Tree Risk Assessment

2019 Tree Risk Assessment Training Program

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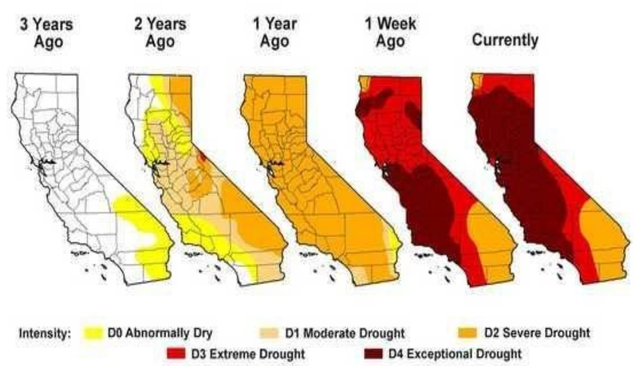
Introduction

Addressing the hazards and risks associated with trees around utility lines is an ongoing challenge for utility managers everywhere. Forest lands throughout California are currently in a state of heightened stress. The continued drought conditions have contributed to increased pest outbreaks and as a result have created a situation that presents ongoing safety hazards to SDG&E customers and its facilities. If left unmanaged, hazard trees can result in personal injury, excessive property damage, interruptions in electrical service and an increased threat to critical infrastructure. They can also become the source of catastrophic wildland fire events.

Managing an increasing population of hazard trees is a key issue utilities are facing. The challenges are; from an ecological standpoint of promoting healthy vegetation around electric facilities in communities and forests, from a safety standpoint of ensuring public safety as well as reliable electrical service, and from an economic standpoint of additional mitigation costs not accounted for in annual budget. The combination of all of these factors has intensified the need for systematic and efficient management solutions.



SDG&E has tremendous dedication toward electrical system safety and reliability. They have two main goals; No tree caused fires and reliable cost efficient electricity to the consumer. Although SDG&E's territory is smaller in comparison to other California utilities, tree related interruptions on their system are significantly lower. Tree inventory methodology, annual cycle management and extended scopes of work in at risk areas play a major role in reducing negative consequences in tree and power line conflicts but the Consulting Utility Foresters play an even more important role. If the potential risks are not identified properly they would not be mitigated in the first place. These well trained, skilled and experienced personnel conduct inspections to accurately identify and evaluate potential risks and assign prioritized mitigation measures based on the severity of defect(s) and site conditions.

According to an aerial survey conducted last month by the U.S. Forest Service, approximately 12 million forest trees have died in Southern California and the southern Sierra Nevada mountains over the last year.

Mortality is "widespread and severe" in the foothills among ponderosa, gray pine, blue oak and live oak trees.
http://foresthealth.fs.usda.gov/

Tree Risk Assessment Basics

There's no doubt trees provide numerous benefits. And there's no doubt benefits increase as the age and size of the trees increase. However, just like us humans, generally as a tree gets older it is more likely to have conditions that predispose it to failure. It is impossible to maintain trees to the point that they are free of any risk. Some level of risk must be accepted. Tree failures during what is considered "normal" weather conditions are often predictable and preventable. However, any tree, visible weakness or not, can fail at any time especially if the forces applied exceed the strength of the tree or its parts. Consulting Utility Foresters must be able to recognize and evaluate the signs and symptoms of potential tree failure.

Tree Health vs. Structural Soundness – Separate but Related

When assessing risk, *do not* confuse tree health and structural stability. A healthy tree, vigorous canopy and root system, can have a trunk rotten to the core. Conversely, a sickly-looking tree canopy, with spotted, falling and discolored leaves can still be structurally sound.

Naturally, the distinction between health and structural stability is not simple. The two can be related and one can affect the other. Some diseases that harm tree health by attacking living tissue can also destroy the wood that keeps it standing upright. Oak root fungus (Armillaria mellea) is a great example of this. Armillaria is found in temperate soil regions around the world and is native to California. It infects and kills cambial tissue in woody plants, causing major roots and the trunk at ground level to die. Symptoms start above ground in the canopy first with undersized, discolored and prematurely dropping leaves. Soon, twigs and branches start to die. Armillaria will form white Mycelia plaques between the bark and wood not usually visible unless the bark is peeled away. Clusters of honey – yellow to tan colored mushrooms will also form at the base of infected woody plants.

So, don't be quick to assume that if it looks healthy it is structurally sound. Likewise, don't assume a tree that looks sick is structurally unstable. A systematic and thorough evaluation must be completed.

Utility Inspections

Typically, each utility develops a maintenance plan that includes methods for patrolling and inspecting its electric facilities. This can include patrolling from the ground, on foot, from a vehicle, or by using aircraft, whether fixed wing or helicopter, or by the use of Light Detection and Ranging (LIDAR) in combination with other methods to determine tree health. These methods vary significantly between utilities as can the methods for assessing tree risk.

SDG&E has adopted what is considered a **Detailed Line Patrol** approach over the entire service territory conducted during the annual routine inspection process. A Detailed Line Patrol consists of a periodic, ground based visual assessment of trees within the "strike zone", in order to identify tree defects that could cause a tree or parts of a tree, to fall into and cause harm to the overhead electric facilities. While conducting this type of inspection a Consulting Utility Forester should be looking for "triggers" or signs indicating potential failure. If the inspector identifies a potential for failure a Detailed Tree Inspection shall occur.

SDG&E has also adopted, in at risk fire areas (HRFA), a **Detailed Tree Inspection.** The Detailed Tree Inspection includes; close proximity, 360 degree visual inspection of every individual tree within the "strike zone". SDG&E has also implemented additional patrols beyond the annual routine inspection process take place in at risk fire areas to ensure safety and reliability.

A primary goal of utility tree risk assessment is to evaluate the level of risk posed by a tree or parts of a tree and assign it an appropriate mitigation plan. This is accomplished by first determining the categories for likelihood and consequences of tree failure. These factors are determined by:

- Evaluating the structural conditions that may lead to failure; the potential loads on the tree; and the trees' adaptations to weaknesses—to determine the likelihood of failure.
- Evaluating the likelihood that a tree or branch could strike the target with negative consequences.
- Assessing the injury, damage or disruption—to estimate the consequences of failure.

Tree Risk Assessment Guide (TRAG)

Davey Resource Group (DRG) has partnered with SDG&E's Vegetation Management Department as well as other California utilities for more than 20 years. Davey and DRG are heavily involved and very supportive of ISA, UAA and other industry leaders. DRG has put this experience together in a collaborative effort to come up with the Tree Risk Assessment Guide (TRAG) as a quick reference field tool specifically for Consulting Utility Foresters on the SDG&E Project.

This risk assessment process is designed to ensure compliance with state laws and regulations relating to hazardous, dead or dying, decadent, diseased and rotten trees adjacent to overhead power lines. This process does not completely eliminate the risk of tree failure due to unseen or unpredicted factors. Instead, this process is intended to assist in managing the risk present by vegetation near overhead electric facilities.

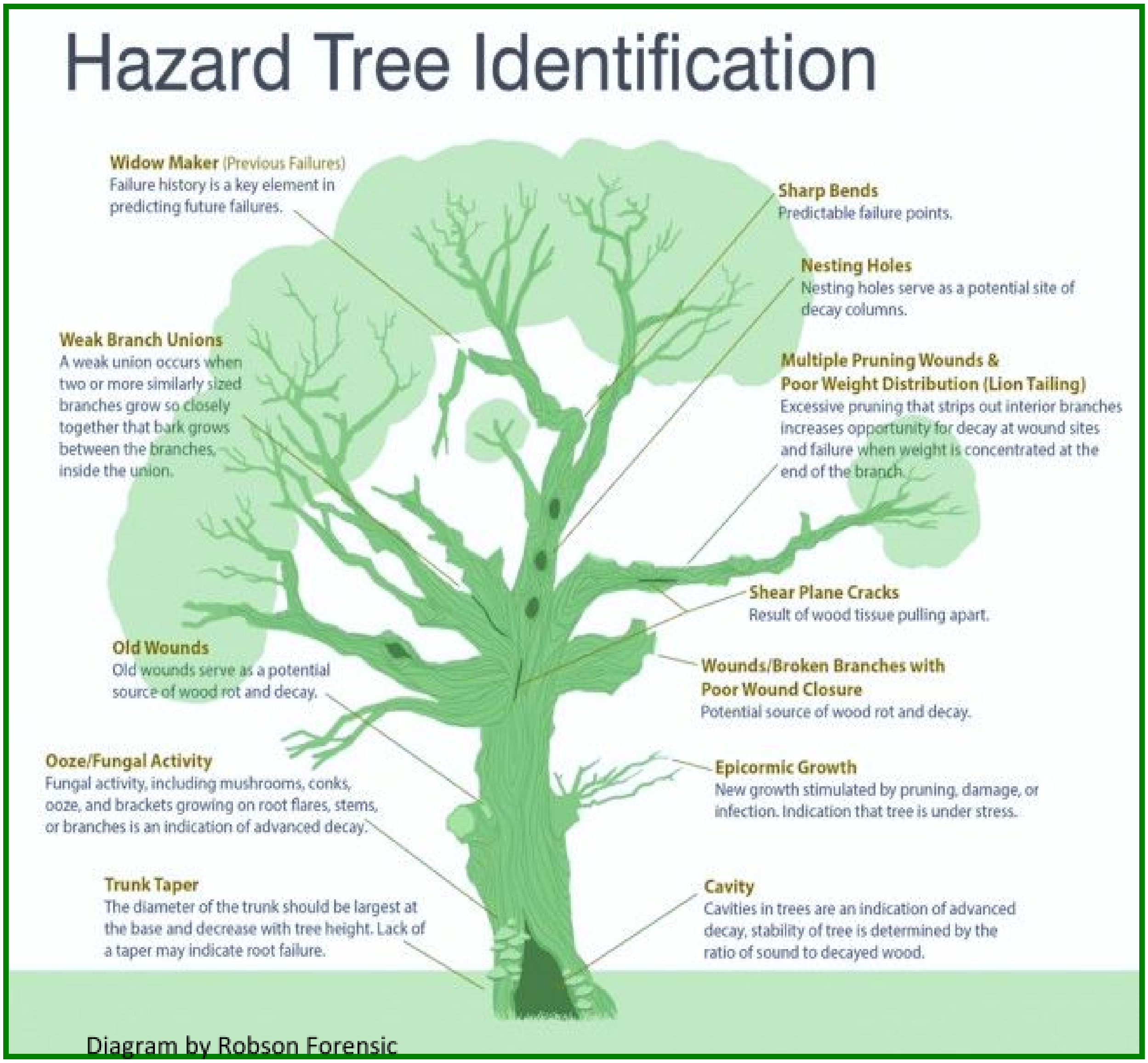
A TRAG is used to bring objectivity to the subjective nature of tree risk assessment. By evaluating the probability of failure and site conditions, the Utility Forester is provided a guideline to determine if a tree crosses the threshold of acceptable risk. All trees at risk shall be considered for accelerated mitigation based on severity of both defect and site conditions. This evaluation does not take into account timing of failure.

If the risk category defined for the tree risk exceeds the level of acceptable risk, mitigation is required. If ever in doubt, do not hesitate to contact Supervisor or peer for additional support.

Risk = the combination of likelihood of an event and severity of the potential consequences.

Tree Risk Assessment = a systematic process used to identify, analyze and evaluate tree risk.

Tree Risk Evaluation = is the process of comparing the assessed risk against given risk criteria to determine significance of the risk.



Utility Tree Risk Assessment

Tree Risk Assessment is an integral part of Utility Forestry. Minimum clearance regulations in California have since lowered the number of outages caused by trees growing into power lines; however, trees and or portions of trees falling into the power lines have become a greater concern of utilities.

It is important to understand that all trees have potential to fail. The challenge is to manage trees within an acceptable level of risk. It is the job of the Utility Forester to identify trees with defects that could cause partial or whole tree failure that will impact utility facilities. Identifying and assessing defects in trees as well as inadequate site conditions is a matter of training, skill, and experience. Over time, an individual can become very skilled in Tree Risk Assessment.

A skilled tree risk inspector will:

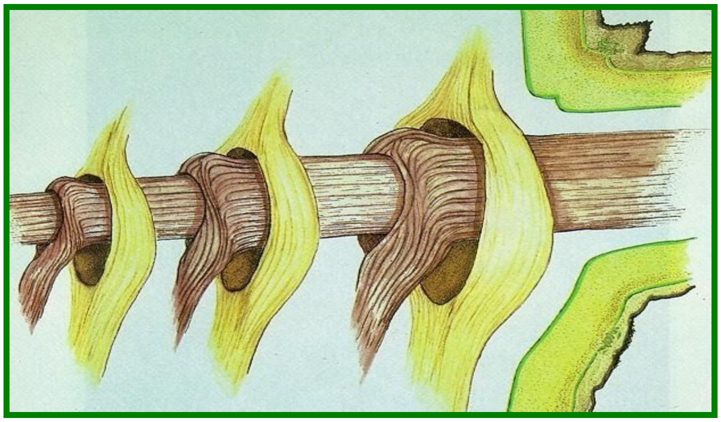
- Have a systematic and consistent inspection process that includes a 360 degree inspection.
- Look beyond the tree to the site. Is there anything to indicate recent changes? Soil type? What do other trees in the area, maybe off the ROW, look like? Is there potential risk of fire?
- Whenever possible, discuss the site history and any changes with the land or property owner.
- Utilize industry tools. Use binoculars to see upper canopy and branch attachments. Use a sounding tool to verify integrity.
- Keep up-to-date with industry practices.

Here are some basic concepts:

- Failures are not random events. They usually result from a combination of identifiable defects and unfavorable conditions. Some failures appear random because the defects may not be evident at first and it may take some investigation and analysis to determine the defect.
- Health and Hazard are not the same. Crown condition reflects health not structural soundness. Trees can have a full crown of green leaves with no obvious branch or trunk decay and appear healthy to the untrained person. Yet the same tree may have narrow branching angles with included bark and symptoms of internal decay that are indicative of structural defect to the trained person.
- The level of risk associated with a hazard tree is directly related to the severity of the defect(s) and the amount of damage that would result if tree failed. The target, site conditions and defect each play an important role when deciding whether or not to implement an action plan to mitigate or remove potential risk(s) and how quickly mitigation should take place.

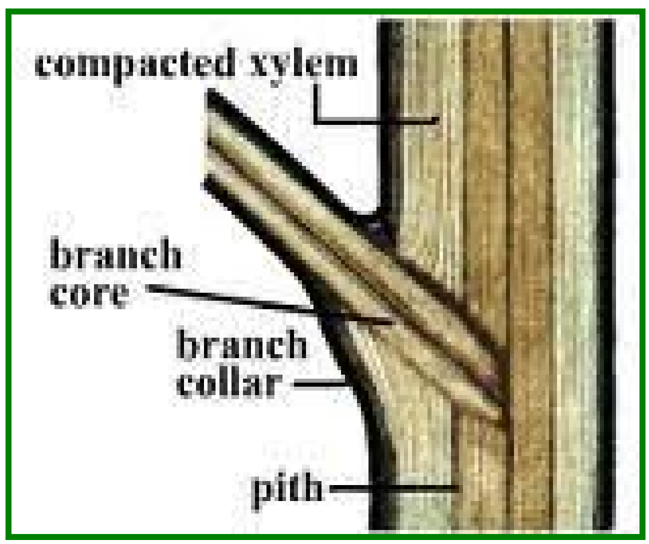
Branch Physiology

Because a tree's leaves are essential to the food making process, trees need to make sure it's leaves are exposed to as much sunlight as possible. The function of a tree branch is to position the foliage where sunlight is most available, to transport photosynthates from the leaves, and water and nutrients to the leaves.



To understand the anatomy of included bark, we must first look at tree physiology and how branches develop on parent trunks. For hundreds of years, it was commonly accepted that branches were an extension of the tree in no way separate from the parent trunk. It is now known that branches are attached to the trunk through a series of overlapping conductive tissues, which forms a branch bark ridge. In other words, there is a distinct physiological difference between branch tissues and trunk tissues and a branch has little or no direct structural or conductive connection above its attachment to the trunk or parent branch to which it is attached.

The attachments develop in several stages as the branch and trunk tissues begin to form. Once the branch tissues begin to develop, they turn to form a collar. After the collar has been created by the branch tissues, the trunk tissues then circle around the branch collar and the newly formed branch collar fits over the shaft of the tissues in the existing branch. The branch collar and the trunk collar are collectively called the branch collar. The design of this joint (branch attachment) is absolutely optimal and could hardly be better in its perfection. The branch is essentially held to the trunk the way a dowel holds a leg to a chair.

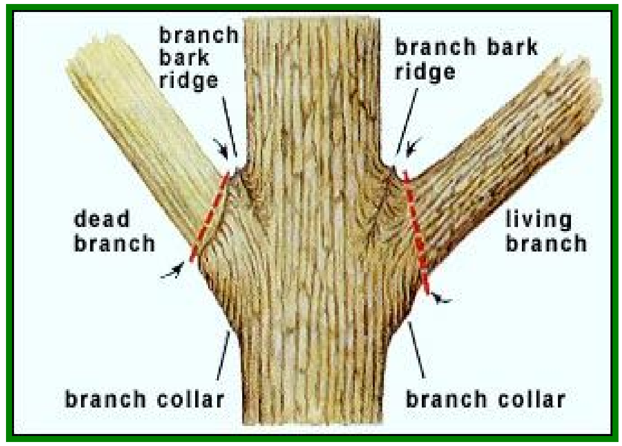


Now that we have reviewed branch anatomy and physiology, we can begin to understand the problems associated with the progression of included bark, co-dominant stems and epicormics branches. The branch bark ridge (BBR) is defined as the enlarged area of bark tissue on the upper side of a branch junction (a normal pattern of development). In many species, the BBR is clearly identified by the change in diameter and the difference in color. This is not true for all species. Nevertheless, learning to identify the BBR is an import step in developing an eye for proper tree form and development, and will aid in recognizing poor branch structure.

Included Bark

Weak branch union = a branch union with included bark or an epicormic branch

Included bark is defined as bark pinched or embedded between two stems or between a branch and trunk preventing formation of a branch bark ridge. Included bark forms when two branches grow at sharply acute angles to one another, producing a wedge of inward-rolled bark between them. Included bark prevents strong attachment of branches, often causing a crack at the point below where the branches meet.

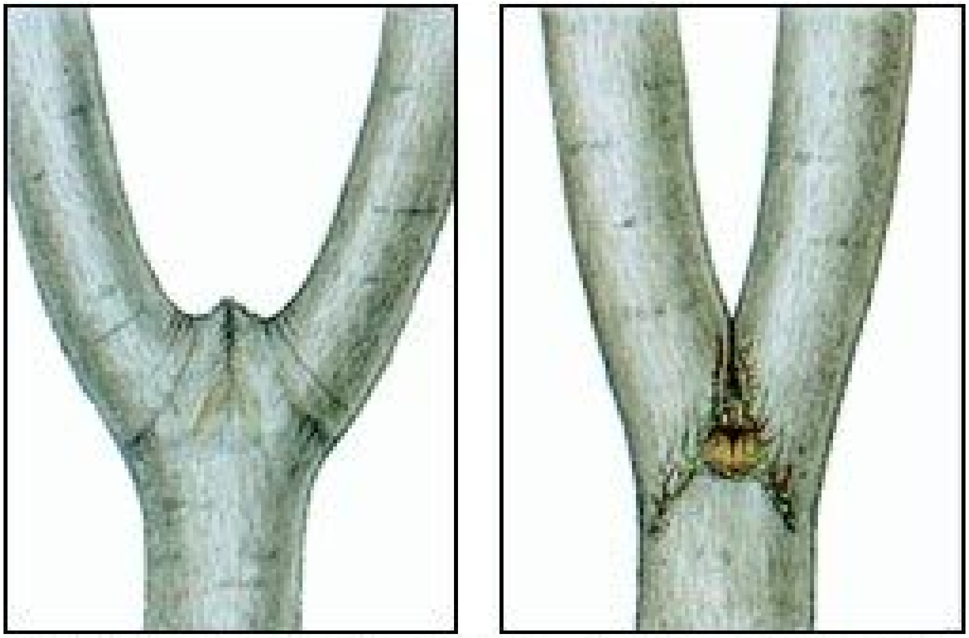


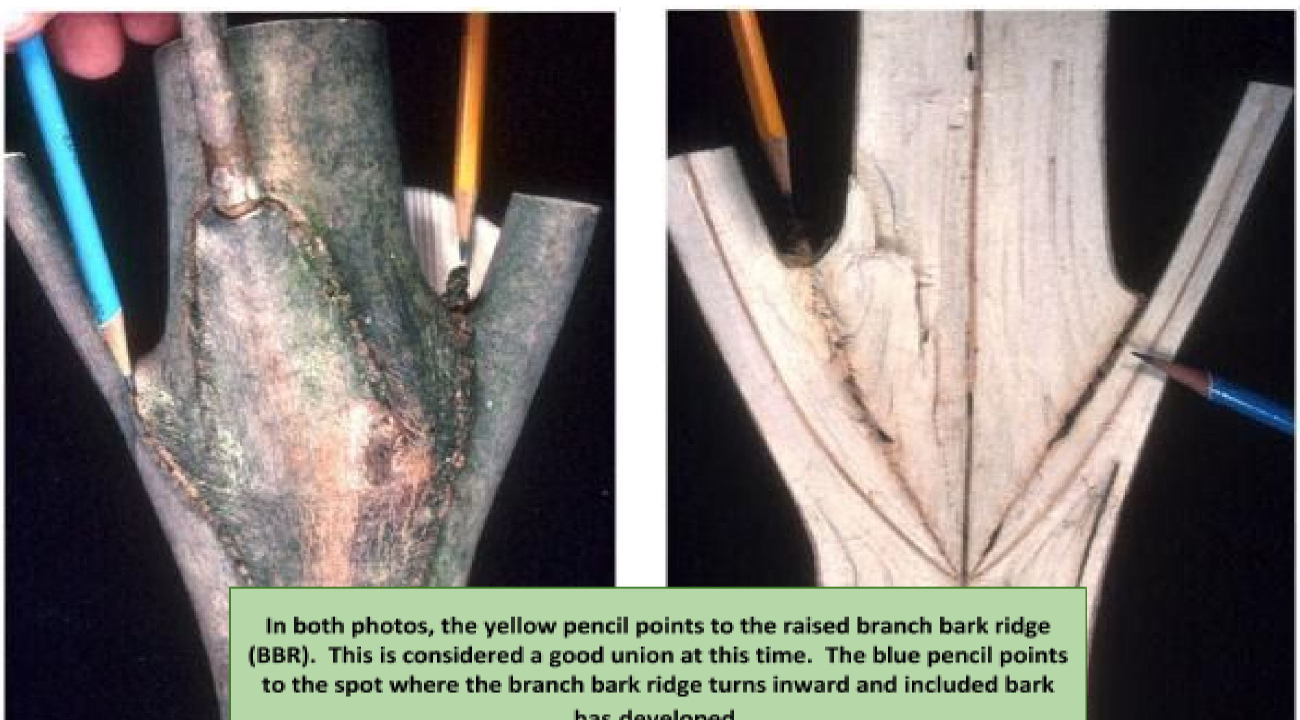
Another term closely associated with included bark is co-dominance, which occurs when branch angles to the main stem are very small so that a branch competes with the stem.

A co-dominant stem will often develop included bark. Much emphasis is placed on the weakness of a branch attachment that has included bark. There are two reasons for this, the first having to do with the size of the branch in comparison to the parent trunk. The diameter of branches and stems should be no more than one-half to two-thirds the trunk diameter. The only way trunk xylem can grow around a branch and form a strong attachment is for the trunk to be larger in diameter than the branch at its attachment. If the branch and trunk are near the same size, their attachment will be weak because their xylem tissues are essentially parallel neither is able to grow around the other. They would be considered double leaders or co-dominant stems. An understanding of branch physiology shows why having a good branch-trunk ratio is crucial to strong attachment.

The second reason has to do with cracking and fracturing at the union. As any tree or woody plant (dicot) grows, it continually expands in diameter, adding growth rings with each passing year. When the tree expands at the union where included bark has developed, there is very little room for the increase in growth. The two limbs push against each other, causing a crack at the attachment. Once a crack has developed, the likelihood of the fracture becomes extremely high (in most cases). Often, the tree will bleed or sap near the wound. This is a pathogen and pest deterrent mechanism but also is a sign of structural or internal damage.

The photo below shows two similar types of unions. The one on the left is much stronger since the stems are not pushing against each other and the branch bark ridge is raised. The branch on the right is in danger of splitting as the tree grows larger because the stems are pushing against each other and the branch bark ridge is turned inward.





In both photos, the yellow pencil points to the raised branch bark ridge (BBR). This is considered a good union at this time. The blue pencil points to the spot where the branch bark ridge turns inward and included bark has developed.

Epicormic Branches

Epicormic branches, also known as “water sprouts” or “suckers” are, growth that emerge from dormant buds along trunk or branches of a tree. They are formed as a response to injury or environmental stress. Epicormic branches are new branches that replace declining, injured or pruned branches. Some species of tree such as the coast live oak (Quercus agrifolia) produce a large quantity of this growth and others like the Sycamore (Platanus occidentalis) will produce comparably fewer.

Epicormic sprouts may appear for a variety of reasons and mostly in areas newly exposed to sunlight and are often a symptom of stress in the tree. Trees that have suffered fire or storm damage, or those that have been overly pruned and thinned will grow epicormics sprouts to compensate for the loss of leaf canopy. A tree will push these epicormics sprouts out when there is a need for it to increase photosynthesis. The production of these sprouts requires enormous amounts of energy and resources.

Epicormic sprouts also serve the purpose of protecting tree bark that is directly exposed to sunlight by providing shade. Sun scald is a common cause of decline in trees in the southwestern United States. Continuous exposure to the sun will cause the bark to crack thus exposing the vascular system making it vulnerable to entry of pests. Pests will accelerate the decay of the wood, making the branch weak and vulnerable to breakage. Lion-tailed branches also have a very high tendency to break under heavy winds. The leaves are positioned at the tips of the branches which act as a sail instead of being spread out along the branch where it can better distribute wind pressure.

Although epicormic branch growth is a unique survival trait, especially in Eucalyptus, the branch unions have a much weaker attachment point similar to included bark. Epicormic branches by their very nature form weak attachments due to lack of overlapping trunk tissue at the attachment point.

Branching Habits of Common Trees

Excurrent — good apical control, 1 central leader, horizontal scaffold branches

- Bald cypress
- Blackgum
- Junipers
- Lindens
- Pines
- Pin oak
- Spruces
- Sycamore
- Sweetgum
- Tulip poplar

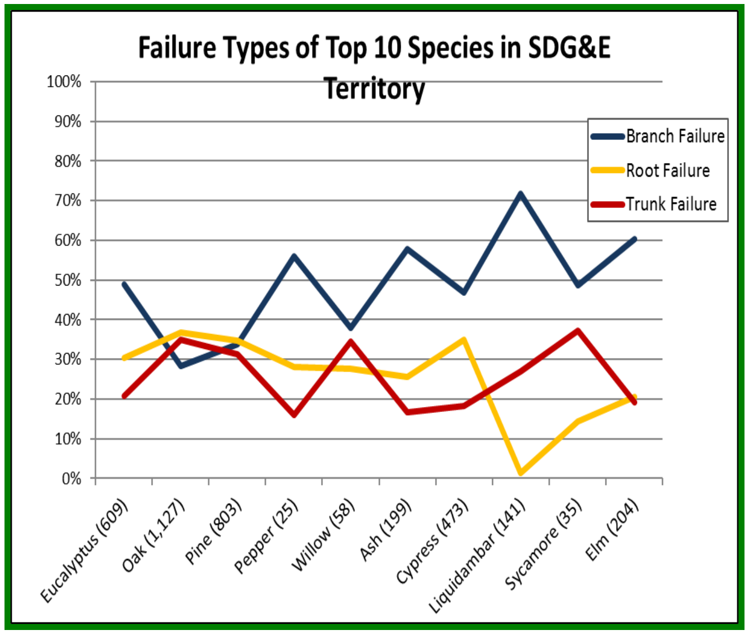
Decurrent — weak apical control, spreading habit due to scaffold branches growing vertical, acting as co-dominant branches, leaders

- Ash
- Elm
- Cherry
- Hackberry
- Honey locust
- Maple
- Redbud
- Eucalyptus

Species Failure Patterns

Every tree species has unique characteristics, such as wood density and flexibility, structure, and growth rate that can influence the likelihood of a specific type of failure. Understanding these characteristics can help an inspector focus on the areas of the tree where structural issues are most likely to cause failure.

The International Tree Failure Database is a good source for exploring the failure tendencies of different species. In the chart below, the percent failure by type is shown for the top ten species in SDG&E territory. The number of tree records for each species in the ITFD is shown in parenthesis.



Common Defects

Defects are signs of structural weakness. Defects are injuries, decay, abnormal growth patterns or other conditions that reduce overall strength and indicate a tree has failed, is failing or has the potential to fail. Defects can occur over long periods of time or overnight and most are easily recognizable therefore early detection is critical.

The 7 main categories to defects are:

- Poor branch attachments - co-dominant stems / included bark / epicormic sprouts.
- Poor tree architecture – abnormal growth pattern that indicates weakness.
- Internal decay – chemical alteration of wood composition. Wet wood = fungi.
- Root failure – Loss of strength due to rot or decay, girdling, erosion, construction activity, toxic chemicals introduced to soil or saturated soils.
- Cracks – due to lightning strikes, cold weather or freeze cracks and high temperatures (south facing side of tree).
- Trunk abnormalities – Over time decay can set in compromising trunk integrity. Cankered (swellings or flattened areas) oriented to the windward or leeward side of bole are more likely to fail.
- Dead

Roots and the Soil

Roots are the vital lifeline for all woody plants. The function of the root system is to provide stability by holding the tree firmly in the soil, and to provide water and nutrient uptake. We seldom have the opportunity to inspect the roots of a tree below the surface, and if the crown is green and living, the normal assumption is that the roots are performing as expected. However, even a tree with well developed, healthy roots can fail unexpectedly, and a professional needs to be aware of the symptoms.

Root problems are very difficult to detect and assess since they are underground and out of sight, however, anything that alters or compromises the structural support provided by any part of the root system decreases tree stability. Two major culprits that jeopardize the integrity of roots are; 1) root rot pathogens that attack stressed trees or enter through wounds (mowing) and cause decay and 2) actions that severe or cut any portion of the root system. In addition, tree roots also often have to withstand soil compaction from parked or driving vehicles, grade changes from construction, soil erosion, drought, sudden soil saturation or flooding and even gas or chemical leaks. Roots thrive when they have the appropriate amounts of water, nutrients and oxygen. Compact soil deprives the root system of water and oxygen compromising strength. Over irrigated soils or swamp areas also compromise strength by forcing the root system to stay shallow to survive thus compromising stability.

Signs and Symptoms

Signs of root damage usually appear long before the tree dies. There are certain signs and symptoms that let you know a tree is in distress. The loss of root function impairs the tree's ability to obtain water and nutrients. How much root material a tree can lose and survive varies with the individual tree. Moderate damage to the root system, by construction, is considered 15% - 30% of root surface. Anything more than 30% the tree may be at risk of failure.

Wilting (drying out, drooping, withering of leaves) is considered an obvious sign of root damage, caused by the inability to take up soil moisture. Other significant signs are premature leaf drop and yellowing; conifers may drop most of their inner needles. Leaf scorch can develop when roots can't pull up moisture from the ground fast enough to match the leaf evaporation rate, another telltale sign of root damage. Thinning foliage, poor yearly growth, yellow undersized leaves, dead branches in the upper canopy, wilted brown leaves in the spring or summer or out-of-season flowering. An extremely stressed tree puts out an excessive amount of suckers and seeds as a survival tactic. Fungi attack stressed trees. The presence of fungal fruiting bodies around the root flare and on the tree trunk is a sure sign of internal decay.

The signs of root damage may not appear in all parts of the tree. The roots in some trees are tied directly to the vascular system on that side of the tree, so the stress signals will appear on just that side. Other tree roots attach to the canopy, which will display the signs of tree root damage in the canopy.

Trees are “self optimizing”, as described by Mattheck and Breloer(1998), meaning that they take advantage of the conditions in which they exist. Essentially, trees will alter their form to compete more successfully. For example, a maple that emerges from a seed in a dense natural wooded area will devote energy to growing a tall slender trunk to reach the available sunlight needed for photosynthesis in a high canopy forest. The same maple seed that sprouts in an open field will develop a shorter, thicker trunk with more taper and strength to be able to withstand wind events. However if you take a tree species outside of its natural range, it may or may not be able to withstand the different set of climate forces that are characteristic of that region. So be sure to look around the site for other signs and symptoms that may clue you in or aide in the decision making process.

Species and Age

In addition to observing the size and placement of tree branches, attachment points, trunk, root zone and site conditions, it is also very important to consider additional characteristics including species and age of tree.

A tree’s structural support is most important during high wind events, snow accumulation on branches or uncommon saturated soil. For example, the accumulation of snow or ice can increase the weight of branches by 30 times or more. This additional weight may not pose a problem for relatively young trees, however, as trees grow older, they are less likely to be able to compartmentalize or wall-off injured portions and decay is more common. In addition, older trees have greater tendency to shed branches due to unavoidable decline in woody tissue quality. Besides age, growth rate and ability to respond to injury will influence the lifespan of the tree. Fast growing trees like silver maple, willow, poplar and eucalyptus allocate a relatively small portion of their resources to building compartments to ward off pests and decay from spreading. Instead, they rely on rapid growth to outdistance decay causing pathogens. However, as these fast growers age, their rate of growth slows, and the decay catches up with failure short behind. On the other hand, trees such as an oak grow slowly and allocate a significant portion of their internal resources to defense. Oaks effectively compartmentalize injury and, in general, are long lived and less likely to fail.

The following is a list of species and their failure patterns taken from “Evaluation of Hazard Trees in Urban Areas” by Matheny and Clark:

Fir - trunk failure of volunteer and dead tops; trunk failure due to dwarf mistletoe and internal decay; root failure due to butt and root rot.

Acacia – branch failure due to poor attachments; root failure due to decay, circling and kinked roots.

Boxelder – relatively high rates of failure of living (decayed poorly attached) and dead branches; trunk failure due to decay; ranked as high hazard.

Ailanthus (tree-of-heaven) – high failure rate when large (older mature); trunk and branches due to decay.

Eucalyptus – high branch failure; root failure due to root rot.

Liquidambar (sweetgum) – branch loss with load (snow or ice) and poor attachments; trunk failure from internal decay.

Sycamore – branch and trunk failure due to heart rot; multi stem may split out due to weak attachment stump decay.

Coast live oak – scaffold limbs fail to internal decay and unknown reasons; root failure due to Armillaria and butt rot Poria, especially on irrigated sites; branch failure due to heavy lateral; sudden limb drop.

California black oak – root failure due to Armillaria

Valley oak – branch failure due to poor taper and excessive end weight or decay; root failure to decay, especially on irrigated sites.

Black locust – trunk failure due to decay and borers; branch failure due to decay and or poor attachments; ranked as high hazard.

Monterey cypress – rarely fails as large tree; failure of co-dominant branches.

Monterey pine – branch loss due to poor attachments and heavy end weight; co-dominant stems fail; trunk failure and windthrow often associated with girdling roots.

Western cottonwood – branch and trunk failure due to decay.

Lombardy poplar – trunk failure in wind events, often associated with Hypoxylon cankers (fungus thrives on stressed trees); prone to Armillaria; branch failure; ranked as high hazard.

Willow – branch and scaffold limbs fail in wind, snow and ice events normally due to decay and poor attachment points; high failure rate.

California pepper – scaffold branch and trunk failure due to decay.

Elm – branch and scaffold limb failure due to poor attachments;

Individual species vary widely in wood strength and resistance to decay. As with all living organisms, trees have limited life spans. The expected life span is influenced by species characteristics, quality of site, species and site suitability, ability of tree to resist disease and insect infestation, which in turn is influenced by the tree's vigor or health.

The importance of species and age is very simple. As all trees age, their ability to defend against invasion diminishes, increasing probability of failure. Large, old trees fail more frequently than young trees in similar circumstances. In urban areas, a tree's life span is even shorter, rarely approaching the maximum potential of size and longevity. Trees in urban areas are also more likely to fail sooner.

R.J. Laverne, urban forester for the Davey Tree Expert Company, suggests this four-part, seasonal inspection is a simple way to identify risks before they become a danger.

Step 1: Bottoms up! Take notice to what is happening at the base of the tree, says Laverne. "Pay attention to the tree's roots, looking for soft spots or decay."

Step 2: Look at the tree's collar. The collar is where the trunk and roots meet at the soil surface. Laverne says to pull back the ground-cover to check for decay. If bark is missing, falling off, or broken, or if there are cracks in the trunk, it's a sign of developing decay.

Step 3: Examine the trunk. Look for deep, large cracks in the trunk. These indicate structural weakness in the tree and need careful evaluation. Trunk swelling, or an overgrowth of one area of the bark, also signifies advanced decay. A certified arborist can determine the extent of decay by using a probe.

Step 4: Look up. Pay close attention to the crown, or top of the tree. From the ground, Laverne says to look out for broken or hanging branches, limbs with missing bark, and bare branches with no new leaf or bud growth.

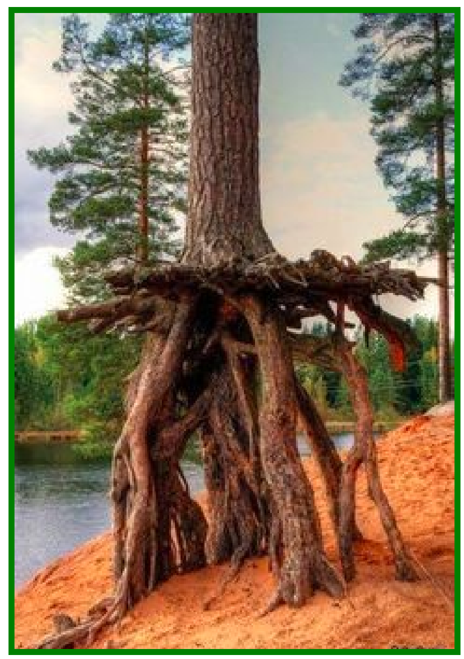
Tree Risk Assessment

Whole tree or portions of tree failures can cause severe damage to electrical conductors, poles, towers, other structures and equipment, or simply cause short circuits in electrical supply lines. Healthy, live trees seldom cause such problems except in unusual circumstances (hurricane force winds, ice storms, etc.). Trees are also subject to injury, disease, insect and fungus attacks, and ultimately death. When afflicted, they become hazardous and damages can be catastrophic and life threatening.

Most defects in trees are readily apparent to the trained observer; however, some defects cannot be detected, even by a trained observer, with just a cursory glance. One must conduct a systematic, ground to crown, 360 degree inspection of the tree and the surrounding area to properly identify and evaluate a tree for defects.

In applying experience, training, guidelines and standards, an inspector should always bear in mind the presence of power lines magnifies risk. The goal for everyone, the inspectors and the electric utility, is to mitigate that risk in order to prevent facility damage, outages and fires with sound judgment and experience.

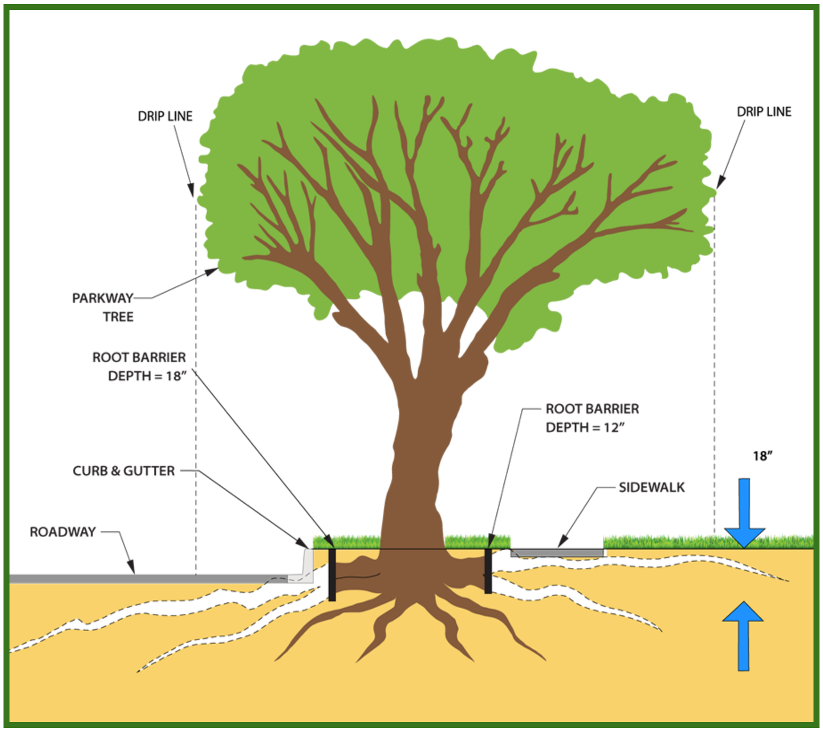
Recognizing Potential Root Defects



Roots are the lifeline of a tree. They not only provide water and nutrient uptake, they also provide stability. Roots require 3 things; water, oxygen and the right soil pore space (compaction) to allow roots to grow to their full potential. With enough void soil, sufficiently large enough for root penetration, roots can grow to tremendous depths.

Orjan Stahl, a tree researcher in Stockholm, made an exhaustive study of over 500 trees that had root and utility conflicts. He regularly found roots at depths of 7 to 9 feet (2.1 to 2.7 meters) and the deepest root he encountered was at 23 feet (7 meters). In their 1991 paper, "On The Maximum Extent of Tree Roots," E.L. Stone and P.J. Kalicz summarized previous root depth studies of 49 genera and 211 species growing in a wide variety of soil types. They found numerous examples of trees reported to be growing roots to over 33 feet (10 meters), and one report of a tree that grew roots to a depth of 174 feet (53 meters). Clearly, a tree's ability to grow deep roots is not a significantly limiting factor in soil design.

Root Growth Limitations



In urban areas, the typical limitations to tree rooting are soil compaction and poor drainage. These are often related, with a compaction layer creating a poorly draining hard-pan. This creates a perched water table limiting root depth and therefore shallow roots are typical in urban areas. Another limiting factor is space. If both vertical and horizontal root growth are restricted, the tree's stability is less than ideal and severely weekend.

Saturated soil has been weakened and can also lead to root disease. As soils get saturated, roots will move (slip) in the soil when the wind pushes on the tree. If the root system is not strong enough, the tree may blow over. Soil fails when it lacks the strength to keep the roots and subsequently the tree anchored. Three major issues may be the reason trees fail in this way. Poor planting techniques, infrastructure crowding, and root damage.

The following information on tree survival came from the U.S. Forest Service.

- Flood-tolerant trees can survive one growing season under flooded conditions: Red maple, silver maple, pecan, hackberry, persimmon, white ash, green ash, sweetgum, sycamore, eastern cottonwood, pin oak, and baldcypress.
- Trees moderately tolerant of flooding can survive 30 consecutive days under flooded conditions: river birch, down hawthorn, honeylocust, swamp white oak, southern red oak, bur oak, willow oak, and American elm.
- Trees sensitive to flooding are unable to survive more than a few days of flooding during the growing season: redbud, flowering dogwood, black walnut, red mulberry, most conifer, white oak, blackjack oak, red oak, and black oak

Recognizing Heart Rot

Heart rot refers to a type of fungus that attacks mature trees and causes rot in the center of the main stem, trunk and branches. All hardwood trees are susceptible to varieties of fungal infection known as heart rot tree disease. Hardwoods are the botanical group of trees that have broad leaves, produce a fruit or nut and generally go dormant in winter (ash, maple, oak, willow, cottonwood, poplar). The damage is initially invisible from the outside, but diseased trees can be detected from fruiting bodies on the outside of the bark.

Most types of heart rot in trees cause fruiting bodies that look like mushrooms to form on the outside of trees. These structures are termed conks or brackets. Look for them anywhere on the tree but, especially around an old wound or at the root crown. Some are annual and only appear with the first rains; others add new layers each year.

The heart rot causing fungi can be divided into 3 types: brown rot, white rot and soft rot. Brown rot is generally the most serious and causes the decayed wood to become dry and crumble into cubes. White rot is less serious but does weaken the tree by turning the decayed wood moist and spongy. Soft rot is caused by both fungus and bacteria and causes the least structural harm. Soft rot is very slow moving and does not spread very far from it's origin.

- Open wounds showing visible rot.
- Old wounds that have partially or fully healed over.
- Conks or brackets anywhere on the tree (butt, bole, trunk, branches and limbs)
- Hollow trunks can be detected by sounding.
- Decreasing crown vigor.
- Cracks or splits not caused by lightning and swelling cankers on the bole.
- 25% or more of root system
    - Exposed or undermined roots due to erosion
    - Severed roots caused by construction activity.
    - Roots loosened by saturated soils or winds.
    - Grade alteration, buried roots and/or trunk & root zone compaction
- Root rot is a major cause of uprooted trees. Root rot can often be detected in hardwoods by open butt rot wounds near the ground line. In conifers, it is indicated by excessive casting of exterior needles, yellowing, abnormally short needles and internodes, rounding off of the upper

crown, and fungus fruiting structures in the cambium layer at the root crown (ground level or on the trunk of the tree).

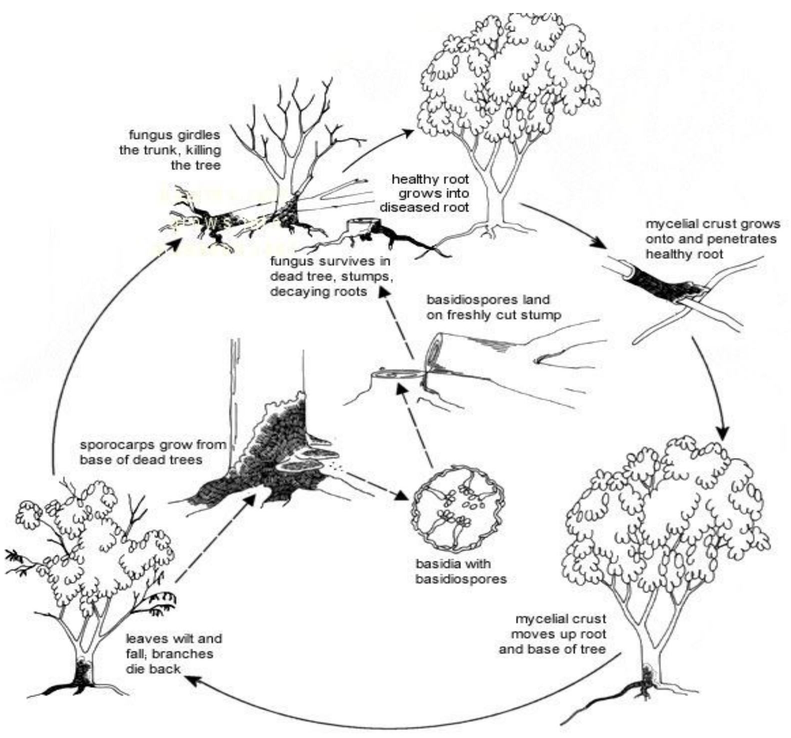
- A leaning tree may be the result of root failure, root or butt rot.

Let's clear up any "butt rot" anxieties. These don't have anything to do with with your posterior! The term "butt rot" refers to decay fungi that attack the base ("butt") or roots of trees. These fungi set up shop in living trees which make them different from sap-rotters, which attack dead trees and lumber products. Butt and root rot fungi can weaken and even kill trees prematurely.

How do they find their way into the tree? Butt and root rot fungi are wound invaders, they slip through the smallest of openings. Basically, anyplace the bark has been removed, mowers, string trimmers, incorrect pruning, car accident, squirrels just to name a few.

Degree of Concern from Heart and Butt Rot

- Amount of radial wood remaining for support.
- Basic form of the tree relative to weight distribution.
- Rate of growth versus the loss of strength due to decay.
- Orientation to the prevailing winds (potential of failure is greater if the wound faces or is opposite the prevailing winds).
- Other contributing factors: cracks, sap rot, leaning, root rot.
- Age of tree and species



Courtesy V. Brewster

Leaning Trees

Leaning trees should be evaluated carefully! Inspection of the root zone is a critical part of risk assessment, particularly if the tree is leaning. In most cases it is obvious when a tree has grown naturally with a lean. Trees that are leaning because of weakness in the root system may exhibit soil heaving or mounding at the base of tree opposite of the lean. Cracking in the soil near the butt of tree or along the drip line can sometimes be readily observable and is a sign the roots are failing.

There are a variety of reasons trees develop a lean and many are outside factors such as wind and soil conditions. Construction activities that sever roots or strike trees may also cause trees to lean, as does the impact of other trees falling, either natural or man caused.

A leaning tree is often rendered more hazardous when the lean has not corrected itself or there are open wounds or cankers present, especially if accompanied by decay. Wounds facing toward or directly opposite the direction of the lean will have the greatest weakening effect. Removal shall be considered if there is a potential for root failure with evidence of butt or root rot. These defects combined with a lean increase the likelihood of failure. If corrective pruning will result in additional lean potential, consider removal.

References for Tree Risk Assessment

- International Society of Arboriculture – Arborist Certification Study Guide
- International Society of Arboriculture – Utility Specialist Certification Study Guide
- International Society of Arboriculture – Best Management Practices for Tree Risk Assessment
- Utility Best Management Practices – Tree Risk Assessment and Abatement for Fire Prone States and Provinces in the Western Region of North America
- California Department of Forestry – Power Line Fire Prevention Field Guide
- United States Department of Agriculture - www.usda.gov
- Tree Risk Assessment: Recognizing and Evaluating Potential Hazards – R.J. Laverne / revised by L.F Burkhart Jr. Davey Tree Expert Company
- Matheny & Clark – A photographic Guide to the Evaluation of Hazard Tree in Urban Areas
- Alex Shigo – Tree Anatomy
- Urban Tree Risk Management – A Community Guide to Program Design and Implementation – USDA Forest Service / Jill D. Pokorny and others
- Tree Risk Assessment: Recognizing and Evaluating Potential Hazards – R.J. Laverne / revised by L.F Burkhart Jr. Davey Tree Expert Company
- Community Trees: Recognizing Living Hazard Trees – Jeff Iles / Department of Horticulture, Iowa State University
- Identify and Manage Hazardous Defects in Trees – a cooperative project of: National Arbor Day Foundation, USDA Forest Service, Forestry Department of Natural Resources