

Exceptional White Pines of Mohawk Trail State Forest, MA with Comparison to Other Northeastern Sites

A Statistical Survey and Personal Perspective

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Named pines, shown left to right: Ouray, Sacajawea, and Saheda
Elders Grove of Mohawk Trail State Forest (MTSF)



Young pines in Stafford Meadow, MTSF

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I. Introduction

The Eastern White Pine (*Pinus strobus*) has a long, distinguished history throughout much of its native range for its economic, ecological, cultural, aesthetic, mythical, and even spiritual contributions. It can be argued that across a span of four centuries no other species in New England and the upper Midwest has been more important. Its economic value gave the species a major role in the lead-up to the American Revolutionary War. The white pine was important in Native American culture, serving as the tree of peace for the Iroquois Confederacy. The ceremonial burying of the hatchet that brought five warring tribes together occurred under the roots of a white pine.

The species has always been recognized for its size and especially for its unsurpassed height, usually being considered the tallest eastern species. Accounts of colonial giants are legendary, with reports of whites reaching 250 feet and more. These largely anecdotal accounts are, in all probability, exaggerations. There is little reliable information suggesting that heights above 220 feet were achieved. Some of the early height estimates occurred before the inch and foot had become standardized. Regardless of its absolute maximum height, in New England and the upper Midwest, chroniclers conveyed a valid picture of the white pine's height dominance over other species. Today, the white pine shares the honor of our tallest eastern species with the lordly tuliptree (*Liriodendron tulipifera*). Presently, it is neck and neck, with the tuliptree holding a slight advantage, courtesy of a tuliptree climbed and tape-drop-measured to the height of 191.9 feet in the Great Smoky Mountains National Park (GSMNP) by arborist Will Blozan of Black Mountain, NC, a cofounder with the author of the Native Tree Society (www.nativetreesociety.org). The Fork Ridge Tuliptree was originally discovered through a LiDAR scan. The original height champion in the East was the Boogerman Pine at 207 feet (located in the Cataloochee District of the GSMNP) until its top broke in an October 1996 early snowstorm.

Today, we are fortunate to have a number of stands of old-growth white pines that serve to remind us of the past glory of the species. Some sites have been extensively studied, such as Hearts Content Natural Area and Cook Forest State Park in western Pennsylvania and Hartwick Pines State Park in Michigan. Other less widely known stands such as the Tamworth Pines in New Hampshire, the *Elders Grove* in New York State, and more recently, Mohawk Trail State Forest in Massachusetts, are locally known but have not received widespread recognition. The best-known white pine sites are sometimes portrayed by authors as all that is left of pines suggestive of what once grew in abundance, i.e. the colonial giants. However, while the handful of iconic sites serve as flagships for the species, what has gone largely unnoticed is the lesser stands, and even more to the point, the maturing of many white pines that are beginning to rival their old-growth counterparts for stature. These maturing pines are often between 100 and 175 years. If we accept an age maximum for the species as between 300 and 400 years, these new contenders are often not even middle-aged.

Who knows about the new challengers? Our late-blooming sites are largely invisible in statistically driven forestry databases, which concentrate on population aggregates and means. It is also safe to say that these maturing natural stands are often located in conservation areas, parks, etc. where harvesting is not allowed.

II. Native Tree Society Measurements

From the early 1990s onward, the Native Tree Society (NTS) has searched for, measured, and documented outstanding individuals and stands of white pines throughout the native range of the species. As a consequence, NTS has extensive datasets on outstanding individual trees and stands of larger white pines. These data are scattered, but are gradually being uploaded to a database maintained by the Virginia Tech Dendrology Lab. In addition, and very importantly, the NTS measurements reflect a very high level of accuracy. This is explained in the appendices.

What has NTS discovered from its measurements of the white pine over the past several decades? In brief, we can say that where the species is left to grow, it is achieving significant stature across much of its native range. This said, the trees of which we speak should not be confused with individual white pines listed in the champion tree registers, national and state. For example, the National Register lists the national champion as a tree in New Hampshire with the following dimensions: circumference 23.25 feet, height 119 feet, average crown spread of 65 feet. However, photographs of the tree reveal it to be open-grown and multi-trunked, hardly fitting the descriptions of colonial giants with trunks free of limbs for 100 feet or more. The New Hampshire champion is not representative of the pines that are the focus of this report. The author is a senior advisor to American Forests on the Champion Tree Program and the coauthor of the *American Forests Tree-Measuring Guidelines Handbook*, an 86-page manual on how to measure champion trees. (See [Appendix I, p. 37 for web address.](#)) So, the distinction between isolated, open-grown pines in big tree registers and stand-grown pines, the subject of this report, will be clearly maintained.

This report was initially conceived to cover the pines in Mohawk Trail State Forest and speak to their significance. However, it soon became evident that in order to make the case for the significance of the Mohawk pines, they would have to be seen in context with what grows elsewhere in Massachusetts and in the Northeast. So before turning specifically to Mohawk, the author would first like to summarize what NTS has confirmed as maximums for the species in 16 states, followed by a selection of outstanding Northeastern white pine sites. With that background, we will then present the Mohawk pines.

It is important to note that some of the confirmations of outstanding individual pines and sites have been relatively recent and often to the considerable surprise of on-site managers. For example, the height champion for New York State is presently 163.9 feet tall. The pine was measured in the fall of 2017. No source known to the author was aware of the pine. When a local Adirondack guide was taken to the tree, he was astounded. Why had he not known? Where do you hide a 13.27-foot circumference, 163.9-foot white pine? Answer: deep in the High Peaks Wilderness of the Adirondacks.

The table on the next page lists the tallest white pine that NTS has measured in each of 16 states. But before presenting the list, the author emphasizes that heights from other than NTS sources are usually not accepted. This needs an explanation.

We have measured dozens of trees submitted by other sources that proved to be in error by from 20 to as much as 50 feet. The sources include amateurs and professionals alike. For example, a white pine quoted as being 193 feet in height and submitted by the Chattahoochee National Forest as the Georgia state champion turned out to be 168 feet tall when measured by Jess Riddle, an ecologist and accomplished big tree measurer. A red maple, submitted by a Michigan big tree hunter, that was the

national champion for years, was listed as 179 feet tall. In fact, it was 119 feet tall as measured by NTS President Will Blozan – a 60-foot height error. But the largest error was of a former national champion pignut hickory in Robbinsville, NC, which was measured by a state forester at 190 feet in height. When measured by Dr. Robert Van Pelt, using an Impulse 200LR laser, the hickory proved to be 123 feet tall, representing a 67-foot error. The hickory is partially open-grown, making exceptional height unlikely. Many other examples could be given.

Table I: Tallest White Pine by State

	A	B	C	D	E	F
	State	Property	Tallest White Pine's Height	Measurers	Measurer's Status	Likelihood of taller tree in state
1	NC	Great Smoky Mountains NP	188.9	Will Blozan	AF National Cadre	Very Low
2	GA	Chattahoochee NF	185.7	Jess Riddle, Will Blozan	AF National Cadre	Very Low
3	TN	Great Smoky Mountains NP	182.0	Will Blozan	AF National Cadre	Moderate
4	KY	Red River Gorge	178.8	Matt Markworth	AF National Cadre	Very Low
5	MA	Mohawk Trail State Forest	176.0	Bob Leverett	AF National Cadre	Very Low
6	SC	Ellicott Rock Wilderness	174.6	Jess Riddle, Bryan Beduhn	AF National Cadre	Moderate
7	PA	Delaware Water Gap	174.0	Elijah Whitcomb	AF National Cadre	Low
8	NH	Private Property, Claremont	170.0	Bob Leverett	AF National Cadre	Low
9	NY	Elder Grove, Adirondack Park	163.9	Erik Danielson	AF National Cadre	Moderate
10	MI	Hartwick Pines SP	161.0	Doug Bidlack	AF National Cadre	Moderate
11	OH	Clear Fork, Mahican River	156.2	Steve Galehouse	AF National Cadre	Moderate
12	WI	Private Site	167.0	Lee Frelich, Paul Jost	UMN	Moderate
13	WV	Private Plantation	155.2	Turner Sharp	AF National Cadre	High
14	ME	Ordway Pines, Norway Maine	152.0	Bob Leverett	AF National Cadre	Moderate
15	VT	Marsh-Billings-Rockefeller NHP	150.0	Bob Leverett	AF National Cadre	High
16	IA	Conservation area	144.0	Mark Rouw	Big Tree Hunter	Moderate
17						
18						
19	Notes	1. Before the tree was broken in a 2018 microburst, the Longfellow Pine in Cook Forest, PA was 184.5 feet in height.				
20		2. Reports exist of a 168-foot tall white pine in Maine. The measurement has not been verified.				
21		3. The reported 202-foot tall white pine in Michigan, shown for a time in the National Register, was mis-measured.				
22		4. The 188.9-foot white pine in NC was originally 207 feet and was the tallest accurately measured tree of any				
23		species in the East.				

These are significant numbers. How do they compare with popular descriptions of maximum heights? One source, the Arbor Day Foundation website, states: *“Likes moist, well-drained soils. Grows 50' to 80' with a 20-40' spread in the landscape, up to 135' or more in the wild. (zones 3-8)”*

Another source, the prestigious *Silvics of North America – Volume I*, states the following:

“Growth and Yield- White pine is a long-lived tree commonly reaching 200 years if undisturbed; maximum age may exceed 450 years. It has a remarkable rate of growth compared to other pine and hardwood species within its range (20). Trees 102 cm (40 in) in d.b.h. and 46 m (150 ft) tall were common in the virgin forests of Pennsylvania,

Michigan, and New England (71). In the "National Register of Big Trees" (54), there are two champion white pines: one in Michigan is 168 cm (66 in) in diameter and 48.2 m (158 ft) tall, and the other in Maine is 173 cm (68 in) in diameter and 44.8 m (147 ft) tall."

For such an otherwise reliable source of information to be so out of date suggests a gap in the understanding of what the white pine is achieving in height growth today, and where.

As a final comment before turning to sites in the Northeast, NTS typically names exceptional trees. This practice helps to emphasize a tree's importance, e.g. the Thoreau Pine. The names are not "official" in the usual context of how names are typically awarded, however, the repeated use of a name eventually gives it official standing.

III. Notable White Pine Sites in the Northeast

1. Cook Forest State Park, PA

In 1994, the author was asked to go to Cook Forest State Park near Clarion, PA to assist in documenting and measuring the white pines in the park. The pine stand in the Cathedral Section of Cook dates to a fire in 1644, and prior to a tornado in the 1950s was said to have pines reaching to 200 feet. Based on our work, we do not consider that claim to be accurate. However, several of the pines that blew down were likely over 170 feet, and possibly one or two reached 180.

The author teamed up with Anthony Eaton Cook, grandson of Anthony Wayne Cook, the original owner, and DCNR personnel. In 1997, DCNR environmental educational specialist Dale Luthringer joined the measurement team. That is when a measurement and documentation project of the outstanding pines in Cook Forest picked up speed. The mission is still ongoing. By 2018, we had confirmed 113 pines to heights of 150 feet or more. There were 5 pines measured to over 170 feet in height with the Longfellow Pine at 184.5 feet, being the 4th tallest known of its species in the East. Then a microburst hit on May 4, 2018 and blew down or broke the three tallest pines. Today, post-microburst, we have around 100 pines over 150 feet remaining, with the tallest now at 170.6 feet and a second at 170.5 feet. The tallest trees are obviously vulnerable to damage by high winds. It is often surprising that they can reach the heights that we find. Beyond their stature, these old-growth trees reach considerable circumferences. There are 11 pines reaching a girth or 12 feet of more (3.82 feet DBH), 60 reaching 11 feet or more (3.50 feet DBH), and 144 reaching 10 feet or more (3.18 feet DBH).

While they were at their maximum heights, the Longfellow (184.5 feet) and Seneca (172.5 feet) pines were climbed and tape-drop-measured by Will Blozan. Will is a veteran climber-measurer who worked with Dr. Steve Sillett in climbing the giant sequoia Presidents Tree. However, our first measurement of Longfellow came in 1997 at an old-growth forest conference at Clarion University, PA. Jack Sobon used his transit to confirm Longfellow at 179.1 feet then. Between 1997 and 2018, Longfellow added 5.4 feet to its crown, representing an annual growth of 3.1 inches. Compare this to the Jake Swamp Pine that added 21 feet in 26 years for an average growth rate of 9.7 inches. The Jake Swamp Pine is less than half the age of the Longfellow Pine, a fact that reinforces the significance of the Mohawk pines as illustrative of today's growth rates.

2. Private New Hampshire Site

A private site in Claremont, NH, has around 60 pines that reach to 150 feet or more. Since the site is privately owned, our access to it for a complete inventory and measurement of the pines is limited. However, a LiDAR measurement shows the tallest to be 170 feet, with another 4 or 5 pines over 160 feet. No other known stand in New Hampshire approaches this one for stature, although the pines are not exceptionally large. Circumferences of 7.5 to 10.5 feet are the rule. Ages are likely between 140 and 180 years. The 170-footer was climbed and tape-drop-measured in 2006 by Will Blozan to 164.7 feet. The tree has grown since at an average rate of 5.7 inches per year.

The area of significant pines is between 20 and 25 acres. This is sufficient to include between 1,500 and 2,000 stems.

3. Hearts Content, PA

Hearts Content is a famous big tree site in the Allegheny National Forest. The site's area is approximately 122 acres. A portion of that, about 20 acres, is home to some immense pines. A Wikipedia description states:

"Many of these trees have [diameters](#) of over 40 inches (102 cm) and heights of over 140 feet (43 m),^[2] and most of the white pine are between 300 and 400 years old."

In fact, a total of 20 white pines have been measured by PA DCNR's Dale Luthringer to over 150 feet with 6 of those exceeding 160 feet. The tallest is 167.2 feet. At one time a quarter of an acre was inventoried as having 50,000 board feet of merchantable lumber. The site currently has the fourth highest concentration of 150s within the Northeast for a site under 2,000 acres, excepting a private property in Wisconsin, which likely has more. Hearts Content boasts 7 pines with girths of 12 feet or more, 12 with girths of 11 feet or more, and 25 reaching 10 feet or more.

4. Adirondack High Peaks

In 2017, the author and companions made a significant tall tree discovery in the High Peaks Wilderness region on Halfway Brook. The author's son was the original discoverer of the site. Thereafter the NTS team of Erik Danielsen, Elijah Whitcomb, and Jared Lockwood successfully confirmed 16 white pines reaching to 150 feet or more with one pine at 163.9 feet, New York's tallest accurately measured tree, and another at 162.9 feet. There is only one other Adirondack site with a pine reaching to 160 feet that we have currently confirmed. There are many sites in the Adirondacks with one or more 150-footers. For example, the *Elders Grove* has 7 or 8. A site near Paradox Lake has one. There is one in Pack Forest, and two in the Pine Orchard. These sites are spread over a huge geographical area and must be treated separately to be comparable to locations like Hearts Content. So far, the largest concentration is the 16 mentioned above. However, we expect there to be many sites with a handful of exceptionally tall pines to be confirmed in 2019. This site has 21 pines reaching a girth of 12 feet or more, a remarkable statistic.

IV. The Massachusetts Contribution

In contrast to old-growth sites like Cook Forest and Hearts Content, PA, in Massachusetts, white pine heights over 150 feet are a recent achievement. In the early 1990s, the author and timber framer friend Jack Sobon of Windsor, MA set out, using a transit, to identify and measure all white pines over 140 feet tall in Massachusetts. We were able to confirm only a handful of sites. While we likely didn't find them all, it is doubtful that the total exceeded 10 across the entire state. It is easy to be confident in this conclusion now because we have a good inventory of tall tree sites and can project current heights back to the early 1990s. Since that time, the number of sites with 140-footers has grown substantially. Within the Connecticut River Valley in Massachusetts, we have confirmed seven pines to a height of 140 feet, though none have reached 150.

At the 140-foot height threshold, there are now 33 confirmed sites and the strong likelihood of at least half a dozen more. The trees on these sites have grown into that height class, a point that will be periodically reinforced. And finally, the number of sites with 130-foot white pines state-wide likely exceeds 100, possibly as high as 125. New sites are continuously being found and existing trees remeasured. For example, Jared Lockwood, an accomplished performer for NTS, measured a white pine in eastern Massachusetts to 136.5 feet. The tree had grown 2 feet in two years from his last measurement, reinforcing the point that many pines are achieving new height thresholds.

But as impressive as these numbers may sound, we should keep in mind that their percentage of the total of mature white pines is extremely small, and the tall trees grow only on highly favorable sites.

As a bit of history, we confirmed our first 150-footer in Monroe State Forest in 1990. It is a huge pine that we measured to 152.4 feet. We named it the Thoreau Pine, and it is doubtful that Thoreau ever saw its equal during his life. Although it has suffered minor crown damage several times, today it is 160.1 feet tall and 13.2 feet in girth. Based on our annual check on new growth, its annual height increase has slowed greatly. We do not expect it to reach 165 feet with 163 feet the more likely upper limit.

The table on the next page shows Massachusetts pines currently reaching the 150-foot threshold.

Table II: Massachusetts Pines Currently Reaching the 150-foot Threshold

Location	# 150-foot tall pines	Tallest tree – ft – as of last measurement	Age Class	Likelihood of more	Other pines close to 150 feet
Mohawk Trail State Forest	145	176.0	130 – 190 years	Very high	Yes
Bryant Homestead	19	162.4	120 - 160	Moderate	Yes
Kenneth M. Dubuque SF	9	159.7	160+	Low	Yes
Ice Glen	6	160.2	180 - 300	Moderate	Yes
TNC-Harvard Forest, Petersham	2	152.8	140	Low	Yes
Monroe SF	2	160.1	180	Very Low	Yes
Monterey	1	150.6	150	Low	Yes
Lincoln	2	151.0	140+	Low	Yes
Catamount SF	1	150.2	??	Low	Yes
Total	187				

As a brief digression, for those who may find conflicting information on the Internet, we emphasize the problem of insuring accuracy. Throughout our quest for tall pines, one factor that has deterred us from accepting otherwise credible sources of data has been the common method of tree height measurement, which often leads to mis-measurements, some substantial. Tree height has traditionally been measured by professionals with tape and clinometer. These tools come from the days before infrared laser rangefinders. The tape and clinometer method has been named the Tangent Method by the author. It relies on a baseline from eye level to the trunk of a tree with angles taken to what is selected as the top and base. To accurately compute the vertical separation between top and base, those points must be positioned vertically over the end of the baseline, otherwise the resulting two triangles are not right triangles – which the clinometer method assumes. With the advent of the laser rangefinder, a method named the Sine Method became possible. A direct distance from eye to target could be obtained. **Appendix I** offers a more detailed treatment of the two measurement methods.

Before concentrating on the Mohawk pines, the author would like to briefly describe an outstanding big pine site in Massachusetts that is virtually unknown.

1. Bryant Pines, MA

The Bryant Homestead in Cummington MA, owned by the Trustees of Reservations, is home to an extraordinary stand of white pines. This site has the highest concentration of trunks over 10 feet in circumference for its acreage that we know of in Massachusetts. Tree ages are between 130 and 160 years. To date, we have confirmed at least 18 white pines to a height of 150 feet or more. The Bryant Pine, named for William Cullen Bryant, is the tallest in the stand and was 162.4 feet at the time of measurement in early May 2019. It will likely make 163 feet by the end of this growing season. It is the only tree within the 18 to exceed 160 feet. The site is characterized by a sand-silt base and receives ample moisture. Its big challenge is to endure ice storms and winds that limit stature. The stand has suffered major ice storms in the past, and although the larger trees received damage, they fared better than smaller trees of many species in the general area.

Presently, Bryant has 4 pines reaching a girth of 12 feet or more with the largest at 13.2 feet. There are 15 pines reaching 11 feet or more, in girth, and 20 reaching 10 feet or more.

The main area of large pines covers approximately 16 acres. Adjacent areas of younger pines add another 5 to 10 acres. Some of the younger pines show weevil damage, but the main area of big trees escaped the weevil.

V. An Overview of Mohawk Trail State Forest

With this introduction, the author turns to the primary purpose of this paper, i.e. to present a statistical summary of the exceptional white pines of Mohawk Trail State Forest. Beyond what the author and colleagues provide, there are no other authoritative descriptions of the Mohawk pines that reveal their exceptional statistics.

We first present an image from Mohawk. This photograph was taken from the north end of the upper meadow looking toward the *Trees of Peace* in the center of the image and in the distance. The *Trees of Peace* is a stand dedicated by Peter Webber, then the Commissioner of the Department of Environmental Management, in recognition of the Native American tribes that passed across the historic corridor now called the Mohawk Trail. The site has 24 pines reaching to a height of 150 feet or more.



Mohawk Trail State Forest (MTSF) is one of the earliest state forests established in Massachusetts. Discussions on its creation began in 1916. It was formally established in 1921. Today Mohawk covers approximately 6,800 acres with elevations ranging from 610 to 2080 feet. A principle distinguishing feature of MTSF is that it and adjoining Savoy Mountain State Forest (SMSF) contain approximately 50% of the known old growth reserves in the state. As a consequence of the Forest Visioning Process, MTSF along with a small part of SMSF, and Monroe State Forest (MSF) comprise a large forest reserve. There is no formal commercial timber harvesting allowed within reserves.

In June 2009, a report was submitted to DCR entitled *Massachusetts Forest Reserves Long Term Ecological Monitoring Program*. It was prepared by the Department of Natural Resources Conservation of the University of Massachusetts. The report presents a detailed discussion of physical features, climate, forest disturbance history, forest types, old growth, and summaries from the Continuous Forest Inventory (CFI). This and other reports presumably were meant to establish the important natural features of the proposed reserves. The report on Mohawk discusses the old growth as an important feature of the region. However, it does not mention the exceptional white pines that grow in several areas of MTSF. These areas feature separate stand developments of 60-80, 80-120, 120-160, and above 160 years. In terms of the forest resource, the acknowledged timber focus of the CFI data leaves an obvious gap in our understanding of where white pines such as those in Mohawk fit into the local, regional, and species-range picture. We fully recognize that it is not the purpose of CFI data to report on

exceptional growth in individual trees or within a stand. However, some official source should. Accordingly, the responsibility for developing full statistical descriptions of the Mohawk pines has been assumed as a role of the DCR Forest Reserves Science Advisory Committee (FRSAC).

The mature white pines in MTSF have achieved exceptional vertical growth for the species within the Northeast. The pines are located in named areas, some of which are small and have only a scattering of stems. Other pines are located in larger areas and exhibit greater stand densities. Before summarizing these areas, it would be useful to present our definition of exceptional height for the species.

Historically, there is evidence that the white pine, on rare occasion, exceeded 200 feet in height with 220 being the maximum. Heights up to 180 feet would have been more common, but still rare. The threshold height for the species stature is often quoted as 150 feet in the distant past, as suggestive of what once grew fairly widely. But with the clearing of the pre-settlement forests and subsequent outbreak of white pine blister rust and attack by the white pine weevil, authors of tree-guides more commonly quoted the species as “up to 100 feet tall.” This maximum height may have been true in the 1950s, but is no longer applicable. As a consequence, we have adopted the 150-foot threshold as representative of what the species can and is achieving over an increasingly wide geographical area.

The following table presents a summary of white pines in Mohawk reaching/surpassing the 150-foot height threshold. As shown in the table, we have confirmed 145 pines reaching the threshold. What is especially noteworthy and deserving of study is that Mohawk has achieved this number mainly within the last 20 years. Before then, there would have been only a handful.

Table III: White Pines in MTSF Exceeding 150 Feet

Named Area	Approximate Acreage	Largest Individual Girth (single stem)-ft	Greatest Individual Height	Same Tree ?	# of 150-159.9 foot tall pines	# of 160-169.9 foot tall pines	# of 170-179.9 foot tall pines	# 150-foot or more
Algonquin Grove	4.0	11.4	168.8	no	12	6	0	18
Campground	8.0	12.5	153.7	no	2	0	0	2
Cherokee-Choctaw	5.2	11.2	158.0	no	6	0	0	6
Cold River	6.8	11.2	152.7	no	2	0	0	2
Elders Grove	1.3	12.2	172.4	yes	9	5	1	15
Encampment	2.3	11.7	152.3	yes	2	0	0	2
Ents	17.1	11.8	158.3	no	22	0	0	22
Frog Pond	2.7	8.1	151.6	yes	2	0	0	2
HQ	3.6	10.2	151.0	no	1	0	0	1
Indian Springs	1.6	12	144.5	no	0	0	0	0
Pocumtuck	12.0	10.4	162.1	no	21	3	0	24
Rachel Carson	2.0	9.9	156.5	no	9	0	0	9
Shunpike	2.2	11.3	157.4	no	6	0	0	6
Trees of Peace	2.3	11.2	176.0	no	20	3	1	24
Trees of Peace -Mast	2.3	11.6	160.5	no	4	2	0	6
Trout Brook	7.0	14.1	155.6	no	5	0	0	5
Tuscarora	1.0	10	156.1	no	1	0	0	1
	Average	11.2	158.1					
Totals/Maximum	81.4	14.1	176.0		124.0	19.0	2.0	145.0

Beyond these exceptional heights, quite a few of the Mohawk pines attain significant trunk volumes. We have volume-modeled these pines, and now regularly employ a ground-based method relying on the following formula.

$$V = \frac{C^2}{4\pi} HF$$

Where V = trunk volume

C = circumference at 4.5 feet (1.37 meters)

H = full height of tree

F = trunk form factor (calculated for some trees and estimated for others)

The trunk form factor can be interpreted as the proportion of a cylinder with basal area equal to the cross-sectional trunk area at 4.5 feet and with height equal to the full height of the tree that is taken up by the trunk. Our many modeling exercises for the species show that this factor varies from 0.333 to around 0.47. Most of the mature pines in Mohawk have factors ranging from 0.39 to 0.436. Young pines are usually between 0.333 and 0.35.

As of the last survey, Mohawk had 8 single-trunk pines reaching a circumference of 12 feet at breast height. Counting double-stem pines, the number rises to 14. Based on what we see across Massachusetts and elsewhere, this is a relatively high count. For example, the well-known Pack Forest in the Adirondacks has only three pines meeting the circumference threshold of 12 feet. Still, there are other white pine sites in the Adirondacks with a slightly higher number, but the trees are older.

As of the last update, Mohawk had 8 pines reaching a girth of 12 feet or more, 28 white pines reaching 11 feet or more, and 77 making 10 feet or more. Note that Cook Forest has 144 pines reaching the 10-foot girth threshold. The Cook Forest pines are over double the age of the Mohawk pines.

The advantage Mohawk gains is that when the great heights of its trees are combined with these substantial circumferences, trunk volumes regularly exceed 400 ft³ and a substantial number exceeds 500 ft³. The following table gives the volumes of the 53 largest pines in Mohawk by volume. There are likely 6 to 10 more that reach 500 ft³.

Table IV: Volumes of Mohawks 53 Largest Pines

Tree Name	Location	Girth	Area	Hgt	Trunk Form Fact	Volume	Volume m ³	Comments
Dave's Double	MTSF-Campground Area	14.80	17.43	150.9	0.390	1025.8	29.0	double
Big Bertha	MTSF-Trout Brook	14.60	16.96	148.0	0.390	979.1	27.7	dead
Massasoit	MTSF-Pocumtuck Grove	14.10	15.82	150.1	0.400	949.9	26.9	double
Nina Leopold	MTSF-Trout Brook West	14.10	15.82	143.0	0.400	904.9	25.6	
Calibration	MTSF	13.30	14.08	158.5	0.400	892.4	25.3	double
Saheda	MTSF-Elders Grove	12.20	11.84	172.4	0.430	878.0	24.9	
Logging Road Double	MTSF-Ents Grove	13.70	14.94	148.8	0.390	866.8	24.5	
Tecumseh	MTSF-Elders Grove	12.10	11.65	165.5	0.430	829.1	23.5	
Hiawatha	MTSF-Trout Brook East	13.20	13.87	143.0	0.400	793.1	22.5	
Andrew Joslin	MTSF-Trout Brook West	13.00	13.45	141.4	0.390	741.6	21.0	double
Jefferson Pine	MTSF-Trout Brook West	12.55	12.53	143.5	0.410	737.4	20.9	dead
Madison Pine	MTSF-Trout Brook West	12.00	11.46	155.6	0.410	731.0	20.7	
Sitting Bull	MTSF-Elders Grove	11.60	10.71	156.9	0.430	722.4	20.5	
Big Boy	MTSF-Campground Area	12.50	12.43	142.5	0.400	708.7	20.1	
Jake Swamp	MTSF-Trees of Peace	10.83	9.33	176.0	0.405	665.3	18.8	
Joseph Brant	MTSF-Shunpike Area	11.30	10.16	157.0	0.410	654.1	18.5	
Crazy Horse	MTSF-Elders Grove	11.40	10.34	150.2	0.420	652.4	18.5	
Encampment	MTSF-Encampment Area	11.50	10.52	150.5	0.410	649.4	18.4	
Indian Springs	MTSF-Indian Springs	12.00	11.46	140.7	0.400	644.9	18.3	
William Commanda	MTSF-Algonquin Grove	10.90	9.45	163.9	0.416	644.6	18.3	
Campground	MTSF-Campground Area	12.10	11.65	141.5	0.390	643.0	18.2	
Wampanoag	MTSF-Elders Grove	11.50	10.52	152.5	0.400	642.0	18.2	
Bear Tree	MTSF-Algonquin Grove	11.20	9.98	153.2	0.416	636.2	18.0	
Jani Leverett	MTSF-Cherokee-Choctaw	11.20	9.98	152.5	0.415	631.7	17.9	
Mirror Pine	MTSF-Trees of Peace	11.20	9.98	156.1	0.405	631.1	17.9	
Paula Horn	MTSF-Trees of Peace	11.00	9.63	155.0	0.416	620.9	17.6	
Frank Decontie	MTSF-Algonquin Grove	10.50	8.77	166.4	0.410	598.6	16.9	
Pooh Pine	MTSF-Trees of Peace-Mast Area	11.50	10.52	141.9	0.400	597.3	16.9	
Trout King	MTSF-Trout Brook West	11.80	11.08	137.5	0.390	594.2	16.8	
Ed Frank Tree	MTSF-Ents Grove	11.10	9.80	154.2	0.390	589.6	16.7	
Totem Trail Pine	MTSF-Cold River	11.30	10.16	144.0	0.400	585.3	16.6	
Sacajawea	MTSF-Elders Grove	10.40	8.61	161.4	0.420	583.5	16.5	
Ouray	MTSF-Elders Grove	10.24	8.34	154.5	0.436	562.3	15.9	
James Monroe	MTSF-Trout Brook	10.90	9.45	143.0	0.410	554.3	15.7	
Unnammed	MTSF-Elders Grove	10.30	8.44	155.2	0.410	537.2	15.2	
Unnamed	MTSF-Trout Brook West	11.10	9.80	140.0	0.390	535.3	15.2	
Oneida	MTSF-Shunpike Area	10.20	8.28	157.0	0.410	532.9	15.1	
Little Hiawatha	MTSF-Trout Brook East	10.70	9.11	144.5	0.400	526.6	14.9	
Lonesome Pine	MTSF-Campground Area	10.60	8.94	142.5	0.410	522.4	14.8	
Moomaw Pine	MTSF-Elders Grove	10.20	8.28	153.1	0.410	519.7	14.7	
Unnamed	MTSF-Algonquin Grove	10.50	8.77	144.2	0.410	518.7	14.7	
Cold River	MTSF-Cold River-at Black Brook	10.20	8.28	152.7	0.410	518.3	14.7	
Campground Cutie	MTSF-Campground Area	11.30	10.16	124.0	0.410	516.6	14.6	
Will Blozan	MTSF-Ents Grove	10.10	8.12	155.1	0.410	516.2	14.6	
Big Boy	MTSF-Pocumtuck Grove	10.40	8.61	146.0	0.410	515.2	14.6	
Hill Pine	MTSF-Algonquin Grove	10.50	8.77	143.4	0.410	515.8	14.6	
Unnamed	MTSF-Shunpike Area	10.70	9.11	144.2	0.390	512.4	14.5	
Ed Perle	MTSF-Algonquin Grove	10.70	9.11	133.5	0.420	510.8	14.5	
Lisa Bozzuto	MTSF-Ents Grove	10.20	8.28	149.0	0.410	505.8	14.3	
Karl Davies Tree	MTSF-Algonquin Grove	10.05	8.04	153.0	0.410	504.2	14.3	
Unnamed	MTSF-Cherokee-Choctaw	10.10	8.12	151.3	0.410	503.6	14.3	
Dave Rich	MTSF-Shunpike Area	10.10	8.12	151.2	0.410	503.2	14.2	
Upper Mast Tree	MTSF-Trees of Peace-Mast Area	10.00	7.96	153.3	0.410	500.2	14.2	
Average		11.4		150.3		640.7	18.1	
					Total ft³	33,956.4	961.5	
					Carbon tons	195.6	177.4	<== metric
					With Limbs	Carbon tons	207.3	188.1 <== metric
					Avg Size	3.4	< === metric tons	

The average volume of these 53 pines is 640.7 ft³. For comparison purposes, the fastest growing 50-year old pine that we've measured (on private property) measures 7.0 feet in circumference at breast height and reaches to 114.0 feet. Its form factor is estimated to be 0.34. This yields a volume of 157.4 ft³. So, what are we to make of these two volumes, i.e. 640.7 and 157.4?

The average age of the Mohawk pines contributing to the 640.7 ft³ volume is around 150 years. Were they all extremely fast growing at 50 years, while their ages increasing by a factor of 3, their volumes were increasing by a factor of 4.1. However, it is more likely that the average volume for these pines at 50 years would have been below 120 ft³ since the 157 is an absolute maximum. Using the 120, the volume increase is by a factor of 5.4 to 1. Admittedly, this ratio does not represent an entire stand, which would contain both dominant and subordinate trees. **Our analysis (to be shown in an upcoming peer-reviewed paper) suggests that for an entire stand on a good site, the ratio of volume increase will more typically range from 2.5 to 3.5 as the stand ages from 50 to 150 years.**

As an independent check on these figures, *Silvics of North America Vol. I (for conifers)* includes the table below. Looking at the column for a site index of 70, if we interpolate to get stand board feet at age 50, we get:

$(14,948 + 32,604)/2 = 23,776$ board feet. At age 100, the amount is 60,845. The age ratio is 2 to 1 while the volume ratio is 2.66 to 1. According to the *Silvics* manual, volume is still increasing at 100 years, though very slowly. That does not appear to be the case in places like Mohawk where rapid growth will likely continue for at least another 50 years.

NEXT PAGE:

Table V: *Silvics of North America – Vol I*

Comparison of Board Feet for Stand Ages of 40 to 100 Years and Site Indexes of 50, 70, and 90

Site index at base age 50 years			
Stand age (yr)	15 m or 50 ft	12 m or 70 ft	27 m or 90 ft

m³/ha

Sawtimber¹

40	108	209	405
60	236	456	-
80	349	674	-
100	440	852	-

Pulpwood²

20	100	137	187
40	247	339	464
60	334	458	628
80	388	533	731
100	425	583	800

fbm/acre

Sawtimber

40	7,729	14,948	28,909
60	16,858	32,604	-
80	24,898	48,152	-
100	31,460	60,845	-

Pulpwood

20	1,423	1,952	2,677
40	3,526	4,836	6,632
60	4,771	6,543	8,974
80	5,550	7,611	10,439
100	6,077	8,334	11,431

¹Volume to a 15 cm (6.0 in) diameter top outside bark- fbm measured using the International 0.25-inch log rule.

²Volume to an 8 cm (3.0 in) diameter top inside bark.

As a further check on stand growth, we established a point-centered plot for an acre of the *Trees of Peace*. We tallied 44 white pines in the plot. Prior to a microburst in July 1989, and counting the remaining stumps, stand density would have been around 50 trees in the acre.

For the 44 pines, we established an average trunk volume of 307 ft³. If we assume 50% of the theoretical board feet are merchantable (percentage is probably a little higher), we have 81,048 board feet (307 x 12 x 0.5 x 44). While Mohawk is in a forest reserve and not open to timber harvesting, it is instructive to recognize the volumes in these unmanaged stands.

Elsewhere in Mohawk, there are scattered acres that will be even higher. In terms of a cluster of pines, the *Elders Grove* is the most impressive. The following table shows the volumes of the 27 pines that make up the *Elders Grove*.

Table VI: Elders Grove Volumes

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	Elders Grove in Mohawk Trail State Forest							Approximate Age of Pines: 175 - 195 Yrs				Percent Vol in limbs			7	Red font = recently measured		
2	Tree	Name	Tag No	Form Factor	Hgt -ft	Circumference -ft	Diameter ft	Vol ft ³	Density - lbs/ft ³	Trunk Mass in Lbs	Trunk Mass in tons	Trunk & Limbs in tons	Proportion of Elemental carbon	Elemental carbon - tons	Cumulative Carbon -tons	Equivalent CO ₂ tons	Cumulative CO ₂ tons	
3	1	Saheda	154	0.43	172.4	12.2	3.88	878.04	24	21,073.02	10.54	11.27	0.48	5.41	5.41	19.84	19.84	
4	2	Tecumseh	160	0.43	165.6	12.1	3.85	829.64	24	19,911.36	9.96	10.65	0.48	5.11	10.52	18.75	38.58	
5	3	Sitting Bull	155	0.43	156.9	11.7	3.72	734.94	24	17,638.62	8.82	9.44	0.48	4.53	15.05	16.61	55.19	
6	4	Wampanoag	158	0.42	152.5	11.5	3.66	674.07	24	16,177.68	8.09	8.66	0.48	4.15	19.21	15.23	70.42	
7	5	Crazy Horse	157	0.42	150.2	11.4	3.63	652.41	24	15,657.78	7.83	8.38	0.48	4.02	23.23	14.74	85.16	
8	6	Sacajawea	153	0.42	161.4	10.6	3.37	606.11	24	14,546.75	7.27	7.78	0.48	3.74	26.97	13.69	98.85	
9	7	Unnamed	165	0.42	152.6	10.3	3.28	541.09	24	12,986.13	6.49	6.95	0.48	3.33	30.30	12.23	111.08	
10	8	Moomaw	159	0.42	153.1	10.2	3.25	532.37	24	12,776.92	6.39	6.84	0.48	3.28	33.58	12.03	123.11	
11	9	Ouray	152	0.4362	154.5	10.24	3.26	562.35	24	13,496.32	6.75	7.22	0.48	3.47	37.05	12.71	135.81	
12	10	Osceola	161	0.42	160.2	9.3	2.96	463.09	24	11,114.22	5.56	5.95	0.48	2.85	39.90	10.46	146.28	
13	11	Unnamed	164	0.42	153.3	9.3	2.96	443.15	24	10,635.52	5.32	5.69	0.48	2.73	42.63	10.01	156.29	
14	12	Unnamed	167	0.42	151.5	9.2	2.93	428.58	24	10,285.82	5.14	5.50	0.48	2.64	45.27	9.68	165.97	
15	13	Unnamed	below trail	0.42	141	9.5	3.02	425.31	24	10,207.44	5.10	5.46	0.48	2.62	47.90	9.61	175.58	
16	14	Unnamed	below trail	0.42	145.2	9.3	2.96	419.73	24	10,073.56	5.04	5.39	0.48	2.59	50.48	9.48	185.07	
17	15	Unnamed	above trail	0.42	129.2	9.5	3.02	389.72	24	9,353.20	4.68	5.00	0.48	2.40	52.88	8.81	193.87	
18	16	Unnamed	at trail	0.42	138.1	9.12	2.90	383.90	24	9,213.70	4.61	4.93	0.48	2.37	55.25	8.67	202.55	
19	17	Unnamed	156	0.42	134.7	9.19	2.93	380.22	24	9,125.34	4.56	4.88	0.48	2.34	57.59	8.59	211.14	
20	18	Unnamed	below trail	0.42	143.9	8.8	2.80	372.45	24	8,938.75	4.47	4.78	0.48	2.30	59.89	8.42	219.55	
21	19	Unnamed	163	0.42	150.5	8.6	2.74	372.03	24	8,928.61	4.46	4.78	0.48	2.29	62.18	8.41	227.96	
22	20	Unnamed	at	0.42	129.3	8.89	2.83	341.54	24	8,196.96	4.10	4.39	0.48	2.10	64.29	7.72	235.68	
23	21	Unnamed	162	0.42	160.1	8.41	2.68	378.46	24	9,083.10	4.54	4.86	0.48	2.33	66.62	8.55	244.23	
24	22	Unnamed	166	0.42	140.3	8.1	2.58	307.66	24	7,383.77	3.69	3.95	0.48	1.90	68.52	6.95	251.18	
25	23	Unnamed	None	0.42	125.4	8.5	2.71	302.81	24	7,267.52	3.63	3.89	0.48	1.87	70.38	6.84	258.02	
26	24	Unnamed	168	0.42	150	7.7	2.45	297.24	24	7,133.84	3.57	3.82	0.48	1.83	72.21	6.72	264.74	
27	25	Unnamed	below trail	0.42	124.7	8.4	2.67	294.08	24	7,057.90	3.53	3.78	0.48	1.81	74.03	6.64	271.38	
28	26	Unnamed		0.42	106	9.3	2.96	306.42	24	7,353.98	3.68	3.93	0.48	1.89	75.91	6.92	278.30	
29	27	Unnamed	below trail	0.42	120.7	7.2	2.29	209.13	24	5,019.07	2.51	2.69	0.48	1.29	75.32	4.73	283.03	
30	sum							12,526.54		300,636.89	150.32	160.84		77.20		283.03		
31	Avg							463.95										

As impressive as these numbers are, it is at the individual tree level that Mohawk's pines achieve their greatest distinction.

VI. A Sample of Mohawk's Outstanding White Pines

1. Jake Swamp Pine

At 176.0 feet tall, the Jake Swamp white pine is presently New England's tallest accurately measured tree, and based on what we've documented, possibly the tallest in the Northeast. It is named after Mohawk Tree of Peace Treaty Chief, the late Jake Swamp, who visited the tree on two occasions. Jake was an international figure who planted trees around the world to promote peace. He would recite an abbreviated version of the story of the rise of the Iroquois Confederacy. The Internet has many descriptions of Jake Swamp and his legacy. One reference follows.

<https://www.thetrackingproject.org/native-communities/remembering-jake-tekaronianeken-swamp/>

The story of the Jake Swamp tree began in 1991 when the author recognized its significant height, but didn't possess the equipment needed to obtain a truly accurate measurement. Timber framer and big tree hunter friend Jack Sobon of Windsor, CT brought a transit to the tree in November of 1992. Through cross-triangulation of the top, we determined its height to be 155 feet above the midslope of its base. Later, the tree was climbed and tape-drop-measured in Nov 1998 by Will Blozan and team. It had reached 158.6 feet at that time. In six growing seasons, it added 3.6 feet for an average annual height growth of 7.2 inches. The Jake Swamp Pine continued to add height and was climbed three more times.

Starting in 1996, we began tracking Jake's height annually using the combination of laser rangefinder for distance and clinometer for angle. The first laser-based measurements used a Bushnell Litespeed 400 and later a Bushnell Yardage Pro and Bushnell 800. We added Nikon instruments included the Nikon Prostaff 440. These instruments have a display accuracy of approximately 1.5 feet. Jake's last climb was in 2001 when we confirmed a height of 163.6 feet. It had increased its growth rate to 8.8 inches per year. This surprised us. In the last few years, the pine has suffered from the needle cast fungus. We expect its upward growth will slow or stop, but so far, it hasn't.

The current height of 176.0 feet was established using an LTI TruPulse 200X, which has an advertised accuracy of +/- 4 centimeters, but is often accurate to +/- 2.5 centimeters to a clear target. As an independent check on Jake's height, Michael Taylor of California, co-discoverer of Hyperion, the world's tallest tree, processed LiDAR data collected in 2015 on the Jake Swamp Pine. Michael got a LiDAR height of 174 feet. This indicates that in three additional years, the tree has grown 0.67 feet or 8.0 inches per year, which is consistent with the tree's growth rate since the 2001 climb. At the end of the 2019 growing season, Jake will be re-measured with an Impulse 200LR, which is slightly more accurate than the TruPulse 200X and has greater precision.

We recently modeled the pine to a trunk volume of 663.6 ft³ using ground-based modeling. Applying a factor of 1.07 to add in limb volume, we get 710 ft³. This equates to 4.10 tons of carbon. DCR Forest biometrician Bill Van Doren applied the Westfall & Scott stem profile model (2010) and got 636.9 ft³. The difference of 26.7 ft³ is only 4% of the author's result. However, a Forest Service carbon estimator gave a trunk volume of only 587.0 ft³. The difference of 76.6 ft³ is significant and suggests that the Forest Service model may underestimate the volume, and carbon, in the bigger trees.

Below is a photograph of the Jake Swamp tree showing its lower trunk. Height measurements are taken to the midpoint of the cavity in the middle of the trunk shown below. Projected to the center of the tree, this is where we judge the seed to have sprouted. It is generally equivalent to a mid-slope position. The 10.83-foot circumference is taken at 4.5 feet above this point. When we began tracking circumference in 1992, Jake's girth was 9.58 feet. This is an increase of 1.25 feet or 15 inches or 0.58 per year. Taken over its life, Jake's average ring width is 0.129 inches or 7.7 rings per inch.



We do not advertise the location of the Jake Swamp Pine to the public. Its protection is a high priority. However, in 1994 when DCR's forerunner, DEM, had given permission to choose a pine to replace a broken mast of the schooner *Ernestina*, this pine was a candidate. The author discovered an orange ribbon on the tree. Informing the supervisor of the tree's significance led to the removal of the ribbon. It became obvious to the author that the significance of the Mohawk pines to all parties needed to be better understood.

In order to more accurately determine the volume of the Jake Swamp Pine, Will Blozan and team climbed the tree in 2004. The effort involved taking circumference measurements at intervals of a yard. Each interval was modeled as the frustum of a right circular cone. (See **Appendix I: Tree Height & Diameter Measurement Routines.**) The last 20 feet were modeled as a complete cone.

As a side issue, three other outstanding pines in MTSF have been climbed and volume modeled: (1) the Joe Norton Pine, (2) Saheda, and (3) Tecumseh. However, now with our superior ground-based equipment, including terrestrial LiDAR, there is no longer a need to climb these trees to get accurate data.

The photo on the next page was taken on the last climb made of the tree, where we see people, including DCR officials, standing by. The image reveals more of the tree's long straight trunk. The taper is obviously slow, which accounts for the form factors of 0.4 and above for these mature pines.



2. Saheda

One of the most impressive white pines anywhere in the Northeast is located in the *Elders Grove*. Its name is Saheda, after a Mohawk Elder who was killed by the Pocumtucks in the late 1600s over the beaver trade. Saheda had been sent on a mission of peace. His death unleashed a war between the Mohawks and Pocumtucks that led to the destruction of Pocumtucks as a functioning tribe.

The Saheda Pine is huge. At 172.4 feet tall, it is New England's second tallest accurately measured tree. The pine measures 12.2 feet in circumference, and as of our last reticle modeling, we place Saheda's volume at between 860 and 890 ft³. Near the top, the tree splits into two trunks and is extremely difficult to measure from the ground. Saheda has been climbed and tape-drop-measured twice. In 1998, it was measured to 158.3 feet in height by Will Blozan, only 0.3 feet behind Jake Swamp. Using LiDAR, Michael Taylor got 172.0 feet for the tree, a close match to the 172.4 feet obtained by two separate measurers using different instruments, though both were TruPulse 200Xs.

Saheda's girth in 1998 was 11.3 feet. As mentioned above, today it is 12.2. This works out to the addition of 11.6 annual rings per inch between 1998 and 2018. For a tree Saheda's age, this is fast growth.



If we take the more conservative measurement of 860 ft³ and add 7% for limbs, we get 920 ft³. This corresponds to approximately 5.3 regular tons of carbon. Assuming Saheda grew fast in early years, a likely trunk volume at 50 years would have been between 100 and 120 ft³. Assuming 120 ft³ and allowing for an additional 7% for limbs, we get 128.4 ft³. Based on a core from a nearby pine, we believe that Saheda is now between 180 and 190 years old. Assuming 190, its age has increased by a factor of 3.8 from age 50. During this time, its volume has increased by a factor of 7.2. This illustrates the growth capability of the dominant pines over a period of 200 years. The bigger trees can perform spectacularly.

As a brief digression, the lesser pines of the *Elders Grove* do not show such a dramatic increase in growth beyond 50 years. There are 27 large white pines that constitute the grove. A past stand-based modeling of these pines led to a cumulative above-ground carbon load of 77.7 regular tons. This represents an average of 2.85 tons per tree. If we assume an average of 100 ft³ (probably slightly high) of trunk and limb volume at age 50, we get 0.58 tons per tree. This yields a ratio of 4.45 to 1 in terms of carbon at 50 years versus 190. This compares to the age ratio of 3.8 to 1, and suggests that at the stand level, the larger, older pines are still performing well in terms of sequestration. However, the density would have been much greater at 50 years. Offsetting, at least partially, loss of the early pine density is the growth of other species filling in the space between the pines. Estimating the total amount of carbon at a stand age of 50 years relative to the current amount requires more analysis. The replacement trees are denser, but slower-growing hardwoods. Additionally, to get a complete picture, the below-ground carbon needs to be included, but this is beyond the scope of the author's present measuring capability.

3. Lee Frelich Pine

Dr. Lee Frelich, Director of the University of Minnesota's Center for Forest Ecology, is also the Vice President of Friends of Mohawk Trail State Forest. The author named a tree for Lee in appreciation for his contribution to our better understanding of the ecology of Mohawk Trail State Forest. We chose a tree growing in the *Algonquin Grove* that represents the maximum height growth achievement within the grove. The stand is approximately 140 years old and named in honor of Frank Decontie, an Algonquin elder from Canada who became an advisor to Friends of Mohawk Trail State Forest. He has a separate tree named for him in the stand.

Lee's tree, also named the Algonquin Pine, is 168.8 feet tall and a relatively slender 9.2 feet in girth. Its trunk and limb volume is slightly less than 500 ft³.

The Lee Frelich Pine is one of six in the stand reaching a height of 160 feet. The center of the stand is crowded and individual tree size is smaller. However, the density compensates for the smaller tree size and the actual stand volume is slightly greater than that for the *Trees of Peace*.

In the next image, we still see the remaining limbs on the lower trunk. The other pines in the immediate vicinity are fairly densely packed, generating a basal area of around 300 ft²/acre. Most of the intact pine stands in Mohawk have a basal area of 220 to 320 ft² per acre. As they self-thin, the dominants speed up their growth.



Lee Frelich Pine

4. Crazy Horse Pine

The next image shows former Vice President for Communications of American Forests Lea Sloan next to the Crazy Horse Pine. Lea was on a visit from American Forests' Washington D.C. HQ to see what the author was making all the fuss about. Its dimensions are: circumference 11.4 feet, height 150.2 feet, trunk volume 652 ft³ (43.5 inches DBH). The significance of this large pine is that it was named for Chief Crazy Horse of the Oglala Lakota at the request of Chief Arvol Looking Horse, carrier of the Nineteenth White Buffalo Calf Peace Pipe of the Lakota Nation.



Crazy Horse Pine

5. William Moomaw Pine

The next image shows Dr. William Moomaw, professor emeritus, Tufts University, next to a pine in the *Elders Grove* that NTS named in his honor for his outstanding work on climate change. Through Bill's role as Chair of the Board, we escorted scientists from the distinguished Woods Hole Research Center through the *Elders Grove* to give them an opportunity to directly assess the effectiveness of the older big tree white pine forests at continuing to sequester carbon. While young trees grow faster on a percentage basis and rapidly accumulate mass, and therefore carbon, between the ages of 20 and 50 years, the annual volume increase of the bigger trees exceeds that of younger ones even though the percentage increase is very small. The big pines in Mohawk demonstrate this clearly. However, it becomes a tradeoff between individual tree size and stand density as to how long pines continue effective sequestration. Some sources claim 100 years as approaching the limit. But heretofore, carbon models have tended to underestimate volume increases of the larger trees growing on locations with high site indexes.



Bill Moomaw Pine

6. Chuck Bellows Pine

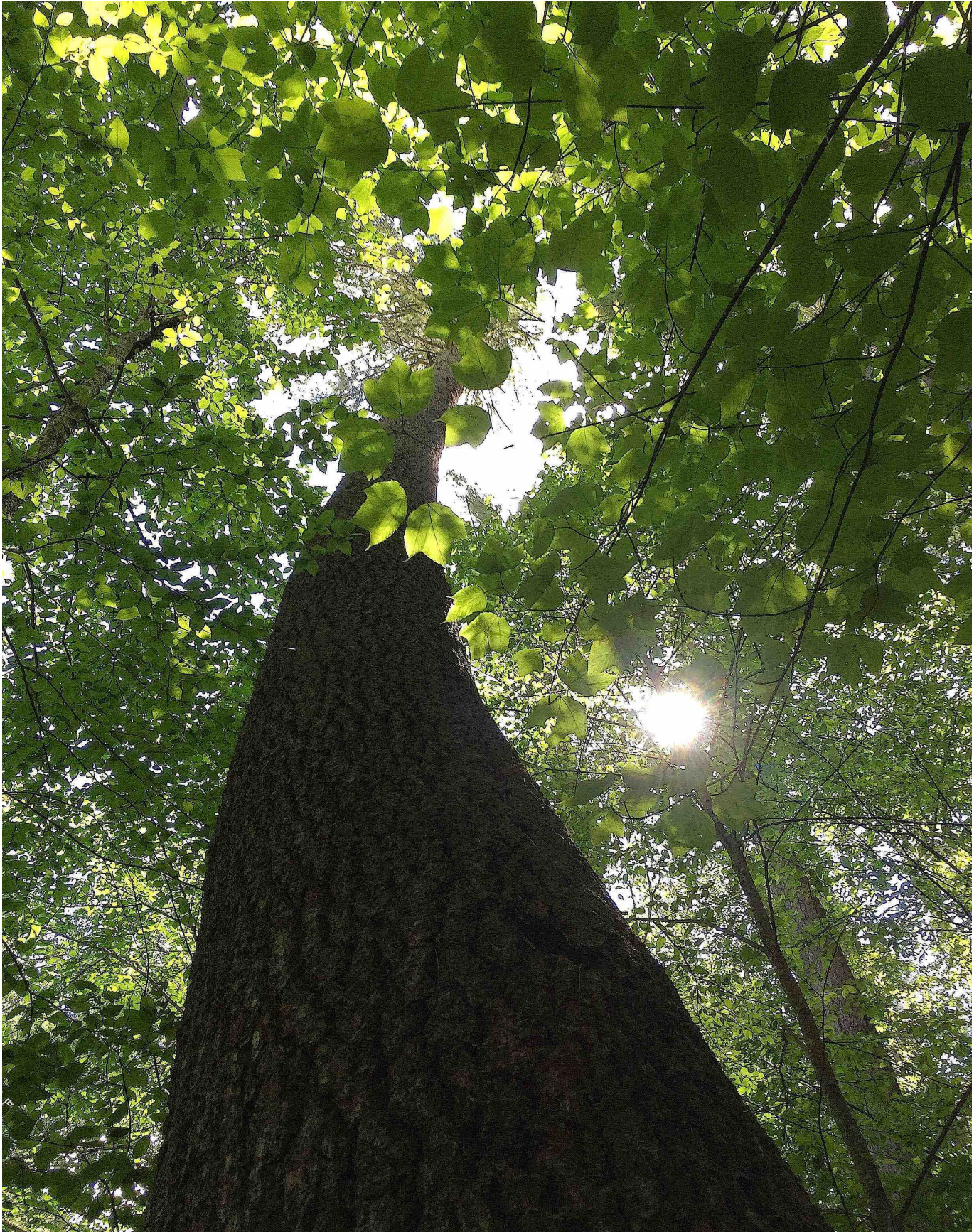
This image honors MTSF park employee, Charlemont, MA policeman and city councilman, and good friend of the author, the late Chuck Bellows, who was an outstanding proponent for the park.

This image reveals a photogenic sub-canopy of the highly reflective leaves of striped maples. Above that is the main canopy, which often includes red and sugar maple. Above the main canopy, the white pines create a super canopy.

In 2015, the author measured Chuck's pine to the dimensions: circumference 8.6 feet and height 150.5 feet. Based on its trunk taper, the pine's trunk probably contained at least 350 ft³. The tree will be re-measured after the current growing season. At the time of measurement, the pine's crown was very thin (as seen in the image), presumably from the needle cast fungus. Since then, the tree has rebounded somewhat, but is probably still in trouble.

As a digression, there have been six striped maples in MTSF measured to heights of over 60 feet with the tallest at 68. This small understory species is usually described as reaching heights of 25 to 45 feet. However, in mature forests where striped maple grows under a canopy of much taller trees, heights of 50 feet and occasionally 60 are not uncommon. We become accustomed to younger woodlands as the norm and can lose sight of what a species can achieve when left to mature.

As an example, over the last 15 years, when averaging the tallest member of each of the ten tallest species in MTSF, we get a range of from 134 to 136 feet. We call this average a site's Rucker Index after NTS icon, the late Colby Rucker of Maryland.



Chuck Bellows Pine

7. Bruce Kershner Pine

The next image shows a special tree to the author. The late Bruce Kershner was coauthor with Robert Leverett of *The Sierra Club Guide to Ancient Forests of the Northeast*.

Bruce was an ardent conservationist and worked hard to get recognition for our remaining old-growth forests in the Northeast. Today the *Bruce Kershner Old-growth Forest Preservation and Protection Act* is a law on the books in New York State and reflects Bruce's dedication to preserving old-growth forests in the Empire State.

Bruce was instrumental in getting the author involved with searching for old growth in New York State. His discovery of the Zoar Valley old-growth site changed our view of what a number of species could achieve growth-wise in upstate New York.

On behalf of NTS, the author named the pine in the following image for Bruce. When last measured in 2010, Bruce's pine measured 151.2 feet in height and 9.5 feet in girth.

In the following image, Bruce's pine is framed on the left by a yellow birch and on the right by a black one. Young hemlocks add to the woodland ambience. Logs accumulating on the ground suggest the surrounding area is returning to a more primitive and natural condition. It is just this kind of forest setting that Bruce valued and spent so much of his life protecting.

As a final commentary, higher on the ridge above and south of Bruce's pine grows a black birch dated by Dr. Tony D'Amato to an age of 332 years. Tony's study was conducted under the supervision of his academic advisor Dr. David Orwig of Harvard Forest, who has visited and studied all the Massachusetts old-growth sites. In the view of the author, the level of academic excellence committed to the study of MTSF's old-growth sites now needs to be turned to better understand the ascendancy of Mohawk's exceptional white pines.

The proximity of the old growth above and large pines below provide us with a range of values from the ecological to the highly aesthetic. It is for such reasons that the author coined the title *Forest Icon of Massachusetts* to describe MTSF.



Bruce Kershner Pine

VII. Aesthetics and Other Values of the Mohawk Pines

Across the years, the author has borne witness to the visual impact of the Mohawk pines on visitors. These trees have long passed their ugly duckling stage, and today they present a regal, statuesque appearance that suggests a landscape of the past.

The next image seeks to capture the feel of the Mohawk woodlands. Large white pines mix with other tree species and a shrub layer of mountain laurel to dispel an appearance of a heavily managed woodland. Since MTSF is a designated reserve, it affords us an opportunity to monitor how an exemplary forest deals with forest pathogens and climate change. It gives us a baseline to compare what is happening in Mohawk with less resilient forests.



The next image captures the aesthetic quality of Mohawk's mix of pine, hemlock, and mountain laurel. The lineup of attractive mature pines suggestive of what the British Navy so coveted stands in sharp contrast to the same pines at an earlier age when still supporting dead lower limbs. These three handsome pines are all over 140 feet in height, joining over 300 others reaching that height threshold.



The final image shows the Council Pines, as we call them. These trees are part of the research population, as shown by the shiny metal tags at their bases. The Council Pines still have lots of limb whorls, and we estimate the stand to be about 120 years old.



VIII. Conclusion and Other Information

Mohawk Trail State Forest has a population of extraordinary white pines, mostly in the age range of 100 to 200 years, that shows us what the species can achieve today growth-wise on good sites. With 145 pines having been measured to the height threshold of 150 feet, these pines are noteworthy for that accomplishment alone. In fact, this statistic is number one in New England, and possibly the Northeast -- not something either professionals or amateurs would have predicted. The author is disinclined to claim the whole Northeast because of recent big pine discoveries in New York's vast Adirondack Park. However, for a property the size of MTSF, the probability of a site with a greater number of white pines surpassing 150 feet is small. The big sites do stand out and now with LiDAR available on finer levels of resolution, new discoveries will likely be limited to smaller stands and individual trees.

Beyond their heights, over the last 25 years, the Mohawk pines have achieved significant size and are continuing their absolute volume growth. The largest pines now contain almost 1,000 ft³ in trunk and limbs volume, with 52 having been modeled to 500 ft³ of trunk volume. When the entire Mohawk-Savoy Mountain-Monroe Forest Reserve is considered, the number of exceptional pines increases further. The Grandfather Pine in Monroe has been volume modeled to 1094 ft³ in its trunk and is one of the largest half dozen single-stem white pines we know of in the Northeast. The trunk of the state champion Thoreau Pine in Monroe has been modeled to a volume of 986 ft³.

Beyond being statistical curiosities and providing us with big tree trivia, do these mature white pine sites have greater significance? Our data support the hypothesis that the sites contribute to climate mitigation, and perhaps, should give us pause to reflect on strategies to keep sequestration high in the species. Outside the forest reserves, this does not rule out silvicultural treatments to enhance sequestration, but not the short-term economic prescriptions that have been the reigning paradigm.

Standard forestry data collected via the FIA and CFI programs do not capture the information needed to profile the big Mohawk white pines. From growth rates to volume determinations and carbon sequestration, to ground-truthing other statistical methods and LiDAR, accurate on-the-ground measurements, as described in the appendices, are invaluable. Utilizing the expertise of NTS and the Champion Tree Certification Cadre (established to assist American Forests in measuring national champion trees), DCR's FRSAC has stepped in to fill the gap. A lot remains to be done.

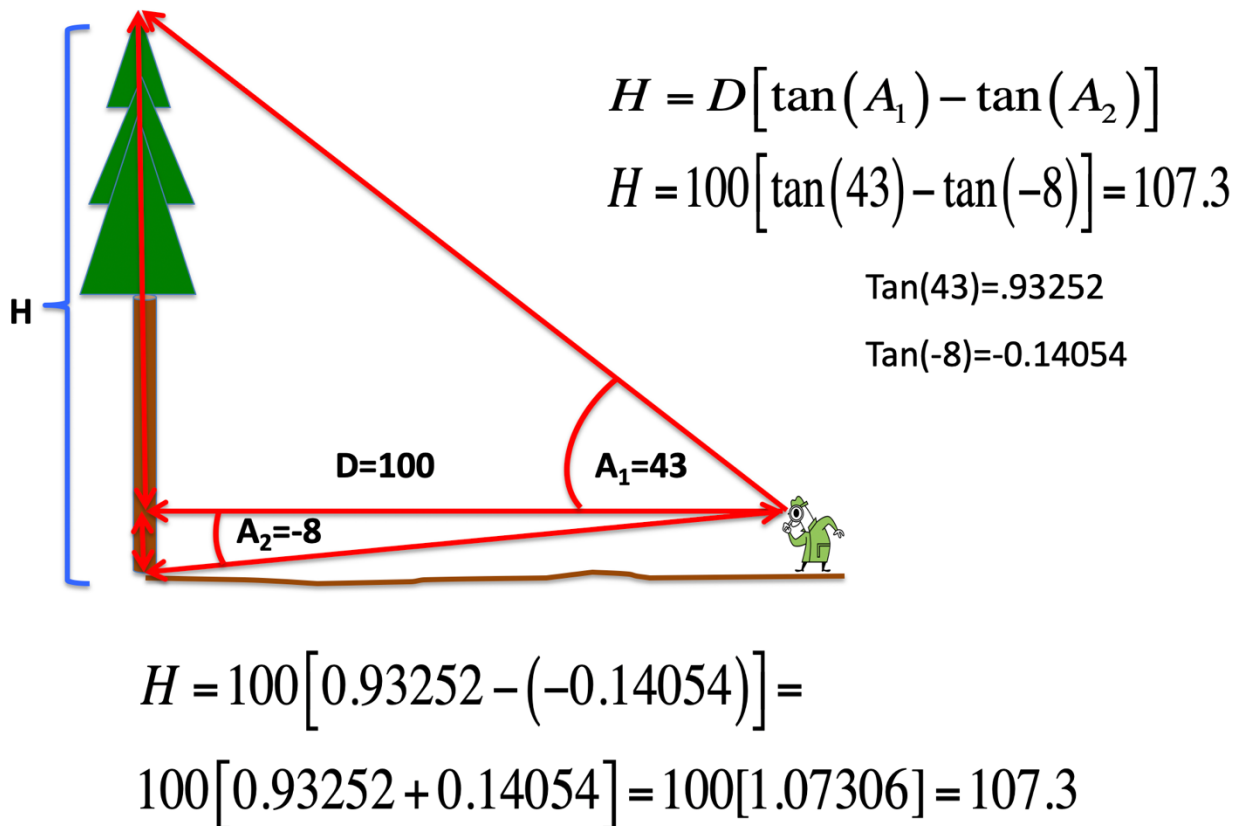
MTSF has long been a popular camping destination. Its principal attractions have been its proximity to the Deerfield and Cold Rivers, its hiking opportunities to scenic spots on Todd and Clark Mountains along the old Indian trail, its rich Indian history, and more recently, its abundance of old-growth and mature second-growth forests. Until recently, Mohawk's other natural treasure, its champion white pines, had gone unrecognized. The pines have considerable ecological value and serve us well as a carbon reserve -- one that continues to grow. But for visitors seeking a woodland experience, the value of the great trees goes beyond their impressive physical dimensions. Walking among them along the Mahican-Mohawk Trail, through the *Algonquin Grove*, one has a sense of reconnecting with New England's rich historical past, both cultural and natural. The author coined the phrase, *The Forest Icon of Massachusetts*, and given the statistics presented in this report and its observable impact on visitors, Mohawk Trail State Forest has earned the distinction.

Appendix I: Tree Height & Diameter Measurement Routines

Accurately measuring the height of large, asymmetrically shaped trees is not as easy as the instructions accompanying clinometers and popular hypsometers would suggest. There are three common ground-based tree-height measuring methods that we commonly use today: (1) Tangent Method, (2) Sine Method, and (3) Sine-Tangent Method. The American Forests Champion Tree-Measuring Guidelines Handbook (https://www.americanforests.org/wp-content/uploads/2014/12/AF-Tree-Measuring-Guidelines_LR.pdf) discusses these methods and what can go wrong with them.

1. Tangent Method

The Calculations

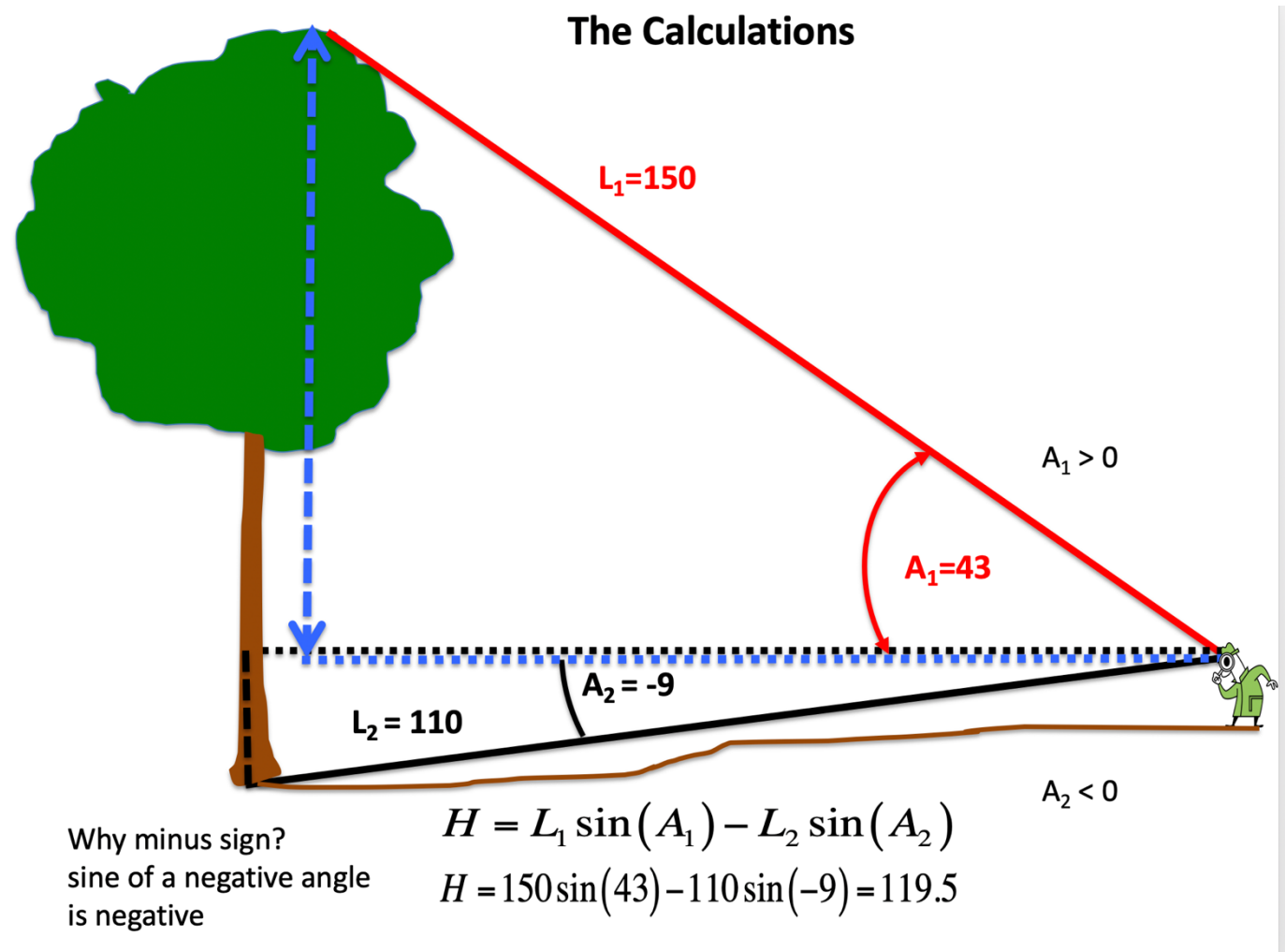


The tangent method has been the bread and butter tree-height routine used in the field by forestry professionals. It is most often implemented with a tape and clinometer. Modern laser-based hypsometers usually implement the method as a three-shot routine: (1) level distance shot to the trunk, (2) angle to the base, and (3) angle to the top. The instrument returns the height. However, if the straight line connecting the top and base is not vertical, an error occurs unless the measurer can position himself/herself so that the distance of the line to the trunk equals the distance to the spot at eye level vertically beneath the target, which is the true baseline. A horizontal offset distance between base and

top frequently happens when the measurer is too close to the tree to see the actual top and hits the end of a branch. But regardless, if the top being measured is horizontally offset from the base in the direction of measurement, an error will occur.

In confirming national and state champions, the author and colleagues have corrected numerous tangent-based errors, often over 20 feet, and in extreme examples, much more. There are compensations for crown-to-base horizontal offset errors. The author has developed several, but none works well in a closed canopy hardwood forest with tall, broad-crowned trees.

2. Sine Method

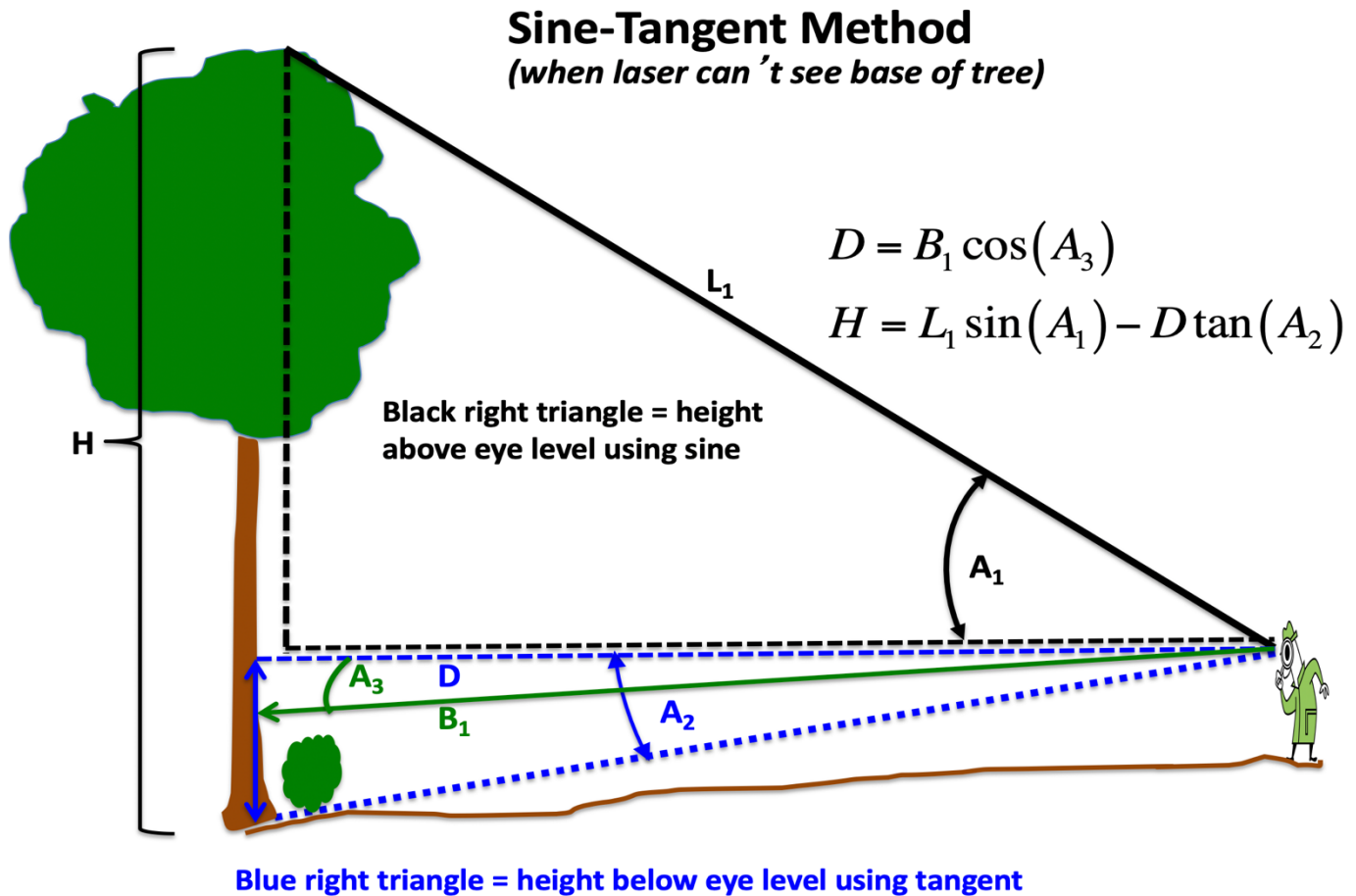


This is the NTS and American Forests preferred method for measuring the height of a tree. Crown-to-base horizontal offset distances do not affect this method.

The challenge with this method is to hit the desired target with a laser beam in a densely cluttered forest. Hypsometers with gate functions allow returns out to a prescribed distance to be ignored. Up to a point, this enables the laser basically to see through the clutter. Distant canopy targets can be hit more easily, but ground based clutter often entirely obscures the base. The measurer can move in

incrementally using a pole and prism. This latter technique is absolutely necessary in the redwood forests. Michael Taylor has perfected the method. However, there is no substitute for experience.

3. Sine-Tangent Method



Method #3 is used almost as much as Method #2 because the horizontal offset of the lower trunk is usually minor to negligible, and attempting to apply the Sine Method in a cluttered understory can be extremely time consuming. Combining the Sine Method for the component of tree height above eye level with the Tangent Method for the part below is the ideal compromise.

4. Diameter Measurements

Volume modeling from the ground requires that diameter measurements be taken at points up a tree's trunk. A laser rangefinder and a monocular with range-finding reticle are used to measure diameter at a distance. The following formula is employed:

$$W = \frac{MD}{F - 0.5M}$$

Where M = reticle reading

D = distance from monocular to middle of the front of the tree in line with the diameter to be measured

F = manufacturer's reticle factor

W = width (diameter) of trunk at the desired point

Diameters of noncircular trunks and sections of limbs at any orientation can be measured with a monocular with range-finding reticle using the following formula:

$$W = \sqrt{\left(\frac{1}{M^2 + 4F^2}\right) (M^2(L_2 + L_1)^2 + 4F^2(L_2 - L_1)^2)}$$

W = width or length of target

M = reticle reading

F = manufacturer's reticle factor

L₁ = distance to closest end of target

L₂ = distance to farthest end of target

This method requires hitting the ends of the target with a laser, which can be difficult, but provides the measurer with an extremely flexible technique that does not place constraints on the shape of the target.

The height of each point above the tree's base can be measured with a hypsometer so that the vertical distance between consecutive trunk points represents the height of a geometrical frustum, usually conical. The diameters of top and base of the frustum and its height are used in the following formula to compute the conical frustum volume.

$$V = \frac{H}{3} \pi (r_1^2 + r_1 r_2 + r_2^2)$$

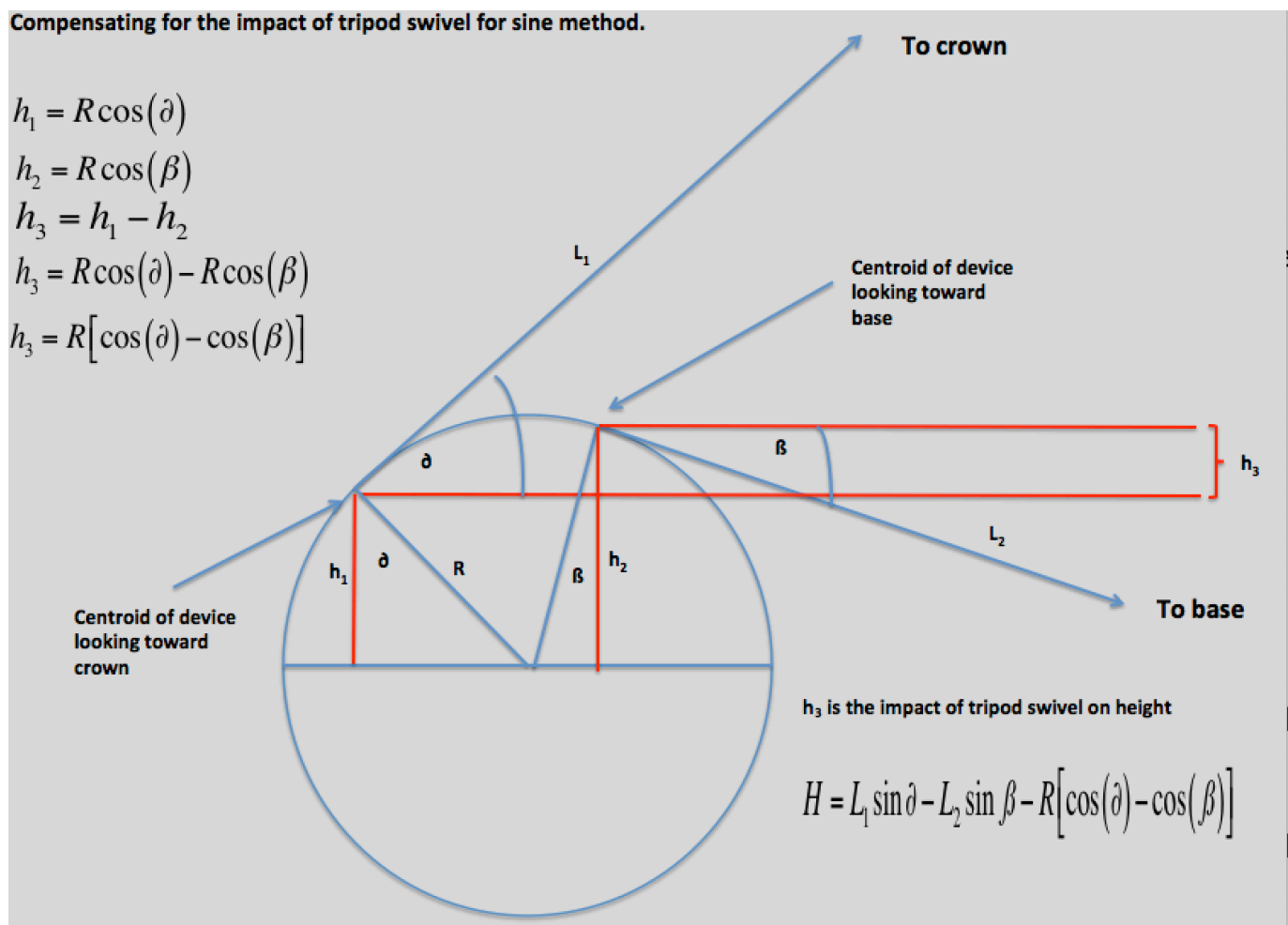
If the frustum is long, e.g. over 10 feet, instead of conical, we may employ a paraboloid or neiloid frustum, using our judgment of the taper.

5. Equipment

Accurate modeling of the Mohawk pines has required the use of precision equipment. The following is a list of instruments that we commonly use.

1. LTI TruPulse 200X
2. LTI Impulse 200LR
3. LTI TruPulse 360
4. LTI TruPoint 300
5. Nikon Forestry Pro
6. Nikon Prostaff 550
7. Bushnell Legend Ultra HD 10 x 42 monocular with range finding reticle
8. Vortex SOLO R/T 8 x 36
9. Bosch GLR 825 (used to check on the accuracy of the infrared laser measurers)
10. Bosch GLM 80 (used to check on the accuracy of the infrared laser measurers)

Hypsometers are set on a tripod for stability and accuracy. If it is a typical photographer's tripod, with a swivel arm, shooting to the top and then to the base moves the centroid of the hypsometer, introducing an error. The following diagram shows how to correct for swivel errors. The diagram is taken from the author's impending guide, *Dendromorphometry*, being written with coauthors Dr. Robert Van Pelt and Dr. Lee Frelich.



6. More

Geographical coordinates and photographs are taken for each measured tree. If the tree is especially important, a photograph is taken of the crown with an arrow pointing to the top.

Other instruments used in documenting the pines of MTSF included an LTI RD1000 dendrometer, a standard D-Tape, several clinometers, and an iPhone with a variety of apps.

7. Carbon Assessment

This report is primarily dedicated to showcasing the MTSF white pines, but the author would be remiss if the role of individual stands like the *Trees of Peace* were not better presented in terms of a biomass assessment. How much above ground live biomass can we account for and how does it compare to that attributed to mature and old-growth white pine stands elsewhere? In a study currently underway by the author and a coauthor, we measured the above ground live biomass to 189 short tons in a *Trees of Peace* plot equaling one acre. In a study entitled

Long-term structural and biomass dynamics of virgin Tsuga canadensis–Pinus strobus forests after hurricane disturbance by Anthony W. D’Amato,^{1,5} David A. Orwig,² David R. Foster,² Audrey Barker Plotkin,² Peter K. Schoonmaker,³ and Maggi R. Wagner⁴

I came across this statement: *average live-tree biomass over the contiguous portion of Transect A where white pine was most abundant (367 Mg/ha; distances 110–150 m) approach maximum values reported for other old-growth forest systems in northeastern North America (Woods 2014).*

Converting 367 Mg/ha to short tons/acre yields 188.7 tons. The author finds the agreement between the two calculations to be striking. But to be thorough, the paper quotes figures as high as 735 Mg/ha. The 367 figure applies to sites where white pines dominate, which corresponds to the *Trees of Peace*.

8. Summary

With the introduction of the infrared laser rangefinder, the challenge of getting accurate height measurements for trees with broad crowns where the highest top is not vertically centered over the base, has been considerably ameliorated. The sine method allows experienced measurers to correctly measure the vertical separation between the highest point and the base regardless of where those points are located in three-dimensional space. Combining the sine and tangent methods provides measurers with an effective solution to dealing with clutter around the base of trees.

In addition, measuring diameter aloft became relatively easy by using the combination of a laser rangefinder, a monocular with range-finding reticle, and the correct mathematical formula. These advances allow us to volume-model the trunks and limbs of trees to a higher degree of accuracy than can be obtained by applying statistically based tools at the landscape level.

Appendix II: Remeasurement of Jake Swamp Pine

On May 26, 2019, the author remeasured the Jake Swamp Pine prior to most of the season's new growth. The flushed tip of the leader affords a good early target. Measurements to the top were taken with an LTI Impulse 200LR that has been tested for accuracy to strongly visible targets. Industrial class 2 lasers with rated accuracies to ± 1.0 to 1.5 millimeters were used for comparison. The Impulse's infrared laser proved accurate to ± 1.5 centimeters. The base on the uphill side was measured with an LTI TruPulse 200X, which was also tested for accuracy. Results were within ± 2.5 centimeters. Tilt sensors of both instruments are accurate to between ± 0.1 and ± 0.083 degrees.

The measurements obtained for the Jake Swamp Pine on May 26 are given in the table below.

Measurement	Value
Slope Distance-Top	201.75 ft
Angle -Top	38.63 degrees
Height Above Impulse Centroid	125.95 ft
Slope Distance-Upper Base	165.2 ft
Angle-Upper Base	-17.1 degrees
Height Below Centroid	-48.57 ft
Mid-slope offset	-1.7 ft
Total Height	176.2 ft

Last year's height at the end of the growing season was 176.0 feet as shown in the main body of the report. As of May 26, the topmost leader had started to put on visible growth. So, the 176.2 feet is a reasonable result. The end-of-season growth will likely be 176.5 feet or possibly more.

As an independent check on the new year's growth, the monocular can be combined with a high-performance instrument like the Impulse 200LR to measure the height of the new candle. Repeated tests on the monocular indicate that at the distances we are dealing with, we can measure new growth to \pm one inch. On close targets, repeatable accuracy is on the order of ± 0.25 inches within confidence limits of 90%.

The appendix will conclude with two images of the Jake Swamp Pine.

The first shows the pine's top in a 2016 image. The top is regularly photographed to track individual candle growth and the number of competing tops.



Over the course of the 27 years of tracking the Jake Swamp white pine, many DCR officials have participated in the observation and documentation of the tree's measurements. It may not be a stretch to claim that outside of research trees that are wired, this pine may be the most measured tree in the Commonwealth.

The last image shows DCR nature interpreter Kristen Mabey who recorded the results of the May 26, 2019 measurement.

