Dec	0	0	0	
1975	0.256	1.214	-0.488	2.23	.	1	0	0	
1974	0.651	1.634	0.875	1.62	.	0	0	0	
1973	0.093	2.005	1.483	2.90	.	0	0	0	
1972	0.256	1.010	-1.271	-1.56	2-Feb	1	0	1	
1971	0.860	1.634	0.232	-1.45	.	0	0	0	
1970	0.000	2.156	1.292	-0.47	.	0	0	0	
1969	0.023	1.450	-0.335	-0.62	28-Jan	1	0	0	
1968	0.837	1.456	-0.434	2.06	.	1	0	0	
1967	0.744	1.497	-0.272	1.08	.	0	0	0	
1966	0.279	1.497	-0.092	-1.98	.	0	0	0	
1965	0.326	1.527	-0.298	0.35	2-Dec	0	0	0	
1964	0.326	1.375	-0.718	-0.56	.	0	0	0	

Story (continued):

Year	R_i Ratio	TRW	Standard	PDSI	Hist	Small	Large	Pointers
1963	0.651	1.182	-2.065	-3.05	25-Jan	1	1	1
1962	0.512	1.474	0.367	0.47	.	0	0	1
1961	0.047	1.995	1.986	2.77	.	0	0	0
1960	0.047	1.467	-0.145	0.27	.	0	0	1
1959	0.372	1.919	1.219	2.10	.	0	0	0
1958	0.256	1.567	-0.004	3.77	---------	0	0	1
1957	0.143	2.194	1.421	4.02	---------	0	0	0
1956	0.390	1.028	-1.591	-3.13	16-Dec	1	0	1
1955	0.854	1.897	0.437	-1.96	11-Feb	0	0	0
1954	0.425	1.176	-1.030	-4.35	11--Jan	1	0	1
1953	0.400	1.538	-0.192	-1.69	---------	0	0	0
1952	0.475	1.282	-0.600	-2.16	16-Dec	1	0	0
1951	0.525	1.310	-0.433	1.73	---------	1	0	1
1950	0.100	2.051	1.535	4.56	---------	0	0	0
1949	0.103	1.479	-0.166	1.42	1---Feb	0	0	0
1948	0.513	1.640	0.490	0.41	---------	0	0	0
1947	0.658	1.341	-0.668	-1.65	1—Feb	1	0	0
1946	0.568	1.458	-0.189	-0.80	---------	0	0	0
1945	0.083	1.923	1.124	4.52	---------	0	0	0
1944	0.111	1.872	0.707	1.99	---------	0	0	0
1943	0.750	0.699	-1.927	-1.69	5—Mar	1	0	1
1942	0.733	1.855	0.726	0.22	---------	0	0	1
1941	0.033	2.606	1.563	1.19	---------	0	0	0
1940	0.000	2.065	0.481	1.50	---------	0	0	0
1939	0.565	1.905	0.103	-0.47	---------	0	0	0
1938	0.905	1.026	-1.072	0.24	---------	1	0	1
1937	0.500	2.804	1.241	0.19	---------	0	0	0
1936	0.000	1.850	-0.286	-2.52	1---Feb	0	0	1
1935	0.286	2.510	0.665	-0.77	---------	0	0	0
1934	0.643	1.761	-0.400	-1.92	24-Feb	1	0	0
1933	0.308	2.505	0.752	-0.08	---------	0	0	0
1932	0.167	2.240	0.233	-0.32	---------	0	0	.
1931	0.909	0.964	-1.813	0.17	---------	1	0	.
1930	0.909	0.889	-1.377	-1.77	29-Dec	1	1	.
1929	0.273	2.162	0.438	-0.36	---------	0	0	.
1928	0.091	1.283	-0.622	2.85	---------	0	0	.
1927	0.100	2.005	0.431	4.89	---------	0	0	.
1926	0.444	1.279	-0.465	0.63	---------	1	0	.
1925	0.100	1.031	-0.672	-1.92	22-Dec	1	0	.

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