Analysis and Preservation Recommendations for Resurrection Tree

Prepared for:

Franklin First United Methodist Church
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Prepared by:

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Certification

I, Martin A. Shaw, certify that:

- The works of this report are my own, and I have no ownership or prospect of ownership in the subject property of this report, although I am a member of Franklin First United Methodist Church.
- The conclusions are accurate within the report scope.
- The contents of this report are both independent and objective, being free from outside influence or conflicts of interest.
- No contingency fees were paid, offered or agreed upon, by any party in lieu of any outcome or conclusion contained within this report.
- I am a member in good standing of the International Society of **Arboriculture**[1] (**ISA**).
- I am a Registered Member of the American Society of **Consulting Arborist**s (**ASCA**).
- I am an **ISA Board Certified Master Arborist**®[2] .
- I am a licensed, bonded, insured and chartered TN Commercial Pesticide Applicator.
- I am a licensed TN pesticide dealer.
- I am a certified TN nursery plant dealer.
- I am an FAA licensed and insured drone pilot.
- All significant professional assistance used in the preparation of this report are disclosed within.
- The observations, methods, analysis, discussions and conclusions are prepared according to the scientific method, and commonly accepted arboricultural practices including, but not limited, to those professed by the International Society of Arboriculture, the American Society of **Consulting Arborists,** the **ISA Board Certified Master Arborist**® Code of Ethics, and the **ASCA Standards** of Professional Practice (Abyta 1995, Keefer 2004, ASCA 2011, and International Society of Arboriculture, 2010)[3]

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[1] Words in bold type may be found in the Glossary appendix. (ISA 2013)
[2] ISA Certified Arborist is a registered trademark of the International Society of Arboriculture.
[3] References may be found in the Bibliography appendix)

Summary

The Resurrection **Tree** is growing on a nearly ideal site for the health, **vigor** and sustainability. The Resurrection Tree exhibits extensive signs and symptoms of decay from white, brown and soft rot type fungi. Brown rot has caused extensive internal decay of the **buttress** and the lower portion of buttress roots. This decay very likely extends to some of the structural roots beyond the main buttress roots. The cavity of the Resurrection Tree is completely dissolved at the base and extensive. The buttress decay has left a solid shell of sapwood and some heartwood that is at least a foot thick around the trees circumference just inside the tree's **bark**. The wood is both elastic and strong as measured with the Resistograph tests and the fractometer test. The callus **tissue** on both sides of the cavity opening is also well developed.

The Resurrection Tree has extensive decay and is in a **stressed** and substantially weakened state. As such, its energy reserves are low and its ability to defend itself against the extensive decay is compromised. Fertilization of the tree would only exacerbate this condition and cause even more aggressive deterioration of the healthy woody tissues and would cause other effects detrimental to the health of this tree and should be avoided. There are measures that would help increase the Resurrection Tree's uptake of micro-nutrients that already exist in the soil and this would help the tree defend against decay. These measures include mulching and vertical mulching with beneficial biological soil amendments.

Wind forces will greatly increase loads on the Resurrection tree and it is far more likely that a **branch failure** of this tree would occur during wind events than at any other time; however, the long and low scaffold branching structure of the tree has a tremendous damping effect on the tree's trunk and greatly reduces the likelihood of trunk failure as a result of wind loading alone.

Although this tree has many **defects**, these defects are common among low **risk** trees in public places. The tree did exhibit many defects in the **scaffold branches** that are commonly associated with tree branch failures and they did fit the patterns of failure that experienced arborists look for in tree **hazard** evaluations. The tree was ranked 10 on a scale from 3 to 12. This ranking is not very common to trees in parks, golf courses, along city streets and other public places. This hazard rating is not normally considered acceptable by the vast majority of tree owners and managers. While the tree is not in danger of catastrophic failure under normal conditions, the dead and decayed scaffold structure could fall at any moment. These branch hazards should be mitigated.

The greatest risk that the Resurrection Tree poses is loss of life. While the chances that someone would be standing or sitting under the tree at the exact time that a branch failure occurs is quite small, about 1 in 960,000 this year, such events are possible and occur with some regularity- and almost all of these events are completely preventable. The odds are quite small in any given year, however the odds increase greatly over time and raise the possibility of an incident to about 1 in 12,000 in the next 75 years. The consequences of such an eventuality are beyond severe. There would be trauma across an entire range of losses, both emotionally and economically. These include the far reaching consequences of individual life being tragically lost, the impact of the loss on loved ones, poor publicity and public image for Franklin First United Methodist Church locally and beyond, and emotional distress and economic consequences for church membership.

There is also the risk that the well-house located under the tree's **canopy** might be damaged or destroyed if a defective branch fell on it. While this could be repaired quite easily, the cost of mitigation would be far less. Simply removing defective branches will mitigate this risk.

The potential that a tragic event might occur on the Resurrection Tree can be mitigated by removing features that are inviting to pedestrians, restricting access with better signage or physical barriers, and removing the most defective tree parts that are that are large enough to cause serious injury or death.

Because of the location, condition and use of the Resurrection Tree, **American National Standards Institute** (ANSI) **A300** (Part 9) Level 2 inspections should be performed annually.

The tree is infested with two lined chestnut borers *(Agrilus bilineatus)* and oak lace bugs *(Corythucha arcuata)*. These **pests** should be treated with trunk injected imidacloprid. The tree is also infected with tubakia leaf spot *(Tubakia dryina)* and this fungus should be treated with trunk injected debacarb. Finally, the tree is infested with gregarious oak leaf miners *(Cameraria cincinnatiella)*. The leaves of the tree should be raked up and burned or composted each fall and the tree should be trunk injected with tebuconazole to prevent re-infestation.

The tree has several types of vines growing on it. Vines should be severed at the ground level and later sprayed with a glyphosate herbicide several weeks after they are cut or when they begin to **stump sprout**. NOTE: Do not spray severed vine wounds at the time they are cut since cuts can expose tree **cambium** and this exposed cambium could cause herbicide sprays to detrimentally and fatally enter the tree. No treatment is necessary for the resurrection ferns.

The soil biodiversity of the site is low in ectomycorrhizal and other beneficial soil fungi. This is likely caused by pedestrian and maintenance traffic under the tree. Efforts should be made to curb traffic under this tree and to remediate the soil components in favor of ectomycorrhizal associations and the reduction of soil compaction through vertical mulching, mulching and irrigation.

The Resurrection Tree is both a landmark tree and a historic tree as defined by the Tennessee Urban Forestry Council. This tree should be recognized as such.

Assignment

Examine the focal site and tree, take photographs and take any samples appropriate to this assignment for testing and analysis. Discuss and evaluate the pertinent facts as they pertain to my opinions and conclusions according to ASCA **Standards** of Professional Practice including the various elements of the Resurrection Tree's conditions as they pertain to Tree Hazard Evaluations, Tree Risk Management, tree health, and tree preservation.

Determine, with reasonable certainty, the likelihood of catastrophic failure of the tree's buttress or trunk, a tree branch failure, or other likely tree partial failure and describe the potential targets of such failures. Describe in detail the likelihood and consequences of such a failure and what may be done to mitigate the risks.

Identify any factors that could limit the trees health and vitality. Make recommendations to minimize any discovered adverse health conditions to promote the Resurrection Tree's optimum safety, health and preservation into the future.

Scope

Discuss and evaluate the pertinent facts as they pertain to the stated objectives and determine the risks that this tree poses to people and property. Perform sufficient testing to determine, with reasonable certainty the structural stability of the tree and the health conditions of the tree including the soil conditions and the biology of the soil. Identify any insect or disease pests that may be visually observed. Identify any factors that may be limiting to health and vitality of the Resurrection Tree. Make recommendations to mitigate risk threats to people and property, make recommendations to treat pest problems, and promote safety, health, vitality and preservation of the Resurrection Tree into the foreseeable future.

Limits

This report is limited to the Resurrection Tree and is limited to reasonable sampling, testing, analysis and research needed to support the conclusions contained in this report. I reserve the right to amend my opinions and conclusions if sufficient evidence is produced to warrant a change beyond these limits.

Purpose

The purpose of this report is to provide Franklin First United Methodist Church with an unbiased and independent opinion regarding the structure and health of the Resurrection Tree and to illuminate Franklin First United Methodist Church as to the best courses of action in practice to meet the stated objectives according to industry standards and best practices.

Background

My involvement with the Resurrection Tree began in October of 2010 when I was contacted by Summer Turvy Shelton. At that time, I was asked to examine the tree and the site and to make recommendations similar to the objectives in this assignment. I prepared a 55-page report to fulfill that assignment and since that time there has been little action by Franklin First United Methodist Church with regard to this tree. (Shaw, 2010) On September 16, 2016, I visited the site to do some recreational UAS flying and as I passed over the tree and I noticed that there was a significant change in the tree's appearance from my previous observations and a similar tree nearby. I took some video of both trees and sent them to Lynn Wallace via YouTube. He emailed me a short time later and asked my advice which lead to the assignment resulting in the production of this report.

Observations

In preparation of this report, I examined the site conditions and I performed a careful and detailed examination of the focal tree. I have also performed several invasive and non-invasive tests in order to determine the structure and integrity of the wood contained in the tree's limbs, scaffold branches, trunk, buttress and roots. I also took plant tissue samples and soil samples which were sent for independent laboratory testing and analysis to assist me in determining the tree's health and vigor, and to identify any factors that could limit the tree's sustained health and vigor into the future. This included identification of any pest problems that may be affecting the tree and analysis of soil biodiversity. In addition to these, I have also researched additional information that pertains to the stated goals of this assignment and I found several resources that were helpful to that end.[4]

Site Conditions

The site is located in the City of Franklin, Tennessee, which was founded in 1799 after the American Revolutionary War as early American settlers migrated across the Cumberland Gap westward. This particular parcel of land was settled by a Revolutionary War hero named Daniel McMahon, also in 1799. McMahon was given this land as a grant by the U.S. Congress for his service during the war. There are also reports that he was given authority to issue similar land grants for the settlement of all regions north of Franklin the same year that the city was founded. His name is inscribed on a marble tablet in the large vestibule of the court house in Franklin. He appears with fifty-six other city fathers who were also revolutionary soldiers. (Hope, 2014) It is certain that this tree predates the white settlement of this land 217 years ago by another 19 to 37 years making the tree a sentinel of the war for independance. (Kauffman, 10/18/2016) This tree likely began to grow between 1762 and1780- around the time of our nation's founding.

This historic site rests alongside State Route 379 (Mack Hatcher Parkway) an important thoroughfare of the City of Franklin that skirts the eastern margin of Franklin and connects all of the major easterly radiating traffic arteries including: US 431 (Hillsboro Road) north of Franklin, US 31 (Franklin Road) and Cool Springs Blvd. northeast of Franklin, State Route 96 (Murfreesboro Road) east of Franklin, US 431 (Louisburg Pike) southeast of Franklin, and US 31 (Columbia Avenue) south of Franklin. Mack Hatcher, for to whom the highway was dedicated, was also an important native of Franklin and who, at one time, was Williamson County's Highway Commissioner. (Brown, 2015)

The nearby residential real-estate properties for sale are valued near the Williamson County mean and are listed between $400,000.00 and $575,000.00. These homes are zoned for single family residence and are typical lot size and square footage for the area. (Zillow, 2016)

The Resurrection Tree is located 893 feet southwest of Franklin First United Methodist Church, 1300 feet south of Mack Hatcher Memorial Parkway and 2200 feet west by northwest of the Franklin water treatment facility where Spencer's Creek and the Harpeth River conjoin. The southern boundary of the site is flanked by Spencer's Creek with Harlensdale Farm on the opposite embankment. The site is very near to Franklin High School and Battle Ground Academy. (Google, Inc., 2016)

[4] Reference materials may be found in the bibliography appendix.

Examination

I visited the site for this assignment on several occasions: September 28, 2016, September 29, 2016, and again on October 14, 2016 to perform testing, gather test samples, take photographs and take measurements. My first visit, was in the evening where the sky was overcast and temperatures were in the upper sixties. At that time, I gathered leaf and twig samples, soil samples and took a number of photographs. On the next visit at mid-day, the skies were clear and the temperatures were in the mid 70's when I performed 6 resistograph tests, took 2 core samples and used one of the core samples to perform a fractometer test. On my last visit, temperatures where cooler and there was light rain.

The "Resurrection Tree" is a Bur Oak (Quercus macrocarpa) located on a riparian embankment of the South Chapel Branch creek (35.944998, -86.859578) 315 feet south by southeast from the Daniel McMahon historic home. The tree is located at the lower edge of an open, gently sloped grassy area. This area, known as "The Glade", is the site of numerous outdoor church events including frequent youth activities and Easter Sunday sunrise services. The Resurrection Tree is very large and mature. The tree is 85 feet tall, has a spread of 122 feet and is 206 inches in circumference. That gives the tree a total of 342 points. The largest Burr Oak in Tennessee has a total of 377 inches, so while the Resurrection tree is quite large, aged, and has historical and/or landmark significance, the tree is not a state champion. (Tennessee Department of Agriculture, Division of Forestry, 2003) It is important to note that thousands of people and children come within striking distance of this tree each year.[5]

Decayed and broken branches hang precariously overhead.[6] These limbs are hazardous to pedestrians and maintenance staff who walk and work below. There is also a park bench situated directly below a dead branch that has extensive decay.[7] These limbs are hazardous to people. If one of the hazard limbs were to suddenly detach and fall on a person, it would almost certainly cause that person's death.

Resurrection ferns (Pleopeltis polypodioides) have made a home in the main scaffold branches of this tree.[8] Various galls have formed on some of the branches and many branches show evidence of borer activity. There is significant twig **dieback** in many of the branches and some of the lower branches have died and are decayed. Much of this trees growth is stunted and epicormics sprouting may be found everywhere in the canopy. There is a seam on the trunk that leads to a large opening at the base where there is a large hollow cavity.[9] I probed the opening with a measuring tape and it surpassed 6 feet before meeting any kind of obstruction.[10] It appears the tree experienced an ancient lightning strike. The opening is about 3 feet wide at the base and about 2 feet tall. Most of the interior of the trunk has been dissolved by brown rot decay fungi and the opening in the trunk is significantly larger than when I examined the tree in 2010.[11] During my examination, the tree was in the process of fall leaf **abscission** and a significant part of the canopy leaves had already fallen. Some branches were completely defoliated while other branches had retained most all of their leaves.

[5] See Site Diagram in the Appendix.
[6] See Photos 3-6.
[7] See Photo 7
[8] See Photo 8
[9] See Photo 9
[10] See Photo 10
[11] See Photo 11

This gave the appearance that some branches were much healthier than others- especially considering that another large bur oak nearby had retained most of its canopy leaves and the Resurrection Tree had lost nearly 70% of its canopy leaves.[12] The soil here is slightly compacted and is very shallow to bedrock compared with other soils in the area. Virginia creeper vines and vine euonymus have begun to climb and spread on the trunk. Although this tree appears to be growing under nearly ideal conditions for the species, the tree is declining as it has been for years. There is much deadwood in the canopy of the Resurrection Tree.[13]

Aerial Video

The aerial imagery shows the location of the tree in relation to the other features of the site. The aerial footage also shows the lighter colored appearance of the tree's leaves in relation to surrounding trees and the other bur oak trees nearby. The aerial footage does an excellent job of depicting the dead limbs and twigs in the canopy and depicts the epicormics sprouting along the major scaffold branches. The video can be viewed on YouTube: https://www.youtube.com/watch?v=_0vCIEBkljQ

[12] See Photo 12
[13] See Photo 12

Methods

All effort has been made to prepare this report according to the Scientific Method by means of the following:

1. Photos taken by me were performed using a Cannon T5i Camera Body and a Cannon 72mm EF-S 18-200 Lens with a UV Haze Filter.
2. Photos were digitally processed and compared to aerial photographs obtained from Google Maps® and Google Earth® aerial images.
3. Aerial videography was taken using a DJI Phantom 3 Advanced Unmanned Aerial Vehicle.
4. Site measurements and tree placements were approximated by using an image that was retrieved from Google Earth and Google Maps measuring tools.
5. The site map was created using Google Earth Imagery. This image was then imported into Microsoft Word and the Site Map elements were labeled using Microsoft Word drawing tools.
6. Function, use and contribution of the trees was judgment derived and determined by physically looking at the focal trees and ascertaining functional and **aesthetic** characteristics of the trees and how they were being used by the trees' owner over time. I also looked at site structures, surrounding trees at the site, vistas from various points on the site, and I looked at the site as a whole. I have observed this tree frequently over the past decade.
7. I considered sun exposure, plant growth rate, **USDA hardiness**, ultimate height and spread at maturity, foliage persistence, canopy density, soil moisture content, seasonal interest, fall color, wildlife **habitat**, tree shape, branch size, branch height bark character, canopy height, root structure, durability and structural strength in hazard evaluation and risk assessment.
8. I also considered aesthetic and functional contribution to the site placement and spacing. In particular, I considered ornamental aesthetics, **transpirational cooling**, wildlife habitat, noise attenuation, canopy height, trunk form, branch form, bark appearance and wind control.
9. Plant information sheets was taken from Horticopia® Dirr and the U.S. Forest Service. (Gilman, 2004) (Dirr, 1983) and (U.S. Department of Agriculture, Forest Service, 1990)
10. Soil and tissue samples were gathered from near the tree's trunk and a large plant tissue sample was taken from the tree about 8 feet above the ground.
11. Each sample placed into a uniquely numbered Waypoint Labs sample bag or sample container. Samples were boxed with a sample form and sent to Waypoint Labs via UPS.
12. I took two **increment borer** core sample. from tree at standard height. One sample was placed in a uniquely numbered plastic sample cylinder.
13. The other borer sample was destructively tested with a fractometer.
14. I also took the large tissue sample directly to the UT lab, and I took the core sample directly to the UT lab and handed the core sample to Dr. Kauffman.
15. All laboratory test results and images were received via email.
16. I used an F400 Resistograph® with pressure sensitive recording paper to test the relative drilling resistance of the Resurrection Tree's trunk/buttress wood. I chose 6 strategic locations around the trunk and penetrated the wood shell of the trunk about a foot deep at each location. Each recording strip was dated, labeled and the location from where it was taken recorded.
17. I used an IML fractometer to test the breaking strength and bending moment of the wood that I retrieved from the core samples I took.
18. I sent the results of the Resistograph® 400 and the fractometer tests to Dr. Bruce Freidreich for an oral opinion on the failure potential of this tree's lower trunk and buttress.
19. I performed a root collar excavation to a depth of about 8 inches to about 6 feet from the trunk. Soil was dug by hand and gently removed from the buttress. Photos were taken and the soil was replaced.

Testing and Analysis

I took soil samples, plant tissue samples and the increment bore samples for laboratory testing and analysis. I gathered the samples using standard methods and placed each sample in to a forensic sample container. These samples were labeled with a unique sample number and were either sent directly to the sample testing laboratory or handed to Dr. Kaufman.

Resistograph Testing

I used resistance drilling to determine the integrity of the outer wood of the Resurrection Tree. The resistograph tests show that the tree has produced uniform growth around its circumference and that the tree has produced adequate tension wood on the southern trunk face to compensate for the slight lean of the tree to the north. The tree has also produce adequate reaction wood to compensate for the large cavity opening at the base. This tree has produced between 1.5 and 3.0 inches of bark, 4.0 to 6.0 inches of sapwood and at least as much heart wood, all of which are typical of bur oak.[14] (Wang & Bruce, 2008)

Core Sample Testing & Interpretation

The increment borer core sample that I took from the Resurrection Tree is 182 mm long and 38 years old at standard height. There has been no significant change in the growth patterns of this tree since 1978.[15] If the growth of this tree has remained constant, then the tree is between 236 and 254 years old. Since the interior of the tree has become completely dissolved by decay, there is no way of knowing for sure, but I am confident in this result. This puts the estimated seedling date of this tree around 1776[16]

The fractometer reading was 6.7 FU, an acceptable reading for bur oak. This indicates that the wood contains adequate structural integrity to support the tree, even in windy conditions. The bending moment of the wood occurred at 27 degrees indicating that the tree trunk wood is both flexible and strong, albeit slightly less than one would expect for oak species. (Johnstone, 2010) (Mattheck, 2013)

Root Collar Excavation

The root collar excavation reveals that the brown rot **decay** extends outward on the underside of the main buttress roots and diminishes with decreasing root **diameter** toward the soil surface. The surface roots and fine **absorbing** root system near to the trunk are diminished somewhat; however, the vast majority of fine absorbing roots that do exist are white and healthy. There are two points along the buttress and root plate where decay has penetrated all the way from the bottom of the root plate roots all the way to the surface.[17] The root plate itself appears to be almost completely solid and structurally sound.

On the whole, it appears that the fine absorbing root system near the trunk is not sufficient to keep the tree healthy and vigorous. The lack of these vital roots is most likely the source of stress that has lead to the pest problems described above and the other symptoms that are associated with tree stress.[18] (Mattheck & Weber, 2015)

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[14] See Resistograph Test Results.
[15] See Photos 14-16
[16] See UT Extension **Dendrochronological** Report Dated 10/18/2016
[17] See Photos 17 and 18.
[18] See Photos 19, 20, 21 and 22.

Tree Hazard Evaluation

The hazard evaluation reveals that the most hazardous problem with the Resurrection tree is found in the dead and decaying branches that overhang the park bench. While there is signage that warns people there is no access, the signage does not specifically warn people about the dead branches that hang above and it does not specifically state that the danger that the dead branches pose could cause serious injury or death. The signage is simply not appropriate to the danger that exists to pedestrians who may enter the danger zone unawares. The park bench is a feature that invites pedestrians to sit directly below a large dead branch that could fail at any moment. If the branch falls on a person, it will almost certainly kill them.[19] (Matheny & Clark, 1994)

Risk Assessment

The greatest risk here is loss of life. While the chances that someone would be standing or sitting under the tree at the same time that a branch failure occurs is quite small, such events are possible and do occur with regularity. The real risk is in consequences that are traumatic across an entire range of losses, both emotionally and economically. These include loss of life of an individual, tragic consequences for family members, poor publicity and public image for Franklin First United Methodist, and emotional distress and potential economic consequences for church membership. The small likelihood that such a tragic event might occur can be mitigated by removing features that are inviting to pedestrians, restricting access with better signage or physical barriers, and removing the defective tree parts that are that are large enough to cause serious injury or death.

There is also the risk that the well-house located under the tree's canopy might be damaged or destroyed if a defective branch fell on it. While this could be repaired quite easily, the cost of mitigation would be far less. Simply removing or reducing defective branches above will mitigate this risk.

Bur Oak Leaf Tissue Analysis

There are no significant nutrient **deficiencies** or imbalances contained within the leaf tissue. While one of the samples contained high levels of calcium and low levels of sulfur, it is my opinion that these variations are related to insect infestation or disease infection and not related to uptake of nutrients from the soil or caused by vascular wilt disease.[20]

Soil Samples & Interpretation

The soil tests did not reveal any nutrient deficiencies or toxicities. There are higher than expected levels of **organic matter** and soil **pH** is neutral. The **cation exchange capacity (CEC)** is high. The soil is very near to optimal levels for health and vigor. The soil of this site appears to be nearly ideal for deciduous tree growth and in particular, bur oak. While the Waypoint recommendation and the ANSI A300 Part 1 standards both recommend the large addition of nitrogen and potassium fertilizer, these recommendations are based on an assumption that the primary objective of fertilizing is for nursery crop production and not for **senescent** tree preservation. Due to the age of this tree and the extensive decay this tree is exhibiting, I am reluctant to make a recommendation that includes high doses of fertilizers.[21]

[19] See Photos 22 and 23.
[20] See Waypoint Plant Tissue Analysis.
[21] See Waypoint Soil Characteristics Analysis

Pest Analysis

The twig sample contained evidence of twig boring possibly by the two lined chestnut borer *(Agrilus bilineatus)* as well as light infections by tubakia leaf spot fungus *(Tubakia dryina)* and light feeding by the oak lace bugs *(Corythucha arcuata)* and gregarious oak leaf miners *(Cameraria cincinnatiella)*. While the fungal infection and the infestations by lace bugs and leaf miners do not represent a serious pest problem on healthy trees, their impact on stressed or weakened trees can cause further deterioration of tree health. Based on these threats I recommend treatments and timing that will act synergistically to manage the more aggressive and serious pest threats as well as those that could have a detrimental effect on the Resurrection Tree. While some treatments would be ineffective this late in the growing season, some treatment regimens that are applied now will be effective in controlling pests in April-August of 2017.[22]

There are three pest plants that are growing on the Resurrection Tree. The most notable pest plants are the resurrection ferns for which the tree has been named. The second is a vine commonly known as euonymus and the third is another vine known as Virginia Creeper. While none of these pests are a serious health threat in and of themselves, such plants can add considerable weight to weakened tree structures, and plants covering the tree structure can obscure severe tree defects from view. This can make it difficult or impossible to identify and mitigate tree defects that can cause structural failure of the tree or tree parts.[23] (Harris, 2004) (International Society of Arboriculture, 2006) et al.

Soil Biology Testing and Analysis

Biological analysis indicates the sample was quite dry. This indicates that some irrigation may be needed when precipitation is not adequate. Earlier this year, precipitation was well above norms and would not have been required, but at this time, conditions are much dryer than before. Additional irrigation will be needed at 1.25 inches per 1000 square feet per week throughout the growing season until precipitation improves.

The bacterial activity is higher than the minimum required for tree health, but fungal activity was far lower than expected for health bur oak trees. The fungal activity and protozoan activity was also less diverse and less active then it should be for oaks. The lack of fungal activity means that there are fewer resources available to the fungi that are very beneficial to trees.

The lack of food and other materials that promote the growth of soil fungi can be a serious problem for oak tree health and vitality.

The flagellates are low indicating anaerobic conations. This is almost always caused by soil compaction if soils are dry.

[22] See UT Extension Report Dated 9/30/2016.

[23] See Photo 13

Discussion

Bur Oak

Quercus macrocarpa, more commonly known as burr oak, bur oak, or mossy cup oak is known for its ¾ to 1½, stemmed, solitary acorns which are conspicuously fringed on the margin. The leaves are quite variable in shape making it very difficult to identify by the leaves. (Symonds, 1958) Trees very considerably in shape and structure leaving some trees tall and more upright while others are shorter and more rounded on top with broad, spreading scaffold limbs as is the case with the Resurrection tree. (Dirr M. A., 1983) With so many variations, there is on truly typical form. The tree will grow in USDA hardiness ranges from 3A to 8A making the site of this trees home near the southern edge of its preferred habitat and at the extreme southern extremity of its natural range. (Gucker, 2011)

The tree will typically reach a mature height 50' to 75' / 15.20m to 22.80m or taller and has a spread of about 50' to 80' / 15.20m to 24.40m at maturity. The deciduous tree has an average growth rate and prefers full sun. This plant tolerates **drought**, flooding and salt well and will grow in very dry to wet or even submerged soil. The tree has a wide pH preference from acidic to slightly alkaline (less than 6.8 to 7.7) soil. Bur oak has attractive copper and yellow fall colors. (Gilman, 2004)

Bur Oak is 'one tough customer'! Well-adapted to alkaline soils, poor drainage, and high clay content, Bur Oak is also very drought-tolerant, perhaps the most drought tolerant of the all oaks. The **taproot** dominates the root system on young trees growing in well-drained soil. As with most trees, the taproot becomes much less prominent as the tree grows older, giving way to a more shallow, horizontal root system. It is well suited to the high plains and is so well known on the great planes it is regionally known as the plains oak. Acorns are enormous, sometimes the size of golf balls, which pretty much eliminates this tree as a street tree if there are other trees available. The wood weighs about 64 pounds per cubic foot.

There are no major pests of concern on bur oak, although the potential list is long. Galls cause aesthetic concerns when abundant. Scales of several types can infest twigs. Aphids cause distorted growth and deposits of honeydew on lower leaves. Boring insects are most likely to attack weakened or stressed trees. Many caterpillars feed on Oak. Gypsy moth caterpillars are extremely destructive on Oaks and several infestations have been recently discovered in middle Tennessee. Fall cankerworm has been a problem in some years. Twig pruners causes twigs to drop off in the summer. Lace bugs occasionally suck juices from leaves causing them to look dusty or whitish gray. Leaf miners cause brown areas in leaves. Dogwood borer enters the trunk through wounds such as **pruning** cuts and other mechanical injuries and may be found inside twig galls when they form. (Gilman, 2004)

There are no diseases that are of major concern although the list of potential problems is long. Anthracnose may be a serious problem in wet weather. **Canopy** diseases attack the trunk and branches. Leaf blister leaves rounded, raised areas on the upper leaf surfaces causing depressions of the same shape and size on lower leaf surfaces. A large number of fungi cause leaf spots but are usually not serious. Powdery mildew coats tree leaves with white powdery growth on stressed trees and is generally harmless. Shoestring root rot attacks the roots and once inside moves upward, killing the cambium and brown rots, white rots and soft rots can dissolve the wood. Bacterial leaf scorch causes leaf scorch, premature browning, and gradual decline of trees. (Dirr M. , 1983)

While this disease can be devastating, neither fertilization nor pruning have any effect on treatment of the disease. Chemical treatments can reduce symptoms. Bacterial leaf scorch can kill oaks and other trees in several years and this disease is common in Tennessee. This tree is native to the site. (Gilman, 2004)

Acorns are an important fall food for black bears. Many studies indicate that bur oak is browsed by various types of deer and elk. Bur oak is considered moderately important browse and cover for white-tailed deer. Bur oak is also important to many small mammals. Scatter-hoarding of bur oak acorns by deer mice and white-footed mice are common in bur oak woodlands In lab feeding trials, live-trapped eastern gray squirrels and eastern fox squirrels preferred bur oak acorns over many other oak acorns, black walnuts, and shagbark hickory nuts.

Bur oak provides cover and forage for sharp-tailed grouse and wild turkeys. Wild turkeys also use bur oak for roosting. Bur oak woodland edges are important habitat for wild turkey broods and wild turkey hens select woodlands over grasslands for nesting. Various other bird species use bur oak for forage and habitat. Bird species presence and abundance are greatest in oak savannas dominated by bur oak, northern pin oak, or northern red oak. Bur oak is used by several cavity-nesting birds including bluebirds, nuthatches, and flickers. Oaks (bur oak, northern red oak, and chinkapin oak) are preferred by winter-foraging birds. White-breasted nuthatches, Eurasian treecreepers, red-bellied woodpeckers, and downy woodpeckers utilize oaks the most.

Several studies indicate that bur oak is important for birds belonging to the woodpecker (Picidae) family. The winter diet of red-headed woodpeckers is primarily hard mast and bur oak provides additional food and habitat for woodpeckers of various types including yellow-bellied sapsuckers. Northern flickers and tree creepers use bur oak for nest sites.

Both cattle and goats are reported to browse bur oak and it is "preferred" by dairy goats. Although cattle may be poisoned by a diet of more than 50% oak (*Quercus* spp.), studies suggest that cattle do not avoid bur oak. (Gucker, 2011)

Wood and Decay Fungi

Types of Wood Decay Fungi

All decay in living trees is caused by one of two taxonomic groups of fungi – the Basidiomycota (*basidiomycetes*) and Ascomycota (*ascomycetes*). (Luley, 2005) The largest group by far is the basidiomycetes. There are thousands of species of basidiomycetes, but only about 500 or so are capable of causing decay in both living and dead trees. Only a small portion of these 500 decay fungi are commonly found among living trees in urban environments. (Schwarze 2004) A second large group of fungi that has only a few significant wood destroyers is the ascomycetes. The fruiting structures are much less conspicuous than those of the basidiomycetes; however, there are two significant root and butt rot fungi that attack live trees. (Shigo A. , 1986)

Decay is a disease that causes both symptoms and signs. Symptoms are seen in tree tissues as a result of affects that the pathogen has on them. Some wood decay symptoms include discoloration of the wood, alteration of the strength of the wood, and the formation of cavities. Visible evidence of the actual causal agent, such as fruiting bodies, **mycelia fans**, or **rhizomorphs** are positive indicators that the actual causal agent is present.

Additionally, there are three types of wood decay and they are classified by the type of decay they cause. Decay fungi dissolve wood by secreting enzymes that have a unique ability to dissolve complex wood molecules. Different types of wood decay fungi secrete different types of enzymes; therefore, different classes of fungi dissolve wood in distinctly different ways. Generally speaking, wood decay fungi are either “white rot”, “brown rot”, or “soft rot”, depending on the mode of enzymatic attack. A few species of fungi are capable of dissolving different wood using several types of enzymes in the same tree. (Schwarze F. , 2008)

White rot is the most common type of decay in trees. Generally, white rot fungi dissolve **lignin** initially, and then later in the decay process, they degrade the **cellulose** and **hemicelluloses** molecules. White rots typically have a white appearance in the wood. White rots cause less strength loss in wood, because they dissolve cellulose molecules from the ends, leaving the strong structural tensile bonds of the cellulose intact.

Brown rot is much less common than white rot, and is more frequently found in conifers than on **hardwoods**. Brown rot fungi dissolve mainly cellulose and hemicelluloses, and leave behind brown colored components of modified lignin. Brown rot fungi eat cellulose all along the molecule, causing a significant amount of strength loss. This mode of action weakens the wood structure, even in the initial stages of decay. Wood attacked by brown rot is brittle and fractures easily in tension. (F. Schwarze 2008) et al.

Some tree species like oak are somewhat resistant to brown rot due to the high degree and quality of lignification along longitudinal walls of parenchyma cells and vessels in the wood. There is also less moisture and there are more phenolic compounds found in heartwood of oaks. Because of this configuration in oaks, brown rot disease takes place much more slowly or reluctantly. (Schwarze 2004) (F. Schwarze 2008)

Soft rot is caused by ascomycete fungi and some basidiomycetes. Soft rots are similar to brown rots in that they dissolve cellulose along the length of the molecule and cause significant strength loss in wood. Some soft rot fungi dissolve the links between wood cells and lignin, causing the wood to be soft. Soft rot in living trees is not visibly different from white rot or brown rot.

Wood decay is one of the most common problems of urban trees. (Luley, 2005) Because decay in trees could threaten people or property, it is also one of the most serious. Presence of a **conk** or mushroom on living trees is a positive indicator of decay, and represents an increased likelihood and potential for the structural failure of a tree while the absence of visually observable fungal decay presence reduces the likelihood and potential for structural failure. (Hayes 2001) Some wood decay fungi cause decay faster than others, and some species of trees decay faster than others, depending on the species decay fungus present in the specific wood type a particular tree species and the conditions in which these exist. Tree wounds and mechanical injury to the bark of trees provide a port of entry for decay fungi into the sapwood. The size and depth of mechanical injuries into the wood is another factor that will affect any assessment of decay in trees. Additionally, environmental conditions play a vital role in both the rate and extent of decay in trees. Because of these variables, the rate and extent of decay can vary widely from tree to tree and even trees of the same species at the same site. (Natheny 2009) There are simply no absolutes when it comes to tree decay and one may only generalize from one’s experience and local knowledge about how trees decay and what affects that decay might have on trees. (Harris R. J., 2004)

Most of the important fungi that form cavities by dissolving the heartwood of trees seldom produce fruiting bodies or any positive indicators that they are present. (Luley, 2005) In fact, most decay in urban trees is found without the presence of any wood decay fruiting bodies. In the absence of conks, an investigator must rely on other indications to be alerted to the presence of internal decay. Indicators such as cavities, carpenter ants, cracks, and swelling in the stem or buttress may suggest that decay could be present, but they do not indicate the extent of decay. (Luley, 2005)

The Resurrection Tree exhibits extensive signs and symptoms of decay from white, brown and soft rot type fungi. No attempt was made to identify the various forms of decay in this assignment because the patterns of dissolved wood were apparent at my examination. Brown rot has caused extensive internal decay of the buttress and the lower portion of buttress roots. This decay very likely extends to some of the structural roots beyond the root collar excavations, but excavation of small roots was beyond the scope of this assignment.

Decay Fungal Infection and Tree Host Response

Wood infections by decay organisms occur in recently exposed wood due to injury of some sort to the bark of the tree. As the living wood is exposed, the exposed cambium cells die and the wood begins to desiccate. Spores of decay fungus are released from fruiting bodies of decaying wood in enormous quantities and these are dispersed by wind. Because decay is ubiquitous in the environment and because decay fungi fruiting bodies are ever-present, spores of decay causing fungi always infect exposed wood. This makes decay infection of open wounds on trees an absolute certainty and tree defense mechanisms must be robust to prevent decay from spreading in trees. (Harris R. W., 2004)

Because of this fact, trees have developed a remarkable strategy for resisting the intrusion of decay into the wood. As the living cells of the exposed cambium die, they send a chemical signal to the neighboring unexposed cambial cells. These cells, in turn, begin to secrete chemical compounds into the wood that form a strong chemical barrier, walling off further intrusion of decay fungi into the newly formed wood that develops after the injury. Likewise, living cells in the sapwood react and begin to deposit similar chemicals within the woody structure; in effect, they wall off intrusion of decay fungi. This model for walling off decay in trees is called Compartmentalization of Disease in Trees or C.O.D.I.T. (Shigo 1986) In addition to wood with living cells (sapwood), the heartwood (which contains no living cells) is still amazingly capable of producing reaction zones in response to decay intrusions. (Shigo 1986) While the C.O.D.I.T. response in trees is variable depending on tree species and condition, stressed trees with lower energy reserve are less capable of C.O.D.I.T. than are healthy trees with high energy reserve. In other words, C.O.D.I.T. is energy expensive and weaker trees have less defensive currency to dedicate to wall-off decay.

This is an important concept to consider when making fertilizer decisions on older trees and trees that are stressed. While fertilization will increase tree vigor regardless of a trees energy reserve, increasing vigor of trees with poor energy reserve will stimulate vegetative growth at the cost of defense against decay organisms. Fertilizing weak and stressed trees often causes the rapid and aggressive spread of decay in healthy woody tissue and causes other detrimental physiological effects.

As has been stated, the rate and extent of decay will be determined by many factors that cannot be measured through visual field observations. Although there may be many signs and symptoms that decay is present, they may tell very little about the amount and the extent of wood decay that is not in view.

Generally, the more pronounced the signs and symptoms can be seen by an inspector, the more likely it is that the decay is present is more extensive. Said a little differently, it is the number of signs and symptoms that are found that is generally the best indication of the extent of decay. (Schwarze 2004) It is assumed by many tree experts that the greater the signs and symptoms of decay the more likely there is a greater strength loss in the wood. As a consequential corollary, there is a greater likelihood of tree failure with greater numbers of signs and symptoms (Natheny 2009)

There are two important questions that should be answered when estimating how quickly wood decay will spread in a tree. Is the fungus capable of overcoming the reaction zone? Can the tree actually hinder the spread of this particular species of fungus in the long term? (Schwarze 2004) Trees in good health do a much better job of C.O.D.I.T. than do trees in a **stressed** or weakened state. Trees in poor health condition are much more likely to have advanced decay and are therefore more likely to fail as a result of decay. (Harris R. J., 2004)

The Resurrection Tree has extensive decay and is in a stressed and substantially weakened state. As such, its energy reserves are low and its ability to defend itself against the extensive decay that exists is compromised. Fertilization of the tree would only exacerbate this condition and would cause even more aggressive deterioration of the healthy wood and would cause other effects detrimental to the health of this tree. Fertilizer treatments should be avoided. There are measures that would help increase the Resurrection Tree's uptake of micro-nutrients from the soil and this would help the tree defend against decay. These measures include mulching and vertical mulching with beneficial biological soil amendments.

Tree Failures

Trees are the tallest free-standing organisms in the world. Trees live longer and become more massive than any other living things. How do they do it? Trees have a unique biological system of structural form that is capable of compartmentalizing decay and can resists heavy wind loading. Most people are familiar with at least some of the properties possessed by processed timber and lumber, and some of these properties can also apply to living trees. It is also important to understand that living tree wood is very different from wood products in many important ways. Living trees are not static structures (trees bend and sway in the wind) and they are alive (they grow, reproduce and respond to stimuli). The wood of live trees contains considerably more water, is heavier, and is more pliable and elastic than wood contained in cut timber and lumber.

When left standing, a dead tree will become dry brittle and decayed, and its ability to withstand loading will become greatly diminished. It is also important to understand that all trees have the potential to fail, even if there are no structural defects. The most we can say about the potential for tree failure is that some are more likely to fail sooner than others, and all trees, left to their own devices, will fall down at some point.

Most trees develop naturally strong structure as they grow; however, injury and disease can interfere with both the development of new structure, and can disrupt natural tree structure that has already formed. Additionally, environmental conditions like wind and ice can create forces that may overcome tree structure if those forces are strong enough or heavy enough. (Mattheck C. a., 1994) All systems have limits, and trees will eventually (if they are not cut) succumb to the natural forces that exist outside the tree system and fall down.

Branches will break, trunks will split, and roots will release their grip on the soil when the forces that hold these structures together are overcome by greater outside forces. When the structure of the tree is most weakened, that is the point where failure is most likely to occur during heavy loads.

To help reduce the likelihood of failure from loads, the tree uses several structural components in a strategy that spreads the load over a larger area and time. These structural components include branch taper, branch union, trunk flare, and reaction wood (tension wood in oaks). Trees also use the natural elasticity of wood to move and sway in wind and to reduce drag. These strategies dissipate the force that wind can apply. Live wood is much more elastic than dead wood, but it is heavier than dead wood because of its water content.

Trees have also developed effective means of dealing with wounds that have become infected with wood destroying fungi, and for repairing woody structures that have been damaged mechanically. Compartmentalization (discussed earlier) prevents the spread of decay within wood structures and preserves **structural integrity**. Another response trees have is the development of callus tissue around the wound. When callus tissue forms, it spreads out over the injured woody tissue and begins to form new wood and bark. Eventually, callus tissue will cover the entire area of injured wood and create a closure that is normal looking in appearance. A small seam or circular patches of smooth bark are the only visible signs that a wound has been closed by callus tissue. Once the callus tissue closes a wound, the strength of the wood around the injury is greatly increased. If the callus tissue does not close quickly enough and the injured wood is not well compartmentalized, depending on the type of decay, it may spread through the sapwood and into the inner heartwood, precipitating the slow development of a cavity.

As the wood inside the cavity is broken down and dissolved, the fungi spreads and space inside the cavity will become large and open. As the callus tissue along the edge of the cavity opening continues to add new growth rings each year, the wood develops a circular “ram’s horn” on the inside of the open cavity. Unimpeded, the ram’s horn always follows a specific pattern of development that is symmetrical until it closes. (Shigo 1986)

The cavity of the Resurrection Tree is completely dissolved at the base and extensive, leaving a solid shell of sapwood and some heartwood that is at least a foot thick around the trees circumference just inside the tree’s bark. The wood is both elastic and strong as measured with the Resistograph tests and the fractometer test. The callus tissue on both sides of the cavity opening is also well developed. The trunk is unlikely to fail, but some of the dead and decayed branches are likely to fail.

Wind

One half of all weather related deaths in the United States occur because of tree failures. Tree failures are by far the number one storm related cause of deaths and injuries to people. There is a strong correlation between strong wind and tree failures. (Schmidlin 2009) The fact is that tree failures seldom happen at any other time (outside of sudden branch drop phenomenon). Trees respond to wind loading in various ways depending on the type of winds that occur.

In light winds, either directional or unidirectional, the tree responds by allowing individual leaves to flutter and branches to sway independently from each other. This absorbs and dissipates the entire wind load over a very broad area. Most tree failures do not occur during light winds.

In strong steady winds, the load gradually increases and the branches tend to sway in a more unified way that allows the natural elasticity of trees to adjust as wind conditions become stronger.

As the wind speed increases, there is less and less individual branch motion and the tree begins to sway with the branches in synchronized motion. With strong winds, the tree relies on the structural support of the trunk and root anchorage to transfer the wind load to the soil. Tree fractures and failures can occur if the wind forces are strong enough and tree failures are common in strong wind events such a certain storms and hurricanes.

Strong gusty winds cause sudden wind loads that can exceed a tree's natural elasticity, especially under special loading conditions where varying wind speeds and loading cause frequency resonance and where wind forces are dynamically amplified. Gusty winds also cause erratic branch sway making their movements random and these winds are capable of causing fracture loads. That means that certain wind loads cannot dissipate through normal trunk sway, wood strength and root anchorage into the soil as in the case with strong steady winds. When strong unidirectional winds are gusty, the dynamic wind load on individual branches is greatly increased and this greatly increases the likelihood of branch and tree failure, even if the winds are not particularly strong. (Schmidlin 2009)

Wind forces will greatly increase loads on the Resurrection tree and it is far more likely that a branch failure of this tree would occur during gusty wind events than at any other time; however, the long and low scaffold branching structure of the tree has a tremendous damping effect on the tree's trunk and greatly reduces the likelihood of trunk failure as a result of sustained wind loading alone.

Evaluation of Hazard Trees

Identifying and managing the risks associated with trees in urban areas is a subjective process that is fraught with uncertainty and therefore requires extensive experience and a high level of professional judgement. Since the nature of tree failures remains largely unknown, our ability to predict which trees will fall and in which fashion is very limited. (Matheny & Clark, A Photographic Guide to the Evaluation of Hazard Trees in Urban Areas, 2nd Ed., 1996) As currently practiced, tree hazard evaluation and risk assessment involves the following considerations:

- The potential of the tree to fall
- The environment that may contribute to failure
- The potential target
- The likelihood and consequences of a tree failure's impact on the target

Examining a tree for structural defects, associating those defects with known patterns of failure and rating the degree of risk based on the environment, the targets, and the amount and likelihood that damage, injury or death will occur as a result of a tree failure is the essence of contemporary tree hazard evaluation. For these reasons, hazard tree evaluation is not limited to tree failure potential alone. Hazard tree evaluation and risk analysis cannot be made solely on the basis of scientific observations and calculations by themselves; there is simply too much uncertainty. Regardless of the limitation that the uncertainty places on these tasks, consulting arborists services are critically important to assist tree owners in their decision making. Tree hazard evaluations and analyses must be done and the must be conducted in the light of broad, local experience and a deep knowledge of tree failure patterns.

People need to know if the decisions they make about their trees reasonable, if their trees are safe enough or not, and what the potential consequences of particular course of action might be. Of particular importance are the foreseeable consequences of a failure that could lead to property damage or loss, a personal injury or a death.

My role as a risk assessment professional is to inform decision makers as to what is reasonable action with regard to tree hazards as they pertain to protecting people and property from falling trees or tree parts. Over 30 methods have been developed and applied to the assessment of hazard trees. The commonly accepted method used by arborists in the evaluation of hazard trees is the one published by the ISA and has become one of the requirements of arborist certification. (ISA 2008) (Gliman 2004) In 2011 **TCIA** authored the “ANSI A300 Part 9 Tree Risk Assessment a. Tree Structure Assessment” standard. That same year the ISA developed an A300 Part 9 companion publication “Tree Risk Assessment **Best Management Practices**”, a practical guide to performing tree risk assessment. While the hazard tree evaluation and risk assessment of this assignment conforms to the standard, the standard itself does not conform to International Standards Organization (ISO) 30000 for Risk Management or ISO 31000 for Risk Analysis. (Tree Care Industry Association, Inc., 2011)

In the ISA method, it is assumed that almost all trees pose some risk of failure. As the tree grows larger and more mature, the degree of risk increases. The challenge for arborists is to inform tree managers what is at risk and what level of risk is reasonable. That level of risk that any owner/manager is willing to take can only be determined by the property owner or manager. Consulting arborists must frequently make recommendations about the level of risk that a particular potential tree hazard poses to people or property and to make recommendations that are reasonable in relation to the risk threshold. When the ability to mitigate the risk is so diminished that the risk remains too high to meet the test for reasonableness or to meet the property owner or managers risk threshold, the arborist must recommend tree removal.

The uncertainty of risk assessment is always high- partly because defects are often not visible. Defects that are hidden inside the tree, behind foliage, hidden by some other obstruction or defects that exist below ground cannot be considered without careful inspection. Additionally, natural forces are unpredictable and all factors that contribute to a failure are not known and/or cannot be known until after a failure has occurred. With experience, consulting arborist can learn to recognize patterns of failure that will help in recognizing risks and aid in developing strategies to minimize or avoid them.

Inspection for tree hazards involves a great deal more than a casual stroll among them. Tree inspection is a systematic process of visually identifying risk factors and failure patterns, and when warranted, performing more detailed testing and analysis. It is not necessary or even possible to perform exhaustive testing on every tree. In reality, the need for additional testing beyond the visual inspection is rare. If there is a serious a defect that fits common patterns of failure with multiple indications, additional testing may be warranted. Sometimes the recommended abatement procedure is less costly than the testing procedure, therefore it may be advisable to skip testing and go directly to abatement. (Lilly 2001)

There are many factors to look for when performing a Tree Hazard Evaluation. The ISA recommends using a Tree Hazard Evaluation Form to determine the relative risk of a tree in a group of trees, and most arborist use this form when performing a tree hazard evaluation for tree owners and managers. (ISA 2008)[24]

The form includes information about tree characteristics, health, site conditions, targets, tree defects, hazard rating, and comments. This information is critical in determining the hazard potential of a tree and is very useful in communicating risk levels to tree owners and managers. (Matheny & Clark, 1996)

The specific defects that could be seen and increase failure potential were:

- moderate species failure potential
- there is minor asymmetry in the canopy
- this tree has a slight natural lean
- the trunk had a previous wound and seam
- the tree has a large trunk and buttress cavity
- there is significant decay on the bottom of the buttress roots
- decay has penetrated from the bottom of the root to the surface at two points
- the tree spread is broad (increases the likelihood of branch failure)
- a codominant fork with a moderate failure potential
- there is no history of pruning to remove deadwood or improve tree structure
- the tree is stressed and has multiple significant signs of branch decay
- there are many epicormics sprouts on the scaffold structure and upward
- there is significant twig, limb and branch dieback/decay
- there are previous limb failures
- there is a two lined chestnut bore infestation
- there are vines growing on the trunk and lower branches
- there are other pest infestations and infections
- the leaves are stunted and discolored

Other observations that reduced failure potential that I considered were:

- the tree has had no previous history of scaffold branch or trunk failure for 200+ years
- the core has healthy growth increments
- callus tissue that could be seen on the wound seams was closed and healthy
- the growth of callus at the cavity opening was vigorous
- no positive indicators of decay (mushrooms) could be seen although decay is present
- the pedestrian and maintenance traffic is not heavy or constant
- the main stem bifurcations have large branch bark ridges/collars indicating branch strength
- the vast majority of the roots appear to be healthy
- there were no termites or carpenter ants that could be seen
- there was no sap oozing down the trunk or branches
- the trunk has excellent buttress formation on all sides
- there is no soil heaving or soil cracks
- there is no severe or non-self-corrected lean
- the trunk shell tests show it to be intact and symmetrical
- the branches have good taper

[24] See Figures 1 & 2

Although this tree trunk has many defects, these defects are common among low risk trees in public places. The tree did exhibit many defects in the scaffold branches that are commonly associated with tree branch failures and it did fit the patterns of failure that experienced arborists look for in hazardous branches. The tree was ranked 10 on a scale from 3 to 12. This ranking is not very common to trees in parks, golf courses, along city streets and other public places. This hazard rating is not normally considered acceptable by the vast majority of tree owners and managers.

While the tree is not in danger of catastrophic trunk failure under normal conditions, the dead and decayed scaffold structure could fall at any moment. These branch hazards should be mitigated.

Risk Assessment

Risk Assessment is the systematic process of evaluating what consequential things could happen, how likely they are to occur and under what constraints, and what the likely outcomes might be. In tree management, it is the systematic process to determine the level of risk posed by a tree, tree part, or group of trees. (ISA 2009) (Tree Care Industry Association, Inc., 2011)

Tree Risk Assessment according to ANSI A300 begins with the assignment definition and scope which determines the extent and level of inspection. The assessment begins with identifying any targets and their occupancy rates. Next comes a description of the consequences of the tree or tree part impacting the target. This is followed by categorizing the risk into general groups by likelihood of failure, likelihood of impact, consequences of impact, the risk rating or the reasonability test/risk threshold test. Next, the reasonability test/risk threshold gap is described in detail and recommendations are developed to bring the risk to a standard conformity or to an acceptable level of risk.

It is also important to consider the part size of the potential failure. Larger tree parts have a greater potential energy than do smaller parts. Targets may have little value with the potential for total loss or they may be of great value with only moderate potential for partial loss. Depending on the size of the potential loss, consequences may be broadly categorized as negligible, minor, significant, or severe.

In evaluating the potential for the tree to fail, an arborist must consider the likelihood that a particular tree part will fail over time. This task is fraught with uncertainty as described earlier, but careful observation of a large number of tree risk characteristics and failure patterns (including the species, growth **habits**, branch attachments, defects, condition of the root system, lean, and the history of the tree) offers experienced tree risk assessors the best means to develop what I call "a picture of potential failure".

Because of the inherent uncertainty and unknowables involved, it is particularly difficult to accurately calculate specific numerical probabilities of failure from observations alone and the ANSI A300 (Part 9) does not dictate that probabilities of failure be reported as such. I do think that a best guess is appropriate and this report provides an estimate that comes with commensurately high uncertainty that falls well outside standard scientific deviations.

The environment plays an important role in the potential for tree failure. Most tree failures occur during or as a result of storms. Exposure to winds, snow, ice, lighting and rain must be considered when assessing the potential risk that a tree may pose. Other environmental factors such as soil conditions and slope may also be important consecrations that should be taken into account. Determining the history of the site may also reveal some factors that could affect the health and structure of the tree on the site.

Normally, an initial investigation involves a visual inspection and photographs of the tree and sounding of the trunk or other parts. A form is used to record observations. If a visual inspection reveals a defects that appear to be severe and/or could potentially cause a failure onto a valuable target, the consulting arborist will make recommendation for level 3 inspection that includes invasive testing and analysis of the defect, or if the hazard is imminent, risk abatement (mitigation) will be recommended. In the end, the tree owner or manager must decide what to do.

A target is a person, object or structure that could be harmed by a tree or tree part in the event of failure. (ISA 2009) If there is no target that could be struck by a failure, then there is no risk. Structures are easy to asses because they are fixed. However, in determining the likelihood of a failed tree or branch striking a person, one must consider the frequency and intensity of use. A tree that poses unreasonable risk on a school playground has greater potential to cause grave consequences of injury/death than dose a defective tree growing in an open field.

Ultimately, the property owner must decide what level of risk is acceptable and what level of risk is not. There are no laws or standard guidelines that can inform tree owners and property managers when it comes to deciding how much risk is reasonable, so they must rely heavily on the knowledge, opinions, experience and judgments of tree experts to help them determine how much risk is reasonable and how much is not. This is a unique challenge for arborists for several reasons. Firstly, the risk of tree failure over time is inherently uncertain and predicting tree failures is notoriously inaccurate, trees are natural living organisms that often have defects that cannot be seen, there are other external unknowns like weather that cannot be accurately predicted. Conversely, trees often produce aesthetic and functional benefits that outweigh the risks of failure as perceived by their owners, and no two arborists have the same level of experience, knowledge, training and judgment. Because of the unique challenges associated with tree risk assessment, two or three competent tree risk assessors may assess the same tree and arrive at very divergent tree risk assessment opinions.

The very best that arborists can do is be vigilant in identifying those factors that could lead to tree failure and make the best recommendations possible given the arborists opinions, experience, and judgments with regard to recognized patterns of tree failures. It is also important to communicate the vast limits of predicting tree failures to tree owners and managers. The fact remains that some trees will fail unpredictably and there are profound limitations to the systematic risk assessment of trees.

The initiation of a **tree risk management program** usually begins when a large tree fails and there is a “close call” or an incident. Once the property owners become aware that trees can pose a hazard, a tree hazard assessment/abatement program is initiated. The frequency of evaluation depends on budget and the level of risk the property manager/owner is willing to accept. Most hazard assessment/abatement programs on private property call for annual inspections. (Lilly 2001)

The greatest risk that the Resurrection tree poses is loss of life. While the chances that someone would be standing or sitting under the tree at the exact time that a branch failure occurs is quite small, about 1 in 960,000 this year, such events are possible and occur with some regularity- and almost all of these events are completely preventable. The odds are quite small in any given year; however, the odds increase greatly over time and raise the possibility of an incident to about 1 in 12,000 in the next 75 years. The consequences of such an eventuality are beyond sever. There would be trauma across an entire range of losses, both emotionally and economically.

These include the far reaching consequences of individual life being tragically lost, the impact of the loss on loved ones, poor publicity/public image for Franklin First United Methodist Church, and emotional distress and economic consequences for church membership. There is also the risk that the well-house located under the tree's canopy might be damaged or destroyed if a defective branch fell on it. While this could be repaired quite easily, the cost of mitigation would be far less. Simply removing/reducing the defective branches will mitigate this risk.

Risk Abatement

Risk Abatement should always be a component of risk management. If a hazard has been determined to be at a level of risk higher than is acceptable to the tree owner or manager, the risk must be dealt with in such a way that the potential risk is reduced to an acceptable level. Sometimes this involves removal of the affected tree or part, but at other times, the treatment of the hazard may mean that structural support system should be installed. Management may also mean removal of the target.

Often times, the best option for lowering risk is pruning to either remove the defective part or reduce the weight of the branch above/beyond the defective part. Risk of failure cannot be completely eliminated without removal of the entire tree or targets. Also, trees tend to grow in ways that promote strong structure, so as the tree increases in size, both their strength and their risk potential may increase. Sometimes, the best way to make a tree stronger is to perform treatments that increase their vigor and health. The more vigorous and healthy a tree is, the more capable it is of adding strong healthy wood.

Risk abatement is usually not a one-time occurrence unless the questionable tree is removed. Whenever trees are being managed on a common property, on a private property, on a public site or within a municipality, they should be evaluated on a periodic cycle that takes into account their size, age, overall condition, and management practices.

The potential that a tragic event might occur on the Resurrection Tree can be mitigated by removing features that are inviting to pedestrians, restricting access with better signage or physical barriers, and removing the most defective tree parts that are that are large enough to cause serious injury or death.

Standard of Care for Public Trees

The standard of care for public trees in the United States is determined locally by municipalities and by individual property owners. There is no federal law or agency that prescribes the standard of care for public trees; however, the courts have determined that the primary test of an owner's duty to protect people and property from their hazardous trees is reasonableness.

Most municipalities across the United States have no prescribed ordinances for the care of public trees and those municipalities that do are usually restrictive against removal. This is because public trees are generally considered to be an asset to the community and trees provide communities with many cost saving environmental service benefits such as air cooling, erosion prevention and control, water runoff control, increase property value, reduced air and noise pollution, carbon sequestration and many others.

Ordinances that require mitigation or removal of hazardous trees normally require the assessment of hazard trees be completed by a certified arborist or another qualified expert. Municipalities perform ANSI A300 (Part 9) Level 1 inspections their trees regularly. Because of the location, condition and use of the Resurrection Tree, ANSI A300 (Part 9) Level 2 and/or Level 3 inspections should be performed annually.

Soil

The soil of this site is nearly ideal for bur oak, although there has been an abundance of maintenance traffic and pedestrian foot traffic that has caused some of the soil in the **critical root zone** under the tree to become compacted, increasing the soils **bulk density**.

Site Soil Type

Soil survey data was obtained by use of the USDA Natural Resources Conservation Service Web Soil Survey Tools and the USDA/Tennessee Agriculture Experiment Station Soil Survey of Williamson County, TN. The aerial imagery was overlaid on the survey data to delineate the locations of the soil type of the Resurrection Tree. The focal soil type of this site egam silt **loam**, phosphatic. (USDA, 2013)

Bulk Density

Bulk density is most often expressed in terms of soil weight/volume in terms of g/cm^3 but occasionally this critical soil attribute is expressed as lb/in^3. Bulk density is defined as the dry weight per unit volume of soil. Bulk density considers all of the solids and the pore spaces between the soil solids. Bulk density, 15 bar, is the oven-dry weight of the soil material less than 2 millimeters in size per unit volume of soil at water tension of 15 bars, expressed in grams per cubic centimeter. Bulk density, 15 bar, is critical in resource assessment modeling, such as soil hydrology, water budgets, leaching, nutrient-pesticide loading and site selection for transplanting landscape plants. (Craul, 1992)

Essentially, the higher the bulk density, the more difficulty tree roots will have growing and thriving in that soil. Tree roots will not grow in silt-loam with a bulk density of 1.69 or greater. The native soils of this site have undisturbed bulk densities of around 1.38. Bur oak tree roots tend to grow deeper and wider in these soils. (USDA, 2013) **Soil compaction** due to traffic on and around the soils under this trees canopy may be mitigated by performing soil vertical mulching. (Macie, 2013)

Soil Nutrients

The soil type (egam silt loam, phosphatic) is derived from clayey allubium and is typical of flood plains at this elevation within this region. The site receives 52-56 inches of precipitation with a 170 to 190 day growing season. The site is very well drained and is capable of producing 86 board feet of water oak (Quercus nigra) per acre per year, a very high rating. This soil is considered prime farmland. While the soil of this site is quite susceptible to soil compaction, undisturbed soils will have an initial and very fertile bulk density of 1.38 grams per cubic centimeter. Typically, these soils have an organic content of about 3 percent, but the tested samples from under the tree are much higher and near optimum levels. (USDA, 2013) The nutritional characteristics of this soil are virtually ideal for the health, vigor and sustainability of the Resurrection Tree. (Dirr M. A., 1983) (Gilman, 2004) et al.

Pests

Two Lined Chestnut Borer

The two lined chestnut borer *(Agrilus bilineatus)* normally does not attack healthy oaks but affect stressed trees. The attack usually begins in the upper **crown** and works its way down over the tree eventually killing the oak in the second or third year. Adult two lined chestnut borers are slender, black beetles with a bluish to greenish hue that are 1/5-1/2 inch (5-13 mm) long with two faint, yellowish stripes along their back.

Two lined chestnut borer larvae live under the bark in cylindrical, winding tunnels tightly packed with fine grain sawdust and excrement. These insects occur in oaks, especially bur oak, throughout the eastern United States, including in Tennessee. Chestnut in the common name refers to the beetle's past status as a principal pest of American chestnut, (*Castanea dentate)* which has been virtually wiped out by this pest and its associated fusarium fungus.

The two lined chestnut borer has one generation per year. Adults are active from April to August, in Tennessee. After emerging, adults fly to the crowns of oak trees and feed on foliage before moving to the branches and trunks to mate. Females lay their eggs in small clusters in bark cracks and crevices. Larvae hatch within 1-2 weeks. The larvae burrow through the bark to the cambial region where they construct meandering galleries, lightly scoring the sapwood. Galleries may be straight rather than serpentine in host trees that are highly stressed. When fully mature, larvae burrow into the outer bark and construct individual chambers in which they overwinter. If the bark is thin, as in small twigs, the larvae construct chambers in the outer sapwood. Adults emerge in April through distinctive D-shaped exit hole about 1/5 inch (5 mm) wide. It can be a devastating pest of stressed trees. (Haack & Acciavatti, 1992)

Adult two lined chestnut borers primarily attack oaks that are weakened by drought or trees that are suppressed or declining. Oaks that have been defoliated by insects or debilitated by root disease may also be attacked by the two lined chestnut borer. The first symptom of borer attack is usually wilted foliage that appears on scattered branches during late summer. The foliage on infested branches wilts prematurely and turns brown but remains attached to the branches The earliest symptoms are wilting of the foliage in late summer and then death of the upper limbs. Adult beetles fly from April to August each year, having one generation per year. Treat with imidacloprid as a trunk injection in early April or use imidacloprid plus cyfluthrin as a basal drench any time from February to mid-April.[25] (Hale F. A., 2012)

Oak Lace Bugs

Oak lace bugs *(Corythucha arcuata)* are 1/8 inch to 1/3-inch-long (3mm – 8mm) and have light colored bodies with dark colored markings. The top of their wings, head, and thorax are composed of many raised ridges. These ridges give the insect a sculptured, lacelike appearance. On adults, the wings extend beyond the abdomen and are held flat. **Nymphs** are wingless and spiny with a flat oval shaped body. They are darker than the adults. When lace bug nymphs **molt** their **exoskeletons**, these cast skins remain attached to the foliage of the plant. Adults and nymphs also leave dark, varnish-like excrement on the undersides of leaves.

Lace bugs overwinter as adults on or near their host plants. They can be found in bark crevices and under leaves and other debris on the ground near host trees. In the spring, adults fly to plants and feed on newly-expanding leaves leaving behind characteristic **stippling**. The adults mate and lay tiny black eggs in small groups on the underside of the leaves. Eggs hatch into nymphs after about two weeks. Nymphs feed for approximately three to four weeks before maturing into winged adults that lay additional eggs. This second generation feeds until late summer or fall. Lace bugs typically have two or three generations per growing season in Tennessee. Adults from the second or third generation overwinter and begin the cycle anew the following spring.

[25] See UT Extension Report Dated 9/30/2016

Adults and nymphs feed on the undersides of leaves. They insert needle-like mouthparts into leaf tissue which creates small white or yellow dots in the leaf surface. Where populations are high, heavy feeding can cause severe leaf discoloration and premature leaf drop. Feeding damage is most noticeable in mid to late summer when populations are at their highest.

While feeding injury can discolor leaves, it does not normally threaten the health of tree unless the tree is stressed or otherwise weakened. Conversely, healthy trees can tolerate damage from high populations of lace bugs. Heavy feeding occurring over consecutive years on stressed trees can reduce plant growth and exacerbate stress conditions. (Johnson, 1988) Lace bug populations vary from year to year. One year of severe damage does not necessarily mean that heavy damage will occur the following year. (Lloyd, 2016)

Many natural enemies, such as assassin bugs, lady beetles, green lacewings, and other predators feed on lace bug eggs, nymphs and adults. When natural enemies are present, lace bugs generally cause little lasting damage. Trunk injected imidacloprid insecticide is very effective in controlling lace bugs while leaving predator populations intact. (Rettke, 2013)

Gregarious Oak Leaf miners

Gregarious oak leafminer *(Cameraria cincinnatiella)* occurs over much of the eastern United States. They attack various oaks, but prefer the white oak- particularly bur oak. Heavy infestations cause browning and premature dropping of foliage. Young larvae are flat and taper toward the rear, and are about .25 inch (6 mm) long at maturity. Adults are pale-silvery moths with bronze patches on the wings.

Larvae of the gregarious oak leafminer feed together, forming large, irregular blotch-like mines just below the upper surface of the leaf; a single leaf often contain several mines. Insects spend the winter in the larval stage in leaves on the ground. Adult moths emerge during the spring and females lay eggs on the newly emerged oak leaves. There are two to several generations per year. (Johnson, 1988)

By raking the fallen leaves each fall and burning them to destroy pupae, excellent control of this pest can be achieved. Natural enemies are also very helpful. Chemical control using cyflurathin as a soil drench or abamectin as trunk injection is very effective on this pest and will leave natural predator populations intact. (Schread, 1968)

Tubakia Leaf Spot

Tubakia leaf spot *(Tubakia dryina)* is a common leaf spotting fungus which affects many oak and other tree species. This unusual fungus is widespread in the Eastern United States and is frequently encountered on necrotic leaf tissues in Tennessee. The tan to dark reddish brown leaf spots are 1-15 mm in diameter, circular to irregular in outline and may coalesce to form larger **necrotic** areas. If the leaves are still expanding at the time of infection some leaf deformity may occur. Tubakia leaf spot can often be found in combination with other foliar pathogens or injury. While the fungus has long been associated with leaf spots on oak and other trees its pathogenicity has not been verified in all cases. It is a primary pathogen of oak species. Since it is often observed in combination with other foliar pathogens, or on injured and stressed trees, T. dryina appears to also be an aggressive secondary colonist. (Sinclair & Johnson, 1989)

Since foliar applications to control this pest are not possible and since there are no soil applications that can be applied to control this pest, the best option is to perform a trunk injection of debacarb and/or tebuconozole in conjunction with trunk injected imidacolprid for two lined chestnut bores, leaf miners and lace bugs. (Windham, 2002)

Euonymous and Virginia Creeper Vines

Vines are plants that cannot remain freestanding to any appreciable height. They must climb by using other plants or structures for support. In nature vines use trees for support and climb trees using four modes: twining, tendrils, tendrils with adhesive disks and aerial roots. Twining vines climb by encircling or winding around upright tree trunks similar to the designs of a barber's pole. They are detrimental to tree growth by wrapping themselves tightly around the tree stem. When the tree trunk grows and expands, the vine constricts the flow of water and photosynthate, ultimately creating defects in the wood. Young trees are commonly girdled and may eventually die without treatment. Winding vines climb by means of tendrils (slim, flexible and leafless stems that wrap around most anything they contact, such as small branches and twigs). Virginia creeper *(Parthenocissus quinquefolia)* is an example of a climbing vine with tendrils where its branched tips form flat disks with a sticky substance that adheres to the tree. Once the substance dries and anchors the disk, the tendril coil contracts and draws the vine closer to the tree.

Vines such as euonymus *(Euonymus fortune)* produce aerial roots that attach to the tree. These aerial roots do not absorb water or nutrients (all vines have root systems in the ground) and thus do not harm the tree bark by penetration. However, the vine and its aerial roots may cause discoloration of the bark and they prevent air circulation, which results in altered temperature and moisture conditions that affect tree bark biology. Wood decay fungi that prefer such conditions will be promoted on exposed wood that is covered by vines and there is some evidence that the bark compounds that protect trees are weakened by these altered conditions. The aerial roots are difficult to remove from the supporting surface once they have anchored. The fastest growing vines are stem twiners and tendril climbers and the slowest are the root climbers.

Most twiners and tendril climbers must have support surfaces at different canopy heights to aid in reaching the top of the tree canopy. These climbers cannot reach the upper canopy on isolated stems with high branches without some lower support. Twiners and tendril climbers tend to grow with the tree as the tree increases in height (Evans E. , 2000)

Most vines do not affect tree growth unless they grow where their leaves displace the leaves of the tree. The trees with fewer leaves and less ability to photosynthesize (like the Resurrection Tree) will begin to **decline** as the vines become more dominant. Vines that tend to be troublesome in Tennessee include, euonymus and to a small extent Virginia creeper, although there are many other potential vines that are far more destructive than these.

The most pressing problem with the vines on the Resurrection tree pose is that the vines have obscured various parts of the tree's anatomy and structure. This makes it impossible to critically observe significant tree defects that may be compromising the tree's structural integrity and makes predicting tree part failure as a result of a defect impossible. Identifying potential failure points as a tree hazards is inherently difficult and is fraught with uncertainty in its own right, let alone compounding the task of risk assessment and management with the presence of wood and foliage from vines.

The presence of vines that obscure the anatomy of the tree dramatically and unnecessarily increases the uncertainty of the risk that a tree may pose to any given target. If a tree is severely decayed (as the Resurrection Tree is), the added weight of vines can contribute to tree or tree part failures.

Vines should be severed at the ground level and later sprayed with a recommended herbicide when cut or when they stump sprout. NOTE: Do not spray severed vine wounds at the time they are cut since cuts can expose tree cambium and this exposed cambium could cause herbicide sprays to detrimentally and fatally enter the tree.

Resurrection Fern

Resurrection *(Polypodium polypodioides)* fern is a fascinating plant very common in the Southeast. Resurrection Fern is an epiphyte or "air plant". Epiphytes can be found growing on other plants, but make their own food the same way other green plants do. Nutrients and moisture are obtained from the air or where they may collect on the surface of a host plant. Some other well-known epiphytes include orchids, bromeliads and Spanish moss. Resurrection fern is often seen growing on pecan, oak and other long-lived trees that have furrowed bark. It creates green foliage on tree trunks and branches. Its rhizomes easily attach to the deep cracks and fissures of tree bark where a firm hold is easily obtained and where moisture is readily available during rainy spells.

While the fern carries with it some unique aesthetic characteristics that many tree enthusiasts and horticulturists find very pleasing, they do come at a price. There is some evidence to suggest that the presence of the ferns in large numbers can causes significant and detrimental changes to the bark of trees and that these changes can result in promulgation of decay in trees. These changes include increased moisture and increased biological activity at the tree bark interface. The presence of these plants also obscures the tree anatomy below them, making it impossible to identify tree defects that may exist. This makes it impossible to critically observe significant tree defects that may be compromising the tree's structural integrity and makes predicting tree part failure as a result of a defect impossible. Identifying potential failure points as tree hazards is inherently difficult and is fraught with uncertainty in its own right without the obviating effect that these epiphytic plants have on Level 1 and 2 inspections. Their presence creates greater uncertainty in risk assessment and risk management. (Shaw, 2010)

The presence of epiphytes that obscure the anatomy of a tree will dramatically and unnecessarily increase the uncertainty of the risk that a tree may pose to any given target. Fortunately, resurrection ferns are limited to growing on the upper surfaces of the oldest scaffold branches of the tree. Considering the limited visibility that an observer has of these parts from the ground and considering the crucial aesthetic that these plants offer to the tree and the site as a whole, I am reluctant to recommend any control measures for these plants.

Soil Biology

Soil Moisture

Soil moisture is the leading limiting factor for tree health and vitality. Water carries all nutrients that have dissolved and are absorbed by the tree for sustenance. Since no nutrients can enter the tree without an abundance of water nutrient levels in the tree system are somewhat regulated by soil moisture.

Water along with carbon dioxide are primary building blocks of photosynthate without which, no life on earth could exist. Carbohydrates (the product of photosynthesis) that are produced in the green parts of plants are the primary component of cellulose, hemicellulose, lignin, (all of which are combined by the tree to make woody tissues) make up 99% of a trees structure. The sugars and starches produced in photosynthesis also provide the fuel energy that living tree cells consume in respiration and growth. Trees also absorb water in a process known as transpiration which cools the tree and provides a mechanism for trees to extract the nutrients they need from soil water. (Harris R. J., 2004)

The sample that was tested for soil moisture was very dry and this tree will require between 1.25 inches (about 1500 gallons of water under the canopy, about 4000 square feet) twice per week during dry periods when there has been no rain water for 7 days or more if soil moisture levels are to be kept slightly above normal. (USDA, 2013)

Soil Fungi Health

Fungi in the soil play an important role, nutrient retention and transportation, soil structure and soil structure's relationship to soil pH. Plant system succession is directly linked to the ratio of Fungi to Bacteria and is the first area to address when approach soil remediation.

The lack of fungal activity means that there are fewer resources available to the tree beneficial fungi that normally exist in the soil. These include the ectomycorrhizal fungi which form a symbiotic relationship with bur oak tree roots and form an extramaturcular root system capable of absorbing far more water and nutrients the tree that trees without ectomycorrhizae. These fungi also filter out toxins and suppress pathogenic organisms in the soil. In exchange for these services, the tree supplies a steady stream of carbohydrates to the fungi. Weakened trees are less able to keep and develop these symbiotic fungi populations and will require remediation in order to reestablish healthy ectomycorrhizal populations.

The lack of soil fungi health is a very serious problem that could lead to the total breakdown of tree health and vitality. Soil fungal health can be restored by introducing fungal resources to the soil and introducing the ectomycorrhizal inoculums that are known to form beneficial associations with bur oak trees. There are several methods that this can be achieved, but the most successful method and least intrusive method is vertical mulching in which soil compaction is reduce while creating conditions where mycorrhizal fungi thrive. Irrigation will also be a critical component of the recovery. (Van Veen, 1979)

Soil Bacteria Biomass

Total population of bacteria provides an indicator of abundance of food for soil organisms, nutrient cycling capacity and general diversity of the bacterial population. The Active population is the component of the total biomass that is currently metabolizing oxygen; i.e., the functional fraction of the bacteria. While high bacteria and diversity are not a problem in soil biology, a high bacterium to fungi ratio points to a lack of fungal resources that can have a series of cascading and very detrimental effects on trees. (Van Veen, 1979)

Protozoa Populations

Protozoa are typically single cell organisms that feed upon bacteria. Flagellates and amoebae are true aerobes, meaning they must have adequate oxygen to survive, while Ciliates are facultative anaerobes, meaning they can survive in low oxygen conditions.

Numbers of protozoa in are very important as an indicator of potential nutrient cycling, if there are sufficient levels of Flagellates and Amoebae then aerobic nutrient cycling can occur. However, high levels of ciliates can be an indicator that anaerobic nutrient cycling is occurring. The lack of fungal health and low flagellate populations indicates that soil compaction is becoming a problem for the Resurrection Tree. Soil compaction can be alleviated by performing a vertical mulching treatment, adding a composted, aged, hardwood mulch to the soil surface and by supplying frequent irrigations in the absence of prolonged periods without precipitation. (Ekelund, 1998)

Nematode Constituents

Identifying and quantifying nematode constituent levels can be a very clear indicator of soil health. Nematodes provide soil nutrient cycling very similar to the protozoa. The serve very specific function and may be into several important functional groups:

Bacterial Feeders: This group of beneficial nematodes feeds on bacteria; they help to keep the bacterial populations in balance. In the process of consumption, they cycle soluble nutrients in the rhizosphere of the fine roots of trees.

Fungal Feeders: As the name would suggest this group of nematodes feeds on fungi, again, keeping these populations in balance and cycling nutrients in the root zone. Many of these types of nematodes also feed on fungi that can cause disease in plants. Having a good population and variety of these organisms can be a valuable asset for the soil which we grow plants that are more susceptible to some types of fungal diseases.

Predatory Nematodes: These Nematodes are specialized in eating other nematodes; typically, they prey on Root Feeding nematodes and can help minimize the damage from them. This group will also consume protozoa and some types of micro-arthropods. Again, this becomes an excellent source of nutrients for plants.

Fungal/Root Feeders: This is an interesting group of nematodes, they typically act as fungal feeders, but if the population of fungi is low, or if the right combination of plant and nematode are present they will eat the roots of the plants. We use this group as an indicator for both healthy fungal populations and, at the same time, for potential disease issues in the plants.

Root Feeders: This is the group of nematodes that is truly parasitic to plants, there is a wide variety of these types, and depending on the genus and the plant being grown can be a real problem for production and health of the plant. As few as 1 root feeder per gram of soil can hinder productivity. As an indicator of soil health, this is a group to watch.

By looking at the total population, examining levels of functional groups, and cross-referencing to the plant being grown we can get a fairly good picture of soil productivity. The high diversity and relatively even population of nematodes in the soil taken from near the Resurrection Tree indicates that there is the potential of high soil fertility at the site. (Goodey, 1963)

Tennessee Landmark and Historic Tree Registry

The Tennessee Landmark and Historic Tree Registry recognizes noteworthy trees or groves for their significance to Tennessee communities, the state, and the nation. To qualify for the registry, a Tree must be commonly recognized as an established and familiar feature of the community, confirmed as a significant part of the community's heritage, or planted to commemorate special events or community leaders more than 50 years ago.

A historic must have been a direct witness to a historic event or cultural movement that was significant nationally, regionally, or within the state and confirmed to date to that time. In my opinion, this tree qualifies as a landmark and historic tree. (Tennessee Urban Forestry Council, 2016)

Conclusions

Summary

The Resurrection **Tree** is growing on a nearly ideal site for the health, **vigor** and sustainability. The Resurrection Tree exhibits extensive signs and symptoms of decay from white, brown and soft rot type fungi. Brown rot has caused extensive internal decay of the **buttress** and the lower portion of buttress roots. This decay very likely extends to some of the structural roots beyond the main buttress roots. The cavity of the Resurrection Tree is completely dissolved at the base and extensive. The buttress decay has left a solid shell of sapwood and some heartwood that is at least a foot thick around the trees circumference just inside the tree's **bark**. The wood is both elastic and strong as measured with the Resistograph tests and the fractometer test. The callus **tissue** on both sides of the cavity opening is also well developed.

The Resurrection Tree has extensive decay and is in a **stressed** and substantially weakened state. As such, its energy reserves are low and its ability to defend itself against the extensive decay is compromised. Fertilization of the tree would only exacerbate this condition and cause even more aggressive deterioration of the healthy woody tissues and would cause other effects detrimental to the health of this tree and should be avoided. There are measures that would help increase the Resurrection Tree's uptake of micro-nutrients that already exist in the soil and this would help the tree defend against decay. These measures include mulching and vertical mulching with beneficial biological soil amendments.

Wind forces will greatly increase loads on the Resurrection tree and it is far more likely that a **branch failure** of this tree would occur during wind events than at any other time; however, the long and low scaffold branching structure of the tree has a tremendous damping effect on the tree's trunk and greatly reduces the likelihood of trunk failure as a result of wind loading alone.

The specific defects that could be seen and increase failure potential were:

- moderate species failure potential
- there is minor asymmetry in the canopy
- this tree has a slight natural lean
- the trunk had a previous wound and seam
- the trunk has a large trunk and buttress cavity
- there is significant decay on the bottom of the buttress roots
- decay has penetrated from the bottom of the root to the surface at two points
- the tree spread broad (increases the likelihood of branch failure)
- a codominant fork with a moderate failure potential
- there is no history of pruning to remove deadwood or improve tree structure
- the tree is stressed and has multiple significant signs of branch decay
- there are many epicormics sprouts on the scaffold structure and upward
- there is significant twig, limb and branch dieback
- there are previous limb failures
- there is a two lined chestnut bore infestation
- there are vines growing on the trunk and lower branches
- there are other pest infestations and infections
- the leaves are stunted and discolored

Other observations that reduced failure potential that I considered were:

- the tree has had no previous history of scaffold branch or trunk failure for 200+ years
- the core has healthy growth increments
- callus tissue that could be seen on the wound seams was closed and healthy
- the growth of callus at the cavity opening was vigorous
- no positive indicators of decay (mushrooms) could be seen although decay is present
- the pedestrian and maintenance traffic is not heavy or constant
- the main stem bifurcations have large branch bark ridges/collars indicating branch strength
- the vast majority of the roots appear to be healthy
- there were no termites or carpenter ants that could be seen
- there was no sap oozing down the trunk or branches
- the trunk has excellent buttress formation on all sides
- there is no soil heaving or soil cracks
- there is no severe or non-self-corrected lean
- the trunk shell tests show it to be intact and symmetrical

Although this tree has many **defects**, these defects are common among low **risk** trees in public places. The tree did exhibit many defects in the **scaffold branches** that are commonly associated with tree branch failures and they did fit the patterns of failure that experienced arborists look for in tree **hazard** evaluations. The tree was ranked 10 on a scale from 3 to 12. This ranking is not very common to trees in parks, golf courses, along city streets and other public places. This hazard rating is not normally considered acceptable by the vast majority of tree owners and managers. While the tree is not in danger of catastrophic failure under normal conditions, the dead and decayed scaffold structure could fall at any moment. These branch hazards should be mitigated.

The greatest risk that the Resurrection Tree poses is loss of life. While the chances that someone would be standing or sitting under the tree at the exact time that a branch failure occurs is quite small, about 1 in 960,000 this year, such events are possible and occur with some regularity- and almost all of these events are completely preventable. The odds are quite small in any given year, however the odds increase greatly over time and raise the possibility of an incident to about 1 in 12,000 in the next 75 years. The consequences of such an eventuality are beyond severe. There would be trauma across an entire range of losses, both emotionally and economically. These include the far reaching consequences of individual life being tragically lost, the impact of the loss on loved ones, poor publicity and public image for Franklin First United Methodist Church locally and beyond, and emotional distress and economic consequences for church membership. There is also the risk that the well-house located under the tree's **canopy** might be damaged or destroyed if a defective branch fell on it. While this could be repaired quite easily, the cost of mitigation would be far less. Simply removing defective branches will mitigate this risk.

The potential that a tragic event might occur on the Resurrection Tree can be mitigated by removing features that are inviting to pedestrians, restricting access with better signage or physical barriers, and removing the most defective tree parts that are that are large enough to cause serious injury or death.

Because of the location, condition and use of the Resurrection Tree, **American National Standards Institute** (ANSI) **A300** (Part 9) Level 2 inspections should be performed annually.

The tree is infested with two lined chestnut borers *(Agrilus bilineatus)* and oak lace bugs *(Corythucha arcuata)*. These **pests** should be treated with trunk injected imidacloprid. The tree is also infected with tubakia leaf spot *(Tubakia dryina)* and this fungus should be treated with trunk injected debacarb. Finally, the tree is infested with gregarious oak leaf miners *(Cameraria cincinnatiella)*. The leaves of the tree should be raked up and burned or composted each fall and the tree should be trunk injected with tebuconazole to prevent re-infestation.

The tree has several types of vines growing on it. Vines should be severed at the ground level and later sprayed with a glyphosate herbicide several weeks after they are cut or when they begin to **stump sprout**. NOTE: Do not spray severed vine wounds at the time they are cut since cuts can expose tree cambium and this exposed cambium could cause herbicide sprays to detrimentally and fatally enter the tree. No treatment is necessary for the resurrection ferns.

The soil biodiversity of the site soil is low in ectomycorrhizal and other beneficial soil fungi. This is likely caused by pedestrian and maintenance traffic under the tree. Efforts should be made to curb traffic under this tree and to remediate the soil components in favor of ectomycorrhizal associations and reduction of soil compaction through vertical mulching, mulching and irrigation.

The Resurrection Tree is both a landmark tree and a historic tree as defined by the Tennessee Urban Forestry Council. This tree should be recognized as such.

Recommendations

Site Restriction

Signage should be posted to warn people that the Resurrection Tree has defective branches that could fall, potentially causing personal injury or death and that pedestrians should only enter that area at their own risk. I also recommend that wooden or other suitable fencing be installed under the outer canopy of the tree to prevent children and other pedestrians from entering.

Pruning

Purpose- remove the dead scaffold branch structure from the tree using drop crotch pruning techniques being careful not to further injure the trunk or neighboring scaffold structure of the tree in order to prevent insect and disease pressure that would result from destructive infestations and infections.

Pruning Specifications:

1. A tree inspection will be performed by arborists prior to any tree pruning activity.
2. Any unexpected defects will be conveyed to the property manager or owner prior to mitigation.
3. Work details will be written down with purpose, scope and limits of work to be performed
4. Climbing spikes or gaffs are not permitted.
5. Limbs that cannot be handled by one person easily will be lowered by rope.
6. Under no circumstances shall more than one percent of the live foliage from an individual tree branch be removed.
7. The removal of limbs smaller than one inch in diameter will not be required.
8. Remove deadwood and severely decayed wood of all branches.
9. Removal of dead limbs or dead stub sprouts one inch in diameter or larger will be required.
10. No live stubs larger than one inches in diameter will be removed.
11. All pruning is to be done within the scope of the approved techniques as described in Pruning Trees companion BMP Tree Pruning published by ISA.
12. Work is to be done by workers trained in compliance with:
    - ANSI Z133.1 Safety Requirements for Tree Care Operations, such as required by
    - OSHA CFR 1910 (General industry),
13. Pruning will be repeated every 5 years or as directed by the owner.
14. No pruning of large diameter branches over 3 inches.

Insect/Disease Control

Arboriculture is founded on the principals of Plant Health Care (PHC) which is defined as a comprehensive system for managing the appearance, structure, and vitality of ornamental landscapes within client expectations. PHC is a proactive, holistic management system that encompasses all aspects of landscape stewardship and cultivation; pest management, usage of plants; and removal of plants. PHC recognizes that trees and woody plants are part of a greater landscape ecosystem that includes turf grasses, perennials, herbaceous plants and even annuals.

Plants and other organisms interact with each other on varying ecologic levels to create a matrix of interdependencies. These ecological interdependencies must achieve equilibrium in order for any particular site to remain healthy and sustainable. Oftentimes, equilibrium is upset by environmental changes, changes in climate, human activity, exotic species invasion, and other factors.

Equilibrium disruptions can set into motion a cascading effect of sequential changes in ecology such as increased competition, changes in allelopathic effects, nutrient cycling, and pest dynamics. In order to achieve and maintain an ecologic stability (sustainability) that meets client goals, landscape professionals and managers must understand and adopt an ecological systems approach in their PHC practices. To achieve landscape ecology equilibrium, trees cannot be managed in isolation from other landscape components, and the impact of management practices on the entire landscape ecosystem must always be considered.

One essential component of PHC is pest management. Pests frequently threaten the health, structure, and appearance or function of landscape plants. For most of the 20th century, landscape pest management had a single dimension: chemical control. Beginning in the 1970s, a multidimensional approach to pest management began to emerge. This approach became known as Integrated Pest Management (IPM). Today, PHC embraces IPM as the cornerstone approach to bringing landscape pests into ecologically sustainability to meet client expectations.

The IPM approach combines preventive and direct control tactics into a single management strategy. Depending on the situation, a single tactic or a combination of tactics may be employed to address specific pest problems. The goal of IPM is to manage pests and their damage to client defined tolerances. Total pest eradication is usually not a feasible goal. IPM strategy considerations include the ecological, social, and economic implications of pest management. An appropriate IPM strategy will:

- Complement other PHC practices to promote plant appearance, structure, and vitality
- Avoid harmful effects on non-targets (people, animals, plants, and beneficial insects)
- Cause minimal disturbance to the built and natural environments
- Achieve the client goals in a cost-effective manner

IPM also incorporates the following concepts:

Action Threshold Factors-

a. Client tolerance
b. Plant value, condition and susceptibility
c. Pest damage potential
d. Timing
e. Site condition
f. Weather conditions
g. Inspection frequency
h. Ecological equilibrium control potential

Monitoring Inputs-

a. Site information
b. Plant information
c. Pest information
    i. Pest ID
    ii. Pest Population
    iii. Current life cycle stage
    iv. Potential for control

Key Plants and Key Pests

Many pests are both seasonal and plant host specific. These are known as Key Plants and Pests. Examples on white oak include gall wasps and scale insects. These two pests frequently attack oak in spring and cause leaf and twig deformities. Certain plants also have a high value because of their location, function, size, appearance, or cultural significance. Because a plant's purpose and use may vary from site to site, key plants should also be defined and identified by the client. Through focusing on key plants pests and client expectations, IPM program designers can better estimate timing of monitoring and predict what, when, and how threshold actions will be implemented, and what the costs will be.

The insects and diseases I saw during my examination do not pose a threat to your tree, however they can be an aesthetic nuisance. If the disfigured leaves and twigs are bothersome to you, we can develop treatment strategies to overcome these problems.

Irrigation

Add 1.25 inches (about 1500 gallons of water under the canopy, over about 4000 square feet) twice per week during dry periods when there has been no rain water for 7 days or more if soil moisture levels are to be kept slightly above normal. A tensiometer may also be used to determine if soil moisture levels are dry and to determine when soil moisture is adequate.

Vertimulching

Vertical mulching will be a critical part of the Resurrection Tree's recovery from the loss of mycorrhizal fungal association and from soil compaction.

Drill 2.5 to 3.5 inch no less than 2 but no greater than 3 feet deep on approximately 3 foot centers throughout the entire drip area of the tree as topography and structures allow starting about six feet from the trunk. The resulting excavate will be mixed with inert soil aeration materials, composted organics and mycorrhizal inoculant.

The mycorrhizal inoculum shall consist of the following components:

A soil amendment containing no less than 2,000,000,000 endomycorrhizal propagules per lb. applied 7 lb. per1000 square as part of a Vertimulching treatment. The spores will be applied with sufficient biostimulants containing no less than 2% humic acid derivatives at a rate of .25 lb. per 4,000 square feet. This mixture will also contain a fine grade, water-retaining polymer, yucca extract and green sand or equivalent.

Mulching

The third most common limiting factor for tree health and vigor is soil nutrient availability. Adding mulch increases the organic content of the soil and, when combined with the increase in soil oxygen and soil moisture, organic mulch provides a synergistic increase in soil biodiversity and bioactivity.

When greater soil biodiversity and bioactivity is achieved, higher nutrient uptake by plants is realized and this translates into increased tree health and vigor levels. Increased bioactivity and enhanced soil biodiversity will also result in the displacement of most soil borne pathogens. Finally, a manicured mulch bed under a tree improves aesthetics. Hence, the perceived value of trees in manicured beds is higher than that of un-mulched trees.

Mulching Specifications:

1. All mulching will be performed with organic material that is free of toxins or foreign materials.
2. This organic matter will be composted for at least 8 months, be of dark color, and free of odors. The mulch will be of fine, uniform texture and will be placed under the canopy of the tree to a depth of 2.5 to 3 inches.
3. The mulch will cover a circular area, with the trunk in the middle, to cover no less than 2/5 of the trees **drip area**.

Vine Removal and Weed Suppression

Weed suppression during recovery is essential. A thin layer of mulch will do much to suppress weeds; however, additional applications of glyphosate weed controls will need to be carefully and selectively applied to keep weeds from affecting tree health and vigor. When and where needed, apply a rate of 6oz. of glyphosate 46% (Roundup Pro® or equivalent) per gallon of water to wet the foliage of the weeds within the mulched area under the tree. Repeat monthly as weeds reappear. Be careful not to spray the tree foliage or permit the drift of spray to make contact with the foliage of any desirable plants or open wounds on the tree. Vines should be cut at the base being careful not to cut into the bark of the tree or to penetrate the bark in any way. As vines resprout or as new vine plants germinate, spray them with weed suppression treatment.

Pest Control Specifications

In late March 2017, trunk microinject the tree with imidacloprid\debacarb at a rate of 3ml per inch of trunk diameter. Use the same holes to trunk inject tebuconozole at a rate of 3.75ml per inch of trunk diameter. Create no more than 33 holes less than 3/16" diameter at 1-inch depth of the sapwood.

Landmark and Historic Tree Registry

Submit an application of the Resurrection Tree to the Tennessee Urban Forestry Council for registration on the Tennessee Landmark and Historic Tree Registry.

Other Recommendations

In my previous report dated 12-10-2010

- Efforts should be made to propagate these trees and produce seedlings that can be made available for sale to church members, the local community, and regional nurseries
- Develop a tree safety policy for the property and train maintenance staff in the recognition and proper reporting procedure for trees that appear to be dangerous.
- Resolve the tree/utility conflict to prevent further utility pruning on the circle drive tree.
- Perform proper arboricultural practices according to the specifications included in this report
- After fertilization, foliage samples should be taken to assess the effectiveness of the fertilization program
- Since the tree has been harmed by previous utility line clearance, the amenity value of the tree should be determined, using CTLA guidelines and the tree insured
-

- A tree inventory should be performed on the entire property to identify any other trees of special significance, and to identify any other hazardous trees. Since an inventory will be a requirement of any new construction on this site, there will be no added cost to the church, and the information contained in the inventory will be very helpful in making future decisions regarding future building, resource allocation, and maintenance expenditures.

Appendix

Site Diagram

Site Soil Type Analysis

Map Unit Description

The map units delineated on the detailed soil maps in a soil survey represent the soils or miscellaneous areas in the survey area. The map unit descriptions in this report, along with the maps, can be used to determine the composition and properties of a unit.

A map unit delineation on a soil map represents an area dominated by one or more major kinds of soil or miscellaneous areas. A map unit is identified and named according to the taxonomic classification of the dominant soils. Within a taxonomic class there are precisely defined limits for the properties of the soils. On the landscape, however, the soils are natural phenomena, and they have the characteristic variability of all natural phenomena. Thus, the range of some observed properties may extend beyond the limits defined for a taxonomic class. Areas of soils of a single taxonomic class rarely, if ever, can be mapped without including areas of other taxonomic classes. Consequently, every map unit is made up of the soils or miscellaneous areas for which it is named and some minor components that belong to taxonomic classes other than those of the major soils.

Most minor soils have properties similar to those of the dominant soil or soils in the map unit, and thus they do not affect use and management. These are called noncontrasting, or similar, components. They may or may not be mentioned in a particular map unit description. Other minor components, however, have properties and behavioral characteristics divergent enough to affect use or to require different management. These are called contrasting, or dissimilar, components. They generally are in small areas and could not be mapped separately because of the scale used. Some small areas of strongly contrasting soils or miscellaneous areas are identified by a special symbol on the maps. If included in the database for a given area, the contrasting minor components are identified in the map unit descriptions along with some characteristics of each. A few areas of minor components may not have been observed, and consequently they are not mentioned in the descriptions, especially where the pattern was so complex that it was impractical to make enough observations to identify all the soils and miscellaneous areas on the landscape.

The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The objective of mapping is not to delineate pure taxonomic classes but rather to separate the landscape into landforms or landform segments that have similar use and management requirements. The delineation of such segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, however, onsite investigation is needed to define and locate the soils and miscellaneous areas.

An identifying symbol precedes the map unit name in the map unit descriptions. Each description includes general facts about the unit and gives important soil properties and qualities.

Soils that have profiles that are almost alike make up a *soil series*. All the soils of a series have major horizons that are similar in composition, thickness, and arrangement. Soils of a given series can differ in texture of the surface layer, slope, stoniness, salinity, degree of erosion, and other characteristics that affect their use. On the basis of such differences, a soil series is divided into *soil phases*. Most of the areas shown on the detailed soil maps are phases of soil series. The name of a soil phase commonly indicates a feature that affects use or management. For example, Alpha silt loam, 0 to 2 percent slopes, is a phase of the Alpha series.

Some map units are made up of two or more major soils or miscellaneous areas. These map units are complexes, associations, or undifferentiated groups.

A *complex* consists of two or more soils or miscellaneous areas in such an intricate pattern or in such small areas that they cannot be shown separately on the maps. The pattern and proportion of the soils or miscellaneous areas are somewhat similar in all areas. Alpha-Beta complex, 0 to 6 percent slopes, is an example.

An *association* is made up of two or more geographically associated soils or miscellaneous areas that are shown as one unit on the maps. Because of present or anticipated uses of the map units in the survey area, it was not considered practical or necessary to map the soils or miscellaneous areas separately. The pattern and relative proportion of the soils or miscellaneous areas are somewhat similar. Alpha-Beta association, 0 to 2 percent slopes, is an example.

An *undifferentiated group* is made up of two or more soils or miscellaneous areas that could be mapped individually but are mapped as one unit because similar interpretations can be made for use and management. The pattern and proportion of the soils or miscellaneous areas in a mapped area are not uniform. An area can be made up of only one of the major soils or miscellaneous areas, or it can be made up of all of them. Alpha and Beta soils, 0 to 2 percent slopes, is an example.

Some surveys include *miscellaneous areas*. Such areas have little or no soil material and support little or no vegetation. Rock outcrop is an example.

Additional information about the map units described in this report is available in other soil reports, which give properties of the soils and the limitations, capabilities, and potentials for many uses. Also, the narratives that accompany the soil reports define some of the properties included in the map unit descriptions.

Williamson County, Tennessee

Eg—Egam silt loam, phosphatic

Map Unit Setting

National map unit symbol: kkr4
Elevation: 800 to 1,300 feet
Mean annual precipitation: 52 to 56 inches
Mean annual air temperature: 54 to 57 degrees F
Frost-free period: 170 to 190 days
Farmland classification: All areas are prime farmland

Map Unit Composition

Egam and similar soils: 92 percent
Minor components: 8 percent

Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Egam

Setting

Landform: Flood plains
Landform position (three-dimensional): Tread
Parent material: Clayey alluvium

Typical profile

H1 - 0 to 20 inches: silt loam
H2 - 20 to 40 inches: silty clay loam
H3 - 40 to 55 inches: silty clay loam

Properties and qualities

Slope: 0 to 5 percent
Depth to restrictive feature: More than 80 inches
Natural drainage class: Well drained
Capacity of the most limiting layer to transmit water (Ksat): Moderately high (0.20 to 0.60 in/hr)
Depth to water table: About 36 to 48 inches
Frequency of flooding: Occasional
Frequency of ponding: None
Available water storage in profile: High (about 9.7 inches)

Interpretive groups

Land capability classification (irrigated): None specified
Land capability classification (nonirrigated): 2w
Hydrologic Soil Group: C
Hydric soil rating: No

Minor Components

Dunning

Percent of map unit: 8 percent
Landform: Depressions
Hydric soil rating: Yes

Data Source Information

Soil Survey Area: Williamson County, Tennessee
Survey Area Data: Version 11, Sep 11, 2015

Leaf Tissue Analysis

Report Number
16-274-0009

Lab No:
212991

Waypoint ANALYTICAL

2790 Whitten Road, Memphis, TN 38133
Main 901.213.2400 * Fax 901.213.2440
www.waypointanalytical.com

PLANT ANALYSIS

Customer Account Number : **29651**

Send To : Green Season Consulting
Mr. Marty Shaw
605 Laurel Court
Franklin TN 37064

Grower :
FFUMC

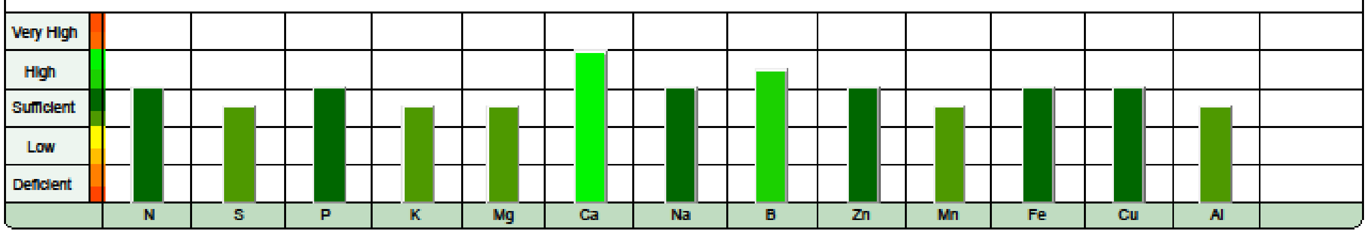
Report Date : 10/3/2016
Page 1 of 2

Field id:
Sample Id : **16J28001**

Crop : **Oak, Bur**
Growth Stage : **Summer**

	Nitrogen %	Sulfur %	Phosphorus %	Potassium %	Magnesium %	Calcium %	Sodium %	Boron ppm	Zinc ppm	Manganese ppm	Iron ppm	Copper ppm	Aluminum ppm
Analysis	2.38	0.17	0.25	1.11	0.20	0.91	0.02	57	33	64	95	16	63
Normal Range	1.65	0.13	0.10	0.80	0.18	0.39	0.00	25	13	50	45	6	0
	2.99	0.29	0.29	1.79	0.39	0.79	0.01	50	35	250	100	20	500

	N/S	N/K	P/S	P/Zn	K/Mg	K/Mn	Ca/B	Fe/Mn	Ca/K	Ca/Mg
Actual Ratio	14.0	2.1	1.5	75.8	5.6	173.4	159.6	1.5	0.8	4.6
Expected Ratio	11.0	1.8	0.9	81.3	4.5	86.3	157.4	0.5	0.5	2.1



Comments :
Please call lab for recommendations for Trees
02002) Nutrient levels are adequate at this time.

Analysis prepared by: Waypoint Analytical Tennessee, Inc.

Report Number
16-274-0009

Lab No:
212992

Waypoint ANALYTICAL

2790 Whitten Road, Memphis, TN 38133
Main 901.213.2400 * Fax 901.213.2440
www.waypointanalytical.com

PLANT ANALYSIS

Customer Account Number : **29651**

Send To : Green Season Consulting
Mr. Marty Shaw
605 Laurel Court
Franklin TN 37064

Grower :
FFUMC

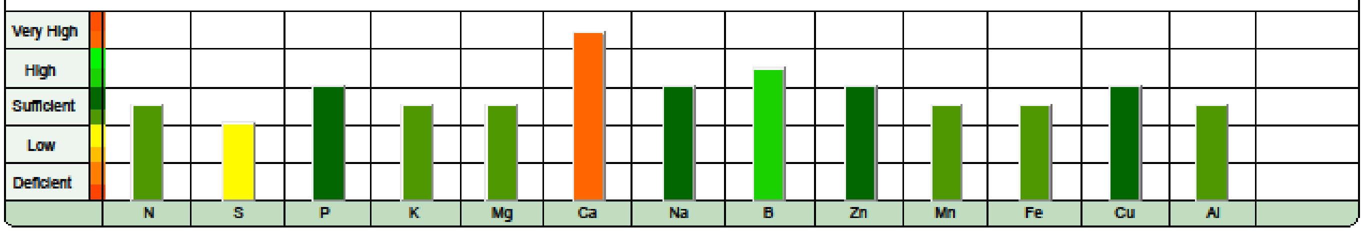
Report Date : 10/3/2016
Page 2 of 2

Field id:
Sample Id : **16J28002**

Crop : **Oak, Bur**
Growth Stage : **Summer**

	Nitrogen %	Sulfur %	Phosphorus %	Potassium %	Magnesium %	Calcium %	Sodium %	Boron ppm	Zinc ppm	Manganese ppm	Iron ppm	Copper ppm	Aluminum ppm	
Analysis	2.16	0.13	0.25	1.10	0.24	1.03	0.02	56	33	62	65	15	50	
Normal Range	1.65	0.13	0.10	0.80	0.18	0.39	0.00	25	13	50	45	6	0	
	2.99	0.29	0.29	1.79	0.39	0.79	0.01	50	35	250	100	20	500	

	N/S	N/K	P/S	P/Zn	K/Mg	K/Mn	Ca/B	Fe/Mn	Ca/K	Ca/Mg				
Actual Ratio	16.6	2.0	1.9	75.8	4.6	177.4	183.9	1.0	0.9	4.3				
Expected Ratio	11.0	1.8	0.9	81.3	4.5	86.3	157.4	0.5	0.5	2.1				

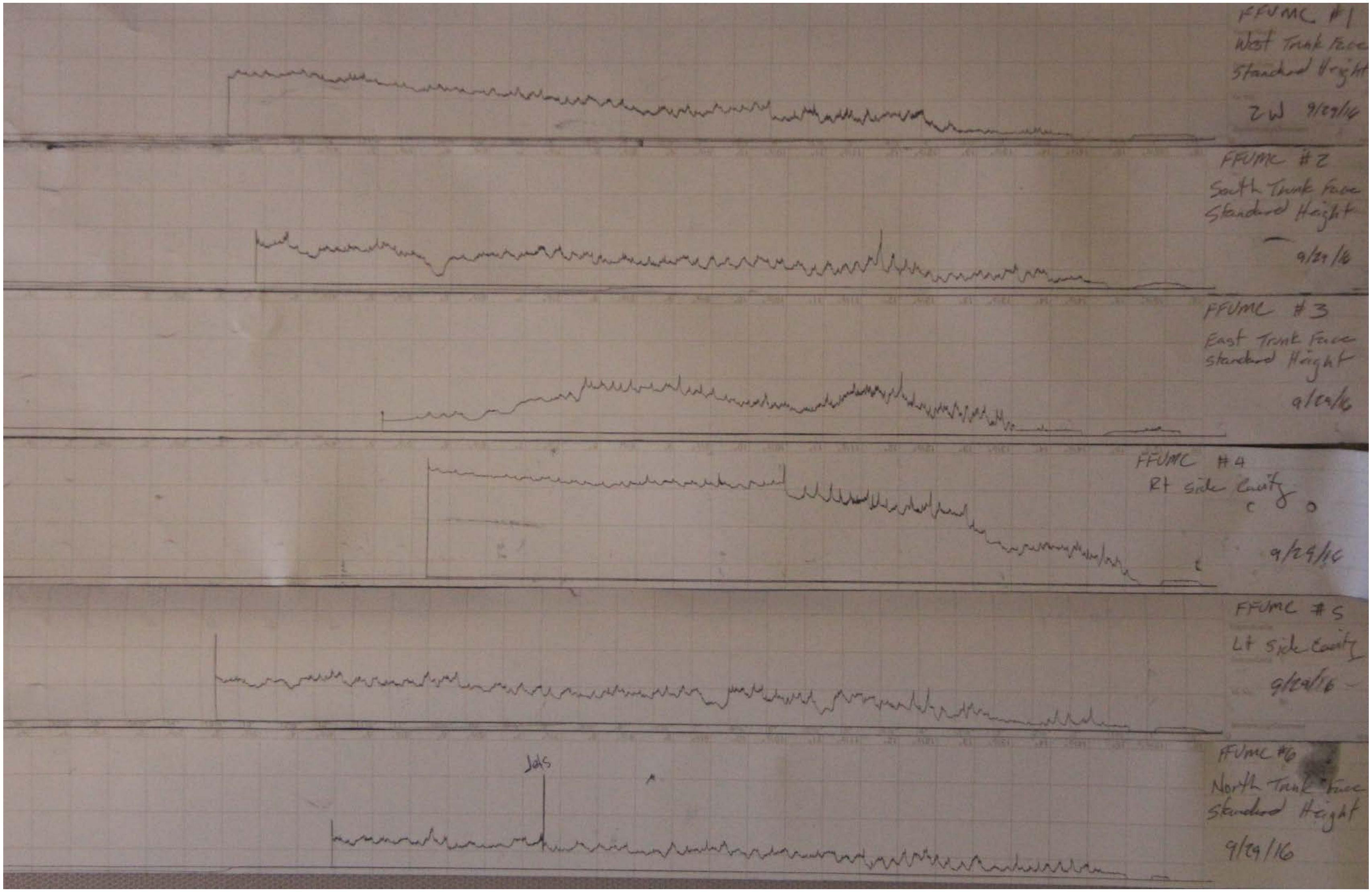


Comments :

02023) These plants are low or deficient in sulfur. This could be a result of low soil sulfur content, poor root development or inadequate drainage. Sulfur may be applied to the crop in the sulfate form with sidedress or topdress applications or in irrigation water. Apply at a rate of 10 to 20 lbs of sulfur per acre. For foliar application, apply 1 to 2 lbs of sulfur per acre.

02114) One or more nutrients are very high at this time. Please monitor.

Analysis prepared by: Waypoint Analytical Tennessee, Inc.


FFUMC #1
West Trunk Face
Standard Height
ZW 9/29/16
FFUMC #2
South Trunk Face
Standard Height
9/29/16
FFUMC #3
East Trunk Face
Standard Height
9/29/16
FFUMC #4
Rt Side Cavity
9/29/16
FFUMC #5
Lt Side Cavity
9/29/16
FFUMC #6
North Trunk Face
Standard Height
9/29/16

Soil Biodiversity Analysis

Biological Analysis
Soil

earthfort

Report prepared for:
Green Season Consulting
Martin Shaw
PO Box 680716
Franklin, TN 37068 USA
(615) 614-3398
martyshaw@bellsouth.net

Report Sent: 10/21/2016
Sample#: 01-123973 | Submission:01-025679
Unique ID: J031601
Plant: Oak
Invoice Number: 0
Sample Received: 10/10/2016

For interpretation of this report please contact:
Earthfort Labs
info@earthfort.com
(541) 257-2612

Consulting fees may apply

Organism Biomass Data		Dry Weight	Active Bacteria (µg/g)	Total Bacteria (µg/g)	Active Fungi (µg/g)	Total Fungi (µg/g)	Hyphal Diameter (µm)
Results		**0.870**	108	1693	14.5	417	2.85
Comments		Above Range	Above range	Above range	Below range	Below range	
Expected Range	Low	0.45	45	300	225	1500	
	High	0.85	90	600	450	3000	

		Protozoa (Numbers/g)			Total	Mycorrhizal Colonization (%)	
		Flagellates	Amoebae	Ciliates	Nematodes #/g	ENDO	ECTO
Results		**660**	49005	32	**6.55**	Not Ordered	Not Ordered
Comments		Low	Good	Good	Low		
Expected Range	Low	20000	20000	0	10	40%	40%
	High	200000	200000	400	20	80%	80%

Organism Biomass Ratios		Total Fungi to Tot.Bacteria	Active to Total Fungi	Active to Total Bacteria	Active Fungi to Act.Bacteria	Nitrogen Cycling Potential (lbs/ac)
Results		**0.25**	**0.03**	**0.06**	**0.13**	100-150
Comments		Low	Low	Low	Low	
Expected Range	Low	5	0.15	0.15	5	
	High	10	0.2	0.2	10	

Nematode detail (# per gram or # per mL)
Classified by type and identified to genus.
(If section is blank, no nematodes identified.)

Bacterial Feeders	4.09	
Acrobeles		0.55
Cephalobus		1.91
Eucephalobus		0.27
Plectus		0.82
Rhabditidae		0.55
Fungal Feeders	0.55	
Eudorylaimus		0.27
Microdorylaimus		0.27
Fungal/Root Feeders	1.64	
Aphelenchus		0.82
Ditylenchus	Stem & Bulb nematode	0.27
Filenchus		0.55
Root Feeders	0.27	
Paratylenchus	Pin nematode	0.27

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(541) 257-2612 | info@earthfort.com
www.earthfort.com

01-123973: Page 1 of 2

Green Season Consulting
Martin Shaw
PO Box 680716
Franklin, TN 37068 USA
(615) 614-3398
martyshaw@bellsouth.net

Report Sent: 10/21/2016
Sample#: 01-123973 | Submission:01-025679
Unique ID: J031601
Plant: Oak
Invoice Number: 0
Sample Received: 10/10/2016

For interpretation of this report please contact:
Earthfort Labs
info@earthfort.com
(541) 257-2612

Consulting fees may apply

Dry Weight:	Add organic matter to build soil structure, increase water holding capacity.
Active Bacteria:	Bacterial activity above expected level.
Total Bacteria:	Excellent bacterial biomass.
Active Fungi:	Fungal activity low, foods may be required.
Total Fungi:	Low fungal biomass, foods and biology may be required.
Hyphal Diameter:	Good balance of fungi.
Protozoa:	Lacking species diversity.
Total Nematodes:	Low numbers, OK diversity.
Mycorrhizal Col.:	
TF/TB:	Too bacterial for oaks
AF/TF:	Low fungal activity, foods may be required.
AB/TB:	Low bacterial activity relative to total biomass
AF/AB:	Bacterial dominated, becoming more bacterial.

Interpretation Comments:

Actinobacteria Biomass = 3.29 ug/g
Fairly good fungal diversity, hyphal diameter: 1.5 to 5.5um

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01-123973: Page 2 of 2

Soil Characteristics Analysis

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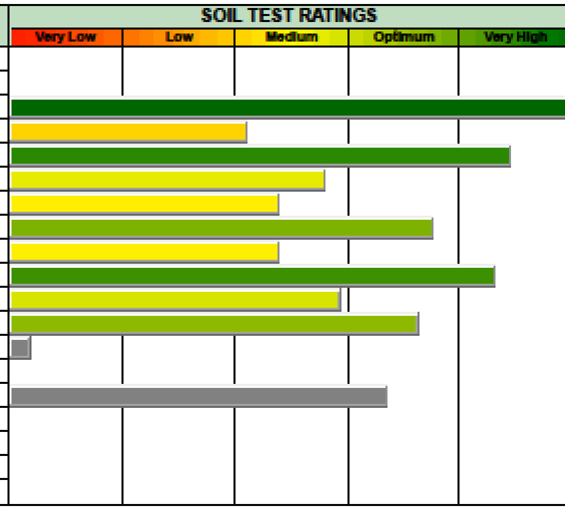
SOIL ANALYSIS

Client :	Grower :	
Green Season Consulting Mr. Marty Shaw 605 Laurel Court Franklin TN 37064	FFUMC 120 Aldersgate Way Franklin, TN 37069	Report No: 16-274-1495 Cust No: 29651 Date Printed: 10/03/2016 Date Received : 09/30/2016 PO: Page : 1 of 2

Lab Number : 44100 **Field Id :** **Sample Id :** J1628003

Test	Method	Results
Soil pH	1:1	7.1
Buffer pH		
Phosphorus (P)	M3	426 LB/ACRE
Potassium (K)	M3	258 LB/ACRE
Calcium (Ca)	M3	6996 LB/ACRE
Magnesium (Mg)	M3	378 LB/ACRE
Sulfur (S)	M3	28 LB/ACRE
Boron (B)	M3	2.8 LB/ACRE
Copper (Cu)	M3	3.2 LB/ACRE
Iron (Fe)	M3	558 LB/ACRE
Manganese (Mn)	M3	290 LB/ACRE
Zinc (Zn)	M3	13.2 LB/ACRE
Sodium (Na)	M3	30 LB/ACRE
Soluble Salts		
Organic Matter	LOI	7.1 % ENR 186
Nitrate Nitrogen		

SOIL TEST RATINGS



Calculated Cation Exchange Capacity

19.6 meq/100g

%Saturation

	%cat	meq
K	1.7	0.3
Ca	88.2	17.6
Mg	8.0	1.6
H	0.6	0.1
Na	0.3	0.1

K/Mg Ratio: 0.18

Ca/Mg Ratio: 11.16

SOIL FERTILITY GUIDELINES

Crop : Trees **Yield Goal :** 1 Optimum **Rec Units:** LB/1000 SF

LIME (lbs)	LIME (tons)	N	P_2O_5	K_2O	Mg	S	B	Cu	Mn	Zn	Fe
0		3.0	0	2.0	0	0	0	0	0	0	

Crop : **Rec Units:**

Comments :

Trees

- To convert the fertilizer recommendations from lbs/1000 sq ft to lbs/acre, multiply by 44.
- Shrubs and Trees: Apply half of the recommended fertilizer in early spring and again in mid-season.
- The recommendation provided is for maintenance of established trees.

M3 - Mehlich 3 BPH - Lime Index LOI - Loss On Ignition 1:1 - Water pH

Analysis prepared by: Waypoint Analytical Tennessee, Inc.

Waypoint ANALYTICAL

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"Every acre...Every year."

SOIL ANALYSIS

Client : Green Season Consulting Mr. Marty Shaw 605 Laurel Court Franklin TN 37064	Grower : FFUMC 120 Aldersgate Way Franklin, TN 37069	Report No: 16-274-1495 Cust No: 29651 Date Printed: 10/03/2016 Date Received : 09/30/2016 PO: Page : 2 of 2

Lab Number : 44101 **Field Id :** **Sample Id :** J1628004

Test	Method	Results	SOIL TEST RATINGS (Very Low / Low / Medium / Optimum / Very High)
Soil pH	1:1	7.0	
Buffer pH			
Phosphorus (P)	M3	494 LB/ACRE	
Potassium (K)	M3	332 LB/ACRE	
Calcium (Ca)	M3	6438 LB/ACRE	
Magnesium (Mg)	M3	348 LB/ACRE	
Sulfur (S)	M3	22 LB/ACRE	
Boron (B)	M3	2.6 LB/ACRE	
Copper (Cu)	M3	4.6 LB/ACRE	
Iron (Fe)	M3	568 LB/ACRE	
Manganese (Mn)	M3	218 LB/ACRE	
Zinc (Zn)	M3	23.4 LB/ACRE	
Sodium (Na)	M3	22 LB/ACRE	
Soluble Salts			
Organic Matter	LOI	6.4 % ENR 172	
Nitrate Nitrogen			

Calculated Cation Exchange Capacity: 18.1 meq/100g

%Saturation

	%sat	meq
K	2.4	0.4
Ca	88.8	16.1
Mg	8.0	1.6
H	0.8	0.1
Na	0.3	0

K/Mg Ratio: 0.27

Ca/Mg Ratio: 11.11

SOIL FERTILITY GUIDELINES

Crop : Trees **Yield Goal :** 1 Optimum **Rec Units:** LB/1000 SF

LIME (lbs)	LIME (tons)	N	P_2O_5	K_2O	Mg	S	B	Cu	Mn	Zn	Fe
0		3.0	0	2.0	0	0	0	0	0	0	

Crop : **Rec Units:**

Comments :

Trees

- To convert the fertilizer recommendations from lbs/1000 sq ft to lbs/acre, multiply by 44.
- Shrubs and Trees: Apply half of the recommended fertilizer in early spring and again in mid-season.
- The recommendation provided is for maintenance of established trees.

M3 - Mehlich 3 BPH - Lime Index LOI - Loss On Ignition 1:1 - Water pH

Analysis prepared by: Waypoint Analytical Tennessee, Inc.

UT Extension Report Dated 9/30/2016

UT Extension

SOIL, PLANT AND PEST CENTER
5201 Marchant Drive
Nashville, TN 37211-5112
615.832.5850 fax 615.832.4936
soilplantpestcenter@tennessee.edu

c/o martyshaw@greenseasonconsulting.com
Marty Shaw, RCA
PO Box 680716
Franklin , TN 37068

Report Date: September 30, 2016

Lab Number: 3890

Insect and Plant Disease Diagnosis

Sample Identification: Plant problem

County: Williamson

Name of Plant: Bur oak

Diagnosis and Recommended Treatment or Control

Hi Marty,

Your sample had twig boring possibly by the twolined chestnut borer as well as light infection by tubakia leaf spot and light feeding by the oak lace bug and gregarious oak leafminer. The last 3 pests do not usually impact the tree's health so that no controls are necessary this late in the growing season.

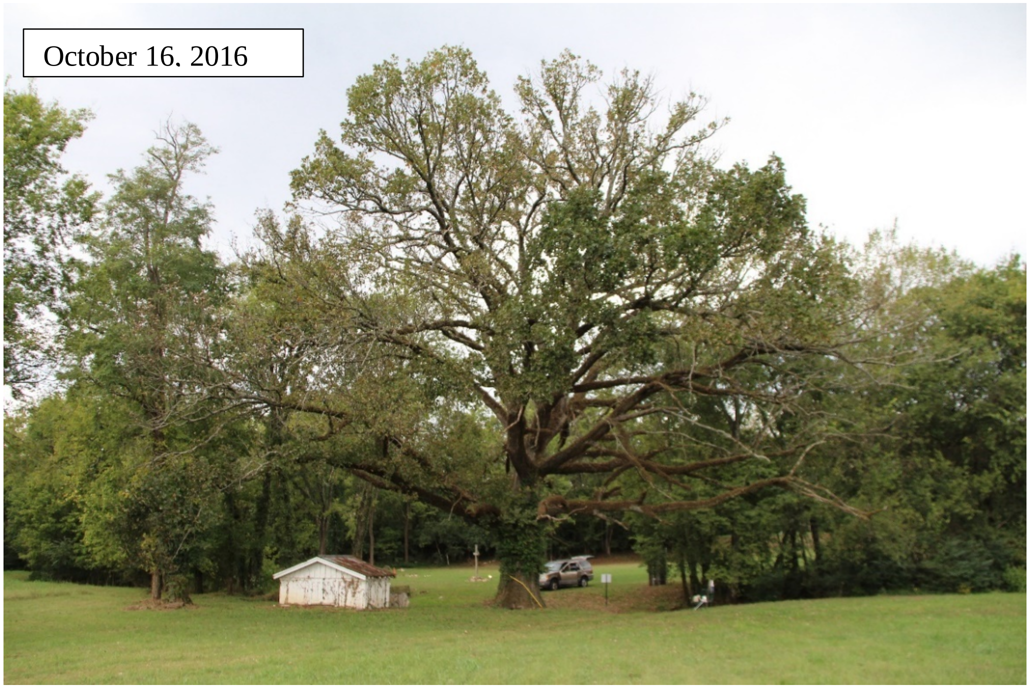
The twolined chestnut borer normally does not attack healthy oaks but affect stressed trees. The attack usually begins in the upper crown and works its way down over the tree eventually killing the oak in the second or third year. The earliest symptoms are wilting of the foliage in late summer and then death of the upper limbs. Adult beetles fly from April to August each year, having one generation per year. Treat with imidacloprid (Merit, Marathon) or imidacloprid plus cyfluthrin (Discus) as a drench any time from February to mid-April.

Sincerely,

Bruce Kauffman
Plant Diagnostician

THE UNIVERSITY of TENNESSEE
INSTITUTE of AGRICULTURE

Photos



October 16. 2016

Photo 1

December 4. 2010

Photo 2

Photo 3

Photo 4

Photo 5

Photo 6

Photo 7

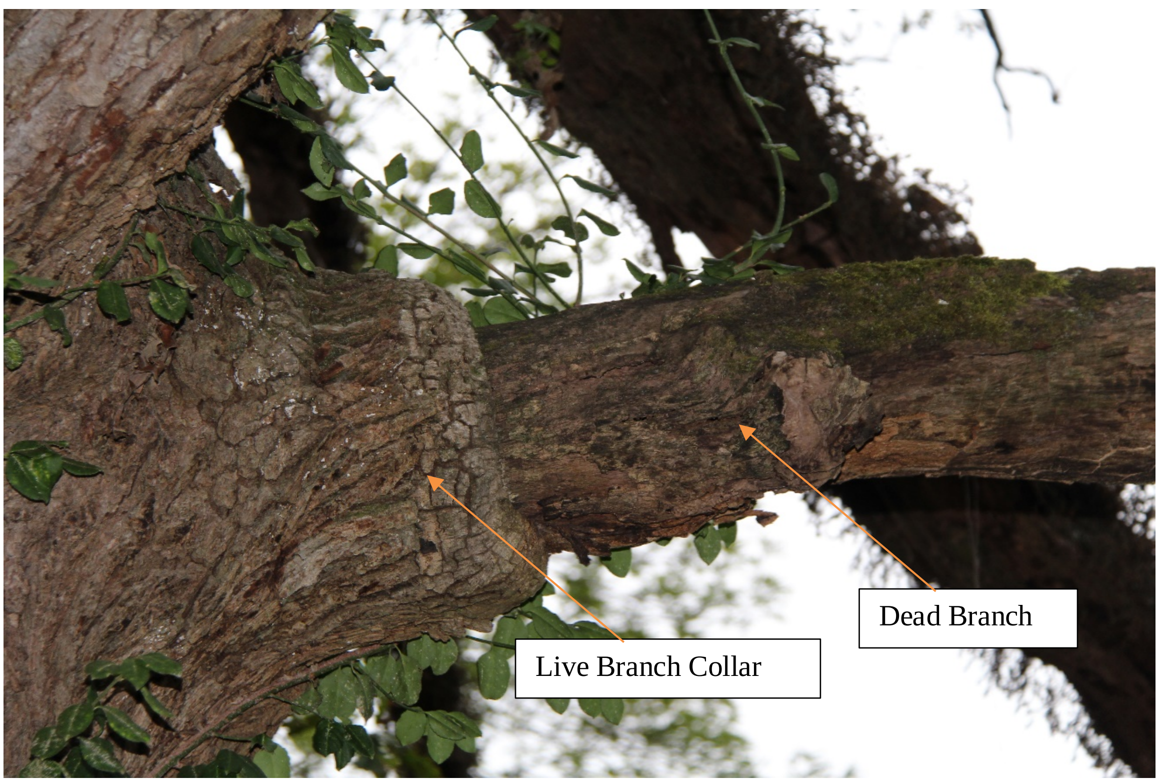


Photo 8

Photo 9

Photo 10

Photo 11

Photo 12

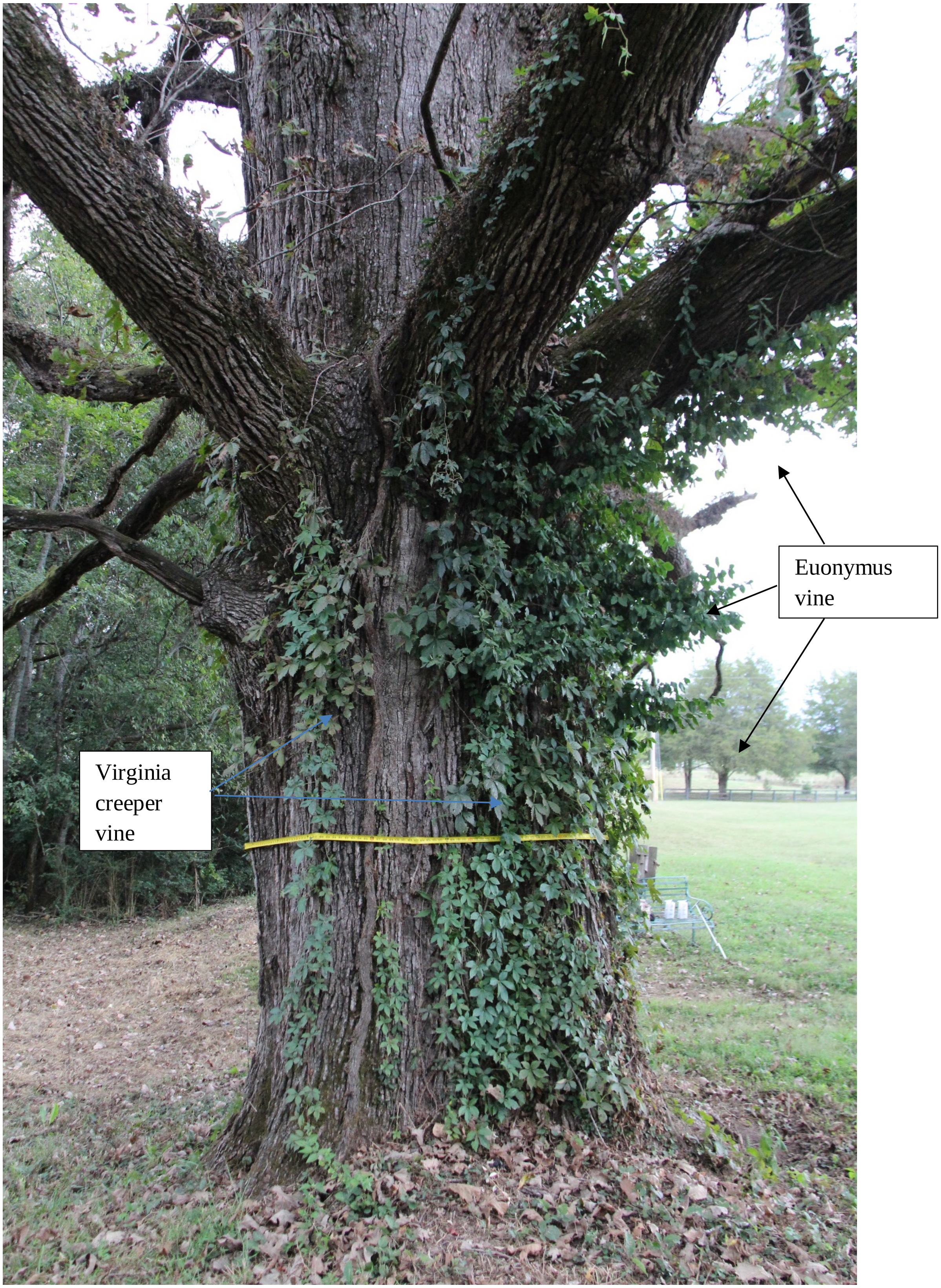


Photo 13

Photo 14

Photo 15

Photo 16

Photo 17

Photo 18

Photo 19

Photo 20

Photo 21

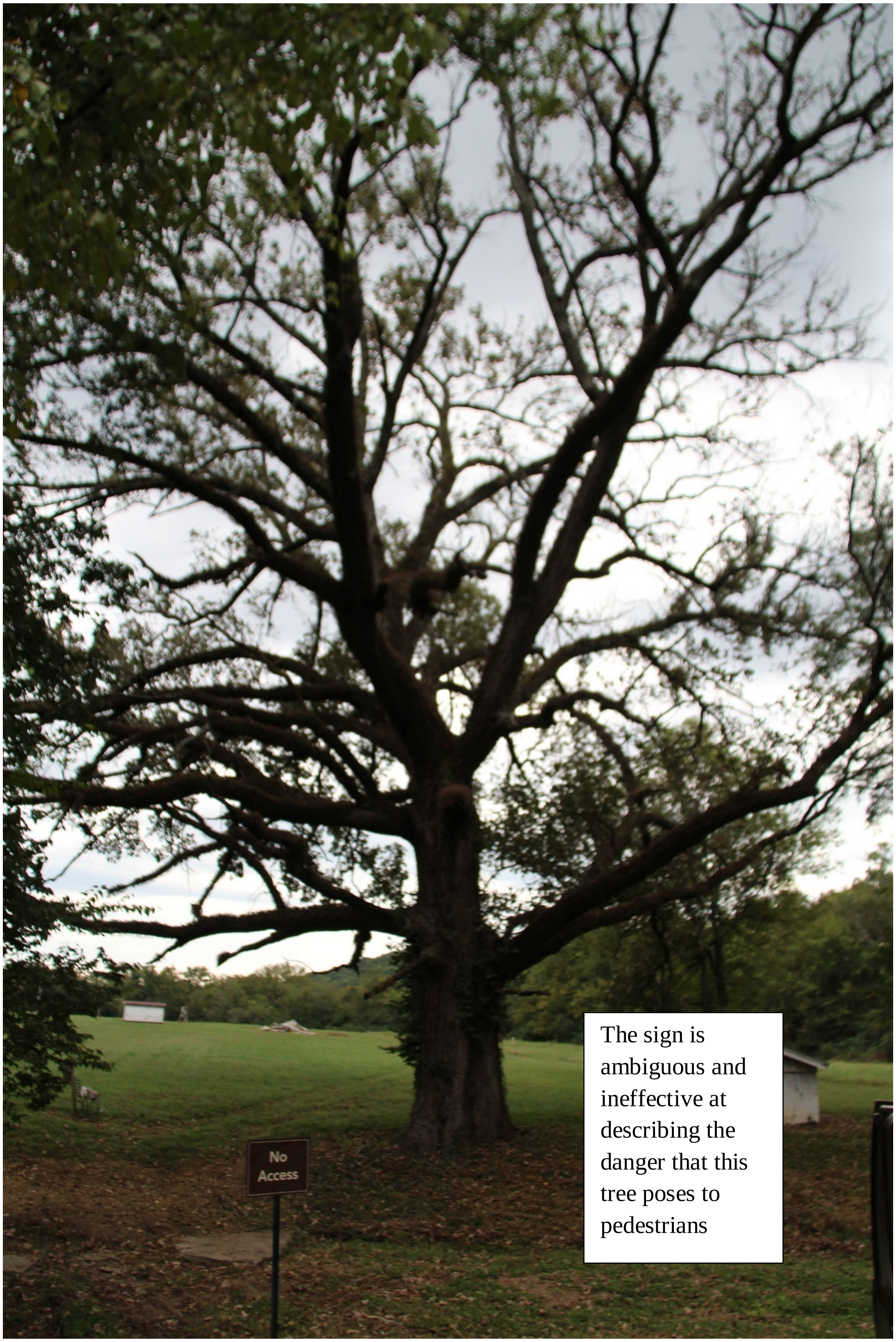

No
Access
The sign is ambiguous and ineffective at describing the danger that this tree poses to pedestrians

Photo 22

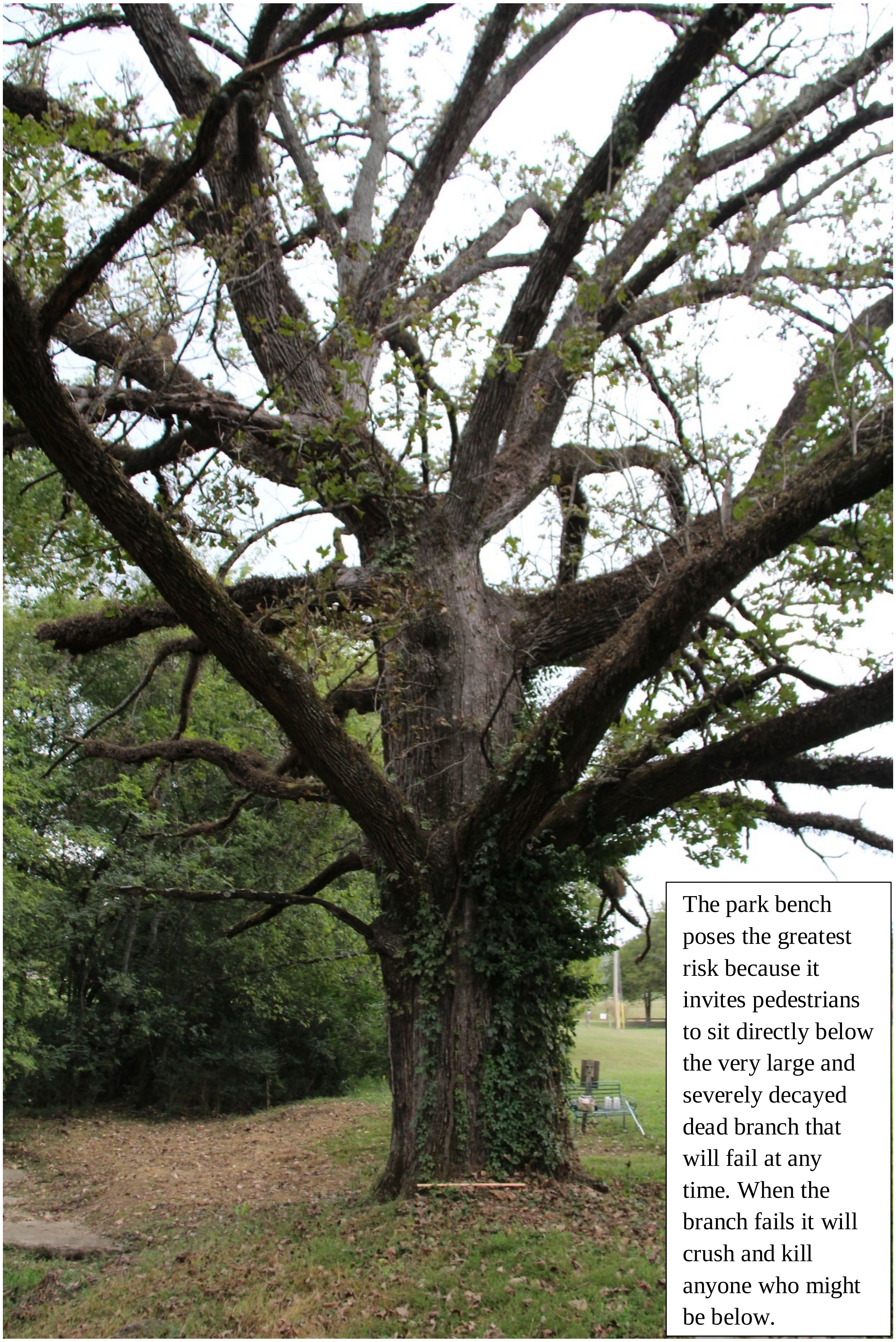

The park bench poses the greatest risk because it invites pedestrians to sit directly below the very large and severely decayed dead branch that will fail at any time. When the branch fails it will crush and kill anyone who might be below.

Photo 23

Glossary

Absorb: To take up.
Abscission: the natural detachment of parts of a plant, typically dead leaves and ripe fruit or dead twigs, branches or limbs: self-pruning.
Aesthetic: pleasing to the senses, visually or otherwise.
Aggregate: a material or structure formed from a loosely compacted mass of fragments or particle; in soil it is the larger than sand components mostly comprised of stone and small rocks; in concrete is the rocky material that is larger than sand.
American National Standards Institute is a private non-profit organization that oversees the development of voluntary consensus standards for products, services, processes, systems, personnel and units of measure in the United States.
ANSI: Acronym for American National Standards Institute.
ANSI A300: in the United States, industry developed national consensus standards of practice for tree care.
Arboriculture: practice and study of the care of trees and other woody plants in the landscape.
Arborist: professional who possesses the technical competence gained through experience and related training to provide for or supervise the management of trees and other woody plants in residential, commercial and public landscapes.
ASCA: acronym for American Society of Consulting Arborists
Bark: protective outer covering of branches and stems that arises from the cork **cambium**.
BMP: an acronym for **Best Management Practices**
Best Management Practices: best-available, industry-recognized courses of action, in consideration of the benefits and limitations, based on scientific research and current knowledge.
Branch: stem arising from a larger stem. A subdominant stem.
Buttress: base of the tree where it enters the ground. Normally forms a flare where roots and trunk come together.
Bulk density: dry mass of soil per unit of volume, often used as a measure of compaction.
Cambium: thin layer(s) of meristematic cells that give rise (outward) to bark and inward to the sapwood, increasing stem and root diameter. Also gives rise to callus tissue near the edges of wounds.
Canker: localized diseased area on stems, roots and branches. Often sunken and discolored.
Canopy: collective branches and foliage of a tree or group of trees' crowns. Aggregate or collective tree crowns.
Cation Exchange Capacity (CEC): acronym for Cation Exchange Capacity; the total capacity of a soil to hold exchangeable cations. CEC is an inherent soil characteristic and is difficult to alter significantly. It influences the soil's ability to hold onto essential nutrients and provides a buffer against soil acidification.
Cellulose: complex carbohydrate found in the cell walls of most plants, algae and certain fungi. A major component of wood fibers.
Conk: fruiting body or non-fruiting body of a basidiomycete fungus.
Consulting Arborist: arboricultural or other expert who, through training, knowledge and experience investigates tree related matter including but not limited to land assessments, tree canopy assessments, plant appraisals, tree hazard evaluations, tree risk assessments, or analytical testing services. They are frequently involved in forensic and other investigations and are skilled at reporting. Many also provide expert witness services.
Critical Root Zone: volume of soil and roots around a tree where the minimum number of roots are critical to the structural stability and health of the tree. Is dependent on site conditions.
Crown: upper part of a tree, measured from the lowest branch, including all the branches and foliage.

Decline: gradually diminishing health or condition of a tree.
Defect: an imperfection, weakness, or lack of something necessary. In trees, defects are injuries, growth patterns, decay, or other conditions that reduce the tree's structural strength.
Deficiency: pertaining to plant nutrition, lack or insufficient quantity of a required element.
Dendrochronological: pertaining to the study of age of wood, particularly growth rings. Since trees produce new growth rings each year, the study of growth rings provides a historically accurate way to measure the age of wood and the rate at which trees have grown over time. Growth patterns may indicate environmental changes, tree injury events, and even when trees have died.
Diameter: a straight line passing from side to side through the center of a circle at its widest point or the average distance of a tree canopy spread across the drip area. Also, the average measure of a tree trunk across its trunk.
Diameter at Brest Height (DBH): standard measurement of the size of a tree in distance across its trunk at 4.5' above the ground.
Dieback: condition in which the progressive death of small twigs, twigs, limbs and branches in the tree crown die from the tips toward the trunk. Can be caused by many factors. (See inner canopy dieback)
Drip Area: imaginary area defined by the branch spread of a single tree or trees in a group.
Drip Line: imaginary that traces the circumference of a trees drip area.
Drought: period of unusually low precipitation.
Dynamic Wind Loading: loading that gives rise to motion in a structure, creating oscillations in any direction.
Exoskeleton: a rigid external covering for the body in some invertebrate animals, especially insects, providing both support and protection. Because the exoskeleton is rigid, insects must molt in order to grow and mature into adulthood.
Failure: uprooting or mechanical breakage of a tree, its parts, and/or associated soil.
Habit: characteristic form or manner of growth.
Habitat: an environment suitable for sustaining a population of a given organism.
Hardiness: genetically determined ability of a plant to survive at low temperatures.
Hardwood: 1) wood of an angiosperm tree as distinguished from that of a conifer; 2) referring to an angiosperm or broadleaf tree.
Hazard: a tree or tree part identified as a likely source of harm.
Hemicellulose: any of a class of substances that occur as constituents of the cell walls of trees and are polysaccharides of simpler structure than cellulose.
Increment Borer: device used to extract corer samples from trees to permit examination of tree rings and determine a trees age.
ISA: acronym for International Society of Arboriculture
ISA Certified Arborist®: an arborist who has passed an independent exam administered by the International Society of Arboriculture and maintains continuing education and who agrees to adhere to the ISA Certified Arborist® Code of Ethics.
Lignin: organic substance that impregnates certain tree cell walls to thicken and strengthen the cell to reduce susceptibility to decay and pest damage.
Loam: soil texture classification consisting of somewhat less clay and more or less equal parts sand and silt. Considered ideal texture for plant growth.
Molt: part of the metamorphosis process in which part of the old exoskeleton is shed after a new cuticle is formed
Mycelia fans: Mycelium is the vegetative part of a fungus or fungus-like bacterial colony, consisting of a mass of branching, thread-like hyphae. The mass of hyphae is sometimes called shiro, especially within the fairy ring fungi. Often radiating out from a central point in the shape of an oriental fan.
Necrosis: dead tissue, typically found in leaves or tree wounds.
Nymph: immature form of an insect with incomplete development, resembling a smaller version of the adult without wings.

Organic: carbon containing substance; normally acids and other substances from decaying plant and animal matter
Organic Matter: dead remains of organisms in the process of decay by actions from live organisms like mulches derived from wood products. The bioactive, organic components of soil.
Pest: organism (including but not limited to- weeds, insects, or fungi) that is damaging, noxious, or a nuisance.
pH: a figure expressing the acidity or alkalinity of a solution on a logarithmic scale on which 7 is neutral, lower values are more acid, and higher values more alkaline. The pH is equal to -log10c, where c is the hydrogen ion concentration in moles per liter.
Pruning: removing branches (or occasionally roots) from a tree or other plant, using approved practices, to achieve a specified objective.
Registered Consulting Arborist: members of ASCA who have completed the rigorous requirements of the ASCA RCA program to achieve registered status.
Rhizomorph: a root-like aggregation of hyphae in certain fungi.
Risk: the combination of likelihood of an event and the severity of the potential consequences. In the context of trees, risk is the likelihood of a conflict or tree failure occurring and affecting a target, and the severity of the associated consequences- personal injury, property damage, or disruption of activities.
Scaffold Branches: permanent or structural branches that form the scaffold architecture or structure of a tree.
Soil Compaction: compression of the soil, often as a result of vehicle, heavy-equipment, traffic, that breaks down soil aggregates and reduces soil volume and pore space, especially macropore space.
Standard: an established or widely recognized authority of acceptable performance.
Stippling: speckled or dotted areas on foliage or bark.
Stress: a factor that negatively affects tree health; a factor that stimulates a response.
Structural Integrity: the ability of a tree to hold together under load, including its own weight while resisting breakage and exceeding its bending strength.
Stump sprout: fast growing new stem or branch that originates from the base part of a plant that remains after being cut.
Tree Risk Management Program: the application of policies, procedures, and practices to identify, evaluate, mitigate, monitor and communicate tree risks.
Taproot: initial root of a seedling; a straight tapering root growing vertically downward and forming the center root structure from which subsidiary rootlets spring, typically on very young seedling trees. In typical nursery stock or mature trees the taproot is either lost or diminished to a lateral root.
Tissue: group of cells with similar structure that have a special function.
TCIA: acronym for Tree Care Industry Association.
Transpirational Cooling: the effect of water loss through the stomata of leaves that cools the environment.
Tree: woody perennial usually having one dominant trunk and a mature height greater than 16 feet.
USDA hardiness: aka cold hardiness map; the standard by which plant selection can be determined most likely to thrive at a location. The map is based on the average annual minimum winter temperature, divided into 10-degree F zones
Vigor: overall health. capacity to grow and resist stress.

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Notes: