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Tree Risk Assessment and Hazard Tree Mitigation in the Southwestern Region

Cover photos: Dead hardwood tree threatening a developed campsite (above) and *Inonotus munzii* fruiting bodies and stem breakage on a large cottonwood (below).

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PREFACE

This technical report addresses identification, prioritization, and mitigation of hazard trees in developed sites operated and maintained by the Forest Service in the Southwestern Region (Region 3). Region 3's hazard tree management training provides more information, examples, and a field component.

The purpose of this technical report is to provide procedural information on hazard tree management to Forest Service employees, although the technical report is available for use by other federal and state agencies and concessionaires. The Forest Service is not responsible for operation and maintenance of developed sites under a special use authorization. Holders of a special use authorization are responsible for operation and maintenance of the NFS lands covered by their authorization, including but not limited to inspecting, identifying, and mitigating hazard trees on the NFS lands covered by their authorization. See Forest Service Handbook (FSH) 2309.13, Chapter 50 for more information.

This guide supersedes in their entirety previous Southwestern Region technical reports regarding hazard tree management, including:

USDA Forest Service. 2020. Tree risk assessment and hazard tree mitigation in the Southwestern Region. Southwestern Region, Forest Health, TP-R3-16-37.

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Introduction

Sustainable recreation and safety are major priorities in the Southwestern Region of the USDA Forest Service. Therefore, maintaining safe developed areas (e.g., administrative sites, developed recreation sites, etc.) is an important responsibility of the national forests in the Region. The threat posed by hazard trees within developed sites or along roadways can be quite severe, and a tree risk assessment and hazard tree mitigation plan is a vital component of any recreation program.

A tree becomes hazardous when a structural defect increases the probability the tree or part of the tree will fail and cause damage to people or property. Any area with tree cover can be temporarily or permanently rendered unsafe by structural defects such as dead tops, defective/broken branches, or large mortality events. The Forest Service is responsible for mitigating these hazards and maintaining safe developed areas as enumerated in relevant directives. Developing a tree risk assessment and hazard tree mitigation program with staff trained in the identification of the most common tree defects is critical to fulfilling this obligation. This requirement is codified in the Forest Service Manual (FSM 2300) and Forest Service Handbook (FSH 7709.59). The FSM contains legal authorities, objectives, policies, responsibilities, instructions, and guidance needed on a continuing basis by Forest Service line officers and primary staff to plan and execute assigned programs and activities, whereas FSH are the principal source of specialized guidance and instruction for carrying out the direction issued in the FSM.

A tree risk assessment and hazard tree mitigation program provides a systematic method of mitigating tree hazards to decrease the likelihood of damage to people or property. Evaluations should be performed by personnel trained in the identification of hazard trees and should prioritize areas by level of visitor use or other assigned value (e.g., cultural sites, high value infrastructure, etc.). High priority areas may include developed areas such as parking lots, walkways, visitor centers, campsites, and picnic grounds. Evaluating trees for risk involves identifying trees within striking distance of a known target (e.g., a fire ring or picnic table), assessing for structural defects on those trees, associating those defects with a known pattern of failure, and assigning a relative rating for the degree of risk of that tree or part of that tree striking the identified target. A familiarity with local vegetation as well as tree defects or forest health issues common to the area will greatly improve the efficacy of tree risk assessors, as defects and tree risk issues can vary by species and geographic location.

The complex, dynamic nature of tree failures limits our ability to accurately predict where and when failures will occur. Risk of damage to person and property cannot be eliminated but can be reduced by identifying and mitigating the most obvious tree defects in developed high use recreation areas. Tree risk assessment and hazard tree mitigation programs are challenged with striking a balance between increasing public safety while retaining as much of the vegetation resource as possible.

Hazard Tree Definition and Ratings

For the purposes of this guide, a hazard tree is defined as a tree that has both:

1. A structural defect that increases the probability that the whole tree or tree parts will fail and
2. A known target (e.g., people, buildings, vehicles, etc.) that could be hit when the tree or its parts do fail.

Tree risk ratings in the Southwestern Region are calculated by multiplying the relative risk value associated with probability of defect failure by the target value / priority level. Various defects that can be found in the region are described in detail in the “Hazard tree defects” section of this document.

Tree Risk Assessments

Tree risk assessors should consider the size and location of a tree to determine if an in-depth inspection is warranted. Small trees that cannot cause damage to targets and trees that are too far away from a target to strike it should not be inspected. A flow chart that can help tree risk assessors move through a given site is shown in Figure 1. Trees that do warrant thorough inspection should be surveyed from top to bottom and 360° around the tree. Defects may occur in the roots, base, trunk, or in large limbs throughout the crown. A tree may look defect-free from one angle, while another angle may reveal defects. Due to the nature of the target, hazard trees along roadways (previously known in some regions as danger trees) can be assessed using rapid “windshield surveys”. Only the most obvious defects will be identified in these rapid surveys, such as dead or dying trees and severe, unnatural leans. Mitigating the most obvious defects will reduce some risk of hazard tree failures along roadways but will likely not address subtle defects that could be identified during an intensive survey. For roadway tree risk management, more attention could be focused on chokepoints near pullouts for overlooks or trailheads and other areas where vehicles are present in high numbers and potentially traveling at low speed. Thorough assessments are required to the extent practicable in developed recreation sites and other areas with high-value targets.

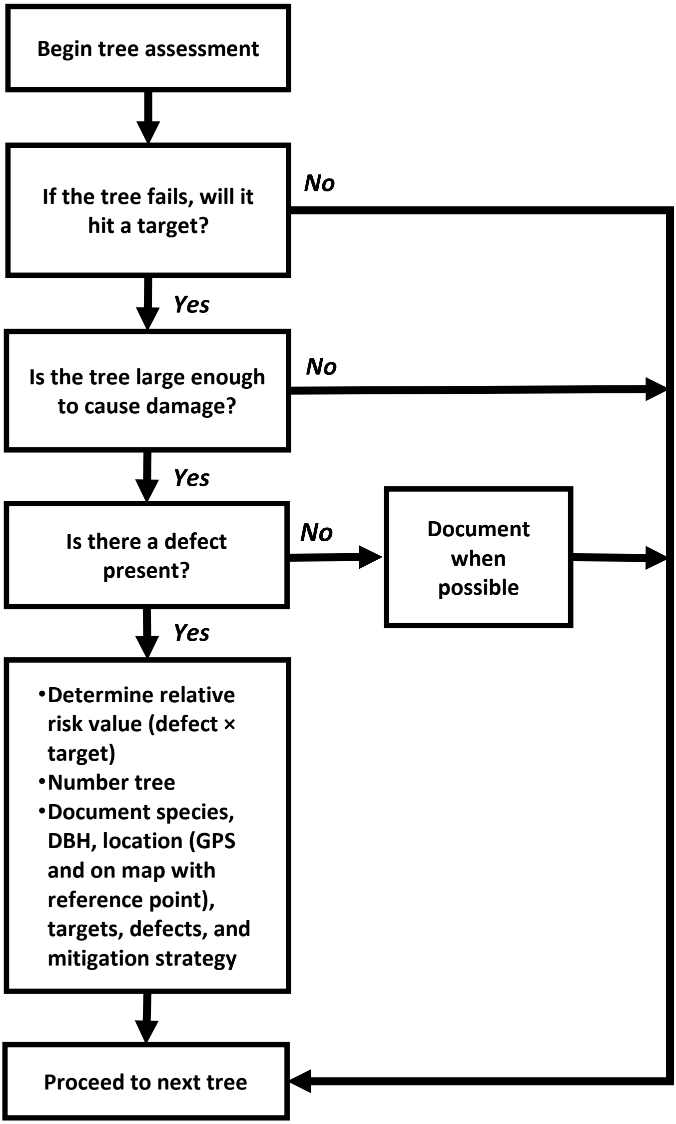

Figure 1. Flow chart to aid tree risk assessors in surveying developed recreation sites.

Potential Impact Zone

The potential impact zone (PIZ) refers to any area that could be impacted by any part of a failed tree. The graphics below display some of the many site characteristics which may influence the potential impact zone. Keep in mind, the failure of a tree can cause adjacent trees, or parts of trees, to fail (a domino effect). This can result in impacts outside the PIZ of a particular tree.

- **Flat Ground; slope and lean of tree both < 15°:** the PIZ of a tree with these characteristics can be represented by a circle around the tree in question with a radius equal to the total height of the tree, h (Figure 2).

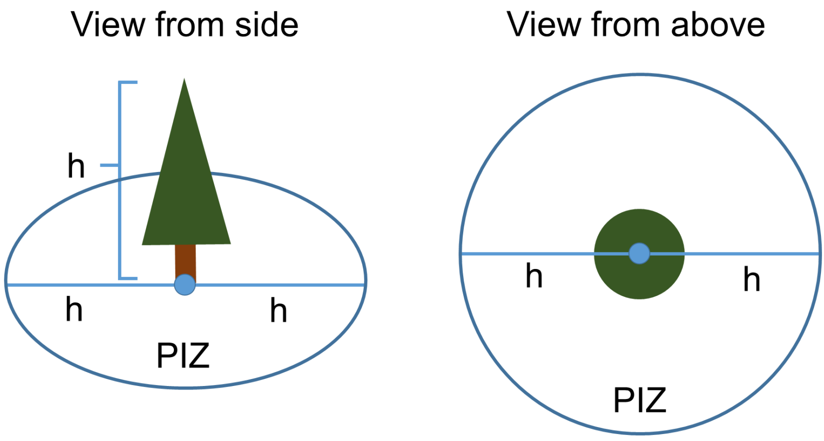

Figure 2. Potential impact zone (PIZ) for a tree with less than a 15° lean on less than a 15° slope; PIZ is represented by a circle around the tree with radius equal to tree height (h).

- **Tree on slope > 15°:** trees on slopes greater than 15° can slide downslope and may affect a larger area on this side. The PIZ will therefore need to be extended in these scenarios. There is no standard for extending the PIZ; this decision should be made by a trained tree risk assessor and extended to a distance deemed necessary to ensure public safety. Topographic features, presence of other trees, steepness of the slope, and other factors should be considered when determining PIZ. A PIZ of 1.5 to 2 times the height of the tree is often used for trees on moderately steep slopes (Figure 3).

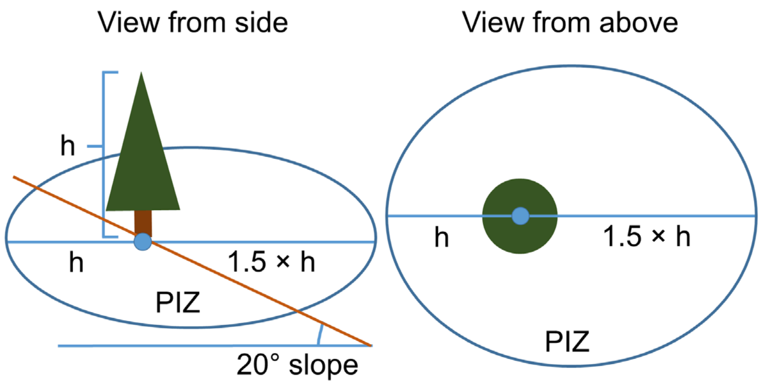

Figure 3. Potential impact zone (PIZ) for a tree on a greater than 15° slope; the PIZ is extended beyond the tree height (h) in the downslope direction.

- **Tree lean > 15°:** the majority of failures on trees with a lean > 15° occur anywhere from the direction of the lean to 90° on either side of the direction of the lean. A distance equal to the total tree height in this area (90° on either side of the lean) will comprise the PIZ in these situations. Slope as well as other trees and objects in the area will also need to be considered. In severe storms or windy days, trees with significant leans may experience backlash and fall in the opposite direction of the lean. This zone is generally much smaller than the PIZ in the direction of the lean (Figure 4).

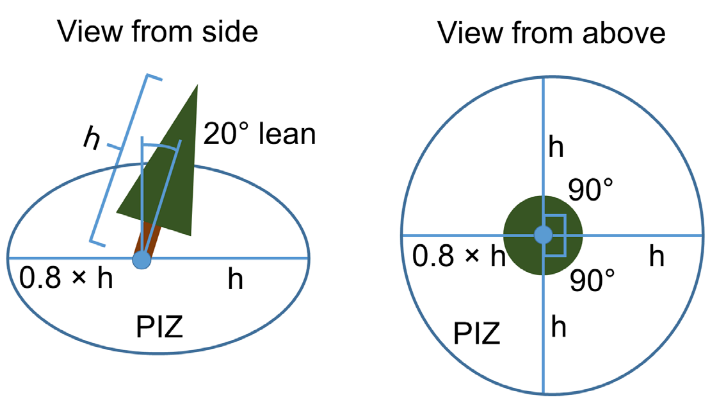

Figure 4. Potential impact zone (PIZ) for a tree with greater than a 15° lean; the PIZ is equal to at least the height of the tree (h) in the direction of the lean and within 90° of the lean in either direction. The PIZ may be reduced from h on the side opposite the lean.

One quick and easy method for determining if a given tree could potentially hit a target involves measuring angles to the top and bottom of the tree from the target in question using a clinometer, laser hypsometer, or cell phone app. If twice the angle to the top of the tree (A') minus the angle to the bottom of the tree (A) from the target is greater than or equal to 90°, the tree in question could potentially hit that target if it fails ($2 \times A' - A \geq 90°$). Examples are shown in Figure 5. It should be noted that the trees depicted in the diagram below are assumed to be on a < 15° slope. The 90° cutoff can be reduced if the assessor believes adjusting the PIZ by 1.5 × h (67° cutoff) or 2 × h (53° cutoff) is warranted to account for steeper slopes.

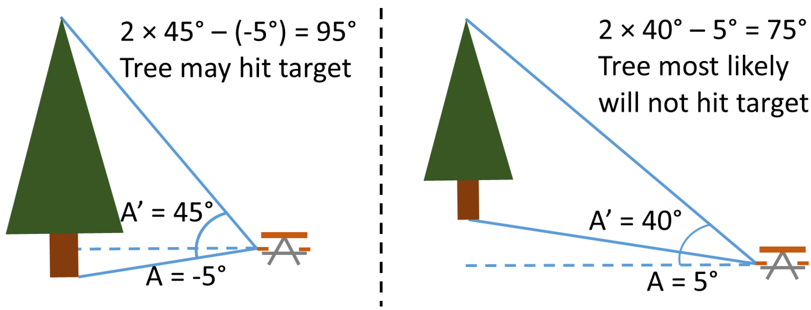

Figure 5. From a given potential target (e.g., a picnic table), it is 45° to the top of one possible hazard tree and -5° to the bottom ($2 \times 45° - (-5°) = 95°$). Because the result is greater than or equal to 90°, the tree could potentially hit the picnic table. From that same target, it is 40° to the top of another possible hazard tree and 5° to the bottom ($2 \times 40° - 5° = 75°$). Because the result is less than 90°, this tree would most likely not hit the target if it failed.

Rating Tree Risk

The tree risk rating system presented here includes two components: a target value and a defect value. These two ratings are multiplied together to give a final risk rating for the tree.

1. **Target Value (1-2):** this value represents the likelihood that there will be damage to people or property.

    1: A value of one corresponds to an area where people will not be stationary for long periods of time but rather will be moving/driving through, such as roads or trails. These areas have a lower probability of being affected by a hazard tree due to the target moving through the area of concern rather than being stationary.

2: A value of two indicates areas with higher probability of damage to people or property. This value will generally be used for campsites, picnic tables, visitor centers, parking areas, information kiosks, and any other areas in which people may congregate and be stationary for longer periods of time.

2. **Defect Value (1-3):** this value represents the likelihood that a tree or part of a tree will fail and cause damage to the target.

1: A value of one represents a minor defect with a lower probability of failure, indicating that the tree should be assessed annually to monitor any progression of the defect. Generally, no action will be taken to mitigate a defect with a value of one.

2: A value of two represents a defect that has a moderate failure potential and does not represent an imminent failure. These defects will need to be monitored closely at least annually and possibly removed depending on the level of acceptable risk, the value of the tree, and the value of the target.

3: A value of three represents a high hazard defect with imminent failure potential. Targets with a value of two that can be damaged by trees with a defect value of three should be prioritized for mitigation.

After a value has been assigned to the target and the defect, the two values are multiplied together for a final risk rating. The higher this value the higher the risk of resource damage or injury from a tree or tree part failure. In developed areas with high priority targets, trees will typically have risk ratings of 2, 4, or 6. A rating of 6 indicates a high risk hazard that should be mitigated as soon as practicable. A value of 4 indicates a moderate hazard, and a value of 2 indicates a low hazard. In some instances, multiple defects may interact and increase the risk of failure. Some examples of interacting defects could include:

- Codominant stems with included bark and associated decay or cracking
- Leaning trees with root rot or other root damage
- Leaning trees with decay or cracking
- Large diameter, overextended branches with decay or cracking
- Large branch unions with decay or cracking

It may be prudent, depending on the value of the trees present, to optimize the use of crews when they are on site and mitigate as many hazard trees as possible, including trees with lower risk ratings that would otherwise be monitored (trees that were rated a 4 or less). It should be noted that trees with lower value/occupancy targets like roadways will have a maximum risk rating of 3; hazards posed by these trees should nevertheless be mitigated to the greatest extent practicable. An acceptable level of risk should be communicated by the line officer and ideally would be included in the unit's vegetation management plan for developed sites. Line officer direction and these management plans will dictate which hazards are deemed acceptable. Region 1 provides a guide and template that can be adapted for developed sites in the Southwest, available at the following link: https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5334504.pdf.

The mitigation of hazard trees along roadways is an important component of a comprehensive tree risk program (USDA Forest Service 2016). Land management adjacent to major roadways can be convoluted, with various land management agencies involved, including state, federal, and local governments. It is important to know who is responsible for mitigating the hazards along roads. While trees along roadways may only have risk ratings of 1, 2, or 3, they still should be managed to the greatest extent practicable to reduce risk. Inspection of a road system is often hampered by the number of miles that need to be covered. An example of a decision tree for prioritizing inspections for roadways can be found below (Figure 6).

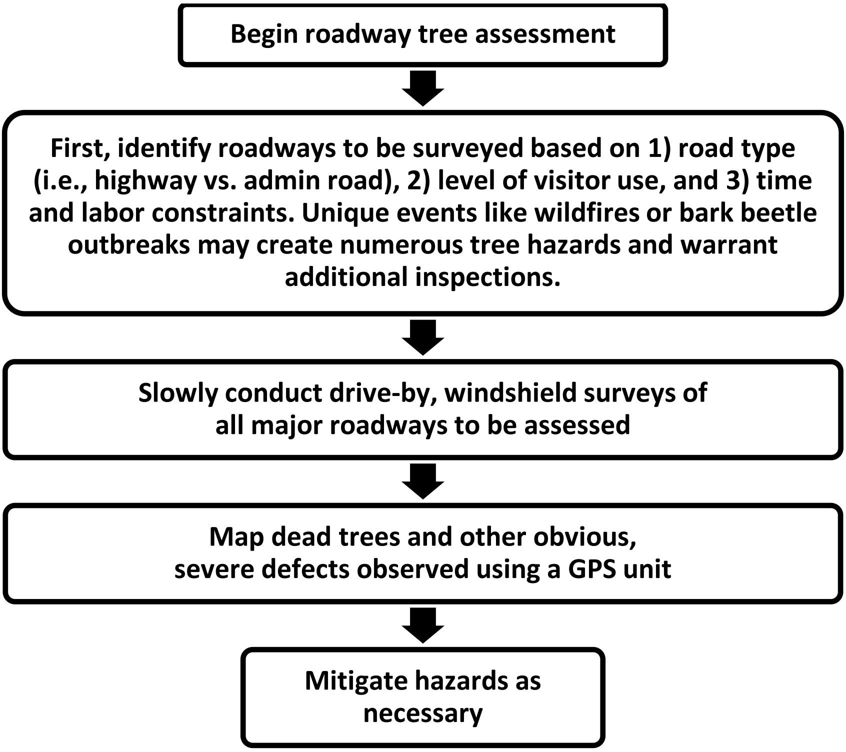

Figure 6. Flow chart to aid tree risk assessors in surveying along roadways.

Assigning a relative hazard value depends on several interacting factors, including tree species, presence of insects/diseases, stand age, past disturbances, and site or environmental conditions. Predicting tree failures is therefore not an exact science, but there are certain characteristics we can look for to reduce the probability of a hazard tree causing harm to person or property. Some of the most important characteristics to look for include:

1. Is the tree alive or dead?
2. Presence of dead or dead hanging limbs in the crown.
3. The lean of the tree. Is the lean natural or was it caused by damage?
4. Presence of significant insect or disease activity.
5. Presence of mechanical damage to bole or roots of the tree.

Inspection Tools

There are several tools that are useful when conducting tree risk assessments. These include:

- Blank hazard tree forms and forms from past inspections
- Site maps
- GPS unit
- Compass
- Diameter tape to measure diameter at breast height (DBH)
- Measuring tape (100' or so)
- Clinometer or other tool to measure tree height
- Tree tags and nails (aluminum)
- Camera
- Binoculars
- Chaining pins
- Rubber/plastic mallet
- Cordless drill
- Earplugs
- Increment borer
- Tablet or smartphone

Binoculars can be helpful for inspecting potential hazard trees for defects of large branches in the crown. Chaining pins or similar tools can be used to investigate the inside of decay cavities and determine the extent of decayed wood.

Mallets (rubber or plastic) can be used for sounding trees potentially hollowed by stem decay. The sound produced by a hollow or decayed tree will differ from the sound produced when striking solid wood. Different tree species have different densities of wood and produce varying sounds, so this technique requires skill and experience. Practicing with an experienced tree risk assessor is necessary.

When hollows are detected by sounding, or if obvious decay is present in association with a fruiting body, cavity, or wound; it may be necessary to measure the amount of sound wood present in that tree part. Increment borers or handheld, battery-powered drills with long 1/8" bits can be used for measuring percent sound wood. Using an increment borer, the extent of decay can be determined visually from the cores. Using a drill, constant power and pressure should be applied to a trunk or large limb with suspected decay until the drill reaches about halfway through the diameter or until a reduction in resistance occurs, whichever occurs first. If a reduction in resistance occurs, drilling should immediately stop, and the drill bit should be marked at the edge of the bark where the bit enters the tree. The length of the drill bit from the tip to the point on the bit where resistance decreased (minus an estimate of bark thickness) will represent the radius of sound wood. An earplug can be used as a marker and will stay in place where drilling stopped once the bit is removed. Trees that have significant decay should be measured in at least two more locations around the circumference of the trunk or limb to determine uniformity of the decay and an average sound wood thickness.

An alternative drilling method is to calculate the amount of sound wood necessary for the particular tree part you are inspecting and set a stopper (earplug, marker, tape, etc.) on the drill bit corresponding to that length, taking into account bark thickness. Then drill into the tree using constant steady pressure until the stopper is reached. With this method, it can be confirmed that the tree meets sound shell limits without drilling into decay columns.

Maintaining records of tree risk inspections is vital. Many of these items can be consolidated with the use of electronic data collection and storage tools. Federal tree risk assessors with agency access to ArcGIS Online may use the app Survey123, which can be downloaded on a personal or government phone or tablet. Each National Forest or National Park Service (NPS) unit can contact Region 3 Forest Health Protection for an Excel file template they can use to generate a Survey123 survey based on the tree risk assessment form presented in this guide. The form collects date, species, DBH, height, and location data for each tree surveyed, as well as information on targets and defects (including automatic risk rating calculation). Additionally, up to five photos can be stored in association with each survey entry, allowing for the assessor to include photos of the general area where the tree being surveyed is found, along with overview photos and detailed images of any major defects. Recommended mitigation actions can be stored in the system as well. All data can then be uploaded to a cloud-based storage service for each respective Forest or NPS unit.

Documentation

Proper documentation is a critical component of the tree risk assessment process. Maintaining documentation of tree risk assessments as well as subsequent hazard tree mitigation provides evidence that these tasks were conducted. It is of the utmost importance to have these records available in the event of a hazard tree incident and subsequent litigation. These records are a vital tool for personnel who will be performing future surveys, providing locations of trees and defect information, aiding in planning, and helping to prioritize future surveys. This information can also be used to inform long-term vegetation management plans, as information on insects, disease, and other defects can help guide which species will be preferred in the future. Proper documentation includes:

- Date of inspection
- Name of tree risk assessor
- Tree species
- DBH
- Distance/azimuth to permanent reference point or GPS coordinates and a photo of the tree
- Identification of target, potentially including a photo
- Description of defects present along with photos of these defects
- Risk rating and mitigation strategy
- Date of mitigation
- Any other pertinent information

These data can be collected using whichever collection form fits with your agency priorities. This guide will focus on the Region 3 Tree Risk Assessment Form found in Appendix 2 and the associated Excel-based survey in Survey123 that can be provided by Region 3 Forest Health Protection. Tree risk assessment and hazard tree mitigation data should be stored based on agency record retention guidelines in paper and/or electronic form. Documenting information for trees with no defects is encouraged when possible to give a complete picture of each site.

Prioritizing Areas for Intensity of Inspection

Areas should be prioritized based on their respective level of development or risk level (e.g., increased risk following tree damage or mortality event). This can include prioritizing areas surrounding a visitor center over a minimally used, undeveloped campground. It can also include breaking up a given site into priority zones based on relative risk (Figure 7). For example, a campground can be considered to have high risk areas (e.g., tent pads, bathrooms, and other facilities) as well as more moderate or even low risk areas (e.g., roadways and trails between sites). A more liberal tree risk policy may be maintained for the lower risk areas. Higher risk zones, however, where tree failures could forseeably cause major property damage, personal injury, or even death, should be managed with a more conservative tree risk policy.

In-depth inspections may not be possible for every site every year. As such, inspections may be structured so that each site is initially thoroughly inspected with in-depth, 360° surveys with follow up, walkthrough inspections occurring annually thereafter as resources allow. Additional thorough inspections should occur on a semi-regular basis but at least every five years or following storms, insect or disease outbreaks, etc. Each unit must dictate their own schedule based on needs. The schedule should be defined in the unit's tree risk assessment program and should be followed. An example is provided below:

Year 1: 360° full inspection of all moderate and high risk areas
Year 2: Walkthrough survey
Year 3: 360° full inspection of all high risk areas
Year 4: Walkthrough survey
Year 5: Walkthrough survey
Year 6: 360° full inspection of all moderate and high risk areas

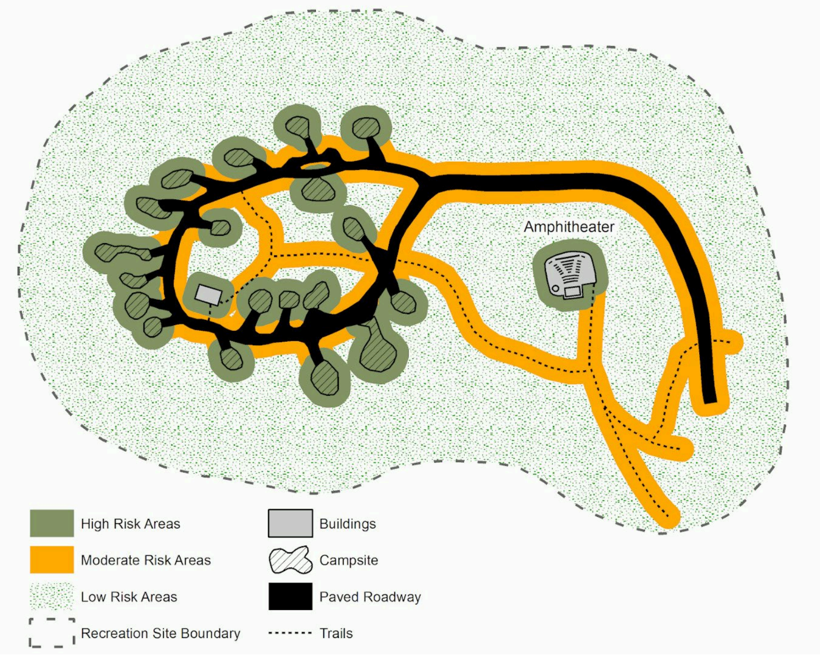

Figure 7. Recreation areas should be divided into hazard risk zones which determine the intensity of inspection.

Timing of Tree Risk Inspections

Developed recreation sites should be assessed at least on an annual basis. The timing of each tree risk assessment should be prior to the season of highest use, as resources allow. For most recreation areas this will be in the early spring before sites open for the summer season. New hazards, such as dead hanging branches and broken tops, may develop over the winter due to severe storms and heavy snow loads. In addition, mortality and defects that developed and progressed through the last growing season can be assessed, documented, and mitigated if necessary. Recreation areas that see peak use in the winter should be assessed in the late summer prior to opening. Sites with a large component of deciduous trees should, to the greatest extent practicable, be assessed after bud burst or before leaves drop in the fall. This will aid in the identification of dead trees, tops, and large limbs (Figure 8).

Figure 8. Dead tree missed due to tree risk assessments being conducted during dormant season before bud burst.

As resources allow, hazard trees should be assessed and high hazards mitigated prior to the opening of the site or the season of highest use. In addition to surveying prior to the peak season, ad hoc surveys may be performed as needed, for example following severe weather events midway through the field season or post-wildfire, before reopening sites. Events like these can create severe hazards quickly and warrant a thorough reassessment of the recreation area.

Post-Fire Marking Guidelines

Wildfires that burn through developed recreation areas and along major roadways present unique challenges to managers. It is important to understand characteristics that best serve as predictors of post-fire mortality and determine the level of risk your forest or district is willing to accept. For example, one district may choose to cut a tree that has an 85% probability of mortality, whereas another district, willing to accept less risk, may choose a threshold of 60%. The most important and easily assessed predictors of tree mortality following wildfire are crown scorch, crown consumption, and crown kill. Crown kill refers to the percent of crown in which all buds are killed. Crown scorch is defined as the percent of crown that was scorched but not consumed by the fire; needles will still be visible, attached to the tree, and likely a red/brown color. Bud survival depends on species, and crown scorch may represent crown kill for species with buds less adapted to high heat. For example, ponderosa pine buds are relatively large and can tolerate higher levels of scorch than species with smaller buds like Douglas-fir. Crown consumption is defined as the percent of the crown that is directly consumed by the fire; needles are consumed, and buds are killed. Crown consumption can be assumed to represent crown kill in most situations. Crown kill is very difficult to assess in the same season or year as the fire and will be most accurate in the season following the fire as the flush of new green growth (live buds) will be easy to identify in fire-affected trees.

In the Southwest, most studies related to post-fire mortality have focused on ponderosa pine, which is among the most fire adapted trees of the region. These metrics therefore represent the upper limits of tolerable fire damage that trees in the Southwestern Region can survive. Metrics are presented below for ponderosa pine and Douglas-fir as examples of how crown scorch and crown consumption are used to estimate probability of mortality. In addition to directly killing trees, fire can also predispose trees to bark beetles. Bark beetle activity may increase for many years following fires and may affect trees not significantly impacted by the fire itself. Fire-affected areas should be monitored closely for many years following fire. A thorough review of fire marking is beyond the scope of this guide. Please refer to Hood et al. (2018), Hood and Lutes (2017), Fowler et al. (2010), and Smith and Cluck (2011) for in-depth descriptions of this process.

The criteria below can be used for ponderosa pine (Fowler et al. 2010):

1. If no crown consumption is present, crown scorch affecting greater than 85% of the crown indicates 85-90% probability of mortality.
2. Crown consumption greater than 40% indicates 85-90% probability of mortality.
3. Crown consumption between 5 and 40% coupled with crown scorch > 50% indicates greater than 50% probability of mortality.

The criteria below can be used for Douglas-fir (Smith and Cluck 2011):

1. Crown scorch or kill of 65% indicates 50% probability of mortality.
2. Crown scorch of 80% indicates 80% probability of mortality.

In severe fires, it is possible for trees to suffer no visual crown damage, but still suffer mortality from cambial death due to high temperatures at the base of the tree, particularly where duff and litter have built up over many years. Large roots and whole root systems can also be killed and sometimes consumed by fires (Figure 9), creating unstable trees which can pose high hazards, especially when roots on the uphill side of trees are lost. Fire damage may also burn heartwood, reducing the amount of structurally sound wood, and may burn conks or other signs of significant decay. Assessing bark char or cambium kill directly can assist in the identification of trees likely to die post-fire.

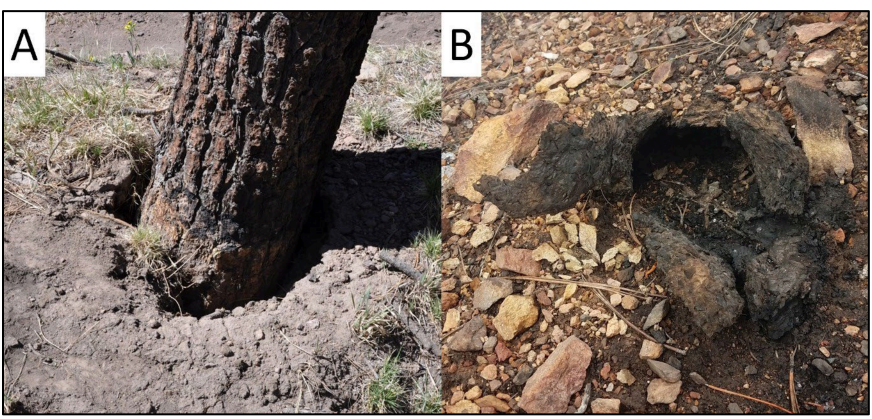

Figure 9. Ponderosa pine roots damaged by fire (A) and completely excavated by a severe fire (B).

Bole char can be divided into three categories, each corresponding to a probability of mortality:

> **Light bole char**: Light burning with many areas displaying no sign of burning. Bark furls and pattern easily distinguished. Indicates affected tree has a low probability of mortality.
>
> **Moderate bole char:** All bark blackened with no areas left unburnt. Bark features are still distinguishable. Thin barked species such as five needle pines and true firs may suffer mortality at this level. Direct sampling of cambium is required to assess mortality of trees with this level of bole char.
>
> **Severe or deep bole char**: All bark blackened; bark features no longer distinguishable. Assume cambium is dead.

It is important to assess cambium kill in trees with moderate bole char. Divide the bole into four quadrants and remove the bark from a small area in each quadrant to see the cambium. Samples should be taken within 3"of the ground and should be as small as possible to minimize injury to the tree. Live cambium will be light in color, moist, and pliable. Dead cambium will be darker, resinous, and much less pliable. Bark may be easier to remove when the cambium is dead. Most trees suffering 25% (one quadrant) or less cambium kill will survive, while trees suffering 75% or greater (3 quadrants) cambium kill have a high probability of mortality.

Hazard Tree Defects

Defects in trees are a natural part of forest ecosystems. They may provide food and shelter for various organisms in some cases. Defects that seriously weaken trees are considered hazardous if the tree or its parts can strike areas where people are known to congregate or investments in facilities have been made, such as in campgrounds or parking areas. In these cases, tree risk takes priority over wildlife or other resource considerations. The following summarizes some major defects occurring in trees of the Southwestern Region.

Dead Trees

Dead trees receive the highest defect value of 3 because they represent imminent hazards. Decay processes degrade the structural integrity of recently killed trees quickly. In bark beetle- or drought-killed trees, the process starts just under the bark and progresses rather uniformly toward the pith. Most activity during the first year is from blue stain fungi and incipient decay with little structural degradation. By the end of the second year, degradation of sapwood can be complete depending on its thickness, tree species, and tree size. By the end of the third year, virtually no sapwood is sound, especially in smaller trees and the tops of larger trees. Outer heartwood will also have appreciable deterioration in some trees. Decay and failure can progress much more rapidly, sometimes within one year of death, if the tree is killed directly by fire or root disease. The primary agents causing deterioration are fungi and insects, with a succession of types and species changing from year to year until no sound wood remains. Deterioration occurs most rapidly in the butt portion and root system where moist conditions favor decay. Recently killed conifers without root rot may remain in a structurally sound condition for up to 3 years, but most do not. Dead hardwoods begin to lose branches earlier than conifers and pose a greater hazard. Large trees will take longer to decay and in many cases will lose their tops prior to failing at the base (Figure 10). If a dead tree is in a high hazard zone, it should be removed as soon as practicable, or other mitigating actions must be taken.

Figure 10. Failed top broken out of a ponderosa pine snag near high value picnic table and fire ring targets.

Root Injuries

Up to 75% of all tree failures are root-related (Figure 11). The majority of failures occur when winds exceed 50 mph, but root system failures may occur under any wind conditions if roots are sufficiently weakened. Areas prone to root injuries include:

- **Edges** – trees on forest edges along fields, roads, driveways, parking areas, and other open areas are less protected and may have experienced root damage during land clearing.
- **High traffic areas** – trees in high traffic areas are prone to soil compaction, root wounding, and root decay.
- **Wet sites** – trees growing on wet sites generally have shallow root systems. Trees on sites that have been altered suddenly by grade changes, resulting in poor drainage, and those in areas that receive excess irrigation are more likely to have root rot.
- **Areas with previously documented root disease** – biotic diseases that weaken the root structure; these will be discussed in more detail in the "Root Disease" section of this document.

Figure 11. Failed tree primarily due to a shallow root system as indicated by the large root system that remains attached.

Leaning Trees

Not all leaning trees are hazardous. For example, trees that lean naturally are reinforced by corrected, or compensatory, growth, often after the tree has grown into a canopy gap (Figure 12). Trees that lean because of damaged roots, however, are very hazardous. These unnaturally leaning trees will not have compensatory growth (Figure 13). Root systems can be loosened and/or damaged from outside forces such as soil erosion, floods, heavy winds, root disease, or nearby trees falling. Look for soil mounding, root uplift, or cracking of soil at the base of the tree on the side opposite the lean. These are indicators that failure is already occurring. Unnaturally leaning trees should be removed as soon as possible or otherwise mitigated. The greater the lean of damaged trees, the greater the probability of failure during wind gusts or snow loads. Measuring the angle of a leaning tree with a tool such as a protractor from a designated spot annually can help to assess the safety of a valuable leaning tree. If the angle of the lean changes, the tree represents a high hazard. Although leaning trees may have aesthetic value, corrective action must be taken if visitor safety is threatened or recreational structures may be damaged. This can include closure of sites threatened by the leaning tree if removal is not an option or cannot be implemented immediately.

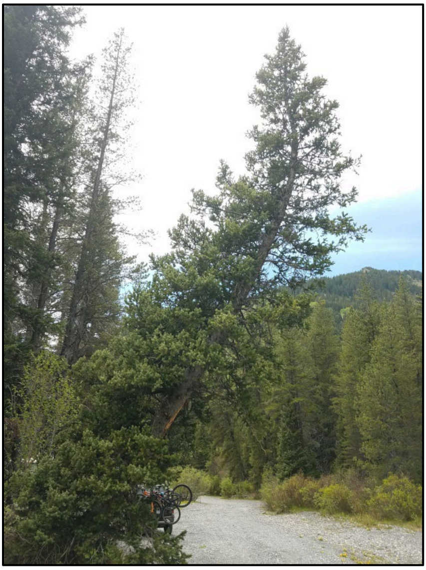

Figure 12. Naturally leaning tree with corrected or compensatory growth after the tree had grown into a canopy gap provided by a bike path.

Figure 13. Unnaturally leaning tree with no corrected growth; note the soil mounding and cracking on the side opposite the lean.

Height-to-Diameter Ratio

One structural issue that should be considered is an undesirable height-to-diameter ratio. Height-to-diameter ratios (H:D) represent an index of slenderness. Trees with a high H:D (tall and skinny) are more prone to break due to heavy snow loads and/or high winds. Trees with high H:D that have large brooms due to dwarf mistletoe or other diseases will pose an even higher risk of failing because of these additional defects. Trees with high H:D will most often be encountered in densely overstocked stands. In developed recreation sites, these types of trees could become an issue after thinning or other work exposes these “noodle” trees to increased wind and reduced support from neighboring trees. To estimate the H:D, measure the height of the tree and the DBH, both in feet. Conversion of DBH to feet from inches will likely be necessary. Then divide the height (in ft) by the DBH (in ft) to obtain the H:D. Trees with an H:D from 60:1-80:1 represent a moderate hazard that may warrant removal if additional compounding defects are present, while trees with H:D greater than 80:1 represent high hazards.

Dead Tops / Branches and Other Crown Architectural Issues

Dead tops are potentially dangerous on all hardwoods (Figure 14) and most conifers (Figure 15), especially true fir and spruce. Dead tops should be mitigated as soon as possible. Removing the top is often only a temporary fix because stubs left from topping generally decay. Also, sprouts (branches) from topping cuts are more prone to breakage due to their weak attachment.

Dead limbs may also be hazardous and require pruning (Figure 16). If a bucket truck / pruning crew will be onsite and mitigating additional moderate or even lower risk hazards is desired, the following rule of thumb will help in deciding whether a dead limb should be pruned, provided it could fall on a target:

1. Prune conifers if the limb has defects such as decay or cracks or is greater than 3” in diameter and 6’ in length and has a high probability of hitting a target.
2. Prune hardwoods if the limb size exceeds 2” in diameter and 4’ in length and has high probability of hitting a target.

Figure 14. Dead hardwood tops missed due to tree risk assessments being conducted during dormant season before bud burst.

Figure 15. Dead-topped ponderosa pine with potential target in nearby parked vehicles.

Figure 16. Dead branches on a ponderosa pine.

Branches that have been dead for several years usually form callus tissue around the branch stub. These branches should be severed at the point where the dead branch and callus meet. Do not cut into callus tissue, as this will enlarge the wound and increase the chance of decay. The callus area can be found by removing loose bark. More details on proper pruning technique can be found in the "How to Prune Trees" guide listed in the references of this document (Bedker et al. 2012).

Other architectural issues that may require pruning include overextended branches and volunteer tops. Overextended branches, those that extend past the majority of the canopy or are excessively long and have poor taper, can be a serious issue in riparian hardwoods like Arizona sycamore and cottonwood. When numerous vertical branches arise from an overextended horizontal branch, sometimes called "harp trees", great strain is put on the branch's union to the trunk. These unions should be inspected thoroughly for cracking or decay. Healthy volunteer tops that emerge as a result of the loss of a leader, although not immediately hazardous, may develop a fracture point where the new leader takes off. Top breakage could occur years later from wind, heavy ice, or snowstorms, posing a hazard primarily in areas of year-round occupancy or where people gather for winter sports.

Trunk Injuries and Defects

The trunk must support the weight of the entire crown, and any structural injury in the trunk increases the chance for failure. Trunk defects include forked trees, which are also known as codominant stems. Single stems represent stronger architecture than forked stems. Codominant stems with a U-shaped union are less likely to have "included bark," so in the absence of cracking or obvious decay, this is considered to be a minor defect (Figure 17). V-shaped unions present a moderate hazard as they often have "included bark", visible as a widened ridge between the two stems (Figure 18). In these situations, each stem pushes against the other with increasing pressure over time as they grow in girth, eventually leading to failure of one (Figure 19) or both stems. Trees should be removed or otherwise mitigated if cracking is present, signs of decay occur at the union, or after failure of one of the stems. Failure of one stem leaves behind a major wound for stem decay fungi to enter and also drastically alters the structural integrity of the remaining crown.

Figure 17. U-shaped codominant stem union with no included bark.

Figure 18. V-shaped codominant stem union with included bark.

Figure 19. Codominant stems with included bark eventually fail, leaving behind a major wound and structurally compromised crown.

Trunk wounds of any type, although they may not be structurally compromising, may serve as an entry point for decay fungi that reduce the volume of sound wood and increase the probability of stem breakage. Trunk wounds may be caused by animal damage, fire scars, lightning, canker diseases, mechanical injury, and other agents. Some of the more common trunk injuries and entry points for stem decay fungi are discussed in more detail below.

Cankers

Cankers are characterized by localized dead areas on the bark of stems and branches caused by fungal and bacterial pathogens. Wood beneath cankers may be decayed. Many cankers occur on aspen because of their easily wounded and colonized living bark, but most do not represent immediate hazard tree issues and should primarily be considered as a possible entry point for decay pathogens. Their severity in a tree risk assessment context therefore depends on the proportion of the stem circumference that is occupied by the canker. One exception, however, is the disease sooty bark canker, caused by the fungal pathogen *Encoelia pruinosa.* The disease is easily recognizable by alternating dark and light patches of bark (Figure 20) which has led to an alternative common name, barber pole canker. The disease may also be identified by the cup-like fruiting bodies found on killed bark (Figure 21). Aspen infected by this pathogen may be considered dead trees during tree risk surveys and mitigated as if the tree had already succumbed, as this canker is lethal. It is important to note that canker pathogens are generally considered secondary organisms which impact stressed host trees, although this is not always the case.

Figure 20. Sooty bark canker of aspen.

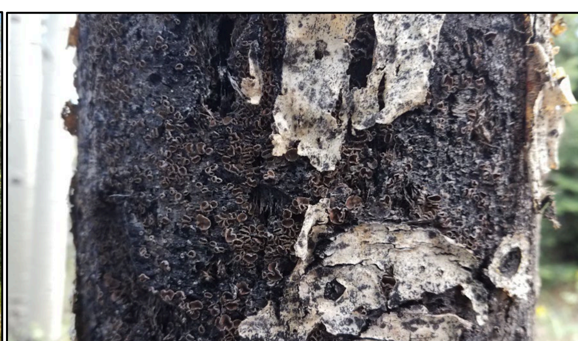

Figure 21. Cup-like fruiting bodies associated with sooty bark canker.

Lightning Scars

Trees standing alone, especially tall trees, are more prone to lightning strikes. Lightning can kill trees immediately, create wounds that may become entry points for decay, or cause structural damage to xylem that may lead to failure (Figure 22). Lightning strikes also attract bark beetles which may contribute to top-kill or mortality. Lightning scars can be shallow or wide cracks that extend into the bark. Depending on when the strike occurred, callus tissue may have formed on either side of the blown-out bark strip. Probability of failure increases with size and extent of the crack. Old lightning scars may indicate the presence of decay. Trees with multiple strikes are more likely to have internal cracking and decay. Large trees with lightning scars and major targets should be monitored closely over time for stem decay issues or other structural problems.

Figure 22. Failed ponderosa pine with lightning scar, the likely source of the stem decay that ultimately compromised the tree.

Cracks

Radial separations in the wood and bark may be associated with extensive internal decay, minor wounds, rapid growth rate, or sudden temperature changes. Many cracks are eventually sealed over by callus tissue. However, they can still serve as entry points to decay prior to healing. Cracks are considered severe defects if they shear through the main stem or large limbs or if they occur against the grain of the wood. This indicates that failure is already occurring and represents a severe hazard. Similarly, cracks associated with codominant stems should be considered severe hazards. “Ram’s horn” cracks occur where healing is initiated from either side of a large wound, but the wound is never able to be fully sealed, causing callus tissue to roll inward (Figure 23). These can hide large areas of decay. Ram’s horns are common in Arizona sycamore.

Figure 23. Ram's horn crack from an Arizona sycamore.

Broom-Inducing Pathogens

Dwarf mistletoes cause growth loss, vigor reduction, and mortality. These parasitic plants, along with a number of fungal pathogens, can induce witches' brooms, proliferations of branches originating from a single point (Figure 24), as well as swellings on branches. These defects are generally not a serious structural hazard except when subjected to heavy snow loads. Infected living trees are not inherently hazardous, but mortality is more common in older mature trees. Additionally, dead brooms on living trees can provide opportunities for stem decay fungi to enter these trees and initiate heart rot. Large brooms may also increase the impacts of wind on a tree, increasing the chances it will fail in storms.

Figure 24. Dead ponderosa pine witches' brooms induced by southwestern dwarf mistletoe.

Insect Damage

The risk of insect damage contributing to the potential of hazard trees can range from inconsequential to extreme. Light damage, such as small amounts of defoliation, will likely have little impact on tree health/integrity. Bark beetle attacks, on the other hand, can lead to an immediate hazard. Furthermore, even a small number of bark beetle attacks may indicate the presence of other problems, particularly root rot. Lightning strikes or other abiotic conditions such as drought or large scale blowdown events can lead to bark beetle outbreaks that cause widespread tree mortality within developed sites and an increase in hazard tree issues (Figure 25). Actions such as the removal of infested trees prior to beetle emergence and the removal, debarking, or burning of fresh blowdown material will aid in reducing the impacts from bark beetles. It is recommended that treatments in conifers, including pruning, which do not immediately remove material from the site be restricted to July through January, as this will also help to reduce the likelihood of beetle outbreaks. Chipping will also reduce available host material; however, as stated previously, if chips are not immediately removed from the site, guidelines should be followed with regard to timing (July-January) and placement (in the open, away from the base of trees), as the volatiles released from chips may attract beetles that subsequently attack standing trees.

Figure 25. Ponderosa pine mortality pocket due to localized bark beetle outbreak.

Additionally, carpenter ants often enter conifers or hardwoods that are already suffering from butt rot and expedite the eventual failure of the tree by mining the interior (Figure 26). Check trees for insect frass near the base of the tree (Figure 27). The presence of carpenter ants indicates that stem decay is extensive, and tree removal or other mitigating action is likely warranted.

Figure 26. Carpenter ant damage.

Figure 27. Carpenter ant frass at the base of an infested tree.

Stem Decays

Stem decay is caused by many species of fungi. Heartwood decay fungi are often active while trees are living, while fungi that decay sapwood are generally active after a tree or tree part has been killed. Some fungi can begin as heart rots and move into the sapwood and cambium, girdling and killing the host trees. Most stem rots decay the heartwood, which is nonliving tissue functioning as structural support for the tree (Figure 28). Therefore, many stem rots do little to affect flow of nutrients and water and will cause no outward symptoms on the affected tree, the lack of which can make identifying trees with heart rot rather difficult. Decay of heartwood or sapwood increases the probability of stem breakage and tree failure, and identifying affected trees is vital. Stem rots are most prevalent in large older trees, which are also highly desirable to the public. Recreation sites with large old trees should be monitored carefully for signs and symptoms of stem rots.

Figure 28. Logs showing symptoms of severe stem decay or heartrot, with the heartwood completely hollowed out.

The two most common types of wood decay encountered by tree risk assessors are brown rots and white rots. Brown rot fungi preferentially degrade cellulose and leave behind lignin, giving the remaining material a brown color and a cubical and crumbly texture (Figure 29).

Figure 29. Cubical, crumbly brown rot.

White rot fungi preferentially degrade lignin leaving behind much of the cellulose, and remaining material appears white in color with a spongy, stringy, and/or fibrous texture (Figure 30). In some cases, white rotted wood will separate at the annual growth rings; this condition is known as laminated decay (Figure 31). Brown rots cause strength loss much faster than white rot fungi, often before any symptoms are present, but both types of decay are important in hazard tree management.

Figure 30. Spongy, stringy, and fibrous white pocket rot.

Figure 31. Laminated decay, a type of white rot where the wood separates at annual growth rings.

Stem rots gain access to heartwood or sapwood through injuries, such a lightning scars and dead branch stubs, or they may be vectored by insects. Stem rots can be identified by the presence of conks or punk knots, both of which are signs of the decay. However, there will frequently be no obvious sign of decay, no fruiting body or conk, and the host will show no symptoms of infection. Sap rots will decay sapwood of host trees and generally be associated with stressed or recently dead trees. Decay due to sap rot affects structural integrity far more seriously than heart rots (Figure 32). It is important to assess trees which display signs of injury or any external defect for decay columns even if there is no conk or fruiting body present, as these defects are possible infection courts for stem rot fungi, and fruiting bodies usually only form when decay is advanced.

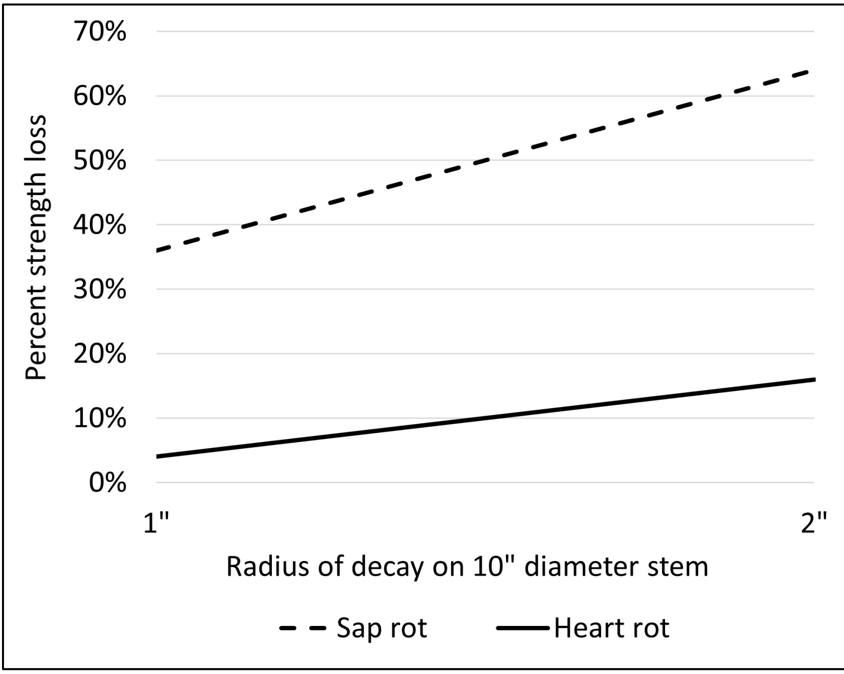

Figure 32. Strength loss for 1" to 2" of decayed wood on a 10" diameter tree with a sap rot or heart rot.

There are many ways to assess rot in trees, as described in the “Inspection Tools” section of this document. The simplest method is sounding with a mallet or other tool. It should be noted that sounding aspen is not recommended due to their limited defenses against canker or decay pathogens. If severe stem decay is suspected with aspen, particularly if fruiting bodies are present, removal of the tree can be justified rather than sounding and potentially wounding the tree and initiating more decay. Another common method used to assess level of decay is to use a borer or drill. This method is necessary even if sounding has been performed because a tree that sounds hollow may have enough structural wood to be considered sound. Again, boring or drilling aspen is not recommended; trees with suspect structural integrity represent hazards that should be mitigated.

Assessing Loss of Wood Strength

Tables 1 and 2 can be used to calculate wood strength loss due to decay. The assessor must consider aggravating conditions that affect interpretation of sound wood measurements, such as lean, shape of the wound and/or cavity, fissures in the shell, etc.

Use Table 1, adapted from the Region 1/4 hazard tree guide (USDA Forest Service 2017a), to determine defect severity based on percent sound shell in trees without external defects. Refer to Wagener (1963) for a more complete discussion of assessing loss of wood strength in trees without external defects. The values in Table 1 are based on precise calculations according to an equation developed by Wagener (1963). In lieu of the table, however, a simple rule of thumb can also be used for determining sound wood necessary to maintain adequate strength in trees with stem decay and no external wound/defect. There must be one inch of sound wood per every six inches of diameter. If less than one inch of sound wood per every six inches of diameter is present, the tree in question represents a significant hazard.

Many trees with stem decay have major wounds, defects, or other openings where the decay was initiated. In these cases, more sound wood is necessary to maintain strength. Smiley and Fraedrich (1992) developed an alternate equation for assessing strength loss in these trees with external openings. The previously mentioned rule of thumb can be expanded for these trees as follows, depending on the percentage of the circumference occupied by the opening:

- 1.5” of sound wood for every 6” of diameter (opening <15% of circumference)
- 2” of sound wood for every 6” of diameter (opening 15-30% of circumference)

Table 2 shows a range of sound wood thicknesses necessary to maintain strength for a similar range of diameters in trees with openings / wounds / defects in addition to significant decay.

Table 1. Reference sound wood shell thicknesses[1] for determining failure potential of trees with different within-bark tree diameters. Trees with sound shell below the 33% column rate as a 3 for defect severity, trees between the 33% and 60% columns rate as a 2 for defect severity.

Within-Bark Tree Diameter in Inches[2]	Inches Radius for 33% Sound Wood Shell	Inches Radius for 60% Sound Wood Shell
6	1.0	1.8
8	1.3	2.4
10	1.7	3.0
12	2.0	3.6
14	2.3	4.2
16	2.6	4.8
18	3.0	5.4
20	3.3	6.0
22	3.6	6.6
24	4.0	7.2
26	4.3	7.8
28	4.6	8.4
30	5.0	9.0
32	5.3	9.6
34	5.6	10.2
36	5.9	10.8
38	6.3	11.4
40	6.6	12.0
42	6.9	12.6
44	7.3	13.2
46	7.6	13.8
48	7.9	14.4

[1]Compare average of bole measurements at bole height of greatest weakness or defect to values in column; if tree measurement is less, record as the higher failure potential value.

[2]Values for most diameters not shown can be calculated by halving, doubling, or averaging

Table 2. Reference sound wood shell thicknesses[1] for determining failure potential of trees with different within-bark tree diameters and external wounds/defects/openings occupying up to 30% of the circumference. Trees with sound shell below the minimum listed value rate as a 3 for defect severity.

Within-Bark Tree Diameter in Inches[2]	Inches Radius for Opening <15% of Circumference	Inches Radius for Opening 15-30% of Circumference
6	1.5	2.0
8	2.0	2.7
10	2.5	3.3
12	3.0	4.0
14	3.5	4.7
16	4.0	5.3
18	4.5	6.0
20	5.0	6.7
22	5.5	7.3
24	6.0	8.0
26	6.5	8.7
28	7.0	9.3
30	7.5	10.0
32	8.0	10.7
34	8.5	11.3
36	9.0	12.0
38	9.5	12.7
40	10.0	13.3
42	10.5	14.0
44	11.0	14.7
46	11.5	15.3
48	12.0	16.0

[1]Compare average of bole measurements at bole height of greatest weakness or defect to values in column; if tree measurement is less, record as the higher failure potential value.

[2]Values for most diameters not shown can be calculated by halving, doubling, or averaging

Common Stem Decay Fungi in the Southwest

Red belt fungus, *Fomitopsis schrenkii* (formerly *F. pinicola*)
Hosts: Conifers and sometimes aspen
Decay type: Brown rot
Defect value: 3

Red belt fungus is one of the most common decay fungi in conifer forests of the Southwest (Figure 33). It is an important saprophyte, decaying the sapwood of dead trees, and its characteristic cubical brown rot can commonly be found in slash piles and on dead trees (Figure 34). It is generally not an aggressive pathogen, but can cause heart rot in living trees, particularly mature trees with trunk wounds. It has been associated with major hazard tree failures in living but fire- or lightning-damaged ponderosa pine. The pathogen is rarely an issue in young trees and is most commonly found fruiting on dead trees. Fruiting bodies occasionally occur on dead parts of live trees, however, and sometimes failure of live trees can occur in the absence of conks (Figure 35). Dead trees should be removed or otherwise mitigated regardless of decay. Fruiting bodies or extensive brown rot on living trees warrant removal of the affected tree or other mitigating action.

Figure 33. Red belt fungus fruiting body.

Figure 34. Failed stump with several red belt fungus fruiting bodies growing at the point of breakage.

Figure 35. Failed live spruce tree due to *Fomitopsis schrenkii* decay.

Red rot, *Dichomitus squalens*
Hosts: Ponderosa and pinyon pines
Decay type: White heart rot
Defect value: 2 (3 if on limbs 6+” in diameter)

This is one of the more common stem decay fungi found in ponderosa and pinyon pines, especially old growth ponderosa pine. It produces flat, white to yellow fruiting bodies that are often found on the underside of dead branch stubs or in slash piles (Figure 36). Fruiting bodies in slash piles are often found on the underside of decaying material in contact with the soil. It is not an aggressive pathogen, and associated signs and symptoms of decay can be considered a moderate hazard and monitored. Large limbs with red rot may need to be pruned if hanging over a target.

Figure 36. Red rot fruiting body on a ponderosa pine.

Red ring rot, *Porodaedalea pini*
Hosts: Conifers
Decay type: White heart rot
Defect value: 2 for 1-2 conks, 3 for > 2 conks

Porodaedalea pini is an aggressive decay fungus which primarily decays the heartwood of living trees (Figure 37). It is considered one of the most common stem decay fungi in North America. In the Southwestern Region, it is commonly found in mixed conifer and spruce-fir forests, being especially common in mature forests and old growth trees. It can be quite common on Engelmann spruce, Douglas-fir, and southwestern white pine. Red ring rot causes extensive decay in the heartwood of severely infected trees, with decay columns up to 30' long, and is therefore an important pathogen for tree risk assessors to be familiar with. Greater than two conks indicates significant decay (Figure 38). If they are occurring in the lower trunk of the tree, take core samples or drill to test the tree for soundness. Multiple conks can often be found spiraling up the trunk in old growth Douglas-fir, often associated with old branch stubs. Punk knots, dense masses of brown mycelium that may extend from a decayed branch stub, may also be found with this disease.

Figure 37. Red ring rot fruiting body.

Figure 38. More than two red ring rot conks found on a single tree indicate major decay.

Paint fungus, *Echinodontium tinctorium*
Hosts: True firs, sometimes Douglas-fir or spruce
Decay type: White heart rot
Defect value: 3

Paint fungus is a common and very important heart rot in the Southwest, most often found on mature true fir. This is an aggressive decay fungus causing many hazard tree issues in mature mixed conifer and spruce-fir forests. The presence of conks is a reliable indicator of extensive decay, with one conk indicating a decay column up to 40’ in length. Trees with one or more conks represent high failure potential and should be removed or otherwise mitigated. Conks are easy to identify because of the teeth-like structures found on the underside of the fruiting body where spores are produced (Figure 39). Conks of most other common stem decay species in the Southwestern Region have pores rather than these teeth-like structures. Conks are frequently found associated with old branch stubs where the fungus first entered the stem and may be found high on the bole (Figure 40). Care should be taken when removing any trees infected by this pathogen, but especially when the decay is occurring high on the bole. In these cases, the tree may start to fall in the desired direction but can buckle midway up the trunk, resulting in the top falling back on the sawyer. Punk knots may also be found with this disease.

Figure 39. Paint fungus fruiting body.

Figure 40. Fruiting body of paint fungus growing high on the bole of an infected tree.

False tinder conk, *Phellinus tremulae*
Hosts: Aspen
Decay type: White heart rot
Defect value: 2 for one conk; 3 for > one conk, conk + defect

False tinder conk is a very common heart rot encountered on aspen. It is ubiquitous throughout the host range and can be found in most aspen clones. The pathogen generally enters through branch stubs, which can provide an easy entry point and give access to heartwood, but may also enter through wounds or be introduced by insects. Conks are hoof-shaped and brown to black in color on the often cracked upper surface (Figure 41). The lower, spore-bearing surface has pores and is tan to white or grey in color. A single fruiting body of *P. tremulae* may warrant removal of an aspen tree with a target if there is a major crack or wound or some other associated compounding defect, and trees with multiple conks should be removed or otherwise mitigated regardless of additional defects. Aspen lacks many of the protective chemicals other trees have to defend themselves against fungal pathogens and is very susceptible to this stem decay fungus and many other fungal pathogens. Therefore, it is highly recommended that new recreation areas should not be developed in aspen groves.

Figure 41. False tinder conk on an aspen stem.

Pouch fungus, *Cryptoporus volvatus*
Hosts: Bark beetle-killed conifers
Decay type: White sap rot
Defect value: 3; take care when removing – severe sap rot

Cryptoporus volvatus is not an aggressive pathogen but rather colonizes trees recently killed by bark beetles, generally within one to two years of tree death. This fungus causes a grayish white rot in the first couple inches of outer sapwood of freshly killed trees. Fruiting bodies, which may emerge out of bark beetle exit holes on the bole of infected trees, are the best diagnostic feature for this fungus (Figure 42). The small, tan-colored fruiting bodies have a sheath covering the spore producing surface on the underside, which is where the common name pouch fungus originates. Because trees with *C. volvatus* conks have typically been dead for at least a year, quick removal of trees is recommended. Care should be taken during removal of trees affected by this decay, however, as the sap rot it causes may significantly reduce sound wood.

Figure 42. Pouch fungus fruiting bodies.

Stem decays of other hardwoods
Defect value: 3 for *Inonotus munzii* on cottonwood, otherwise 2

Stem decays are rather ubiquitous in hardwoods, particularly in Arizona sycamores, cottonwoods, and oaks. This presents a significant challenge to tree risk assessors. Though most riparian hardwood species display signs and symptoms of stem rot on the main stem, most failures in these species tend to be in large, extended to overextended branches. Particular attention should be focused on large branches and their associated branch unions. Fruiting bodies close to or on these branches represent a high hazard.

Inonotus munzii and *I. arizonicus* are the two main stem decay fungi of cottonwood and Arizona sycamore in the Southwestern Region, respectively, causing extensive white rot in the boles and branches of host trees. Both fungi, particularly *I. munzii*, may be commonly observed growing in large clusters and/or on the underside of large limbs (Figure 43). Branch dieback and failure is common on trees affected by these fungi.

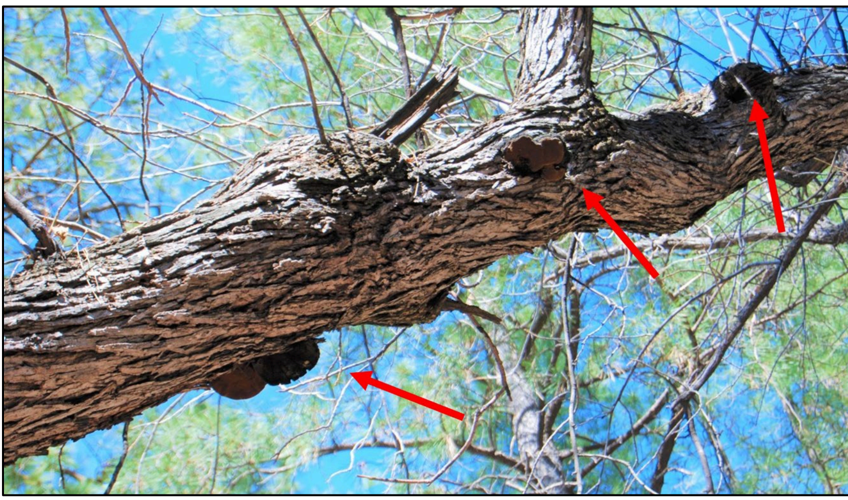

Figure 43. Multiple *Inonotus munzii* fruiting bodies growing on a cottonwood limb.

A number of stem decay species affect oaks in the Southwestern Region, including *Phellinus everhartii*, *I. dryophilus,* and the canker rot pathogen *I. andersonii*. *Phellinus weirianus* causes a white rot of walnuts (Figure 44), and a number of other stem decays occur throughout the Region on less common hosts. Generally speaking, all tree species have at least one associated decay fungus, and most of these produce conks as fruiting bodies. Though there are differences between conks in form and color, they are usually tough and hoof-shaped with spores produced in pores on the underside of the fruiting body. An in-depth description of stem rots that affect hardwoods can be found in Glaeser and Smith (2010, 2013).

Figure 44. *Phellinus weirianus* fruiting bodies on an Arizona walnut.

Root Disease

Root disease, or root rot, is caused by a variety of fungi which parasitize the roots of a wide range of host species. In general, true firs, spruce, and Douglas-fir are the most susceptible species to root disease in the Region, although susceptibility varies by age, site, and genetics of the host and pathogen. Root diseases are a serious concern in developed recreation areas, and root disease centers should be avoided when planning new recreation sites. Sites already built within areas that have root disease issues should either be moved, closed, or converted to a younger age structure due to the danger root disease presents. Intensive actions may also be employed through vegetation management to remove susceptible species and replace them with more resistant species such as southwestern white pine or ponderosa pine, unless these species are being affected by root disease on the site (e.g., *Armillaria* infecting southwestern white pine).

Root diseases have been associated with many tree failure incidents throughout the United States and are therefore a major concern in developed recreation sites. Root disease fungi cause the decay of roots and butts (lower bole) of host trees, severely compromising the structural integrity of the tree. Fungi associated with root disease will often interfere with the movement of water and nutrients, potentially resulting in a loss of host vigor. One exception is *Phaeolus schweinitzii,* which only affects the heartwood of host trees and does not cause crown symptoms. In addition, root diseases predispose trees to bark beetle attacks, windthrow/stem breakage, and premature mortality.

Root disease can spread by root-to-root contacts or by spore dispersal. Species which spread by root-to-root contact will generally form pockets of dead and dying trees. Spore dispersal can spread root diseases long distances through airborne spores. Management activities like thinning infected stands of true fir can exacerbate disease, as spores are able to infect freshly cut stumps. Fire suppression has led to an increase in root disease in many areas, as it favors succession from pines and other more fire adapted species to true firs. The large increase in true firs, which are highly susceptible to most root diseases, has led to an increase in root disease on the landscape. In many cases, severe root rot can be attributed to management activities, particularly for Heterobasidion root disease in white fir.

Root disease is commonly referred to as a disease of the site because many of these pathogens can persist in soil on old woody debris for decades, surviving as saprophytes. When new hosts start growing, root disease pathogens are able to expand from a saprophyte in a dead tree to a parasite infecting a living tree. Therefore, recreation sites built within areas with root disease are susceptible to hazard tree issues. As such, placing recreation sites within these areas should be avoided when possible. Moving or closing sites which were previously built within root disease areas is also recommended where any hazard tree issues cannot otherwise be mitigated. If a site is to remain open, species conversion is recommended. Ponderosa and southwestern white pines and hardwoods like oaks are generally the most tolerant/resistant to root diseases in the Southwest but are not immune. Though these species are generally the best options for root disease affected areas, caution must be exercised, and all trees must be assessed for signs and symptoms of disease. Sites which have no options for alternative species may need to be closed, moved, or maintained in a younger age structure. Contact Forest Health Protection for additional assistance.

General Signs and Symptoms of Root Disease

Depending on the host and the pathogen, root disease signs and symptoms may include all or some of the following:

1. Decline in crown health, including chlorotic or yellowing needles, stunted or “bottle brush” new growth, and premature needle shed.
2. High levels of dead branches resulting in thinning crowns. In older trees, branch mortality will progress from outside in. In younger trees, this mortality may manifest from the inside out.
3. Large cone crops, commonly referred to as stress crops.
4. Basal resinosis, or sap oozing from the lower bole of the tree, and/or bark staining.
5. Evidence of butt rot. It may be necessary to use a drill or borer to determine presence of butt rot.
6. Pockets of dead and dying trees. There will generally be trees at different stages of mortality with some completely dead and others just starting to show decline. The oldest dead will be in the center of the pocket with dying trees at the fringe of the pocket. Root disease may also manifest in a linear, or vein-like, pattern.
7. Large pockets of windthrow or dead and down trees.
8. Lack of roots or the presence of rotted roots on downed trees.
9. Pockets of bark beetle activity may be indicative of root disease.
10. Signs of the causal agent, including fruiting bodies and mycelium on roots or under bark at the base of infected trees.

Common Root Diseases in the Southwest

Armillaria root rot or shoestring root rot, *Armillaria* spp.
Hosts: Any species
Decay type: Spongy, yellowish white root rot
Defect value: 3

Armillaria root rot, caused by various *Armillaria* spp., is the most common root disease in the Southwest, accounting for up to 80% of all root disease-related mortality in the Region. Fruiting bodies are gilled mushrooms, formed singly or in clusters at the base of or near infected trees (Figure 45). These fruiting bodies can be rare in the Southwest, but common signs in the Region include white mycelial fans growing just underneath the bark of infected trees at the root collar and on infected roots as well as root-like rhizomorphs growing along infected roots (Figure 45). Both of these structures are composed of fungal tissues called hyphae or mycelium.

Figure 45. Signs of Armillaria root disease include white mycelial fans growing under the bark at the base of infected trees (left), yellow to tan gilled-mushroom fruiting bodies produced singly or in clusters (center), and root-like rhizomorphs (right).

Root-to-root spread occurs commonly with Armillaria root disease, and infection centers may expand as long as new host material is available. These infection centers have gotten as large as 2 miles in diameter in northeast Oregon. Infection centers are typically smaller in the Southwest, but the pathogen may nevertheless persist in soil, acting as a saprophyte and breaking down old woody debris on infected sites for decades. For this reason, Armillaria root rot is often referred to as a disease of the site. All species in the Region may be affected, but certain host species may do better than others on certain infected sites for a variety of reasons; these hosts should be favored over time.

Recreation sites should not be developed in areas with significant Armillaria root rot problems unless any attendant hazard tree issues can be appropriately mitigated. In preexisting developed areas, Armillaria root rot-affected trees should generally be removed along with highly susceptible neighboring hosts, such as true firs. Maintaining a younger age structure or implementing site closures may be warranted as well, depending on the severity of the situation.

Heterobasidion root rot, *Heterobasidion occidentale*
Hosts: True firs
Decay type: White rot
Defect value: 3

Heterobasidion root rot is another root disease frequently encountered in the Southwestern Region. The pathogen species affecting true firs, *Heterobasidion occidentale*, is common in white fir (see discussion in Worrall et al. 2010). Another species, *H. irregulare*, infects ponderosa pine but is rare in the Region, found more often on limestone soils (Worrall et al. 2010). Like *Armillaria* spp., *Heterobasidion* spp. are also able to survive as saprophytes, living on dead material for many years, and can therefore be considered long-term chronic issues on sites where they are identified. Conk-like fruiting bodies of various sizes often form inside hollow stumps, making them difficult to find (Figure 46), though they can occur on the outside of stumps in wetter spruce-fir forest types. They are brown in color on the upper surface, and the lower surface is white to tan in color and produces spores in pores. Numerous popcorn-like fruiting bodies may be found in stumps.

Figure 46. Fruiting bodies and characteristic laminated decay of *Heterobasidion occidentale* on infected white fir root.

Laminated decay can also occur, with wood separating on annual growth lines (Figure 46, Figure 47). Wood staining can be found in affected trees by cutting into their base, although this should only be done for trees with targets if removal of the tree is already planned (Figure 48). Root-to-root spread also occurs with this disease, and any true fir adjacent to a stump with fruiting bodies or a tree that fails because of this disease may also be preemptively removed. Heterobasidion root disease commonly causes butt rot in host trees, particularly in true firs. Many of the tree failures associated with this disease occur in the lower bole of the affected tree. Assessing old stumps for signs of past heart rot, which would leave a hollow stump, is another good indicator of Heterobasidion root disease (Figure 49). Management should be long term and will likely require species conversion or movement of the recreation site. Partial cutting in mixed species stands with the focus of selecting for species that appear least impacted is recommended. Partial cutting is not recommended in pure stands of infected true fir. Species conversion or moving the site are likely the most effective options in these cases.

Figure 47. Decay associated with Heterobasidion root disease showing lamination, or separation of the wood at the annual growth rings.

Figure 48. Reddish brown staining revealed by cutting into the base of a Heterobasidion occidentale-infected white fir.

Figure 49. Hollow stump of a true fir with Heterobasidion root rot; fruiting bodies are visible inside the hollow.

Ganoderma root rot or artist's conk, *Ganoderma applanatum*
Hosts: Aspen
Decay type: White mottled rot
Defect value: 3

Ganoderma root rot causes a severe root disease on aspen in the Southwestern Region and can be the cause of significant hazard tree issues. The disease mainly affects older, larger aspen stems. Roots smaller than 2" in diameter are seldom infected. Failure of green trees can be common, and the best signs and symptoms to look for are fruiting bodies at the base of stems (Figure 50) and windthrow of nearby trees in varying directions with limited to no root balls attached. Crowns of windthrown trees may be green, healthy, and display no obvious symptoms of problems in the root system prior to failure (Figure 51). Fruiting bodies can be reddish brown to grayish in color on the upper surface and white on the spore-producing underside. The spore producing surface can be easily bruised and turn a dark brown color; the staining becomes permanent upon the conk drying out, thus giving the fungus its common name, artist's conk. As previously mentioned, aspen are prone to many health concerns. If possible, plan for species conversion in developed recreation sites dominated by aspen. Otherwise, regenerating stands of aspen that have Ganoderma root rot and maintaining a younger age structure will be the best course of action. Any trees with *Ganoderma applanatum* fruiting bodies should be removed, or other mitigating actions should be taken (e.g. site closures). Like other root disease pathogens, *G. applanatum* can remain on site for long periods of time and cause problems in older aspen stems and roots. It is highly recommended that new recreation sites, campgrounds, and parking lots not be developed within aspen groves unless impacts of root rot, stem decay, and other common defects can be mitigated.

Figure 50. Fruiting bodies of *Ganoderma applanatum* growing near the ground on its aspen host.

Figure 51. Failed aspen with a green crown, demonstrating that thorough inspection of the base of the tree is necessary for effective tree risk assessments.

Schweinitzii root and butt rot or cow patty fungus, *Phaeolus schweinitzii*
Hosts: Douglas-fir, rarely other conifers
Decay type: Brown butt rot
Defect value: 3

Schweinitzii root and butt rot is most common in older stands, especially old growth Douglas-fir. This propensity to infect older trees makes this pathogen relatively rare on the landscape, as old growth components of many national forests in the region are relatively small. Many recreation areas have been placed in areas with large old trees, however, and therefore have an increased probability of *Phaeolus schweinitzii* being present. Failure from this disease is typically of the lower bole of large old trees with advanced decay. Fruiting bodies can be quite large, up to 1.5’ in diameter, are typically dark brown in color, and often incorporate debris and small herbaceous plants from the forest floor as they grow (Figure 52). These fruiting bodies may resemble cow patties, hence one of the common names of the fungus, and they will typically grow out of infected roots through the soil away from the trunk of the infected tree. This disease causes a brown rot in the roots and base of infected trees, sometimes leading to butt swelling (Figure 53). This pathogen does not spread from root-to-root and is not associated with root disease pockets. Rather, each infection is initiated by spores percolating through the soil and infecting via root tips. This pathogen does not produce crown symptoms and can be difficult to detect. The main signs and symptoms to look for are conks in the root zone and a swollen base. Old growth trees, particularly Douglas-fir, should be assessed thoroughly if any of the above symptoms or signs are observed. Remove affected trees or otherwise mitigate if decay is advanced; stem decay guidelines may be used for decay in the butt.

Figure 52. *Phaeolus schweinitzii* fruiting body next to an infected, decayed stump.

Figure 53. Stump decayed by *Phaeolus schweinitzii* showing the brown rot caused by this pathogen.

Tomentosus root rot or velvet top fungus, *Onnia tomentosa*
Hosts: Spruce most commonly, sometimes corkbark fir
Decay type: White pocket rot
Defect value: 3

There is little information on the extent and damage caused by this pathogen in the Southwest. It has been observed with some frequency in spruce-fir forests of the region and, therefore, is another disease that tree risk assessors should be familiar with. This pathogen is capable of causing significant loss of structural integrity and can therefore create hazard tree issues in developed sites in spruce-fir forest types. Root-to-root spread may occur, and this disease is commonly found in pockets. Long distance spread by spores landing in wounds on susceptible host trees may occur as well. Fruiting bodies may be similar in appearance to those of *P. schweinitzii*, and they are similarly often found growing from the soil in the root zone of infected trees (Figure 54). The fruiting bodies of *Onnia tomentosa* are much smaller (less than 4" in diameter) and generally lighter brown in color than those of *P. schweinitzii,* however, and host preferences and decay types are different between these two diseases as well. Fruiting bodies can be sporadically produced but may be very common during heavy monsoon seasons (Figure 55). Wood decayed by *O. tomentosa* has a honeycomb-like appearance in cross-section due to the associated white pocket rot (Figure 56). Remove susceptible host trees or otherwise mitigate in developed recreation sites if this fruiting body is found nearby and/or obvious root disease symptoms are occurring (e.g., advanced crown dieback, honeycomb-like decay in cross-section of neighboring failed spruce).

Figure 54. ***Onnia tomentosa*** **fruiting body.**

Figure 55. Numerous tan-colored *Onnia tomentosa* fruiting bodies produced across the forest floor in an infected stand during a heavy monsoon season.

Figure 56. Honeycomb-like decay associated with Tomentosus root rot on a cut stump (left) and on a broken root of a failed tree (right).

Hazard Tree Mitigation

A number of mitigation methods are available for hazard tree management. The most common and generally the easiest is removal of the hazard tree. Conifers should be bucked for quick drying and reduced chances of increasing bark beetle populations; material can be left onsite and will typically be used by visitors for firewood. If live trees will be felled and left on site, particularly ponderosa pine, Douglas-fir, or spruce, it is recommended that operations be limited to July through January to reduce the chances of attracting bark beetles. Some defects that generally warrant full tree removal if a high priority target is present include unnatural leans, root disease, severe stem decay, and severe cracking.

Pruning is another common mitigation method. Pruning may be recommended for dead tops and branches, large brooms, overextended branches, and other limbs with poor architecture. This can also be a relatively cheap and simple mitigation method for hazardous limbs lower in the tree. Pruning hazards that are high in a tree crown may require the use of a bucket truck or tree climber, which can be expensive and not readily available. In some cases, removal of the tree may be easier than pruning. Costs of mitigation must be balanced with the availability of resources. As with full tree removal, if the material is to be left on site, pruning should occur between July and January to reduce the chances of attracting bark beetles.

Moving the target may be a viable mitigation method, provided the target can then be secured in some way to avoid visitors moving it back to within striking distance of the hazard tree. An example would be moving picnic tables away from a hazardous cottonwood that recreation staff are hesitant to remove due to its aesthetic value. Warning signs may be used to identify the hazard, and the picnic tables should be secured in their new location. Building pavilion structures for picnic tables is a great way to move targets away from hazard trees and still provide desirable shade.

Site closures and/or warning signs may be appropriate in some circumstances to mitigate risk posed by a hazard tree. For example, a particularly hazardous but aesthetically valuable tree that has a high priority target like a campsite may warrant closing only that campsite to preserve the tree. A hazardous but aesthetically valuable tree could also be gated off and signed to preclude public access to the surrounding area. Entire recreation areas may need to be closed if hazard tree issues are too numerous to manage. These closures may be permanent or temporary, depending on the situation.

Some creativity may be required in mitigating hazards and maintaining desirable recreation sites. Forest Health Protection in the Southwestern Region is available to assist with especially complex sites. Vegetation management plans can be quite helpful in long-term tree risk planning and represent a proactive, rather than reactive, response to hazard tree issues. Forest Service Region 1 provides an excellent template for developing a localized vegetation management plan which can be accessed here:
https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb5334504.pdf.

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Appendix 1: Common Forest Types of Developed Sites in the Region

The forest type of the area being surveyed plays an important role in tree risk assessments and hazard tree mitigation. Certain forest types may be more suitable for developed recreation sites, and the intensity of tree risk assessments may vary depending on the common defects present in a given type.

Pinyon-Juniper Woodland

Key species: two-needle pinyon pine (*Pinus edulis*) and several junipers (*Juniperus* spp.)

This forest type usually occurs between 5,000' and 7,000' elevation in the Southwestern Region. Junipers usually have scale-like leaves (Figure 57) and berry-like cones, while pinyon pines most commonly have short pairs of needles and small, open cones (Figure 58). In general, pinyon pine and junipers are less likely to be major hazard tree issues than tree species in other forest types of the Region. These trees tend to be relatively small in stature, resulting in smaller target zones and less potential damage when failures do occur. Both are also somewhat resistant to decay fungi, though red rot (*Dichomitus squalens*) and Armillaria root rot can occur in pinyon pine, and some stem decays are found in juniper. Developed sites in this forest type should still be inspected annually, subject to resource availability, but fewer trees in any given area will likely need to be monitored over time due to limited target areas and decay resistance.

Figure 57. Scale-like leaves of a Rocky Mountain juniper.

Figure 58. Small, round cone and pairs of needles on a two-needle pinyon pine.

Ponderosa Pine

Key species: ponderosa pine (*P. ponderosa*), sometimes Gambel oak or live oak species (*Quercus* spp.)

This is one of the most widespread forest types in the mountains of the Southwestern Region and is usually found between 6,000’ and 8,500’ elevation. Ponderosa pine has orange, fissured bark when mature; this tree also has long needles in groups of three and medium-sized, prickly cones (Figure 59). They are one of the better hosts for developed recreation areas because they are quite decay resistant. Severe stem decay, often due to red belt fungus (*F. schrenkii*), can occur in lightning- or fire-damaged trees, and these should be inspected closely. Large dead limbs often occur and can develop red rot (*D. squalens*). Dwarf mistletoe brooms can also be common. Pruning dead limbs, as well as mistletoe brooms where possible, can reduce hazard risk and improve vigor of the trees. Codominant stems can occur frequently in some sites; the hazard should be mitigated if cracking and/or obvious decay is present or after failure of one of the stems. Bark beetle activity can cause large pockets of mortality. Sometimes individual trees are strip attacked, leading to mortality, decay, and eventual failure of one side of the tree. Actions such as brood tree removal, which can help to mitigate bark beetle outbreaks, may be implemented in recreation areas if the infestation is observed early in its development.

Figure 59. Medium-length needles in groups of three and prickly young cones on a ponderosa pine.

Mixed Conifer

Key species: Douglas-fir (*Pseudotsuga menziesii*) and white fir (*Abies concolor*)

Mixed conifer occurs at higher elevations (7,800’ to 9,800’ elevation), where Douglas-fir and white fir are the dominant tree species. Douglas-fir trees have cones with bracts resembling the back half of a rodent, as well as single needles that narrow at the base (Figure 60). White fir trees have rounded, blueish-green needles with the point of attachment to the stem resembling a suction cup (Figure 61) and cones that disintegrate at maturity. Southwestern white pine and limber pine can occur as well and are common in some areas; these trees have moderately long needles in groups of five and large cones. Root diseases are very common in this forest type, especially those caused by *Heterobasidion occidentale* in white fir, *Phaeolus schweinitzii* in Douglas-fir, and *Armillaria* spp. in all hosts. Severe stem decay can be common, especially paint fungus (*E. tinctorium*) and red ring rot (*Porodaedalea pini*). Dwarf mistletoe brooms are very common in Douglas-fir. Fir broom rust is common in white fir in the Region and ubiquitous in some parts of New Mexico. Favoring Douglas-fir over white fir is generally recommended in these sites. Southwestern white and limber pines should also be favored where they occur, along with ponderosa pine in drier mixed conifer sites. White pine blister rust caused by *Cronartium ribicola*, a disease characterized by blister-like fruiting structures called aecia (Figure 62), may cause top-kill and large dead limbs in white pines where the disease occurs, which may warrant pruning (Figure 63). Douglas-fir is vulnerable to bark beetle activity following blowdown events, which can spread to living trees and cause mortality. Taking proper action, such as debarking or removing fresh blowdown, will help to mitigate impacts from bark beetles.

Figure 60. Douglas-fir branch bearing an immature cone with rodent-like bracts.

Figure 61. White fir needles with point of attachment to stem resembling a suction cup.

Figure 62. White pine blister rust aecia.

Figure 63. Branch dieback due to white pine blister rust.

Spruce-Fir

Key species: Engelmann spruce (*Picea engelmannii*) and corkbark fir (*Abies lasiocarpa* var. *arizonica*)

This forest type generally occurs at high elevations above 9,800' elevation in the Southwestern Region, where Engelmann spruce and corkbark fir are the dominant tree species. Engelmann spruce trees often have branch tips with cone-like galls due to an insect pest (Figure 64) and produce small cones resembling those of Douglas-fir but without the rodent-like bracts. They have sharp, stiff, and square needles and flaky, potato chip-like bark (Figure 65). Corkbark fir trees have smooth, corky bark (Figure 66); rounded, flexible, and flat needles; and their cones disintegrate at maturity. Root disease pathogens may be common in this forest type, especially *Onnia tomentosa* on spruce and *Armillaria* spp. on either host. Shallow root systems occur, so windthrow may be common even in the absence of root disease. Stem decays can be common as well, especially red ring rot (*Porodaedalea pini*) in spruce. Both species can be infected by broom rusts, though this is not typically a severe hazard unless on the main stem. Dwarf mistletoe can occur on spruce in select areas of the region. Spruce is also very vulnerable to bark beetle activity. Blowdown events, which can be common in spruce, may lead to increasing spruce beetle populations. Taking proper action, such as debarking or removing fresh blowdown, will help to mitigate impacts from bark beetles. This forest type should usually be managed for a younger age structure when it occurs in developed recreation sites, particularly if root rot is a concern.

Figure 64.Cooley spruce gall adelgid-caused galls on Engelmann spruce branch tip.

Figure 65. Flaky, potato chip-like Engelmann spruce bark.

Figure 66. Smooth and corky-textured bark of a corkbark fir.

Aspen

Key species: aspen (*Populus tremuloides*)

Aspen-dominated areas are not recommended for developing new recreation sites because of various hazards that these trees can pose. Aspen have distinctive white-colored bark (Figure 67) and spade-shaped, deciduous leaves. The thin, living bark is easily wounded by wildlife and visitors eager to carve their initials, an activity that should be discouraged. Wounds can be colonized by pathogens causing canker diseases and stem decay, particularly sooty bark canker (*Encoelia pruinosa*) and false tinder conk (*Phellinus tremulae*), respectively. Ganoderma root rot commonly occurs and can cause complete failure of green, otherwise healthy-looking trees. Aspen should be inspected at their base for conks, and any trees with obvious signs of this root disease should be removed, or site closures should be implemented. Where recreation sites already occur in aspen dominated areas, aspen can be managed in a younger age structure if wildlife browsing is not prohibitive.

Figure 67. Small group of aspen trees showing characteristic white bark.

Riparian

Key species: cottonwoods (*Populus fremontii, P. angustifolia, P. deltoides*), Arizona sycamore (*Platanus wrightii*), sometimes velvet ash (*Fraxinus velutina*), Arizona alder (*Alnus oblongifoloia*), Arizona walnut (*Juglans major*), Arizona boxelder (*Acer negundo arizonicum*), netleaf hackberry (*Celtis reticulata*), or blue spruce (*Picea pungens*)

Forests along waterways in the region present unique ecosystems as well as unique hazard tree challenges (Figure 68). Arizona sycamore and various cottonwood species are common. Various other hardwoods can be common as well at certain sites. Blue spruce may occur in higher elevation areas in portions of the region. High water tables, coarse soil structures, and shallow root systems can combine to cause significant windthrow in these areas. Stem decays are common in riparian hardwood species. Large limbs of cottonwood and Arizona sycamores present significant hazard issues and can fail in the absence of decay. Large branch dieback may be caused by *Inonotus munzii* and other stem decays, as well as chronic infections by the foliar disease sycamore anthracnose (Figure 69). Particular attention should be focused on the crowns of these species, assessing overextended branches and decay associated with large branches and branch unions. Crowns should also be thoroughly assessed for dead branches. Development of new recreation sites in cottonwood stands is not recommended due to these issues. In already established areas with older growth Arizona sycamore, extensive stem decay issues may warrant closing some sites to maintain islands of larger trees and avoid completely clearcutting entire recreation areas.

Figure 68. Riparian area on the Gila National Forest with large hardwoods growing along a river in an otherwise arid, juniper savanna ecotype.

Figure 69. Heavy defoliation of an Arizona sycamore due to the disease sycamore anthracnose; repeated infections can lead to large branch dieback.

Appendix 2: Tree Risk Assessment Form

USDA Forest Service — **Tree Risk Assessment Form** — Southwestern Region

Location: ______________________________ Page: _______ of _________

Date: ____________________ Inspected by: ______________________________

(Each column represents one tree)

		Unit number (e.g. campsite #)					
		Tree number					
		Tree species					
		DBH (in)					
		Height (ft)					
Tar-gets	2	People, Permanent Structures, Vehicles					
	1	Major Trails and Roads					
Defects	3	Wounds/cankers > 50% of circumference					
		Height to diameter ratio over 80:1 (see back of form[4])					
		Unnatural lean					
		Root disease					
		Severe stem decay signs (see back of form[5])					
		Exposed roots with decay, > 50% of roots					
		Crack severe or associated with fork					
		Dead tree					
		Sound shell < 33% radius*					
		Dead Top/Branch > 6″ in diameter					
	2	Wounds/cankers 33-50% of circumference					
		Height to diameter ratio 60:1 to 80:1					
		Exposed roots with decay, < 50% of roots					
		Cavities in branch, bole, base					
		Codominant stems with included bark					
		Dead Top/Branch 3-6″ in diameter					
		Sound shell 33-60% radius*					
		Moderate stem decay signs (see back of form[6])					
	1	Wounds/cankers 10-33% of circumference					
		Lightning scar, small crack					
		Large broom, dead top/branch < 3″ diameter					
		Codominant stems with no included bark					
		Exposed or severed roots, no decay					
		Natural lean					
	0	No visible defect; minor wounds, pitch/flux					
		Risk Rating (Target x Worst Defect)					
		*Drilling (if done) – inches of sound wood					
		GPS Coordinates					
		Remove					
		Prune					
		Monitor					
		Date Accomplished					
		Notes					

Use of the Tree Risk Assessment Form

Defective trees are potential hazards to people and property in recreation areas. Indicators of defects are used to identify trees that may fail. Systematic, annual, documented inspections of trees in recreation sites and corrective action are recommended to reduce hazards to the public. (D.W. Johnson. 1981. Tree hazards, Recognition and Reduction in Recreation Sites. Technical Report R2-1. USDA Forest Service, Forest Pest Management Denver, CO.)

The Tree Risk Assessment Form is more than a rating record of potential tree hazards for a particular site. It is a record of the overall structural condition of a tree that can be used to determine progression of defects over time and to document the frequency of certain defects. All defects observed should be checked even though only the highest values are used in the risk rating.

Forms cannot take all situations into account. Trained and experienced evaluation crews may need to exercise judgment in some cases. However, if you need to regularly override the form, need training, or have any questions about the process or a rating a particular tree defect, please contact Forest Health Protection staff:
Arizona Zone Office: (928) 556-2075 **New Mexico Zone Office**: (505) 842-3288

1. Maps of the campgrounds are helpful in planning and performing tree risk assessments. All recreation structures should be drawn on the maps. Maps used or created during the survey should be included with the Tree Risk Assessment Forms to indicate which specific recreation sites were surveyed.
2. Tree locations should be accurately described on the Tree Risk Assessment Form using GPS coordinates.
3. Risk rating of a tree is determined by Target and Defect:

	Definition	Values
Target	Target rating is a combination of the likelihood that a potential target will be hit (assuming the tree fails) and the value of the target.	Potential targets are assigned values of 1 or 2.
Defect	A defect rating is an estimation of the likelihood that a tree will fail based on available indicators.	Defects are assigned values of 0 – 3.

4. Height to diameter ratio is the ratio of the tree height to the trunk diameter at breast height (DBH). The same units should be used for both measurements, so DBH is typically converted from inches to feet.
5. Severe stem decay signs include any fruiting bodies or conks of Indian paint fungus (*Echinodontium tinctorium*), red belt fungus (*Fomitopsis schrenkii*), pouch fungus (*Cryptoporus volvatus*), or any stem decay fungus on white fir or cottonwood; more than one false tinder conk (*Phellinus tremulae*) on aspen or one false tinder conk in association with cracking, cavities, or other major structural defect; or more than two conks of red ring rot (*Porodaedalea pini*). See Tree Risk Assessment and Hazard Tree Mitigation in the Southwest Region for a detailed description of these stem decay fungi.
6. Moderate stem decay signs include one or two conks of red ring rot (*Porodaedalea pini*), one false tinder conk (*Phellinus tremulae*) unassociated with other defects, and conks of any other species not previously mentioned here or in the description of severe stem decay signs above. See Tree Risk Assessment and Hazard Tree Mitigation in the Southwest Region for a detailed description of these stem decay fungi.
7. More than one type of potential target or defect may be identified and checked for any tree. If identified, these defects will inform the land manager of the risk rating following mitigation of highest defect.
8. Calculate risk rating by multiplying target value and hazard value of the worst defect. Removal of highest rated trees for each target category or other mitigation action is recommended.

Possible Risk Ratings (Target × Worst Defect = Risk Rating):

Higher occupancy targets (e.g., picnic tables): 6 = highest, 4, 2 = lowest
Lower occupancy targets (e.g., roadways): 3 = highest, 2, 1 = lowest

For more information contact:

USDA Forest Service
Southwestern Region
Forest Health Protection
333 Broadway Blvd., SE
Albuquerque, NM 87102

Or visit the Southwestern Region's website for tree risk management:

http://www.fs.usda.gov/goto/r3/treerisk