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A Guide to Identifying, Assessing, and Managing Hazard Trees in Developed Recreational Sites of the Northern Rocky Mountains and the Intermountain West

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Figure 6 was derived from:

Filip, G.M., J. Biro, K.L. Chadwick, [and others]. 2013. Field guide for hazard tree identification and mitigation in developed sites in Oregon and Washington forests. R6-NR-TP-021-2013 USDA Forest Service, Forest Health Protection, Pacific Northwest Region, Portland, OR

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Chapter 1. Introduction

Purpose of Guide and Goal of Hazard Tree Management

Direction on hazard tree management for USDA Forest Service developed recreation sites is found in Forest Service Manual section FSM 2332.13 where it states: "Consistent with preserving the recreation resource, remove trees or tree limbs identified as hazardous at developed recreation sites. Obtain assistance from timber management, forest pest management, and recreation specialists, as necessary". By developing this guide, Forest Health Protection, formerly known as Forest Pest Management, provides managers of developed recreation areas with a process and sufficient background information to aid in recognizing, assessing, and making management decisions regarding hazard trees.

The goal of hazard tree management is to minimize, to the extent practical and consistent with overall management objectives and constraints, the potential that trees at public sites will cause injury, death, or property damage. Thorough, systematic surveys of trees that could harm the public or damage property at developed recreation sites, conducted by effective evaluators, are an important part of meeting management requirements. An effective evaluator can be defined as a person who has received training and has experience in evaluating tree hazards. Types of tree defects can vary widely by location and species, so familiarity with locally important tree defects may be needed for hazard tree evaluators to be effective. This guide provides a means to identify tree defects and failure potential using examples of hazard trees chosen to represent tree species and defects likely to occur in the Northern and Intermountain Regions of the USDA Forest Service.

This guide is primarily written for use on developed sites, such as areas established for regular use for camping, picnicking, parking, or other activities. Established, high-use sites are far more likely to have failures of trees and tree parts that could cause personal injury or property damage than at undeveloped sites where people and property normally have more infrequent or shorter exposure.

Hazard tree management has its basis in science, yet its practice cannot identify and remove all trees that may fail. Under high wind or other storm conditions, trees and forests may experience extreme physical stresses that can cause breakage and wind throw in trees lacking detectable defects. Also, as trees and stands age, they have prolonged and repeated exposure to natural disturbances or human-caused injuries that result in increasing amounts of both obvious and hidden defects. Such defects, along with increasing mass, height, and wind exposure, can make aging trees and groups of trees more prone to failure.

Guide Objectives:

1) Provide a process of evaluating tree hazards in developed recreation sites of the Northern Rocky Mountains and the Intermountain West.

2) Provide an up-to-date field guide to aid accurate identification of tree defects and Failure Potential.

3) Provide guidance for recording evaluations of developed sites.

4) Promote development of long-term vegetation management plans for developed sites.

Hazard Trees: Identification

Evaluators need to exercise considerable professional judgment, and no guidance can address every possible situation. Considerations for evaluators include: the presence of a tree or tree part that has the potential to cause harm; the potential that the tree or tree part will fail; the location of the tree or tree part and/or its proximity to a developed recreation site; and the overall degree of risk that the tree or tree part might pose.

Natural resource managers have many, often conflicting, priorities influencing their allocation of resources to projects and management functions. Hazard tree management is a major priority, but this activity often occurs within the context of all other management activities on developed recreation sites. These are best coordinated within the

broader perspective afforded by a vegetation management plan. FSM 2331.4 states to, “Prepare a vegetation management prescription for each recreation site. The primary objective of the prescription is to create and maintain a natural environment”. Consideration of hazard tree risks can inform broader decisions on long-term vegetation management to enable a functioning, healthy, and safe forest environment for future visitors of Forest Service recreational sites.

What Constitutes a Hazard? What is Risk?

The term “hazard” refers to a tree or tree part of sufficient size, mass, and condition to have the potential to cause harm. The term “risk” refers to the relative potential that a hazard may cause harm to someone or something of value. The overall risk of a hazard may change due to changes in the condition of the tree and/or the range of conditions likely to occur over time.

Hazard tree rating deals with both evaluating the failure potential of a recognizable hazard and the risk the hazard poses to persons, property and/or structures. For example, even a tree identified as a possible hazard may receive a low overall hazard tree rating if the evaluator determines that either the potential for damage is low or the distance from people or valuable property is too great.

Chapter 2. Components of Hazard Tree Ratings

Overview

This chapter explains the basis and components of hazard tree ratings and provides a detailed method for assigning numerical values for Failure Potential, Damage Potential, Target Value and overall Hazard Tree Rating for individual trees. Hazard tree evaluation also involves documentation and record keeping of tree ratings and periodically re-evaluating these ratings at some scheduled interval. This chapter also provides guidance to managers and responsible officials for deciding acceptable levels of risk and methods of mitigating hazard.

Hazard Tree Rating

The Hazard Tree Rating system presented here incorporates three components:

1. **Failure Potential**: the potential that a tree or tree part may fail within the time period before reassessment.
2. **Damage Potential**: the potential that property damage, injury, or death may result from a tree or tree part failure.
3. **Target Value:** the value given to a tree based on its proximity to people and property.

The Hazard Tree Rating for each individual tree is determined by adding numerical values of Failure Potential (FP) (scale FP1-4), Damage Potential (scale 1-3), and Target Value (scale 1-3). Possible Hazard Tree Rating ranges from 3 to 10. Trees with lower ratings have lower risk compared to those with higher ratings.

What is Failure Potential?

Failure Potential is the potential for a tree or tree part to fail before the next inspection period. Assessing Failure Potential requires recognition of weaknesses, the conditions that act on those weakness, and the frequency at which those conditions occur. Failure is the end result of many interacting variables: tree size, age, form, species, condition, location; stand structure; site and environment conditions; and presence and extent of tree defects.

Tree characteristics commonly contributing to Failure Potential include:

- Declining, dying, or dead trees.
- Dead, broken, or free-hanging branches.
- Multiple stems; dead, forked, or multiple tops; and if these have recent weakening.
- Wounds, injuries, exposed or damaged roots and associated decay or defect.
- Lean in a tree, its amount and type, and factors that contributed to the lean.
- Recent lean, so tree has not had time to add strength to prevent failure.
- Compromised anchoring of lateral roots (tree is “root-sprung”).
- Disease, decay, or insect infestation and whether these will be lethal or weaken roots, stem, or branches.
- Exposure to wind and other site-specific influences.
- Soil structure and shallow water table that may make a tree prone to root failure.
- Proximity to pockets of root disease.

FAILURE POTENTIAL (FP) SCORES

FP4 = HIGH
Dead trees; live trees with major defects; decayed or burned trees with less than acceptable remaining sound wood.

FP3 = MEDIUM
Live trees with moderate defects; decayed trees where sound wood shell thickness is at or near the minimum preferred amounts.

FP2 = LOW
Live trees with only minor defects such as wounds that don’t impair tree structure; trees with slight decay.

FP1 = VERY LOW
Live trees without visible defects.

See Table 1 for examples.

Table 1. Failure Potential Rating of Tree Defects.

	Indicator	Failure Potential (FP)			
		High; *FP4*	Medium; *FP3*	Low; *FP2*	Very Low; *FP1*
Bole	**Cankers**	Tree killed	>50% circumference of bole girdled	<50% circumference of bole girdled	No cankers
Bole	**Bole wounds (includes fire damage >5 years)**	>50% bole circumference affected **OR** <20% sound wood shell	<50% circumference of bole affected AND 20-30% sound wood shell	<50% circumference of bole affected AND >30% sound wood shell	Callus-sealed OR superficial wounds
Bole	**Cracks**	Structural failure crack with evidence of movement **OR** <20% sound wood shell	Large or deep crack without movement AND >20% sound wood shell	Small shallow crack **OR** partially callus-sealed crack (e.g., frost crack) AND >30% sound wood shell	Fully callus-sealed
Bole	**Height to diameter ratio calculated as Ht (ft)/dbh (ft)**	H:D ratio >100	H:D ratio 80 to 100	H:D ratio 60 to 80	H:D ratio <60
Bole	**Fungal decays (*guidelines for some specific conks / fungi in Chapter 4)**	*Conk(s) present that indicate FP4 **OR** sound wood shell <15% if no opening, wound, or crack OR <20% if an opening, wound or crack	*Conk(s) present that indicate FP3 **OR** significant decay present but >15% sound wood shell if no opening, wound or crack OR >20% if an opening, wound or crack	Sound wood shell >30%	None
Bole	**Fire damage (<5 years)**	Remaining sound wood of cross-section is <50% **OR** structural roots damaged in >1 quadrant	Species except western redcedar, pines, larch, Douglas-fir: remaining sound wood of cross-section is 50-75% **OR** structural roots damaged in 1 quadrant	Western redcedar, pines, larch, Douglas-fir: bole cross-section >50% sound wood **OR** other conifers: bole cross-section >75% sound wood (see Fig. 6)	No visible damage to roots or stem
Butt and Roots	**Leaning and/or root-sprung trees**	Soil cracked or lifted or root breakage	Soil looks intact, uncorrected lean >15°	Soil looks intact, corrected lean of any amount **OR** uncorrected lean <15°	Lower bole vertical with sweep in upper bole
Butt and Roots	**Undermined or severed roots**	<50% of the structural roots remaining in the ground	50-75% of the structural roots remaining in the ground	>75% of the structural roots remaining in the ground	Few exposed roots and no decay
Butt and Roots	**Aggressive root disease or root and butt rot**	Tree with aggressive root disease: has thinning or fading crown or basal resin or stain **OR** butt rot with <15% sound wood shell OR decay in >50% of the structural roots	Aggressive root disease suspected in proximity but not confirmed in tree **OR** butt rot with 15-25% sound wood shell **OR** decay in <50% of the structural roots	Butt rot with >25% sound wood shell and no decay in structural roots; no evidence of root disease	None

Table 1. Failure Potential Rating of Tree Defects, continued.

	Indicator	Failure Potential (FP)			
		High; *FP4*	Medium; *FP3*	Low; *FP2*	Very Low; *FP1*
Tops and Branches	**Forked or multiple tops**	V-shaped fork with embedded bark AND open crack, decay, or conk	V-shaped fork with embedded bark AND no crack, decay, or conk	V-shaped fork without embedded bark AND no crack, decay, or conk **OR** unbalanced multiple tops	None
Tops and Branches	**Dead tops**	Dead top >3" diam. with signs of decay or other defects, or already detached	Dead top >3" diam. without decay or other defect in aspen, cottonwood, large birch or non-resinous conifers	Non-decayed dead top <3" diam. **OR** non-decayed dead top >3" in western redcedar or resinous conifers (pines, western larch, Douglas-fir)	None
Tops and Branches	**Decay in living upper bole (*guidelines for some specific conks / fungi in Chapter 4)**	Any species with indicators of **significant decay** [open crack, exposed rot, or *conk(s)]	True fir, hemlock, spruce, or hardwoods with **little decay** or *conk(s)	Douglas-fir or pine with **little decay**	None
Tops and Branches	**Detached or partially detached tops and branches >3" diam.**	Any detached part	Live and attached but cracked or split top or limb	None	None
Tops and Branches	**Cottonwood and birch branches**	>3" diam. dead branch **OR** live branch in tree with evidence of **decay** and past **breakage**	>3" diam. live branch in tree with evidence of past **breakage** but **no decay**	>3" diam. live branch **without decay** or **breakage**	None
Tops and Branches	**Branch brooms from dwarf mistletoe and other causes**	Douglas-fir **large** (>10' diam.) **dead** broom **OR** any tree species' broom on cracked branch	Douglas-fir **small, dead** broom **OR** other tree species' large, dead broom	Douglas-fir **large, live** broom **OR** other tree species' small, dead broom	Douglas-fir **small, live** broom, **OR** other tree species' large live broom
Interactions	**Multiple interacting indicators (if not interacting, use highest single score)**	Two or more interacting **medium-FP** indicators	Two or more interacting **low-FP** indicators	Two or more interacting **very low-FP** indicators	None

What is Damage Potential?

Damage Potential is an estimation of extent or severity of damage or injury that could result from tree failure. Damage Potential takes account of tree or tree part size and the height at which a defect occurs. The Damage Potential rating is most useful for evaluating tree parts, which are more likely than whole trees to vary in the severity of damage they could cause. Obviously, even a small, defective tree part could cause greater damage if it fell from high in a tree than if it was lower in a tree.

DAMAGE POTENTIAL SCORES

3 = EXTENSIVE
Tree or tree part's size and falling distance indicate its force of impact could cause serious personal injury or death or severe damage to property.

2 = MEDIUM
Tree or tree part's size and falling distance indicate its force of impact could cause at least moderate injury, or moderate but not major structural damage.

1 = MINOR
Tree or tree part's small size (<3 inch diameter) and short falling distance to target indicate its force of impact could cause minor injury or light damage to property.

Rating Damage Potential

Damage Potential is rated on a scale of 1 to 3, with 3 indicating greatest severity. Damage Potential scores given in the text box at right reflect these assumptions:

- Small branches and tops (less than 3 in. in diameter) typically cause minor damage.
- Medium size tree parts can cause serious injury to people, but rarely cause death and can cause some property damage but not loss of an entire structure.
- Larger tree parts can cause extensive damage resulting in death or property/structure loss.
- Tree parts might have less Damage Potential if deflected off or falling through tree canopies, because interactions with branches and trees can slow their fall. Damage Potential could be assigned a lower value for some of these cases.
- Large, whole trees with an unobstructed path to a person or structure should always be given a Damage Potential value of 3.

What are Potential Impact Zones and Target Value Scores?

A Potential Impact Zone (PIZ) is the area that a tree or its parts could normally reach if they fail. Target Value is a score assigned to a tree based on how long and how often the PIZ will be occupied by persons or structures or other valued property. Note that although a Target Value score is determined *relative* to people and property a hazard tree might impact, this score is assigned to a *tree*. It is *not* a value assigned to a particular object or to people. Target Value score is rated on a scale of 1 to 3, with 3 indicating greatest Target Value score. Some important points to consider:

- Length of use and types of activity are critical. For example, sleeping campers are less likely to move during windy or stormy conditions than hikers or day use visitors who may leave an area.
- Target Value scores will always be high when people are frequently in the Potential Impact Zone.

TARGET VALUE SCORES

3 = HIGH
Tree's potential impact zone often has people or valuable property present for long periods. This score is used for trees around developed tent sites, toilets, parking spurs, and other high-occupancy sites.

2 = MODERATE
Tree's potential impact zone includes, at most, features with moderate use and short use length such as water sources or waste disposal stations.

1 = LOW
Tree's potential impact zone includes, at most, features with limited use and short use length such as garbage cans, campground signs, or fences; may also be used for trees with moderate-use features just outside estimated impact zones.

Determining Potential Impact Zone for Tree or Tree Part Failure

Potential Impact Zone (PIZ) is the area on the ground that could be reached by ANY portion of a tree or a tree part that is considered a hazard and is determined by tree height, lean, and slope. Guidelines are as follows:

- **Flat ground, whole straight tree as hazard:** The PIZ for a straight, non-leaning tree on flat ground is a circle around the tree with a radius equal to the total tree height (Fig. 1). For instance, if a tree is 100 feet tall, then its PIZ has a radius of 100 ft.
- **Sloping ground, whole straight tree as hazard:** On sloping ground, the PIZ may be extended downhill from the tree to a distance (the "slide zone") the evaluator deems necessary to protect people or property from a tree sliding, rolling or bouncing if it fails (Fig. 2). The evaluator needs to use judgement and account for steepness of slope, topographic features, and neighboring trees, but the PIZ is often extended to 1.5 times tree height of the downhill side for trees on moderately steep slopes.
- **Flat ground, whole leaning tree as hazard:** For trees leaning more than 15 degrees, failure from the base most often causes the tree to strike anywhere from the direction of the lean to 90 degrees to either side. The PIZ in this area has the same radius as the tree's height. Backlash away from the lean could occur in storms with high winds and would be mostly branches, so the "backlash zone" portion of the PIZ away from the lean is considered to be narrower (Fig. 3).
- **Flat ground, bole top on a straight tree as hazard:** The PIZ for a dead top, or one or more stems of a split or multiple top of a straight, non-leaning tree on flat ground is a circle around the tree with a radius equal to the total tree height, similar to Figure 1. The calculation in this guide accounts for high variability in where short upper bole failures may land if they fail in high wind, because of the distances that they can be cast when trees are swaying. A PIZ of 1.0 times tree height is also less likely to overinflate the PIZ of failures in the lower bole and is easy to calculate.
- **Flat ground, bole top on a leaning tree as hazard:** Like the PIZ for a dead top on a straight tree, the PIZ for a dead top on a leaning tree is a circle with a radius equal to the total tree height, but it is centered below the likely break point of the top instead of at the tree's base (Fig. 4).
- **Flat ground, large lower branch as hazard:** The PIZ for a hazardous lower branch is calculated as a circle 1.5 times the branch length, centered below the likely place it will fail (Fig. 5).

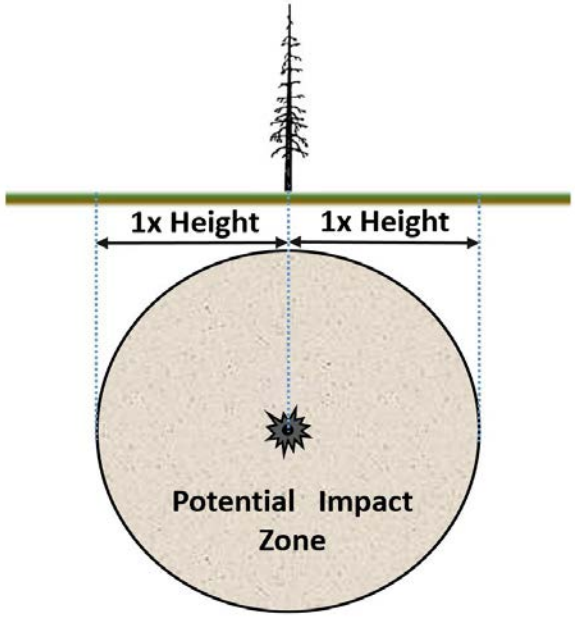

Figure 1. The Potential Impact Zone (PIZ) for a whole tree on flat ground is a circle around the tree with a radius equal to the tree height.

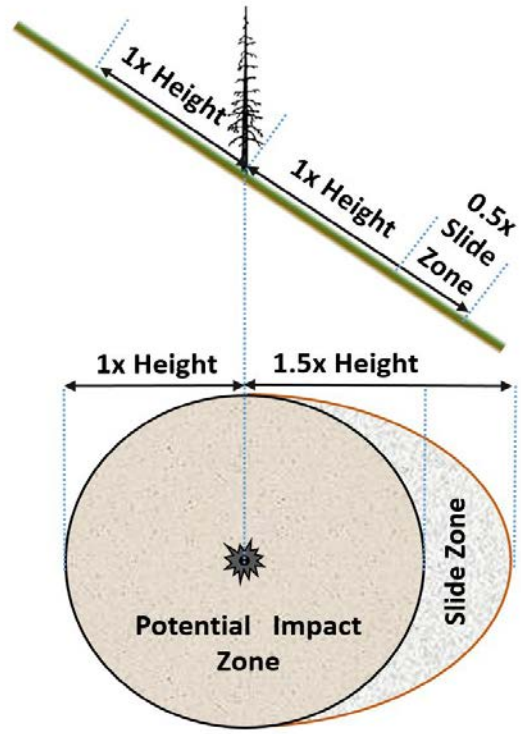

Figure 2. The Potential Impact Zone (PIZ) for a whole tree on a slope is calculated as a circle with a radius equal to the height of the tree plus a "slide zone" to account for a tree's sliding, rolling, or bouncing. Here, maximum PIZ with slide zone is shown as 1.5 times tree height, but larger or smaller slide zones may be appropriate (see text).

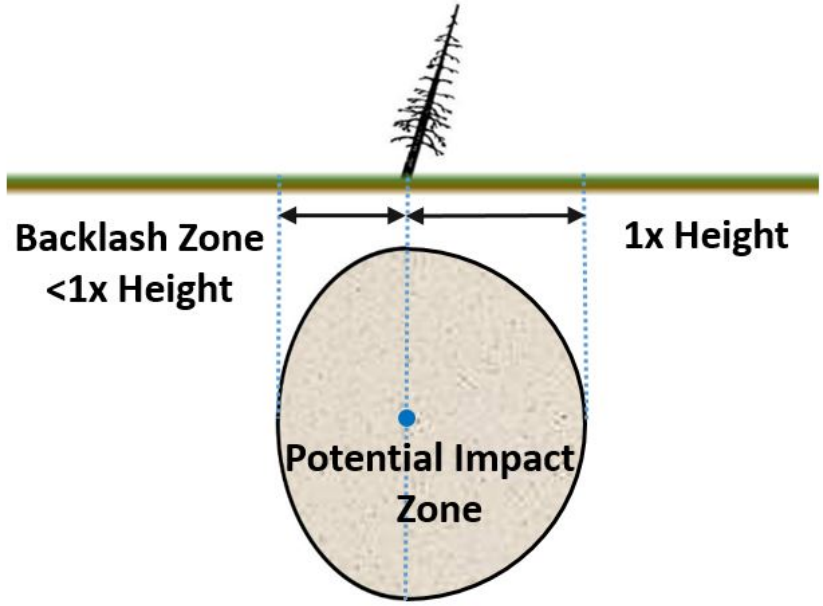

Figure 3. The Potential Impact Zone (PIZ) for a tree with a significant lean (>15°) on flat ground is a half circle with a radius equal to the height of the tree in the direction of the lean, plus a narrower backlash zone away from the lean (see text).

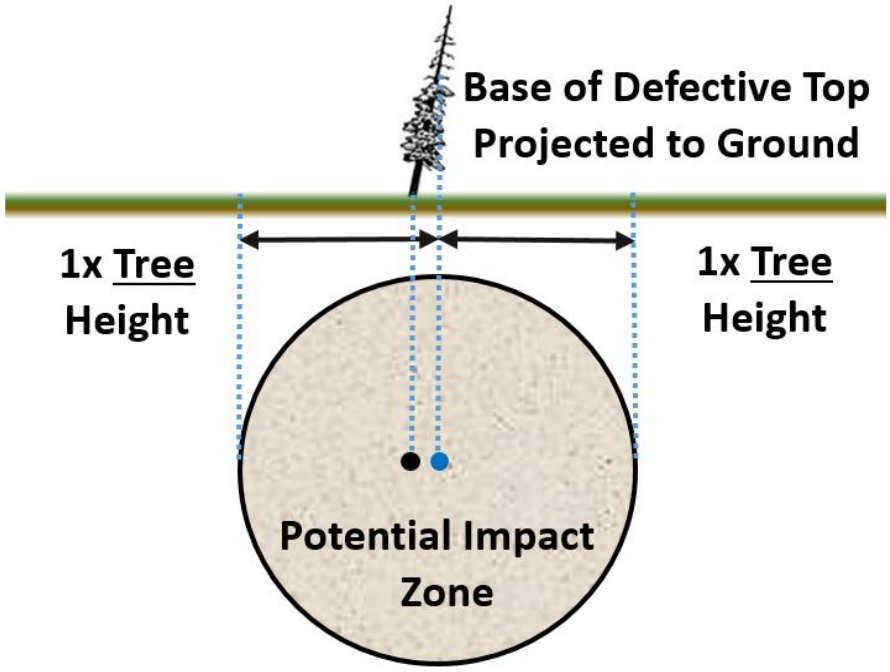

Figure 4. The Potential impact zone (PIZ) for a hazardous bole top for a tree on flat ground and a slight lean is a circle with a radius equal to the height of the tree, centered below the base of the dead top or likely break point.

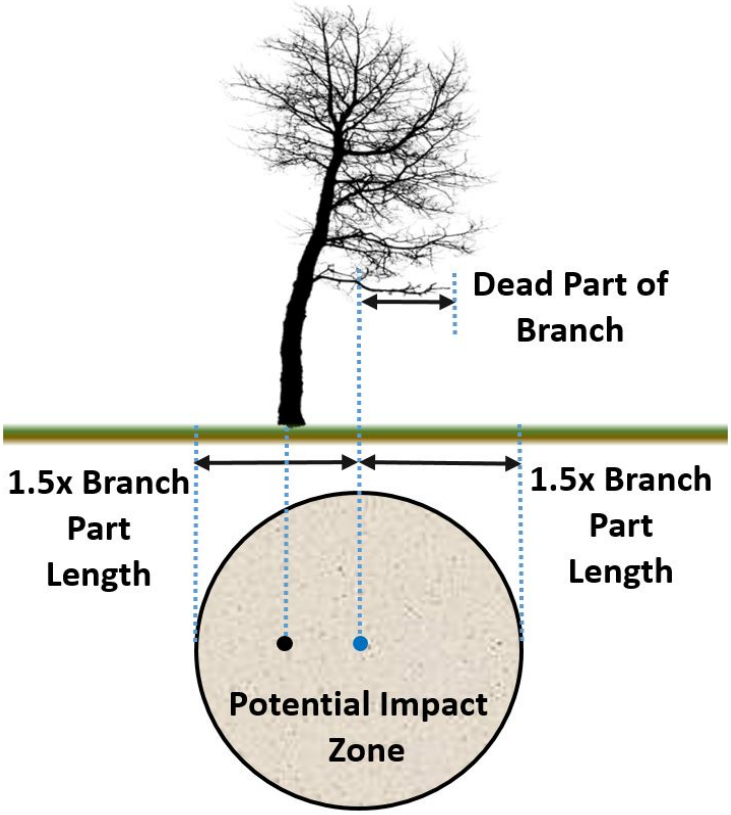

Figure 5. The Potential Impact Zone (PIZ) for a large defective branch is calculated as a circle with a radius 1.5 times the length of the defective branch, centered below the presumed break point.

Chapter 3. Planning and Documentation

Outline of the Process

It is not necessary to mitigate all levels of hazard from trees, only those hazards that have been deemed to create an unacceptable risk to persons, property and/or structures in the judgment of the appropriate managing authority. Recommended steps for evaluating potential hazard trees at a developed recreation site include:

1) Identify staff and managers responsible for all evaluations, mitigation activities and other subsequent activities.
2) Identify and gather the necessary equipment (see Appendix), forms (see Region 1 and 4 Tree Hazard Evaluation Form in Appendix), maps, and previous hazard tree evaluation data if available.
3) Determine area to be surveyed within each recreation site.
4) Determine a Hazard Tree Rating for individual trees;
    - Identify tree defects. Determine a numerical Failure Potential score using tables and data sheets.
    - Estimate Potential Impact Zone (zone a tree or its parts could reach), and numerical Damage Potential and Target Value scores.
    - Add numerical scores of Failure Potential, Damage Potential, and Target Value to determine Hazard Tree Rating.
5) Document the date the site is being evaluated, individual Hazard Tree Ratings and treatment options if practicable.
6) Determine and record possible mitigation options, and whether any immediate action is recommended.
7) Submit hazard tree evaluations to the site's manager or a supervisor as appropriate.
8) Be sure to record dates when recommended actions are completed.

Other Factors Useful for Land Managers to Consider: Timing

- Essentially all trees pose some hazard, it is not possible to eliminate all hazards, and trees and forests are constantly changing, so it is advised to repeat assessments of trees over time at reasonable intervals or after major disturbance events.
- Preserving the safety of visitors and employees is crucial, so evaluators should allow sufficient time to make the decisions on the soundness of individual trees, especially if the evaluator has limited experience.
- Being aware of differences in visitor use and recurrent risk levels at different sites enables managers of multiple sites to prioritize hazard tree evaluation efforts and implement treatments that respond to ongoing patterns of hazard and risk.
- The most intensively used sites may benefit from more frequent or intensive assessments.

Type and Intensity of Survey

Annual Survey: Timing and frequency of examinations may vary, but all developed sites could be examined annually for trees with new or increased hazard. Winter storms can cause failure or weakening of trees or limbs, especially in portions of stands with root disease or stem or branch decay. Annual pre-season site reviews could be a systematic walk-through examination and ideally, will refer to a previous baseline survey.

Baseline Survey: A survey that is more thorough and formal than an annual walk-through is recommended at least every five years, where each tree in all areas of the developed site is examined for new evidence of hazard or defect. Baseline surveys could be more frequent for recreation areas with special site factors such as bark beetle outbreaks, root disease, and soils that become saturated in spring floods. Some forest types, such as white fir or cottonwood, often have many defective trees and if practicable, more frequent assessments may be useful.

Ad hoc or "At Need" Surveys: It is also advisable to examine sites after special circumstances, such as after severe weather events or fires that occur during the usage season. Storm damage often weakens trees, and can be followed within weeks by additional tree and branch failures. Fire can rapidly decrease wood strength and can result in failures in a relatively short time.

Where to Survey

Obtain a detailed map of the developed site and review any past survey information. Places to survey include:

- **Roads:** Roads within the site and immediately entering or exiting the site.
- **Structures:** Buildings, parking areas, restrooms, waste disposal stations, water pumps, picnic tables, or ski lifts.
- **Gathering places of people:** Around tent pads, picnic tables, parking areas, ski-lifts, fire rings, barbecue pits, and all other recognized gathering places or focal points of human activity. Ask site hosts or maintenance workers for additional features.

How to Survey

Evaluate the site from a distance

Examine trees from different angles and vantage points. While approaching the site, look for severe defects that would be a dangerous to examiners. Evaluation by two people is more effective and efficient than with one person, and increases safety. With a 2-person crew, one examiner can work near the tree to look at defects in detail while the other examines the crown and measures height which helps determine Damage Potential, PIZ, and Target Value.

Compare the vigor and overall appearance of trees relative to their nearest neighbors. This allows detection of dead trees or tops and live-crown symptoms of root disease. Indicators could include reduced lateral branch and terminal growth, thinning crowns, chlorosis, distress cone crops, and dead tops and branches. Other indicators of Failure Potential such as defoliator activity, dwarf mistletoe infection, stem conks, bark beetle attack, and recent leans are often initially detected from a distance.

Establish reference points

Locate a large object that is a permanent fixture within the site for a reference point. Examples of useful fixtures include a fire pit in a numbered campground site, an outhouse along a road, and a lift tower at a ski area. Within the survey area, one reference point can often be used per every one to two campsites or other site subunit. These are essential for making maps and for documenting and relocating individual trees. Reference points can be indicated on a site map and/or by GPS. Note distance and bearing of each tree from the reference point. Ideally, reference points will be available from a prior hazard tree evaluation. Evaluations of trees are best made in a systematic fashion, starting at the first reference point.

Examine the area around each tree

Look for evidence of past and current pathogen and insect attack, or other damage. Nearby stumps and old roots can be examined for evidence of decay or root and butt pathogens. Broken-out tops that are lying on the ground, and wind-thrown or wind-broken trees can be examined for causes of failure. Examine conks, mushrooms, and other fruiting bodies on and around trees to aid identification of causes and extent of decay.

Begin systematic examination

- Look at the tree top, limbs, bole, butt, and soil mounds surrounding the roots. All sides of each tree can be examined. Binoculars can be useful for tall trees.
- Look for dead trees, dead tops and branches, whether attached or free-hanging, splits and other crown defects, crown symptoms of root disease, crown symptoms and bole bark beetle attack, and conks and mushrooms that indicate decay and root and butt diseases. Dead tops can be examined for decay and instability indicated by conks, crumbling sapwood, woodpecker feeding activity, and wildlife nesting cavities.
- Examine the bole above the upper butt visually, and look for signs of past injury or fungal fruiting bodies. Fruiting bodies often develop at the site of old branch stubs or wounds. By the time trees exhibit fruiting bodies of stem decay fungi, decay levels often are substantial. Absence of conks, however, does not necessarily mean that a tree is free from decay. Record the presence of all signs of potential defect to aid examiners in the future.

- If decay columns, hollows, and dead sapwood are present low on the bole, physically examine the Sound Wood Shell thickness as described below, or for irregular cavities, visually determine amounts of wood remaining as illustrated in Fig. 6. If it won't damage bark, tap suspect trees with an axe or rubber mallet and listen for hollows. If necessary to increase accuracy, determine the extent of decay in suspect trees (trees with open wounds, plates of dead- attached bark, conks, or mushrooms) with a cordless drill or increment borer.
- Look for evidence of root disease at the base of the bole and root crown such as resin flow, dead bark, and depressions. If a root disease problem is strongly suspected, consider examining the most symptomatic roots with a drill, axe, or Pulaski.
- If root disease symptoms are evident or the tree is close to another tree where root disease has been confirmed, the root collar, butt, and major lateral roots can be inspected. Look for characteristic signs of fungal pathogens or other evidence of decay agents. If root disease is suspected, soil can be carefully removed from roots, out to a distance of one meter to look for evidence of root disease at the root surface. At least two major roots can be checked for root disease if preliminary evidence suggests its presence. The roots most likely infected will be those near other infected trees, hollow stumps, wind-thrown trees with decayed roots, or flat or sunken faces of the tree's bole. For some root diseases, chopping into symptomatic roots or coring with an increment borer or cordless drill can show internal infection.

Decay in Trees

Decay in trees is a complex process involving fungus colonization and host tree defenses. As the two organisms interact, decay weakens the structural integrity of wood. Several methods visually estimate or calculate amounts of remaining sound wood and whether remaining strength is sufficient for safety. Each method has its own uses and limitations, but all are based on a finding that trees do not tend to fail where they retain at least one third of their sound wood.

Hazard tree evaluators should keep in mind that trees are dynamic, living things that adapt to their world, and can change where they deposit wood and add strength in response to damage and defect.

Dead Trees

All dead trees are rated as high hazard (FP4) if their PIZs affect high-use areas and tree failure could result in moderate to extensive damage. Attempt to determine causes of tree mortality, as some causes will affect additional trees at the site. Tree mortality in Intermountain and Northern Rocky Mountain forests often has complex causes. Severe or recurrent drought, competition with other trees, root diseases, bark beetles at endemic or outbreak levels, and prior damage by fire can all contribute. If present, some of these factors will also be affecting nearby trees, predisposing them to mortality or damage.

Trees with Insufficient Remaining Wood Strength

Sound wood or sound wood shell can be estimated to determine Failure Potential values for trees with visible or presumed decay, conks, wounds, open cavities, cankers or wood loss by fire. Sound wood is the remaining wood not affected by decay or other deterioration. Sound wood shell is the remaining wood unaffected by any decay or deterioration that contributes to a tree's strength. Proportions of remaining sound wood and sound wood shell representing high, medium, and low Failure Potentials are given in the Failure Potential Value Table (Table 1).

Sound Wood

Sound wood is estimated visually as the percentage of non-decayed wood remaining in a cross-sectional area of the bole. Figure 6 provides representations of highly irregular wood loss in bole cross-sections that can be used for estimating percentage of sound wood remaining after fire, decay, or both causes. These examples can help assess trees against sound wood values in Table 2 to identify those with obviously high Failure Potential.

Using a minimum sound wood value to estimate Failure Potential is most applicable for conifers. Using a minimum sound wood value for some hardwood species can overestimate Failure Potential for the following reasons: 1) Trunk failures well above the ground line are relatively rare in hardwoods with high mechanical strength such as oaks and maples. This is not true for species with weaker wood and rapid decay, such as cottonwood, alder, and aspen; 2) Many hardwoods have spreading crowns that are more influenced by leverage from wind and gravity than in conifers, so branch and fork conditions cause failures more frequently than trunk conditions.

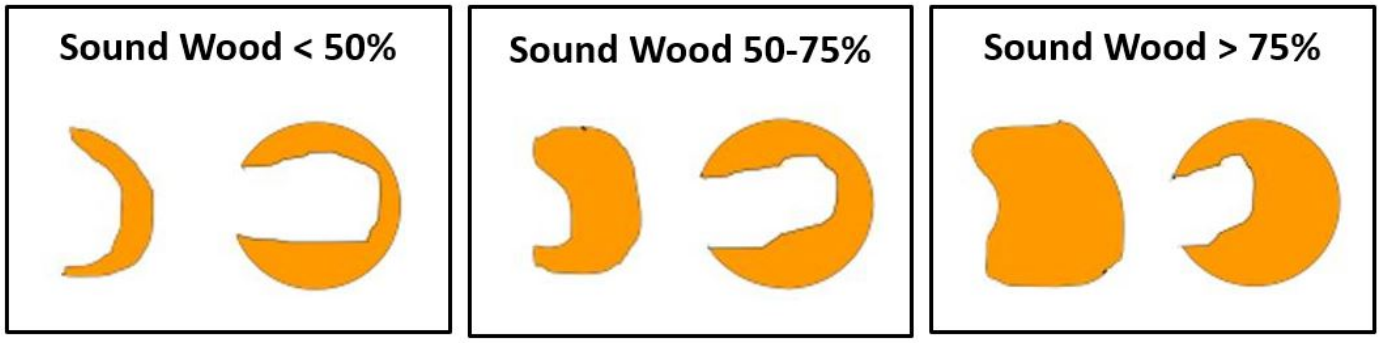

Figure 6. Diagrams of bole cross-sections of remaining sound wood representing percentage ranges used in Table 1 to assign Failure Potential values.

Sound Wood Shell

Sound wood shell is the sound wood completely surrounding internal decay and is estimated as a bole's average thickness of wood with no decay, excluding bark. Calculating the ratio between sound wood shell and diameter can indicate how much of a tree's original strength remains at a point of interest such as the tree's base or an opening. As with minimum sound wood, the concept of minimum sound wood shell thickness is more useful in conifers than in hardwoods. Conifers often have relatively evenly proportioned decay in cross-section, are more likely than hardwoods to retain their full height when mature (have not experienced and survived a break part-way up the bole), and boles have an even taper and are less irregular than hardwoods.

Table 2 shows cut-off values for inches of sound wood shell to assign trees with different diameters their Failure Potential values as shown in Table 1. The leftmost column (Inches for 15% Sound Wood Shell) is for trees without openings or other defects in addition to decay. Other columns are used for trees with decay plus additional defects such as openings, lean, and cracks that require trees to have more strength and sound wood shell to withstand destructive forces (see Table 2). The Failure Potential table (Table 1) and Multiple Defects section of Chapter 4 identify the common combined effects and present cut-off ratios between Failure Potential values.

The two most commonly encountered situations using sound wood shell measurements are trees with decay and no additional defects, and decay with an opening. The cut-off ratio between FP3 and FP4 for conifers that lack surface openings is a sound wood shell thickness of 0.15x tree diameter, displayed as "15% sound shell". For conifers with open cavities with decay visible at the bole surface, the cutoff is 0.2x diameter inside tree bark, displayed as "20% sound wood shell". When the average thickness of the sound wood shell is less than the values given for the tree's diameter in Table 2, the Failure Potential (FP) is the higher FP choice.

Measurement of Sound Wood Shell Thickness

These examinations are done by coring or drilling, but should not be routine; they should only be used to determine critical differences in Failure Potential. For soft-wooded species such as cedar, spruce, or alder, incipient decay may be more difficult to detect, so coring with an increment borer may be more useful than drilling. However, holes made with either tool damage trees and can increase decay, and is not normally needed. Drilling may be warranted when a high incidence of hidden decay is suspected or when nearby trees have fallen from decay not visible from the outside. For example, sites with tomentosus root and butt rot may need closer examination. Drilling or coring does not need to go any deeper than the depth of the required amount of sound wood needed for the tree diameter. For

example, a 10 in. diameter tree only needs 2 in. of sound wood (Table 2). Drilling deeper unnecessarily damages the tree and may spread decay.

Table 2. Reference sound wood shell thicknesses[1] for determining Failure Potential values of trees with different within-bark tree diameters, based on Sound Wood Shell Ratios for single or combined defects listed in Table 1 and Chapter 4.

Within-Bark Tree Diameter in Inches[2]	Inches for 15% Sound Wood Shell	Inches for 20% Sound Wood Shell	Inches for 25% Sound Wood Shell	Inches for 30% Sound Wood Shell
4	0.6	0.8	1	1.2
6	0.9	1.2	1.5	1.8
8	1.2	1.6	2	2.4
10	1.5	2	2.5	3
12	1.8	2.4	3	3.6
14	2.1	2.8	3.5	4.2
16	2.4	3.2	4	4.8
18	2.7	3.6	4.5	5.4
20	3	4	5	6
22	3.3	4.4	5.5	6.6
24	3.6	4.8	6	7.2
26	3.9	5.2	6.5	7.8
28	4.2	5.6	7	8.4
30	4.5	6	7.5	9
32	4.8	6.4	8	9.6
34	5.1	6.8	8.5	10.2
36	5.4	7.2	9	10.8
38	5.7	7.6	9.5	11.4
40	6	8	10	12
42	6.3	8.4	10.5	12.6
44	6.6	8.8	11	13.2
46	6.9	9.2	11.5	13.8
48	7.2	9.6	12	14.4
50	7.5	10	12.5	15

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

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

3 Consult Table 1 for the application of the 15-30% rules.

Proper Drilling Technique

To measure sound wood shell thickness with a cordless electric drill, use a long, narrow-diameter bit and, while drilling, note the depth where resistance or wood color changes. First, drill directly into a wound, canker, or flattened area. If decay is found, up to three more drillings can be made, one on the opposite side of the bole and one each at 90 degrees to the first drill spot using a minimum of three drillings to calculate the average sound wood shell thickness. Note thickness of bark and of sound wood shell for each drill spot. Tree species that have buttress roots or fluted butts (e.g., western hemlock, western redcedar) may require more sampling since the distal portions of fluted areas are often thicker. Estimate sound wood shell thickness by averaging all measurements (Table 2). Measuring sound wood shell thickness with an increment borer or drill can be part of the baseline survey and then repeated no more often than every 5 years to minimize wounding and spreading decay.

Example Determination of Sound Wood Shell

A tree with an outside diameter of 32 in. at its base and an open cavity near its base is being examined. Bark thickness is roughly estimated at 2 in. Twice the bark thickness is subtracted from the diameter to get within-bark diameter of 28 in. For this diameter, the value for minimum sound wood shell thickness at the opening is found in the "20% sound wood shell" column in Table 2 (5.6 in.) or manually calculated (0.20 x the 28 in. diameter = 5.6 in.). Sound wood remaining may be visually less than this value, so coring is not needed. Or, an increment borer may be used at three points at the base, and average sound wood shell thickness determined to be only 4 in. In either case, the tree would be assigned a high Failure Potential value (FP4).

Documentation

A record of inspection provides evidence that a survey was completed for a site. When a formal report submitted to a responsible official includes a record of trees with elevated hazard, protocols used to determine the hazards, and suggested recommendations, it can provide support for the recommendations and aid the official in making management decisions. Data from inspections can be recorded on the tree hazard evaluation form shown in the Appendix or similar forms. Evaluators may choose whether or not to use such forms to record information from inspections of healthy-appearing trees that would have inconsequential Hazard Tree Ratings.

Recording results of trees with elevated ratings in developed site evaluations is helpful for several additional reasons:

1) The assessment of current hazards provides a foundation for future vegetation management activities.
2) Recording principal defects at a site can make future surveys easier.
3) It provides documentation that can be a baseline for future hazard management and monitoring efforts.

A baseline survey and a permanent database can simplify subsequent evaluations. Hazard and monitoring information can be entered into a database so that information can be made available every year, prior to inspection, listing the trees that have been identified as in need of monitoring. Files can provide the locations of specific trees relative to reference points, their species, size, and type of defect, their prior defect severity, the appropriate monitoring interval, prior hazard and risk ratings, and recommended treatments. Maps showing tree locations can be generated using GPS (Global Positioning System) reference points. Maps can aid tree removal by contractors, re-evaluations of trees being monitored, determination of recurring reasons for tree removals, and long-range planning.

For some developed sites, it may be more useful to use individual tree forms instead of a form that records one tree per line. Single-tree forms can aid the evaluator in monitoring trees with disease or defects. Individual tree records can be created during a baseline survey and updated during re-evaluations.

Mitigation

The terms “mitigate” and “mitigation,” as used in this guide, refer to actions that may be taken to reduce, minimize, or eliminate the potential risk posed by a tree hazard.

Trees in developed recreation sites have inherent value and are difficult to replace. Removal decisions can be based on careful hazard evaluations and can consider other hazard mitigation alternatives, such as seasonal closures and moving the location of potential targets. For example, areas with moderate numbers of moderate defects and high visitor occupancy may be repurposed for limited-use interpretive trails. Hazard of individual high-value trees could be mitigated by approaches other than removal, such as limiting visitor access to outside of the PIZ.

Table 3. Simplified Failure Potential table for quick reference during examination. This table is used with the Region 1 and 4 Tree Hazard Evaluation Form (see Appendix).

Code	**DECAY OR CAVITY:** FP in whole tree or tree part is determined by average sound wood shell (**SHELL;** values in table 2) and conk numbers and sizes (Ch. 4). **SHELL** excludes bark and is measured where the greatest decay is suspected.	Code	**LEAN/SWEEP AND SLENDERNESS:** Fully vertical top growth in a leaning tree is termed "corrected". Slenderness is calculated as height to diameter ratio (H:D ratio): height (ft.) / dbh (ft.).
1D	No decay or cavity detected	**1L**	Lower bole vertical with sweep in upper bole **OR** H:D ratio <60
2D	Some decay but **SHELL** >30% diam.	**2L**	Soil looks intact; corrected lean of any amount **OR** uncorrected lean <15° **OR** H:D ratio 60 to 80
3D	No opening, **SHELL** >15% diam. **OR** opening present, **SHELL** >20% diam. **OR** conks present and FP based on species, conk number and size (Ch. 4)	**3L**	Soil looks intact; uncorrected lean >15° **OR** H:D ratio 80 to 100
4D	No opening, **SHELL** <15% diam. **OR** opening present, **SHELL** <20% diam. **OR** conks present and FP based on species, conk number and size (Ch. 4)	**4L**	Soil cracked or lifted or root breakage **OR** H:D ratio >100
	STEM DAMAGE AND WOUNDS (cracks, physical damage, fire damage): Note different FP criteria for western redcedar and resinous conifers (pines, Douglas-fir, western larch) vs. "other conifers".		**BRANCHES AND TOPS** (forks; dead or damaged parts; dwarf mistletoe and other branch brooms): Note different FP criteria for groups of conifers listed under STEM DAMAGE and aspens, cottonwoods, and birches.
1W	Crack or minor wounds fully callus-sealed **OR** no fire scar	**1B**	Douglas-fir small, live broom, **OR** other tree species' large live broom
2W	Small, shallow, partially-callused crack and **SHELL** >30% diam. **OR** minor structural damage, scraped bark, or fire scar <50% circumference and **SHELL** >30% diam. **OR** sound wood remaining after fire >50% for western redcedar and resinous conifers or >75% for "other conifers"	**2B**	V-shaped fork without embedded bark **OR** unbalanced multiple tops **OR** non-decayed dead top <3"diam. **OR** non-decayed dead top >3" in western redcedar or resinous conifer **OR** >3" diam. living branch on cottonwood tree with no evidence of past crown breakage or decay **OR** large living Douglas-fir broom **OR** small dead broom in non-Douglas-fir conifer
3W	Structural crack without movement and **SHELL** >20% diam. **OR** structural damage or fire scar is <50% circumference and **SHELL** >20% diam. **OR** >50-75% sound wood remaining after fire for "other conifers"	**3B**	V-shaped fork with embedded bark **OR** living, cracked top or branch >3" diam. **OR** non-decayed dead top or branch >3" diam. in aspen, cottonwood, birch, or "other conifers" **OR** >3" diam. living branch on cottonwood or birch tree with evidence of past crown breakage but no decay **OR** Douglas-fir with small dead broom **OR** large dead broom in non-Douglas-fir conifer
4W	Structural crack with evidence of movement **OR** wound or fire scar >50% circumference **OR** damage with SHELL <20% diam. **OR** <50% sound wood remains after fire	**4B**	V-shaped fork with embedded bark and crack or decay **OR** detached or dead and decayed branch or top **OR** > 3" diam. dead cottonwood or birch branch without decay **OR** > 3"diam. living branch on cottonwood or birch tree with evidence of past crown breakage and decay **OR** Douglas-fir with large dead broom **OR** broom on cracked branch
	CANKERS (aspen canker diseases, blister rust, dwarf mistletoe, etc.)		**ROOT DAMAGE, ROOT DISEASE, BUTT ROT**
1C	No cankers	**1R**	A few exposed, undamaged roots **OR** no structural root damage in fire-exposed tree
2C	<50% circumference of bole girdled	**2R**	>75% structural roots undamaged **OR** exposed small roots with minor damage and not root-sprung **OR** butt rot with **SHELL** >25% diam. and no aggressive root disease (**ARD**) in tree or proximity
3C	>50% circumference of bole girdled	**3R**	Some roots damaged but 50-75% root system intact **OR** fire damage of structural roots in only 1 quadrant **OR ARD** suspected in proximity (Ch. 4) but **ARD** not obvious or confirmed in tree **OR** butt rot with **SHELL** 15-25% diam.
4C	Tree killed	**4R**	Roots exposed, decayed or substantial damage on >50% of root system **OR** fire damage in >1 quadrant of structural roots **OR** tree has **ARD** symptoms (Ch. 4) **OR** butt rot with **SHELL** <15% diam.

Hazard Tree Rating and Treatment Priority Classes

The numerical scores for Failure Potential, Damage Potential, and Target Value are added to determine the Hazard Tree Rating. Priorities for mitigating hazard range from low to very high based on these numerical values. A Hazard Tree Ratings matrix (Fig. 7) indicates Treatment Priority Classes (low, moderate, high, and severe). Note that even highly defective trees with high Failure Potential may have low treatment priority if scores for Damage Potential and Target Value are minimal. For sites administered by public agencies, the deciding official determines which Treatment Priority Classes and particular trees are to be treated or monitored. Also, there may be reasons why rating of certain trees within Treatment Priority Classes might be modified, such as whether a tree has a protected vs. open position in a stand, and whether a tree recently became more exposed to wind.

Hazard Tree Rating

Target Value + Damage Potential	Failure Potential 1	2	3	4
2	3	4	5	6
3	4	5	6	7
4	5	6	7	8
5	6	7	8	9
6	7	8	9	10

Figure 7. Hazard Potential Matrix. Hazard Tree Ratings (numbers in the matrix) and Treatment Priority Classes (colors) increase in bands from the matrix's top left to bottom right. For trees in developed sites in Intermountain and Northern Rocky Mountain Regions, Hazard Potential and Treatment Priority is considered Low if 3-7 (Green background), Moderate if 8 (Yellow), High if 9 (Red), and Severe if 10 (Purple).

Chapter 4. Identification of Defects and Diseases

Dead Trees

The longer a tree has been dead, the more likely it is to fail (Figs. 8 & 9). Fungi decay roots, boles, and tops of dead trees making them less stable over time. Decay is much faster in sapwood than in heartwood of dead trees because sapwood has nutrients that accelerate the growth of all wood-colonizing fungi, but heartwood has fewer nutrients and has compounds that inhibit decay by some sap-rotting fungi. Smaller dead trees with more sapwood decay faster than larger dead trees or tree parts with more heartwood.

Dead trees of any species, size, or age have a **high Failure Potential.** They are given a high priority for mitigation at developed sites if they have sufficient Target Value and Damage Potential.

FAILURE POTENTIAL (FP) RATING

FP4: Dead trees.

Figure 8. Douglas-fir trees killed by bark beetles (FP4).

Figure 9. Dead ponderosa pine trees. The dead tree on the left with brown and green needles was killed by bark beetles a year before the photo; the dead tree on the right died five years earlier and lacks needles and small branches (FP4).

Wounded Trees

Tree wounds are injuries that break through the bark of the stem, branch, or root. Tree wounds are caused by a variety of factors: vehicles, people, falling trees, weather, fire, animals, or insect attack. A wound is considered open if the sapwood is exposed (Fig. 10). Fresh wounds on Douglas-fir or ponderosa pine are often covered with resin. New wounds on living trees (Fig. 11), especially large, deep wounds, can be entry points for stem decay or canker-causing fungi. Wounds can also activate dormant decay fungi, such as the Indian paint fungus. Wounds on non-resinous tree species, such as true firs (*Abies* spp.), generally result in more decay than do wounds on resinous species, such as pines. In some tree species, wounds occurring on roots and root collars can result in root disease.

After a tree is wounded, decay fungi may be confined to compartments within the tree through a process called compartmentalization, but the ability to compartmentalize varies by tree species. Over time, the tree may seal the wound with new wood resulting in a callus scar. The rate of wound sealing is a function of tree growth rate and vigor. When compartmentalization occurs, new wood formed after the time of wounding will remain relatively free of decay unless another wound occurs. Compartmentalized wood decay may eventually become a decayed or hollow cylinder surrounded by healthy-appearing wood. Non-decayed wood external to either a hollow or decay is referred to as the sound wood shell, and its thickness determines the Failure Potential of the affected tree (Table 2). A tree with an open wound and a sound wood shell thickness <20% of the tree's diameter inside bark has **high Failure Potential** (Table 2).

FAILURE POTENTIAL (FP) RATING

FP4: >50% bole circumference affected **OR <20%** sound wood shell.

FP3: <50% bole circumference affected **AND 20-30%** sound wood shell.

FP2: <50% bole circumference affected **AND >30%** sound wood shell.

Figure 10. This Jeffrey pine had a large basal wound affecting slightly less than 30% of the stem's circumference and 4-6 in. deep, lengthwise cracks in the exposed wood.

Figure 11. The many small insect- and animal-caused wounds in these aspens have little short-term failure potential but are infection sites for canker fungi that can cause tree failures.

Aggressive Root Diseases and Root and Butt Rots

Aggressive root disease can rapidly kill and consume roots without causing butt rot. Trees often fail at the roots without bole breakage (Fig. 12). Root and butt rots can kill roots but can cause extensive internal decay in lower boles and within roots (Fig. 13). Trees can fail either by breaking at the lower bole or at the roots. It is extremely important to document root diseases since they contribute to ongoing problems in developed sites. Some root diseases will continue to cause mortality and structural failure of all sizes and ages of host trees, while others cause failures primarily in very mature trees. And for some root diseases, types of root mortality, decay, and failure can depend both on tree species and how the disease entered the tree, through wounds vs. root-to-root contact. Determining how a root disease could affect tree stability in a hazard tree setting involves identifying the disease, understanding its potential for damage for all tree species present on a site, ages of trees present, and considering the damage already done by the pathogen in and near the site.

The Failure Potential (FP) ratings in the text box at right are general, and can be used for any root disease and root and butt rots. But FP ratings specific to particular root diseases should be used if they can be identified.

FAILURE POTENTIAL (FP) RATING

FP4: Tree with obvious crown or basal symptoms of aggressive root disease OR extensive butt decay: <15% sound wood shell (Table 2) OR decay in >50% of the structural roots.

FP3: Aggressive root disease suspected based on proximity OR moderate butt decay: 15-25% sound wood shell OR decay in <50% of the structural roots.

FP2: Aggressive root disease not suspected in proximity; little or no butt decay: >25% sound wood shell and no decay in structural roots.

General symptoms and indicators:

- Mixture of dead, dying, and declining trees within discrete areas or pockets.
- Entire live crown can be in decline, characterized by fading or yellowing foliage, dying branches, premature shedding of older needles, and reduced shoot growth (Fig. 14).
- Basal resin flow and/or bark staining may be present.
- Wind-thrown trees failed at roots or in bole at or near ground level and have characteristic decay.
- Bark beetle attacks on individual trees when bark beetles are not at outbreak levels.
- Distress cone or seed crops.
- Mushrooms or conks on root collar or in stumps.
- Presence of characteristic mycelia of the fungal pathogens on, in, or under the host bark in the roots and root collar area.
- Some root and butt rots, in particular Schweinitzii and tomentosus root and butt rots cause little or no detectable symptoms until wind throw occurs.

Figure 12. Many lodgepole pine and Engelmann spruce in this root disease pocket were wind-thrown or broke at the lower bole. More than one root disease was present.

Figure 13. This grand fir has Heterobasidion root disease present both as a butt rot, shown by central decay column with conks, and as an aggressive root disease, shown by irregular stained and decayed patches outside the central butt rot.

Figure 14. Thin, upward-receding crowns and dead trees can be observed near the edge of this pine root disease infection center.

Conifers: Heterobasidion (Annosus) Root Disease

Caused by two species of fungi, *Heterobasidion occidentale* and *H. irregulare*

Hosts: Root and Butt Rot: Primarily true firs, Douglas-fir, hemlocks, and spruces (*H. occidentale*). Root disease: pines and junipers (*H. irregulare*)

Identification: Look for nearby symptomatic trees or stumps. This disease occurs in trees of all ages.

- **Crown symptoms**: None or foliage fading and thinning, needle chlorosis, growth reduction, and appearance of scattered dead branches in the crown (Fig. 14).
- **Bole symptoms**: Central columns of decay or basal resin flow (Fig. 15).
- **Decay**: Incipient decay is a light-brown to reddish stain in the outer heartwood. Moderate decay is laminated with elongated pits on only one side of the laminations. Advanced decay is white and stringy and often has black flecks (Fig. 16).
- **Fruiting bodies**: Perennial conks (upper surface woody or leathery black to chestnut-brown, undersurface creamy-white) found within hollows and decay of old stumps or in root crotches of living trees, or on portions of roots in the duff layer or upper layers of the soil (Fig. 17).

FAILURE POTENTIAL (FP) RATING

FP4: Extensive butt decay (<15% sound wood shell) **OR** any decay in >50% of structural roots.

FP3: Susceptible trees adjacent to Heterobasidion-caused tree failure **OR** moderate butt decay (15-25% sound wood shell) **OR** any decay (<50%) of the structural roots.

FP2: Little or no butt decay (>25% sound wood shell) **AND NO** decay in structural roots.

Damage: Root and/or butt rot (the latter common in true firs and western hemlock) that predisposes trees to wind throw or breakage, or can kill the host by killing the cambium around all or most of the root collar.

Figure 15. Heterobasidion (annosus) root disease causes reddish-brown incipient decay staining (just below axe handle) and central butt-rot in some conifers.

Figure 16. Decay from Heterobasidion (annosus) root disease showing laminated decay with black flecks.

Figure 17. Heterobasidion (annosus) root disease is indicated by conks with white edges and laminated decay in this old hollow stump. Nearby trees may also be affected.

Conifers: Armillaria Root Disease

Caused by various *Armillaria* spp. *Armillaria ostoyae* causes an aggressive root disease of conifers.

Hosts: All conifers are susceptible to *A. ostoyae*, particularly when less than 30 years old. This is the most common root disease of conifers in the northern Rocky Mountain region. Douglas-fir and true firs are most susceptible and are damaged at all ages. Engelmann spruce is a common host in southern Idaho, Utah, and Wyoming.

Identification: Wind throw is common in infected stands.

- **Crown symptoms**: Foliage fading and thinning, needle yellowing, growth reduction, and appearance of scattered dead branches in the crown.
- **Bole symptoms**: None, basal resin flow (Fig. 18), basal stain.
- **Decay**: White or yellowish, becoming stringy, with black lines between patches of decay.
- **Fruiting bodies and other fungal signs**: Yellow to tan colored mushrooms may be produced at the base of infected trees in late summer or early autumn. The diagnostic thick, fan-shaped mats of white mycelium under the bark of roots and root crown are the most readily identified indication throughout the year (Fig. 19).

FAILURE POTENTIAL (FP) RATING

FP4: Trees with symptoms or signs are near wind-thrown trees with root disease.

FP3: Trees with symptoms or signs but not adjacent to wind-thrown trees with root disease.

FP2: Uninfected trees near root disease centers.

Damage: Armillaria root disease often extends further in a stand than is apparent from symptomatic trees. Trees in and around root disease centers vary in Failure Potential depending on tree species and condition. Live, symptomatic trees on sites with wind throw may be considered to have **high Failure Potential**.

Figure 18. Armillaria root disease often causes resinosis at the base of the tree. Chopping into bark with basal resinosis often reveals mycelial fans.

Figure 19. Armillaria ostoyae *often produces mycelial fans under the bark of infected trees.*

Conifers: Laminated Root Rot; Cedar Laminated Butt Rot

Caused by *Phellinus sulphurascens*; *Phellinus weirii*

Hosts: Laminated root rot: Douglas-fir and grand fir are highly susceptible; western hemlock and subalpine fir are less susceptible. Larch, spruce, and western hemlock are generally much more tolerant of the disease, but may develop substantial butt rot over time. Cedar laminated butt rot: western redcedar.

Identification: It is found in northern Idaho and northwestern Montana. Mortality can occur in small groups or large disease centers. Infected trees are often attacked by bark beetles.

- **Crown symptoms**: Foliage fading and thinning, needle yellowing, growth reduction, and appearance of scattered dead branches in the crown.
- **Bole symptoms**: Occasional basal resinosis or stain.
- **Decay**: Decayed wood separates easily along annual rings and is extensively pitted on both sides of ring with small white- or cinnamon-colored pockets (Fig. 20).
- **Fruiting bodies and other fungal structures**: The most common diagnostic structure of the fungus is a thin layer of cream- to dark yellow-colored 'ectotrophic mycelium' covering the outer bark of infected roots (Fig. 21) and setal (reddish-brown, thick-walled, and pointed) hyphae in advanced decay. Additionally, fuzzy, cinnamon-colored mycelium often occurs in bark crevices along with the cream-colored mycelium. Conks are rare, but when observed on roots they are thin and flat along the root surface, leathery when fresh and crumbly with age, light weight, yellow to cinnamon brown with small pores.

FAILURE POTENTIAL (FP) RATING

FP4: Signs or symptoms present. Western redcedar use sound wood shell values.

FP3: Douglas-fir, mountain hemlock, or true fir with signs and symptoms absent AND ≤25' from an infected tree or stump (check for butt rot). Western larch, Engelmann spruce, or western hemlock with signs and symptoms absent AND same-species tree or stump is infected somewhere on the site AND ≤25' from any infected tree or stump.

FP2: Douglas-fir, mountain hemlock, or true fir with signs and symptoms absent AND >25' from an infected tree or stump. Western larch, Engelmann spruce, or western hemlock with signs and symptoms absent AND same-species tree or stump is infected somewhere on the site AND >25' from any infected tree or stump.

Damage: Wind throw of green, otherwise asymptomatic trees frequently occurs among highly susceptible hosts. This makes laminated root rot particularly dangerous in a developed site. More tolerant hosts that develop butt rot may break at the butt or lower stem as decay advances with age.

Figure 20. Laminated decay caused by Phellinus sulphurascens.

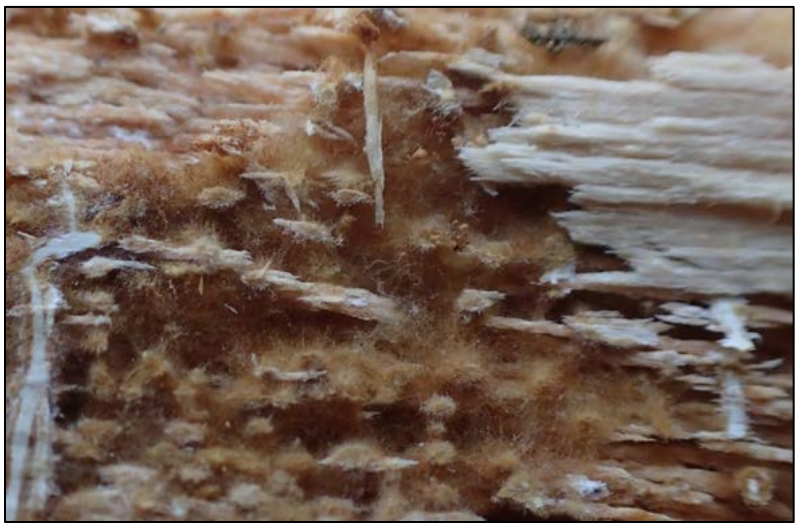

*Figure 21. Close-up of setal hyphae of laminated root disease (*Phellinus sulphurascens*) on grand fir.*

Conifers: Schweinitzii Root and Butt Rot

Caused by *Phaeolus schweinitzii*

Hosts: Douglas-fir; all conifers are susceptible.

Identification: Generally causes tree failures in old (>150 years) conifers. Douglas-fir is most disease-prone. Conks (Fig. 22) are often rare on drier sites, so Schweinitzii root and butt rot is often identified by observing stumps with central brown cubical decay surrounded by a solid outer wood shell, or by uprooted trees with stubbed roots and brown cubical decay. On mesic and wetter sites conks are more abundant, but not always present.

- **Crown symptoms:** Uncommon. Crowns of extensively infected Douglas-fir are sometimes thin and show poor shoot growth and some branch dieback.
- **Bole symptoms:** Butt swell, brown cubical decay, shake or cracking of butt, and ant or wood borer activity in the butt may be indicators.
- **Decay:** Decay is dry and yellow at first, becoming brown and cubical in advanced stages. Thin, resinous felts are often present in cracks within advanced decay. Brown, cubical, advanced decay is easily crushed to a fine powder (Fig. 23).
- **Fruiting bodies:** Conks are occasionally produced on the ground near infected trees or rarely, on infected trees or stumps (Fig. 22). Conks are annual and spongy, with short stems and large, irregular pores on the undersurface. They can persist and can be identified for several years. Caps are usually five to 10 in. in diameter, brown and velvety on top, greenish on the undersides when fresh, and the whole conk becomes brown and brittle. They can resemble cow pies or pieces of bark.
- **Roots:** Girdled roots develop central brown-rot decay and can become club-like or knobby when overgrown by living bark (Fig. 24).

FAILURE POTENTIAL (FP) RATING

FP4: Extensive butt decay (<15% sound wood shell) **OR** any decay in >50% of structural roots OR conks on roots of Douglas-fir.

FP3: Moderate butt decay (15-25% sound wood shell) **OR** any decay (<50%) of the structural roots.

FP2: Little or no butt decay (>25% sound wood shell) **AND NO** decay in structural roots.

Damage: Severely weakened Douglas-fir may have little indication of advanced decay, so presence of conks is an immediate concern. This disease may be slow to weaken trees of other species to hazardous levels. In species where anchoring roots are less affected, suspected trees may be retained and monitored each year or every other year, depending on extent of defect and decay.

Figure 22. Fresh, rust-colored (foreground) and old, dark-colored conks (background) of Phaeolus schweinitzii *have grown from infected Douglas-fir roots.*

Figure 23. Extensive brown cubical butt rot from Schweinitzii root and butt rot.

Figure 24. Schweinitzii root and butt rot causes clubbed or greatly reduced root systems, as in this wind-thrown Douglas-fir.

Conifers: Tomentosus Root and Butt Rot

Caused by *Onnia tomentosa*

Hosts: Engelmann spruce is the primary host. Lodgepole pine, Douglas-fir, subalpine fir, western white pine, and Colorado blue spruce are occasional hosts.

Identification: Honeycomb-like decay in cut stumps or roots of wind-thrown trees is the best indicator of this disease (Fig. 25). Coring or cutting into roots of a stump can help determine if decay is more extensive above ground or in the roots, and eliminate other causes of decay. If decay is much more extensive in roots, then there is an increased likelihood of tomentosus root and butt rot disease as opposed to a stem decay in the stump, such as red ring rot.

- **Crown symptoms:** Uncommon, but can produce crown thinning, yellowing, and dieback when decay is extensive. Infected trees with healthy-looking crowns commonly fail.
- **Bole symptoms:** None.
- **Decay:** Early decay produces a red-brown or brown stain, often resinous, in the heartwood of roots and butts. Advanced decay is a white pocket rot which forms empty, spindle-shaped pockets with firm wood between the pockets. This decay has a distinctive honeycombed appearance in cross-section.
- **Fruiting bodies:** Uncommon, but can be found in late summer or fall during some years. They are small (usually 2 to 5 in. in diameter) yellow to cinnamon colored, and leathery annual conks with short stems. The lower surface is porous and cream colored when fresh, but darkening with age.
- **Root symptoms**: Resin production at the root surfaces and reddish brown staining in the roots (Fig. 26).

FAILURE POTENTIAL (FP) RATING

FP4: Extensive butt decay (<15% sound wood shell) **OR** any decay in >50% of structural roots.

FP3: Susceptible trees adjacent to tomentosus-caused tree failure **OR** moderate butt decay (15-25% sound wood shell) **OR** any decay (<50%) of the structural roots.

FP2: Susceptible trees **NOT** adjacent to tomentosus-caused tree failure with little or no butt decay (>25% sound wood shell) **AND NO** decay in structural roots.

Damage: Host trees (usually spruce) in root disease centers can have **high** or **medium Failure Potential,** depending on extent of butt decay. In developed recreation sites dominated by old, similar-aged Engelmann spruce, the onset of tree failure from tomentosus root and butt rot can indicate that many more trees will soon fail. Many trees can be lost within a decade or two. Spruce with Potential Impact Zone affecting targets may be checked with a drill or borer to detect decay, despite lack of symptoms. Engelmann spruce are relatively shallow-rooted and changing wind dynamics caused by loss of root diseased trees could result in wind throw of otherwise healthy spruce.

*Figure 25. Tomentosus root and butt rot disease (*Onnia tomentosa*) stages of decay on Engelmann spruce include reddish stain and early decay (left) and advanced decay with a "honeycomb" appearance (right).*

*Figure 26. Tomentosus root and butt rot disease (*Onnia tomentosa*) caused surface resin and internal stain and decay on these Engelmann spruce roots.*

Conifers: Yellow Root Rot or Stringy Butt Rot

Caused by *Perenniporia subacida*

Hosts: Suppressed or stressed conifers, especially Douglas-fir, true firs, and western hemlock as well as many hardwoods.

Identification: Because signs and symptoms are below ground, the disease is difficult to detect in live trees.

- **Crown symptoms:** May show no symptoms or general crown stress symptoms (sparse crown with poor growth).
- **Bole symptoms:** Uncommon. Butt swell or cracking and ant or wood borer activity in the butt may be indicators.
- **Decay:** Early decay is a light-brown stain that resembles wetwood. Advanced decay is composed of irregularly-shaped pockets of decayed spring wood that coalesce into masses of stringy fibers with large black flecks (Fig. 27). Annual rings may separate into laminated decay.
- **Fruiting bodies and other fungal signs:** Conks are white, crust-like or leathery and flattened against the wood or bark on the undersides of roots, logs, fallen trees, or exposed roots (Fig. 28). Yellow-white mycelial felts may form between layers of decayed wood.

Damage: Affected trees may be easily wind-thrown.

FAILURE POTENTIAL (FP) RATING

FP4: Extensive butt decay (<15% sound wood shell) **OR** any decay in >50% of structural roots.

FP3: Moderate butt decay (15-25% sound wood shell) **OR** any decay (<50%) of the structural roots.

FP2: little or no butt decay (>25% sound wood shell) **AND NO** decay in structural roots.

Figure 27. Advanced root rot caused by Perenniporia subacida *is typically soft and wet with a white-mottled yellow color. Large black flecks may also be present. Photo credit Blakey Lockman.*

Figure 28. Fruiting body of Perenniporia subacida*. Photo credit Blakey Lockman.*

Ganoderma White Mottled Rot (Artist's Conk) and Hemlock Varnish-Shelf Conk

Fungus species are *Ganoderma applanatum* and *G. oregonense,* respectively.

Hosts: Live or dead hardwoods, particularly cottonwoods and aspen, and dead or partially dead conifers (*G. applanatum*); conifers only (*G. oregonense*)

Identification: Conks are the only useful indicator of decay or infection in live, standing trees. Advanced decay may produce conks before trees fall over. The species affecting aspen is most common on mesic aspen sites.

- **Crown symptoms**: None. Crown damage from other causes or agents, such as wind or snow breakage or canker fungi.
- **Bole symptoms**: None. Basal wounds are infection sites; cavities rarely develop.
- **Decay**: Both species produce a white-mottled rot, white spongy rot with black specks. In *G. applanatum*, the decay alternates between small areas of white and light tan. Black zone lines may develop.
- **Fruiting bodies**: *G. applanatum* conks are shelf-like and occur at the bases of trees, usually within a foot of the ground (Figs. 29 & 30). They are perennial, leathery to woody, with an irregular, brown to gray upper surface. The margin and undersurface are white to creamy with small pores and are easily bruised when fresh. Bruising is permanent, allowing artists to "draw" on the undersurface, giving this fungus a common name of "artist's conk".

  G. oregonense conks are annual, stalked, reddish-brown, and shiny, as if lacquered or varnished.

Damage: When root and butt rot caused by a Ganoderma species is diagnosed in developed sites, host trees can have **FP3-4** depending on the extent of butt decay.

FAILURE POTENTIAL (FP) RATING

FP4: Trees with conks **OR** extensive butt decay (<15% sound wood shell) **OR** any decay in >50% of structural roots.

FP3: Susceptible trees adjacent to trees with conks or tree failure **OR** moderate butt decay (15-25% sound wood shell) **OR** any decay (<50%) of the structural roots.

FP2: Susceptible trees with little or no butt decay (>25% sound wood shell) **AND NO** decay in structural roots.

Figure 29. The wind-thrown trees in a Ganoderma root and butt rot pocket in aspen have little to no attached root system. A conk is visible on the left side of the standing stem.

Figure 30. This young Ganoderma conk has an upper surface of tan, concentric zones and a white undersurface. If undersurface is scratched, a dark brown interior would be easily seen.

Other Root Problems

Other important root defects include undermined roots that result from erosion, severed roots caused by heavy equipment, and roots loosened, cracked, or broken during high winds. Failure Potential is determined based on the proportion of structural roots remaining in the ground (Table 1).

Undermined Roots

These can result from bank erosion near roads or trails in and around developed sites. They are also observed where there is seasonally high water at water's edge by lakes, streams, or rivers (Fig. 31). Severe undermining without compensating root growth causes tree failure from poor root anchoring.

Figure 31. Undermined root systems: At left, trees were felled because of undermining and failure. Failures were away from the undermined side. At right, undermined roots of a western redcedar show ice damage common to trees along streams with winter freezing.

FAILURE POTENTIAL (FP) RATING

FP4: <50% of the structural roots remaining intact and in the ground.

FP3: 50 – 75% of the structural roots remaining intact and in the ground.

FP2: >75% of the structural roots remaining intact and in the ground.

Severed roots

Severed roots reduce anchoring and are entry points for root and butt rot and decay fungi. Roots can be severed installing utilities and building roads, trails, tent pads, or water control ditches (Fig. 32).

Figure 32. Excavation to install a utility line severed many of this tree's roots. Compaction and burying the base of the tree (see soil line on trunks) may have further weakened the root system.

Loosened, Cracked, or Broken Roots; Leaning Trees

Wind events, saturated soils, and soil disturbances occurring singly or in combination often lead to loosening, cracking, or breakage of roots. Trees with such damage often fail under less stress than caused the initial damage. Soil saturation is a leading factor in wind throw of shallow-rooted species and for any species growing at high density or in shallow soil. Indicators of root damage include: trees with newly developed or recently increased lean (Fig. 33); a gap between the base of the tree and soil or litter on the side away from the lean; and recent soil mounds, heaves, ridges or cracks near major lateral roots.

FAILURE POTENTIAL (FP) RATING

FP4: Soil cracked or lifted near tree or root breakage.

FP3: Soil looks intact, **uncorrected** lean ≥15°**.**

FP2: Soil looks intact, **uncorrected** lean <15° **OR corrected** lean.

Root-sprung trees are failing because their roots are compromised. Leaning trees (≥15 degrees) can result from root and butt decay and from high winds that cause root wrenching (Fig. 34). All leaning trees with potential targets can be examined for evidence of root and butt rot.

Trees with recent leans (<5 years) may have a conspicuous gap between the base of the tree and disturbed soil and litter on the opposite side of the tree from the lean. Cracks, mounds, or ridges of recently heaved soil may be found adjacent to major lateral roots of leaning trees. Trees with newly developed lean are tilted over their entire length, and trees that are uprooted or broken but supported by other trees have **High Failure Potential** (Table 1).

Persistent leaning trees are those that have been leaning for a considerable time and have grown upwards towards vertical (corrected lean) (Fig. 35). If they don't fall, leaning trees develop tension and compression wood at stress points to aid in their support. They also often develop a reinforced root system to compensate for prior stress or damage. Unless roots are disturbed or decay is present, persistent leaning trees with vertically "corrected" growth have **FP1-FP2.**

Figure 33. Broken roots and recent lean on a ponderosa pine. This failure was severe and obvious, with the soil crack opening and closing several inches in even moderate wind.

Figure 34. Three western redcedars at left with failed roots and severe lean are supported by a grand fir with a wound on its upper bole caused by years of contact with one of the redcedars.

Figure 35. Leaning Douglas-fir with vertically "corrected" top growth.

Heart Rots

In this guide, heart rots are defined as types of decay confined to the interior wood of living trees. When conducting hazard tree assessments, we include true heart rots that are usually confined within a growth ring when an injury occurred, and canker rots that initially decay heartwood, but encroach on, kill, and then decay sapwood of living tree boles.

All heart rots are caused by fungi. Most enter wounds but some colonize through branch stubs. Wounds, branch stubs, and dead branches are places to look for indicators of decay. Heart rots are more commonly seen in older trees. In conifers, heart rot mostly occurs in trees greater than 150 years old, but decay-prone species such as true firs and western hemlock may have substantial decay at younger ages. The sound wood shell guidelines (Table 2) can be applied to any tree with heart rot. The failure potential guidelines for each specific heart rot given below are designed to supplement the guidelines in Table 2.

FAILURE POTENTIAL (FP) RATING

FP4: Conks visible OR <15% sound wood shell without openings or wounds; <20% if openings, wounds, or cracks present.

FP3: Significant decay present, but >15% sound wood shell without openings, wounds, or cracks OR >20% with an opening, wound, or crack.

FP2: Some decay present, sound wood quantity over thresholds (see Table 2).

Indicators of potential heart rot, from most to least reliable are:

- Conks, mushrooms sprouting from wounds, and swollen areas of sterile fungus at knots. However, conks and mushrooms from some decays may be rare and are less common on drier sites (Fig. 36).
- Decayed wood in broken trees and branches (Fig. 37).
- Large, old wounds or branch stubs.
- Flat or sunken area on the bole with dead bark, indicating hidden damage or disease that has killed bark.
- Evidence of older broken tops on living trees.

How to detect heart rot in trees and assess heart rot severity:

1. Strike ("sound") tree trunk with suspected basal heart rot with a rubber mallet or the butt of an axe and listen for hollowness. Thick-bark species are often difficult to sound.
2. Bore into tree with suspected basal heart rot decay with an increment borer or a cordless drill at the point of defect or as near as possible and determine if thickness of remaining sound wood shell is acceptable using methods described in Chapter 3 (Table 2).
3. Use binoculars to examine the upper crown for decay conks or other evidence of decay. Estimate Failure Potential from numbers and sizes of conks and defects using Table 1.

Figure 36. A stem decay conk on living grand fir.

Figure 37. Severe stem decay was the main cause of failure in this western redcedar.

Hardwoods: Aspen Trunk Rot or Aspen Heart Rot

Caused by *Phellinus tremulae*

Host: Aspen

Identification:

- **Decay**: Early heartwood decay is a yellow-white zone with a yellow-green to brown margin. Advanced decay is soft and yellow-white with fine, black zone lines.
- **Fruiting bodies:** Hard, woody, conks that are generally triangle-shaped in longitudinal section; brown under-surface with small, regular pores (Fig. 38).
- **Breakage:** Nearby trees may have wind breakage in the bole (Fig. 39).

Damage: A single conk generally indicates considerable internal decay; such trees have **FP3**. Coring may determine more extensive decay which could indicate **FP4**.

FAILURE POTENTIAL (FP) RATING

FP4: ≥1 conk **AND** open cracks or exposed rot.

FP3 or FP2: ≥1 conk **without** cracks or exposed rot, depending on sound wood shell.

FP2: ≥1 conk **without** cracks or exposed rot.

Figure 38. Fruiting body of Phellinus tremulae *causing aspen trunk-rot.*

Figure 39. Stem failure due to aspen trunk-rot.

Hardwoods: Brown Cubical Rot of Birch (Birch Polypore)

Caused by a fungus, *Piptoporus betulinus*

Host: Birch

FAILURE POTENTIAL (FP) RATING

FP4: >1 conk.

FP3: 1 conk.

Identification:

- **Decay**: Yellow-brown decay breaks into cubes separated by thin white layers of mycelium. Advanced decay easily crumbles to powder.
- **Fruiting bodies:** Annual, extremely tough and persistent conks have short, sturdy stalks. The conk develops below the level where the stalk emerges. The underside is initially smooth and white, becoming light brown and irregular at maturity (Fig. 40, left). Upper surface is white to tan and very smooth, fading to white. The upper surface curves over the margin to form a ridge all around the pore surface (Fig. 40, right).

Damage: A single conk generally indicates considerable internal decay, and such trees have **FP3.**

Figure 40. Fruiting bodies of birch polypore, Piptoporus betulinus*. On the left, the spore producing surface is shown; on the right is the upper surface. From: http://wildflowers.perverdonk.com. Used with permission.*

Hardwoods: White Spongy Trunk Rot (Tinder Conk)

Caused by *Fomes fomentarius*

Hosts: Dead trees or dead portions of living hardwoods

Identification:

- **Decay**: Early decay is brown and firm. Advanced decay is soft and spongy, yellow-white, with dark to black zone lines.
- **Fruiting bodies:** Hoof-shaped conk with a concentrically zoned, smooth, gray to gray-black upper surface. Underside is brown with small, regular-shaped pores (Fig. 41).

Damage: Trees with multiple conks indicating extensive decay have **FP4.**

FAILURE POTENTIAL (FP) RATING

FP4: **Dead trees** OR live trees with ≥3 conks.

FP3: **Live trees** with 2 conks.

FP2: **Live trees** with 1 conk.

Figure 41. Fomes fomentarius *on birch.*

Hardwoods: Hardwood Trunk Rot (False Tinder Fungus)

Caused by *Phellinus igniarius*

Hosts: Hardwoods

Identification:

- **Decay**: Early decay is seen as a yellow-white portion of the heartwood that is usually surrounded by a yellow-green to brown margin. Advanced decay is soft and yellow-white with fine black zone lines.
- **Fruiting bodies:** Woody and generally hoofed-shaped conks with lower surfaces nearly horizontal. Conks are easy to knock off bole. Upper surface is gray-black to black and rough when old. Underside is brown with small and regular pores (Fig. 42).

FAILURE POTENTIAL (FP) RATING

FP4: Multiple conks and less than 15% sound wood shell.

FP3: 1 conk.

FP2: No conks; symptomatic decay present, sound wood shell over thresholds.

Damage: A single conk generally indicates considerable internal decay; such trees have at least **FP3.** More than 1 conk may have higher Failure Potential, but the relationship between number of conks and amount of decay is not well-established.

Figure 42. False tinder conk, Phellinus igniarius*, on birch.*

Hardwoods and Conifers: Brown Cubical Rot (Sulfur Shelf or "Chicken of the Woods")

Caused in western North America by two species of fungi, *Laetiporus conifericola* (conifers) and *L. gilbertsonii* (hardwoods) (both formerly *L. sulphureus*)

FAILURE POTENTIAL (FP) RATING

FP4: >1 conk.

FP3: 1 conk.

Hosts: Conifers and hardwoods

Identification: Conks are the most reliable indications of decay.

- **Decay**: Early decay is a light-brown stain. Advanced decay is red-brown, crumbly, and cubical with interspersed white, felt-like layers of mycelium.
- **Fruiting bodies:** Multiple horizontal conks are produced in fall, attached directly to decayed wood or knotholes, without stems. The annual conks are initially soft and yellow to bright orange (Fig. 43), becoming very tough, and fading to persistent chalky-white, broken structures that may have black surface molds.

Damage: Decay is usually well-advanced before conks develop, so trees with >1 conk have **FP=4**.

Figure 43. Fruiting body of Laetiporus conifericola *on Douglas-fir. Photo credit Gregg DeNitto.*

Conifers: Brown Top-rot ("Rose-colored Conk")

Caused by *Fomitopsis cajanderi*

Hosts: Conifers; usually living trees with past top damage from wind and ice or snow loading.

FAILURE POTENTIAL (FP) RATING

Identification: Wood strength may be moderately affected before discoloration or texture change is evident.

FP2-4: Follow general guidelines in Tables 1 and 2.

- **Decay**: Early decay is a faint brownish or yellow-brown stain, sometimes marked by greenish-brown zone lines. Advanced decay is yellowish to reddish brown, soft, and with irregular cubes. Thin, white to faintly rose-colored mycelial felts may develop in the cracks between the cubes.
- **Fruiting bodies:** Relatively small, woody, bracket-like to hoof-shaped conks with pink to rose-colored undersurfaces and inner tissue; upper surface can be brown to black and is usually cracked and rough. Often appear stacked in a shelf-like arrangement (Fig. 44).

Damage: Boles and replacement leaders of trees with one or more conks at the base of a replacement leader have a **FP3**. Replacement leaders and boles on trees with top-breaks but no conks would have **FP2**. Monitoring for future conks is advisable.

Figure 44. Rose-colored conk of Fomitopsis cajanderi, usually found decaying damaged Douglas-fir upper boles.

Conifers: Brown Trunk Rot (Quinine Conk or "Chalky Fungus")

Caused by *Fomitopsis officinalis*

Hosts: Conifers

FAILURE POTENTIAL (FP) RATING

FP4: ≥1 conk(s).

Identification:

- **Decay**: Early stain is yellow-green to brownish-green and could be confused with Schweinitzii root and butt rot. Advanced decay is brown, crumbly, and cubical (Fig. 24) with large, thick bitter mycelial felts in cracks.
- **Fruiting bodies:** Large, hoof-shaped or columnar conk (Fig. 45) with a chalky-white upper surface and a white pore surface. Interior is usually soft and crumbly. Develops at branch stubs, over old wounds and especially at old broken tops.
- **Punk knots:** May be observed at large, older branch stubs that have usually rotted and fallen off. Punk knots may have a yellowish-brown exudate that stains the bark below.

Damage: Severe stem decay occurring either as a top rot when it has entered a broken top, or as a heart rot of the main stem when the site of the old broken top is much lower in the bole and no longer visible. This fungus also enters through basal fire scars. Even one conk indicates **FP4.**

Figure 45. Fomitopsis officinalis *conks are typically cylindrical, and many specimens are more massive and longer than this example on an old bole wound.*

Conifer: Juniper Pocket Rot

Caused by *Pyrofomes demidoffii*

Hosts: Juniper

Identification:

- **Decay**: Early decay is a light-yellow color. Advanced decay is a white rot with abundant buff-colored mycelial felts in the decayed wood (Fig. 46). Decay typically forms discrete pockets in infected wood.
- **Fruiting bodies:** Hoof-shaped conk with a brown to black upper surface with a buff to black rim. The undersurface is buff-colored with round pores (Fig. 47).

Damage: Trees with >1 conks have considerable decay but rarely fail and therefore have **FP2**.

FAILURE POTENTIAL (FP) RATING

FP4: Dead trees with conks.

FP3: Trees with 1+ conk(s) and signs of other structural problems such as "v" forks.

FP2: Trees with 1+ conk(s).

*Figure 46. Typical decay of Juniper Pocket Rot (*Pyrofomes demidoffii*). Photo credit Gail Durham.*

*Figure 47. Fruiting body of Juniper Pocket Rot (*Pyrofomes demidoffii*). Photo credit Gail Durham.*

Conifers: Cedar Brown Pocket Rot or Redcedar Pencil Rot

Caused by *Postia sericeomollis*

FAILURE POTENTIAL (FP) RATING

FP4: 1 conk.

Host: Western redcedar

Identification:

- **Bole symptoms**: Trees with a conspicuous bole flattening at the butt called a "dry side" or "dry face" from other damage, including sun exposure, logging wounds, or *Armillaria* infection, may have significant decay. Trees with evidence of a dry side can be sounded with an axe or mallet and/or drilled to determine the extent of decay and the sound wood shell thickness.
- **Decay**: Minor decay appears as long, thin, tapered cylinders ("pencils") of brown cubical decay and are round to irregular in cross-section. Advanced decay is a brown, cubical pocket rot (Fig. 48).
- **Fruiting bodies:** Rarely seen, when present they are thin, flat, white crusts (Fig. 49).

Damage: Stem decay and butt rot; decay is usually confined to the butt (first 40 ft.) of affected trees. Failure potential depends on the amount of sound wood shell thickness (Table 2).

Figure 48. Decay caused by cedar brown pocket rot shown in lengthwise- (left) and cross-sections (right).

Figure 49. Crust-like fruiting of Postia sericeomollis *on western redcedar.*

Conifers: Red Heart Rot (Bleeding *Stereum*)

Caused by *Stereum sanguinolentum*

Hosts: Conifers

Identification:

- **Decay**: Early decay appears as a red-brown heartwood stain. Advanced decay is light-brown and soft, and thin mycelial felts may be present.
- **Fruiting bodies:** Numerous, leathery, gray to light-brown, with a lower surface that is wrinkled and turns red when bruised. Found on infected wounds of live trees and on the bark of dead trees (Fig. 50).

Figure 50. Red staining caused by bruising the conk of a bleeding stereum, Stereum sanguinolentum.

FAILURE POTENTIAL (FP) RATING

FP4: **Any tree species:** ≥1 conks **WITH** open cracks or exposed rot.

FP3: **True fir, hemlock, spruce, hardwoods:** ≥1 conks **WITHOUT** open cracks or exposed rot. **Douglas-fir, pine, redcedar, or larch:** ≥3 conks ≥6" wide within a 3' portion of bole **WITHOUT** open cracks or exposed rot.

FP2: **Douglas-fir, pine, cedar, larch:** <3 conks.

Conifers: Red Ring Rot or White Speck (Pini Conk)

Caused by *Porodaedalea (Phellinus) pini*

Hosts: Conifers: Douglas-fir, western larch, Engelmann spruce, and pines are the most common hosts.

Identification:

- **Decay**: White pocket rot (Fig. 51) that occurs in rings separated by sound wood until decay becomes very advanced (very soft and crumbly).
- **Fruiting bodies:** Irregular hoof-shaped conks are often formed at knots or below branch stubs (Fig. 52). Conk interior and pore surfaces on underside are cinnamon-brown to tan with irregular pores. Also commonly forms "punk knots": lumps of cinnamon-brown fungal tissue. Punk knots and conks have equal value as indicators of decay.

Damage: Failure Potential depends on tree species, number and size of conks per tree, and associated indications of extensive decay such as open cracks or weeping frost cracks (Table 1). If sound wood shell is being determined, core at location of conks when possible.

FAILURE POTENTIAL (FP) RATING

FP4: ≥2 conks ≥6" wide WITHOUT visible cracks or decay; OR any conk ≥6" wide or ≥2 conks <6" AND visible cracks or decay.

FP3: Only 1 conk, ≥6" wide or ≥2 conks <6" **WITHOUT** visible cracks or decay.

FP2: Only 1 conk, <6" **WITHOUT** visible cracks or decay.

Figure 51. White pocket rot caused by Porodaedalea pini.

Figure 52. Porodaedalea pini *producing conks on conifer branch stubs.*

Conifers: Rust-red Stringy Rot (Indian Paint Fungus)

Caused by *Echinodontium tinctorium*

Hosts: True firs and hemlocks, rarely western larch

Identification:

- **Decay**: Tan and water-soaked at first, becoming a rust-red stringy rot that may result in nearly hollow stems (Fig. 53).
- **Fruiting bodies:** Woody conks with a dark brown or black upper surface and a gray, toothed underside (Fig. 54). Conk interior is rusty-red to bright orange-red (Fig. 54). Conks typically develop under dead branches, stubs, or knotholes.
- **Punk knots:** Filled with brick-red tissue.

FAILURE POTENTIAL (FP) RATING

FP4: ≥1 conk(s).

FP3: ≥1 conk(s) but still retaining sound wood shell over guidelines (Table2).

Damage: One conk often indicates enough decay for **FP4**. If trees are cored, amount of sound wood shell will only be accurate at the location of conks or for trees with no conks, at wounds or where closely-spaced branch whorls indicate suppressed growth during tree development.

Figure 53. Stringy decay from Echinodontium tinctorium *in a broken grand fir bole.*

Figure 54. Indian paint fungus conk, Echinodontium tinctorium*, emerges beneath branch stubs and indicates severe decay in grand fir. Its natural appearance is shown at left, and its red internal color is shown in a cross section at right.*

Sap Rots of Conifers

Sap rots are decays that occur in the sapwood. Most sap-rotting fungi cause rapid decay of dead sapwood only. In living trees, sap rots occur on wood tissue killed by other agents, most often bark beetles and mechanical or weather damage (Fig. 55). On dead trees, especially those killed by root diseases and/or bark beetles, sap rot is sure to occur, and the rate of sapwood decay can be rapid (Fig. 56).

Figure 55. Sap rot on standing live tree with a section of dead wood.

Figure 56. Decayed sapwood, cross section.

FAILURE POTENTIAL (FP) RATING

FP4: Dead trees with conks.

FP3: **Live trees** with conks and/or other indicators of sap rot on >25% of the stem.

FP2: **Live trees** with only 1 or 2 conks and/or other indicators of sap rot on <25% of the stem.

Conifers: Brown Crumbly Rot (Red-Belt Fungus)

Caused by *Fomitopsis pinicola*

Hosts: Conifers and hardwoods

Identification:

- **Decay**: Early decay is a faint yellow-brown to brown stain. Advanced decay is red-brown and cubical with white mycelial felts between the cracks.
- **Fruiting bodies:** Woody bracket-shaped conk with a dark-gray to black upper surface and a conspicuous red band near the margin, white under surface, (Figs. 57 & 58). Young conks appear white and round.

Damage: Causes sapwood and heartwood decay of dead trees but sometimes found in butt of very old living conifers, particularly spruce. Live trees with >1 conks may have **FP2 or FP3** depending on the extent of decay (Table 1). Dead trees have **FP4**.

FAILURE POTENTIAL (FP) RATING

FP4: >1 conks.

FP3: 1 conk, decay extensive.

FP2: 1 conk, decay less extensive, sound wood shell over thresholds (Table 2).

Figure 57. Conk of the red belt fungus, Fomitopsis pinicola, *in a dead part of a living tree.*

Figure 58. Brown rot with fungus mycelium layers caused by red belt fungus; conk is at lower right.

Conifers: Gray-brown Sap Rot (Pouch Fungus)

Caused by *Cryptoporus volvatus*

Hosts: Conifers killed or attacked by insects

Identification:

- **Decay**: Gray areas develop in the sapwood beneath the conks. Advanced decay may completely destroy the sapwood in dead parts of trees.
- **Fruiting bodies:** Small, rounded, leathery conk with pore layer in an internal chamber initially covered by a thin membrane that develops a hole over time. Conks develop in trees that were attacked the previous year, are tan their first year, fading to white (Fig. 59).

Damage: Rapid decay of sapwood in bark beetle-attacked trees. Trees attacked by bark beetles with more than 50% of the bole circumference attacked should be considered dead. Dead trees have **FP4**. Trees with strip attacks on less than 50% of the bole may be **FP2** or **FP3** depending on the portion of the stem killed (Table 1).

FAILURE POTENTIAL (FP) RATING

FP4: Dead trees with sap-rot conks.

FP3: Strip attacked trees with 25-50% of the circumference damage AND substantial decay.

FP2: Trees with narrow (less than 25%) of the circumference killed.

*Figure 59. Pouch fungus (*Cryptoporus volvatus*) indicates successful insect attack of conifers and causes sapwood decay. On the grand fir at left, past strip attacks are shown by dark vertical ridges. At right, the tan color indicates fresh pouch fungus conks and attack by bark beetles the previous year. Also, the split conk shows the fruiting bodies' internal structure and fungal colonization in the sapwood near visible insect galleries.*

Canker Diseases, General Information

Canker diseases, also called stem cankers, kill bark and cambium and result in dead bark patches. The fungi that cause canker diseases often enter through various stem wounds or insect damage. Most canker fungi do not penetrate far into wood, but the dead patches they cause can serve as an entry for stem decays or wood boring insects. Aggressive canker diseases can rapidly kill stems and have a flat appearance, while cankers that colonize host tissue slowly can be surrounded by ridges of callous wood laid down as a host defense, which can cause stems to bend or distort. Both decay and distortion create weak spots where stems and branches can fail. Some canker diseases are more prevalent and damaging when a host tree species is under environmental stress. The end result of this dynamic interaction between host and pathogen is a spectrum of damage ranging from tree death to relatively small wounds on the stem.

FAILURE POTENTIAL (FP) RATING

FP4: If the tree is killed by the canker.

FP3: For most canker diseases, if more than 1/2 of the circumference of the stem is killed.

FP2: If less than 1/2 of the stem circumference is killed by the canker.

General symptoms and indicators:

- Localized, flat to sunken, sometimes discolored areas on the bark of twigs, branches, or trunks.
- If the disease kills the cambium all the way around the stem, the stem is girdled, resulting in death above the canker.

Cankers come in 3 categories, with some overlap between categories:

Annual: Damage is associated with wounds, damage limited to the year of infection.

Target: Damage is over several years and degree of damage depends on the defensive reactions of the host which limit canker expansion. Pattern of annual growth of the pathogen and callus production by the host result in concentric ridges (Fig. 60).

Diffuse: Damage is rapid, in some cases killing the host by girdling within a few years (Fig. 61).

Figure 60. A slowly expanding ("target"-type) canker on aspen. The pathogen and the host tree have interacted many times over decades forming multiple ridges of callous tissue. Photo Credit Tom Zegler.

Figure 61. A quickly expanding (diffuse-type) canker on aspen. The entire canker developed within 1 year. Photo Credit Tom Zegler.

Hardwoods: Sooty Bark Canker

Caused by *Encoelia pruinosa*

Hosts: Primarily aspen, but found in cottonwood

Identification: Cankers are uncommon in stands under 60 years of age. Cankers develop rapidly, extending as much as 3 feet in length and 1 foot in width in a year. Young cankers first appear on the bark as sunken oval areas. The bark killed by the fungus will begin to slough after 2 or 3 years, exposing blackened inner bark. This dead inner bark is easily crumbled in the hand to a soot-like residue that is the origin of the common name of this canker (Fig. 62).

- **Crown symptoms**: Usually none, but near-girdling of stems by cankers can lead to dieback and decline of crowns.
- **Bole symptom 1**: Death of the cambium with blackened bark (Fig. 62); in aspen the canker begins as a small, sunken, oval patch of dead bark.
- **Bole symptom 2**: Each year's canker growth typically has an alternation of light and dark, mottled zones.
- **Bole Symptom 3**: On older cankers, you can often see the pattern of canker expansion as alternating black and white stripes.

Damage: This disease is the most aggressive tree-killing canker of aspen.

FAILURE POTENTIAL (FP) RATING

FP4: If the tree is killed by the canker.

FP3: If more than 1/2 of the circumference of the stem is killed.

FP2: If less than 1/2 of the stem circumference is killed by the canker.

*Figure 62. Sooty bark canker (*Encoelia pruinosa*) with characteristic mottling on aspen. Trees may be killed quickly (left) or survive as defective trees (right). Photo credit Tom Zegler.*

Hardwoods: Snake (Cryptosphaeria) Canker-rot

Caused by the organism *Cryptosphaeria populina* on aspen and *C. pullmanesis* on cottonwoods.

Hosts: Primarily aspen and other species in the tree genus Populus.

Identification: This canker disease causes branch, sprout, and sapling mortality, trunk cankers, and discoloration and decay of aspen stems. This disease is called a canker-rot because it is capable of both causing a canker by killing the cambium, and decaying the wood like a stem decay. It's also commonly associated with other decay organisms like white trunk rot and is commonly associated and confused with Cytospora canker, especially on young trees. Snake canker is commonly long and narrow, spiraling around the tree like a snake, hence its common name (Fig. 63). Bark near canker edges can become discolored light brown to orange. The dead, black, stringy, soot-like bark adheres tightly to the sapwood and contains small, scattered, lens-shaped, light-colored areas.

- **Crown symptoms**: Usually none, but near-girdling cankers can lead to dieback and decline of crowns.
- **Bole symptoms**: Often will form a narrow canker visible on the surface which kills a narrow strip of dead cambium and twists around the tree (Fig. 63). Internally, this canker-rot causes decay, necrosis and wood staining.

Damage: Extensive decay and discoloration in the wood is associated with external cankers.

FAILURE POTENTIAL (FP) RATING

FP4: Less than 20% sound shell OR less than 50% of the circumference alive.

FP3: Tree with substantial canker(s), but greater than 20% sound wood shell and over 50% live cambium.

FP2: If less than 1/3 of the stem circumference is killed by the canker and greater than 25% sound wood shell is present.

Figure 63. Cryptosphaeria (Snake) canker rot on aspen.

Hardwoods: Hypoxylon Canker

Caused by *Entoleuca* (*Hypoxylon*) *mammata.*

Hosts: Primarily aspen, but alders, cottonwoods and willows can become infected.

Identification: Hypoxylon causes cankers on all tree size classes, typically when trees are stressed, but is fairly rare in Northern Rocky Mountain and Intermountain forests. The canker surface is mottled, and outer bark is raised in blister-like patches containing fungal fruiting bodies (Fig. 64), and sloughs off exposing the blackened crumbling cortex. Old cankers may be several feet long and are rough and blackened at the center (Fig. 65) and yellowish-orange at the newly invaded margins.

- **Crown symptoms**: Usually none, but larger cankers lead to dieback and decline of crowns.
- **Bole symptoms**: Death of the cambium with discolored bark, in aspen the bark can turn orange as the cambium dies. Dead bark typically has a mottled checkerboard type pattern.

Damage: The disease is often found associated with wounds and other damage.

FAILURE POTENTIAL (FP) RATING

FP4: If the tree is killed by the canker.

FP3: If more than 1/2 of the circumference of the stem is killed by the canker.

FP2: If less than 1/2 of the stem circumference is killed by the canker.

*Figure 64. Typical fruiting bodies of Hypoxylon canker (*Hypoxylon mammatum*) on aspen. Photo credit James Worrall.*

Figure 65. Typical Hypoxylon canker damage on aspen. Photo credit James Worrall.

Hardwoods: Black canker

Caused by *Ceratocyctis fimbriata*.

Hosts: Primarily aspen.

Identification: This pathogen is fairly slow growing and colonizes host cambium fairly slowly, so the host tree has time to react to colonization by forming callous tissue around canker edges. The result is often an elaborate target-type canker with highly deformed, black callous ridges surrounding the dead center (Figs. 66 & 67).

- **Crown symptoms:** Usually none, but larger cankers can lead to dieback and decline of crowns.
- **Bole symptoms:** Death of the cambium and tree death from girdling can occur. More commonly, living trees have highly deformed cankers with margins that blacken over time.

Damage: The most common damage associated with this disease is stem breakage due to stem weakening caused by the highly deformed area caused by host reaction to the disease.

FAILURE POTENTIAL (FP) RATING

FP4: If the tree is killed by the canker.

FP3: If more than 1/2 of the circumference of the stem is killed.

FP2: If less than 1/2 of the stem circumference is killed by the canker.

*Figure 66. Defects caused by multiple black cankers of (*Ceratocystis*) of aspen. Photo Credit Tom Zegler.*

Figure 67. Close-up showing target-like rings of canker development for black canker of aspen. Photo Credit Tom Zegler.

Conifers: Atropellis Canker

Caused by *Atropellis piniphila* and *A. pinicola*.

Hosts: *A. piniphila*: lodgepole pine; and A. *pinicola:* a number of species, predominantly white pines.

Identification: Both species cause a vertically elongated canker on all size classes of trees. This canker does not commonly girdle trees, but can lead to a structural weak spot. Damage is more severe on small trees.

- **Crown symptoms:** Usually none, but larger cankers can lead to dieback and decline of crowns.
- **Bole symptoms:** A vertically elongated canker, typically sunken and resinous. The wood under the canker typically is stained blue to black (Fig. 68).
- **Fruiting bodies:** Tiny (1/32 in. to 1/16 in. diameter), black, cup-shaped fruiting bodies are usually present on older cankers.

Damage: Can cause a structural weak spot at the canker, and can rarely girdle or nearly girdle trees. Infected trees can be evaluated by circumference damage guidelines.

FAILURE POTENTIAL (FP) RATING

FP4: If the tree is killed by the canker.

FP3: If more than 1/2 of the circumference of the stem is killed.

FP2: If less than 1/2 of the stem circumference is killed by the canker.

*Figure 68. Elongated, sunken Atropellis canker (*Atropellis piniphila*) with diagnostic black wood stain on lodgepole pine.*

Conifers: Western Gall Rust

Caused by *Endocronartium harknessii* and occurs west-wide.

Hosts: Lodgepole, Jeffrey and ponderosa pines

Identification: The disease causes galling on branches and small stems and slowly expanding cankers on larger stems. Sporulation typically occurs in June from gold-colored spore-producing surfaces under the bark at the edges of galls or cankers (Fig. 68).

- **Crown symptoms:** Branch flagging, bole breakage, top-kill, and mortality of young trees.
- **Bole and branch symptoms:** The galls are rounded swellings on branches and boles. "Hip cankers" form when the main stem flattens and broadens as it grows at bole infections (Fig. 69).

Damage: "Hip cankers" that develop on trees with main-stem galls increase trees' Failure Potential as more of the stems' circumference is killed or flattened.

FAILURE POTENTIAL (FP) RATING

FP4: If the tree is killed by the canker.

FP3: If more than 1/2 of the circumference of the stem is killed.

FP2: If less than 1/2 of the stem circumference is killed by the canker.

Other Stem Rust Diseases: Other stem rust diseases (e.g. white pine blister rust) can cause branch or stem cankers, bole girdling, and tree death. Infections are most apparent when branches or boles have been girdled and red needles are retained, or when resin is abundant on the tree surface. Infections can also cause stem deformations like galls or swollen irregular cankers that act as structurally weak areas of affected stems. For trees with top-kill, Failure Potential of killed parts depends on bole diameter at the site of girdling. Tree mortality caused by rust has **FP4**.

Figure 69. Western Gall rust caused a flattened "hip canker" on lodgepole pine. Stem flattening and decay at bole cankers increase Failure Potential. The production of orange spores and swelling at right is typical of gall rust.

All Trees, Bole Cracks and Splits

Cause: Load from wind, snow, and any defects in structural form (lean, bends and twists, eccentric canopy, high height to diameter ratio); temperature changes with freezing; and lightning strikes. Variants are listed below. These openings to the wood can allow entry of decay fungi and increase failure potential.

Tension and Compression Failure, Limbs

Identification: Vertical or horizontal cracks in the bole, often where decay is extensive, where fibers of the wood appear folded on one side of the failure, and pulled straight apart by tension on the other (Figs. 70 & 71).

Figure 70. Tension and compression branch failure. On the right side of this branch, fibers are folded from compression; at left, tension caused fibers to pull apart and splinter.

Figure 71. Tension and compression failure of a large whitebark pine branch. The branch to the right side of the picture was heavily loaded with snow when the branch failure occurred.

FAILURE POTENTIAL (FP) RATING

FP4: Structural failure cracks OR if <20% sound wood shell.

FP3: Significant cracks without movement AND 20-30% sound wood shell.

FP2: Small shallow cracks OR partially callus sealed cracks (e.g. frost cracks) AND >30% sound wood shell.

Lightning Strikes

Cause: Electric current seeking the path of least resistance from a strike point in the crown to the ground, often by a mix of conduction on wet bark and through the moist cambium and sapwood. Vaporized water expands and creates cracks (Fig. 72).

Factors contributing to failure: High elevation and exposed ridges.

Identification:

- Shallow spiraling furrows that just penetrate the bark.
- Cracks and blown-out strips that may be several inches wide and penetrate deeply into the wood.
- Occasionally, entire trees or portions will be shattered, severely cracked, or split.

Cracks from Wind and Wind Shake

Cause: Stress from high wind affecting the bole. Frequent high winds contribute to development of wind shake (separation of wood along growth rings) in the lowest section of the butt.

Factors contributing to failure: Frequent winds, trees growing at higher elevations or exposed locations.

Identification: Surface cracks, sometimes hidden by resin in resinous species. For shake, twisting of the tree in the wind causes separations to develop, initially along growth rings, later extending radially outward, breaching the bark and becoming visible. Surface cracks from shake (Fig. 73) are difficult to distinguish from other surface cracks.

Frost Cracks

Cause: Wood at different depths expands and shrinks at different rates as temperatures change during extreme cold weather (Fig. 74).

Factors contributing to failure: High elevation and cold air drainages.

Identification:

- Frost cracks appear as long, raised, nearly vertical callus lines that may extend to the ground.
- Frost cracks often begin from an old wound, and seldom go higher than 15 feet up the bole (Fig. 74).
- Older frost cracks develop "frost ribs", a series of raised vertical ridges of callus tissue parallel to the frost cracks themselves.

Figure 72. Shallow, spiral scar caused by lightning on the upper bole of a Douglas-fir.

Figure 73. Ridges of old resin indicated four wind shake cracks that reached the surface in this leaning Douglas-fir.

Figure 74. Bark has grown over a surface frost crack in this grand fir.

Structural Failure Cracks, Main Bole

A structural failure crack is defined as a deep crack indicating that critical wood supporting a tree or branch has failed or is about to fail. These cracks are typically deep, and may be associated with other wood failure indicators such as compressed or separated wood fibers (Figs. 70 & 71, 75), cracks that go across instead of along the grain, excessive lean, and wood on the opposite sides of the crack moving independantly of each other by slipping past each other or the crack widening and compressing in wind (Figs. 75 & 76). Cracks can be associated with internal decay which has weakened the stems, but can also be found on non-defective wood that has experienced overwhelming physical load from gale force winds or sudden physical shock from another tree. Recent structural failure cracks are indicated by the lack of ridges of callus "wound response" wood (Figs. 75-77).

Figure 75. Recent trunk crack after high wind. The crack is deep, and the lengthwise split and some cross-grain splintering at the recent bend indicate structural failure (FP4).

Figure 76. Western redcedar with cracks, cause unknown.

Figure 77. The sides of this deep crack move independently past each other, indicating high failure potential (FP 4).

Forked Multiple Tops or Trunks (Conifers)

Cause: In conifers, loss of a leader, leader bud, or tree top often causes more than one side branch to grow upward and vie for dominance. In hardwoods, multiple tops develop from growth of adventitious buds after loss of leaders or branches, or in some fork-prone species, from multiple, closely spaced buds at the tips of the leaders.

Factors contributing to failure: Forked tops or trunks with crotches that are tightly V-shaped— having a narrow angle between stems— can split and break from foliage and branch weight, snow or ice loads, or wind. Internal decay at the fork increases the potential for failure under load.

Identification:

- Forked tops or trunks with crotches that are tightly V-shaped (Figs. 78 & 79).
- Multiple tops originating from a broken top with 3 or more stems, some with tight branch angles (Fig. 80).

FAILURE POTENTIAL (FP) RATING

FP4: V-shaped forks **WITH** embedded bark **AND** open cracks **OR** cracks on opposite sides, **OR** v- forks with substantial decay, or a conk.

FP3: V-shaped forks **WITH** embedded bark **AND** at most a minor crack but **NO** visible decay or conks.

FP2: Forks without embedded bark and **NO** visible vertical cracks, decay, or conks.

Figure 78. Broken-out stem from a "V-fork" in a Jeffrey pine. Old sap and decay indicate a crack was present for years.

Figure 79. The remaining stem of the failed "V-fork" in Fig. 78. Failure potential of the surviving top remains high from decay, outward bend, and flattened cross-section where the failure occurred.

Figure 80. Multiple tops that develop after a top-break can be weak due to their off-center structure or to a column of decay starting at the break.

Dead Tops (Conifers)

Dead tops in non-resinous conifers such as grand fir should be regarded to have nearly as **high a Failure Potential** as dead trees, but resinous conifers such as pines and cedars can retain dead tops for a considerable period, depending upon associated defects. Due to the spreading nature of hardwood crowns, Failure Potential for dead hardwood tops can be assessed using criteria for defective branches.

Cause: Dead tops can have many causes, including the top-killing insects fir engraver beetle and *Ips* (engraver) beetles (Fig. 81), dwarf mistletoe, canker diseases, rust diseases, drought stress, and combinations of factors (Fig. 82).

Factors contributing to failure: Decay or signs of structural failure (cracks, decay conks, leaning) near the base of the dead section.

Identification:

- Open cracks or other signs of structural weakening at the base of the dead top.
- Decay conks at the base of the dead top.
- New branches from sites where the original top died, particularly those with cracks or decay signs.

FAILURE POTENTIAL (FP) RATING

FP4: Tops ≥3” diam. with signs of decay or other defects, or if already detached.

FP3: Dead tops in aspen, cottonwoods and large birches or non-resinous conifers >3” diam. without decay or other defects.

FP2: Dead tops <3” diam., or >3” diam. in resinous species.

Figure 81. Approximately 30 foot tall dead top in a ponderosa pine.

Figure 82. Dead top on living Douglas-fir (Approximately 10 feet tall).

Dead or Defective Branches

Defective branches:
Many hardwood species, especially poplars, cottonwoods, maples, and alders are more susceptible to branch failure than most conifers due to hardwoods' lower resistance of branches to decay and frequent occurrence of weak, narrow angles between branches. In contrast, most conifer branches are resinous and nearly at right angles from the boles. Also, long hardwood branches can be heavily weighted with foliage and fruit during the growing season. Early and late season wet snows, when foliage is present, also weigh down branches and tops causing breakage. Once damaged, poplars, cottonwoods, and birches are particularly likely to develop weaknesses and breakage because decay in these species can move outward and consume living sapwood (see description of canker rots in section on decay), rather than being restricted to within a sound wood shell as in most other hardwoods.

Identification:

- Open cracks or splits.
- Resin/sap flow from the defective branch base.
- Embedded bark (bark inclusions).
- New branches formed at the sites of old branch failures.
- Evidence of decay fungi.

FAILURE POTENTIAL (FP) RATING

FP4: Branches ≥3" diam. that are dead **OR** live with indicators of past breaks and decay.

FP3: Live branches ≥3" diam. with evidence of past **breakage** but **no decay indicators**.

FP2: Live branches ≥3" diam. **without breakage or decay indicators**.

Branch Brooms (Conifers)

Branch brooms, or "witches brooms", are defined as dense branching, and are usually caused by infection. They are mostly caused by dwarf mistletoes, broom rusts, or Elytroderma needle disease. In areas with high snow loading or severe winter storms, large brooms can break off in winter storms due to snow and ice load and wind. Breakage from dwarf mistletoe occurs most commonly in Douglas-firs and sometimes on lodgepole and ponderosa pines. Brooms from broom rusts are on true firs and spruce. Elytroderma needle disease is mostly on ponderosa pine.

Cause: Parasitic plants and fungi cause branches of some tree species to produce many more branches than normal.

Factors contributing to failure: Snow and ice loading.

Identification: Deformed branches with unusually dense branching (Fig. 83).

Figure 83. Living dwarf mistletoe brooms in Douglas-fir.

FAILURE POTENTIAL (FP) RATING

FP4: Douglas-fir with large (≥10' diameter) **dead** brooms OR any species brooms with cracked branches.

FP3: Douglas-fir with small (<10' diameter) **dead** brooms OR other tree species with large, dead brooms.

FP2: Douglas-fir with large, live brooms OR other tree species with **dead** brooms <10' diameter.

Fire-Caused Damage

Fire may have consumed sufficient wood of tree boles, limbs, or roots to reduce strength and predispose them to break (Figs. 84 & 85).

Cause: Fire that has consumed wood or killed cambium.

Factors contributing to failure: Root disease or heart rot, bark beetles.

Identification:

- Loss of wood at base of bole or roots consumed.
- Wood char.

Dead cambium encircling the base of recently fire-damaged trees indicates a dead tree, even if crown still appears green. Methods for assessing post-fire survival for individual tree species can differ from the failure potential assessments presented here and are beyond the scope of this document.

FAILURE POTENTIAL (FP) RATING

FP4: Remaining sound wood of cross section is **<50%** of original **OR** structural roots damaged in **>1** quadrant, or with significant decay present (see Table 2).

FP3: **Species except cedar, ponderosa pine, and larch: remaining sound wood of cross section is 50-75% OR** structural roots damaged in **1** quadrant.

FP2: **Cedar, ponderosa pine, and larch:** bole cross section >50% sound wood; **other species**: sound wood remaining **>75%.**

Figure 84. Repeated fire damage to a ponderosa pine has caused little wood loss. If there is no decay in the interior wood, Failure Potential this tree would be FP2.

Figure 85. This ponderosa pine has lost >50% of its interior wood from repeated fires, and Failure Potential is FP4.

Height to Diameter Ratios

Live trees with a high height-to-diameter ratio (an index of slenderness) may affect a tree's Failure Potential rating.

Cause: Stem bending or breaking of tall, thin trees is most likely to occur after densely stocked stands or groups of trees are thinned.

Factors contributing to failure: Thin trees can break or bend permanently after trees with snow or ice load are exposed to wind, especially if dwarf mistletoe brooms are present. High wind causes sway in thin trees, especially those with green crowns concentrated at the tops of their boles. Thin trees with low growth increment have a low amount of sapwood—the portion of the wood that has the greatest strength to tension forces—and are more prone to break at mid-bole.

Identification: Determine height-to-diameter ratio: estimate the total tree height in feet and divide by the DBH measured in feet. For example, a tree 100 foot tall and 1 foot (12 in.). DBH would have a height-to-diameter ratio of 100.

FAILURE POTENTIAL (FP) RATING

FP4: H:D ratio **>100**.

FP3: H:D ratio **80 to 100**.

FP2: H:D ratio **60 to 80.**

Insect-caused Damage

Forest insects can weaken roots, stems, tops, or branches and allow entry of fungal spores that results in wood decay and physical degradation.

Cause: Insect attacks.

Factors contributing to failure: Wood decay and physical wood degradation.

Identification:

- Of insects, bark beetles cause most conifer mortality. Successful attacks are usually on trees with root disease, bole damage, defoliation, or water stress from drought or high stand density, but healthy trees can succumb during outbreaks. Successful attacks produce red boring dust (frass) or pitch with brown boring dust (Fig. 86) and later, galleries under the bark, along with pouch fungus, fading or red crowns, dead tops, and group mortality. Pitch streaming and white pitch tubes with beetles stuck in the pitch can mean unsuccessful attacks, called "pitching out".
- Ambrosia beetles in conifers colonize mostly dead wood, produce white frass, and can indicate internal decay (Fig. 87).
- Large globs of pitch indicate larvae of sequoia pitch moth feeding in the inner bark and cambium, often at branch whorls or galls. This feeding rarely causes permanent damage or mortality so such pitch globs do not indicate increased failure potential.
- Carpenter ants and termites colonize and further weaken trees that are already decayed (Fig. 88).
- Wood borers primarily colonize dead trees, but can attack weak living trees. Their boring into sapwood or heartwood can significantly lower tree's structural integrity even prior to fungus colonization.

FAILURE POTENTIAL (FP) RATING

FP4: If >50% of the bole circumference has red boring dust or pitch, tree should be considered dead regardless of foliage condition.

FP3: If <50% of the bole circumference is affected, the tree is considered to have a "strip attack" and needs further monitoring.

FP2: Bark beetles only successfully attacked at one or no points OR tree only has sequoia pitch moth attacks.

Figure 86. Red bark beetle boring dust.
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Figure 87. White ambrosia beetle frass.

Figure 88. Carpenter ants in decayed wood.

Interacting Indicators (Multiple Defects)

The potential for tree failure increases dramatically with the combined effects of multiple defects.

In the case of multiple indicators, one condition (indicator) often contributes to Failure Potential of another; one weakness enhances another.

Some examples of multiple defects that indicate increased potential for failure are:

- V-forks with decay (Fig. 89).
- Heart rot and cankers, stem injury, or saprot, often with an opening (Fig. 90).
- Root rot in a leaning tree.
- Butt rot in a tree with ring separation (shake).
- Leaning trees with external hollows and internal decay (Fig. 91).

FAILURE POTENTIAL (FP) RATING

FP4: Two or more interacting **medium-FP (FP3)** indicators.

FP3: Two or more interacting **low-FP (FP2)** indicators.

FP2: Two or more interacting **very low-FP (FP1)** indicators.

Figure 89. In this aspen, weakness from crack and decay (indicated by conks) at a "V-fork" interact, so Failure Potential is higher than for the separate defects.

Figure 90. Multiple defects: Including a large wound and visible decay.

Figure 91. Multiple defects. Lean, decay, and crack all interact to weaken this tree.

Glossary

Abiotic – non-living parts of the ecosystem such as soil particles, bedrock, fire, air, or water.

Azimuth – a compass reading of 0 to 359^0, usually adjusted for declination, i.e. variation from magnetic north.

Bark beetles – beetles that bore and feed between bark and sapwood as larvae and as adults.

Basal wound – a wound at the base of a tree.

Biotic – pertaining to the living parts of the ecosystem such as animals, plants, fungi, or insects.

Bole – a trunk or main stem of a tree.

Branch flagging – a dead branch on a live tree with dying or dead foliage attached.

Branch stub – the remnant of a tree branch after it breaks off near the trunk.

Branch whorl – a set of branches that developed from one node on a tree.

Branchlet – a small branch or twig.

Broom or **witches' broom –** an abnormally dense cluster of branches associated with infection by a dwarf mistletoe, rust fungus, genetic aberration, or other insect or disease.

Butt – the base and widest part of a tree stem or bole.

Butt rot – decay developing in and confined to the butt; originating at basal wounds or soil line or entering through roots.

Callus – tissue (wound wood) produced at the edge of wound sites on bole or branches in response to injury; callus may or may not grow to seal an injured area.

Canker – an area of diseased tissue, typically longer than wider and often sunken, on a living stem, branch or root.

Check – a longitudinal fissure in wood resulting from stresses that caused wood fibers to separate along the grain.

Chlorosis/Chlorotic – an abnormal yellowing of foliage.

Codominant stems – two tree stems of equal size that are joined at the base or partway up the bole.

Conk – a shelf-like, usually tough-textured reproductive structure formed by many wood decay fungi; also called a sporophore or fruiting body.

Crook – an abrupt bend in a tree or log.

Crotch – an area in a tree where stems or larger branches diverge.

Crown – the upper part of any tree carrying the main branches and foliage.

Cubical decay – decayed wood that breaks into distinct brown, crumbly cubes.

DBH – diameter of a tree at breast height; a standard at 4.5 feet above the ground on the uphill side of any tree.

Damage potential -- the potential that property damage, injury, or death may result from a tree or tree part failure.

Decay – degradation or decomposition of wood by fungi and other microorganisms resulting in the progressive loss of integrity and strength of affected parts; degree is described as incipient (not yet apparent except by staining), early or advanced.

Defect – any feature, fault, or flaw that lowers the strength, integrity, or utility of an affected part.

Developed recreation site – According to Forest Service Manual, a recreation site that has a development scale of 3, 4, or 5. The numbers refer to degree of development with 5 being most developed.

Disease – a prolonged disturbance of the normal form or function of a tree or its parts.

Distal – away from the point of attachment (e.g. tip of a branch).

Distress cone crops – production of an unusually high number of cones by trees stressed in the current or previous year. The most common stressing agents associated with this condition are drought and root disease. Stress cone crops occasionally add so much weight to a canopy that branches or upper stems break in even mild winds.

Drip line – the maximum radial extent of a tree crown projected to the ground.

Duff – partially decomposed organic material on the forest floor beneath the litter of freshly fallen twigs, needles, and leaves.

Dwarf mistletoe – a parasitic flowering plant that develops extensive absorption systems in the xylem tissue of conifers and derives most of its water and nourishment from the host.

Ectotrophic mycelium – fungal layer, usually white to cream-colored, produced by certain root pathogens on the bark surface of living roots, to cause disease (laminated root disease, Heterobasidion (annosus) root disease, tomentosus root disease).

Embedded bark (bark inclusions) – bark that has formed between parallel, appressed branches or trunk stems in a tree fork. Embedded bark has wood on two sides, and may be interrupted at its edges by at least partial wood grafting of the adjacent stems or branches. As the tree continues growing, the bark inclusion will be a weak spot where splitting can start, and often, will act as a wedge as more wood and bark is deposited.

Failure – partial or total breakage or collapse of a tree or tree part.

Failure potential - the potential that a tree or tree part may fail within the time period before reassessment.

Frost crack – splitting of the outer bark and sapwood that occurs in the trunks of trees subjected to extreme cold. Such fissures follow the grain and are usually superficial and may be called bleeding or weeping cracks if exudates are apparent.

Fruiting body – a conk, mushroom, or other fungal reproductive structure.

Gall – a pronounced swelling or tumor-like structure a tree may produce when parasitized by certain fungi or bacteria, infested by gall-forming insects, or in response to other environmental stimuli.

Hazard – the recognized potential that a tree or tree part may fail and cause injury or damage by striking a target.

Heart rot – decay usually restricted to the heartwood in living trees.

Heartwood – the inner, nonliving part of a tree stem that has been altered to be less prone to decay as a result of normal, physiological processes and which provides structural support, especially for compression forces.

Incipient decay – very early stages of wood decay.

Laminated decay – wood that has separated into sheets along annual rings (delaminated); a typical symptom of some forms of root and butt rot disease (laminated root disease, Heterobasidion (annosus) root disease).

Mitigation – actions that may be taken to reduce, minimize, or eliminate the potential risk posed by a tree hazard.

Mycelial fan – a mass of fungal tissue that grows under the bark of infected roots and butts and has a fan-like shape; a typical sign of Armillaria root disease.

Mycelial felt – a dense and expansive sheet of fungal tissue formed by some decay fungi between layers of decayed wood.

Necrosis – death of a plant or a plant part; usually referring to localized death of living tissues of a host.

Pitch tubes – tubular masses of resin that form on the surface of the bark at the entrance holes of bark beetles.

Potential Impact Zone (PIZ) – the area that a tree or its parts could normally reach after failure.

Pruning – the removal of live or dead side branches or removal of codominant or multiple leaders to restore a single dominant leader; preferred method for pruning live branches is to make a final cut just beyond the branch collar to speed sealing of open wound by callus.

Punk knot or swollen knot – a protruding knot of a tree with heart rot in which abundant, non-sporulating fungus tissue has kept the surface from becoming fully encased ("sealed over") by bark. Punk knots can resembles either normal bark or the interior tissue of normal spore-producing conks of the colonizing fungus.

Resin – aromatic secretions, sticky when fresh, of certain trees, especially conifers; substance generally associated with tree resistance to fungi and insects; also called pitch.

Resinosis – reaction of a tree to invasion by pathogens, insects, or abiotic injury which results in flow of resin on outer bark or accumulation of resin within or under bark.

Risk – the possibility, exposure, or chance of damage, injury or loss; for trees, relative risk is estimated as a combination of its potential for failure, and potentials that a target will be present and be damaged if failure occurs.

Root-sprung – the condition of a tree with a root system that has failed or is failing, as shown by portions of the root wad that are physically lifted above their normal plane; due to major roots breaking, slipping through water-logged soil, or having decayed. Roots that have pulled out may appear to have "sprung out of the ground"—are "sprung".

Rust or rust fungus – term used for a particular group of diseases or the fungi that cause them, which often have one or more visible, orange-to-red colored spore types; those important for tree hazards include gall and stem rusts.

Saprophyte – an organism that lives on dead organic matter.

Sap rot – rapid wood decay of dead sapwood portions of a tree or branch by decay fungi.

Sapwood – the outer wood layers beneath the bark that conduct water up living trees and provide strength for a tree to resist tension forces.

Setal hyphae – thick-walled, reddish-brown fungal filaments that can be seen microscopically to taper to stubble-like points, but are visible to the eye as a fine growth between layers of advanced laminated decay caused by laminated root rot.

Shake – internal separation either along growth rings or radially, originating deep in the heartwood; a physical defect of trees caused by exposure to high winds or in western hemlock, from years of poor growth and wetwood, especially in trees over 100 years old. Shake is of most concern when deep longitudinal radial fissures erupt externally in the butt log portion of a tree. Growth ring separations do not commonly show external fissures.

Snag – a standing dead tree that is more than 20 feet tall.

Sound wood –the remaining wood, not affected by any wood deterioration or damage.

Sound wood shell - the remaining wood surrounding internal wood deterioration or damage

Stem – the main trunk or central stalk of a plant; also called a bole in trees.

Structural roots – major tree roots that provide significant support for a standing tree.

Symptoms (symptomatic) – the outward manifestations of disease in a host such as chlorotic foliage, dead branches or tops, or dead trees.

Target – person or object within striking distance (the Potential Impact Zone) of a tree or its parts.

Target value – the value given to a tree based on its proximity to people and property.

Topping – practice in which large branches are pruned between nodes to remove a tree's upper crown and reduce its height; practice promotes decay and poor architecture and is not recommended.

Undermined roots – roots that are no longer firmly anchored due to removal or loss of their surrounding soil.

Wind shake – a separation along the grain in a tree stem caused by wind stress.

Wind throw – a tree that has been uprooted by wind at the roots, soil line, or butt; though the term attributes failure to excessive wind, roots and bole of wind-thrown trees may include contributing damage or decay, as from construction, heart rot, or root and butt disease.

Wind shatter – a tree that has fallen to the ground as a result of a break above the butt due to excessive wind or perhaps due to a decayed stem.

Witches' broom – see broom.

Wood boring insects – insects that feed in the sap wood and heart wood of trees. Common insects are in the Families: Cerambycidae (rounded borers, longhorned beetles), Buprestidae (flatheaded borers, metalic wood beetles) and Siricidae (wood wasps) and Curculionidae: Scolytinae and Platypodinae (Ambrosia beetles).

Wound – an injury that usually breaks the bark of branches, stems, or roots of a tree and serves as a possible entry point for fungi. Old wounds may become sealed with new bark and eventually become hidden. Scars are wounds that have been sealed by callus (wound wood).

Appendix. Field Form and Instructions

Data Collection Fields

The list below shows types of data used for determining hazard and recording management decisions and completion. These could be collected using a paper form or by direct entry into an electronic database format.

1. Site name
2. Date of survey
3. Name of recorder(s)/examiner(s)
4. Tree tag number
5. Tree species
6. Tree DBH
7. Tree height
8. Height to defect(s) or conk(s) (if present)
9. Symptoms and signs of root or butt disease (resinosis, conks, thin crown, cracks)
10. Thickness of remaining sound wood shell
11. Cause of root disease or root and butt rot if known *(Phellinus sulphurascens, Armillaria* spp., *Phaeolus schweinitzii*, etc.)
12. Stem defects (conks, decay, mechanical injury, fire damage, frost crack, dead top, etc.)
13. Stem decay cause if known (*Porodaedalea pini, Fomitopsis officinalis,* etc.)
14. Scores for Failure Potential, Damage Potential, and Target Value
15. Recommended action
16. Date action was accomplished

Recommended Tools

1. Forms and instructions
2. Tatum, pencils
3. Pulaski and hatchet
4. Binoculars
5. Cordless drill with 1/16 in. to ¼ in. drill bits
6. Loggers tape
7. Clinometer or other means of measuring height (laser range finder)
8. Field knife
9. Increment borer
10. Compass
11. GPS

Instructions for Completing Region 1 and 4 Tree Hazard Evaluation Form

Location: location of site being evaluated
Site name: name of site being evaluated
Evaluated by: name(s) of person(s) conducting the evaluation
Date: date of evaluation
Page: indicate page number for sites with enough trees to fill multiple page numbers
Possible Site Factors: factors that may influence tree hazard rating. These include shallow, compacted, or poor soil; poor drainage, high water table, recent flooding; recent changes near roots; recent stand opening; wind patterns and exposure; loss agents.

Unit #: unit or section number
Map #: map number
Tree #: tree number
Tree species: tree species being evaluated

DBH: diameter at breast height, in inches
Sound Wood SHELL: a trunk's average thickness of wood with no decay, excluding bark. This is not a routine measurement. Drilling may be warranted when a high incidence of hidden decay is suspected or when nearby trees have fallen from decay not visible from the outside. If decayed tree is tested, record average inches sound wood shell; Used to determine if shell is less than 15, 20, 25, 30% diameter for some Failure Potential valuations.
Failure Potential: potential for a tree or tree part to fail before the next inspection period. General Failure Potential severity ratings are:
1 = very low; live trees without visible defects
2 = low; live trees with only minor defects such as wounds that don't impair tree structure; trees with slight decay
3 = medium; live trees with moderate defects; decayed trees where sound wood shell thickness is at or near the minimum preferred amounts
4 = high**;** dead trees; live trees with major defects; decayed or burned trees with less than acceptable remaining sound wood

> **Per Defect:** record all applicable severity codes here. Use simplified Failure Potential table on the back of the datasheet to determine specific severity codes for each tree defect. Dead trees are always rated FP4. Consult Table 1 (Failure Potential Ranking Guide) and Chapter 4, Identification of Defects and Diseases, as needed**.**
> **Combined:** record Failure Potential severity rating of the most severe defect OR if 3 or more defects of the same severity are identified for a single tree (i.e. 3D, 3W, 3L), the overall Failure Potential for the tree may be increased one level.

Failed: record an "F" here if the tree is dead or has evidence it has failed, e.g. cracked roots, broken hanging top.
Damage Potential: estimation of extent or severity of damage or injury that could result from tree failure. Damage Potential takes account of tree or tree part size and the height at which a defect occurs. Damage Potential Ratings are:
1 = minor; failure of a small tree part by direct or indirect impact could cause light damage
2 = medium; failure of a small tree or a medium-sized tree part and direct impact could cause moderate damage
3 = extensive; failure of a medium to large tree part or an entire tree and direct impact could cause severe damage to property or serious personal injury or death
Target Value: score assigned to a tree based on how long and how often the Potential Impact Zone (PIZ; area that a tree or its parts could normally reach) will be occupied by persons or structures or other valued property. Target Value Ratings are:
1 **=** low; tree's potential impact zone includes, at most, features with limited use and short use length such as garbage cans, campground signs, or fences; may also be used for trees with moderate-use features just outside estimated impact zones.
2 **=** moderate; tree's potential impact zone includes, at most, features with moderate use and short use length such as water sources or waste disposal stations.
3 **=** high; tree's potential impact zone often has people or valuable property present for long periods. This score is used for trees around developed tent sites, toilets, parking spurs, and other high-occupancy sites.
Total Rating: sum values for Failure Potential (A), Damage Potential (B), and Target Value (C) to determine Hazard Tree Rating. Hazard tree Rating may need to be modified based on possible site factors as indicated at the top of the page. Hazard Tree Rating ranges from 3 to 10. Priorities for mitigating hazard range from low to very high based on these numerical values (10 = Severe; 9 = High; 8 = Medium; 7 or less = Low).
Recommended ACTION: record recommended action for tree (none; monitor; prune; remove; other) or site (none; restrict access to treat; close; repurpose)
Comments: record additional identifying information such as tree location, target, specific defects, part size, details of recommended actions, etc.
Date Action Taken: record date action was taken

Region 1 and 4 Tree Hazard Evaluation Form

Location: _____ **Site Name:** _____

Evaluated by: _____ **Date:** _____ **Page**_____

Possible Site Factors (See Below): _____

Record Appropriate Tree *Defect / Failure Potential 1-4* (A), *Damage Potential 1-3* (B), *& Target Value 1-3* (C) based on guidance below and on reverse.

UNIT #	MAP #	Tree #	Tree Species	DBH inches	Sound Wood **SHELL***	Failure Potential (FP) Per Defect | Combined **(A)**		Failed (**F**)*	Damage Potential **(B)**	Target Value **(C)**	Total Rating **(A+B+C)**	Recommended ACTION	COMMENTS (Such as tree location, target, defects, part size, recommendation details, etc.)	Date Action Taken

Possible Site Factors: Shallow, compacted, or poor soil; poor drainage, high water table, recent flooding; recent changes near roots; recent stand opening; wind patterns and exposure; loss agents.

***SHELL:** If decayed tree is tested, record AVG inches sound wood shell; used to determine if shell is less than 15, 20, 25, 30% diameter for some FP codes on back of form.

Failure Potential (A): 1 = Very low; 2 = Low; 3 = Medium; 4 = High**.** See reverse side or Table 1 and Chapter 4 for specific FP scores**. LEFT COLUMN**: Enter **FP codes for each Defect.**
RIGHT COLUMN: For tree's **COMBINED FP**, choose most severe FP OR if 2 or more defects of the same severity are **interacting** (e.g. 3L, 3W), record one value higher in column at right (e.g., 4).
DEAD TREES are always FP4.
*** Failed = F:** Tree is dead or has evidence it has failed, e.g., cracked roots, broken hanging top, etc.

Damage Potential (B): 1 = Minor (small tree or tree part could cause light damage); 2 = Medium (small to medium tree or tree part, moderate damage); 3 = Extensive (medium or large tree or tree part, severe damage).

Target Value (C): 1 = Occasional-use trails and signs, vehicles not present; 2 = Intermittent-use such as picnic and day-use areas or busy trails; 3 = Frequent-use and long occupation areas such as camp sites, parking areas, and heavily-used permanent structures.

Total Rating (A+B+C) is the Hazard Tree Rating and Treatment Priority Class:
10 = Severe; 9 = High; 8 = Medium; 7 or less = Low.

Recommended Actions for TREE: None; monitor; prune; remove; (other).
Recommended Actions for UNIT or SITE: None; restrict access to treat; close; repurpose.

Table of Failure Potential (FP) Codes: Codes are FP scores with category identifiers. For each code, different defects with the same FP are separated by "**OR**". Check trees with fire damage for FP codes under both STEM DAMAGE AND WOUNDS (W) and ROOT DAMAGE… (R) categories. Consult Table 1 (Failure Potential Rating) and Chapter 4 as needed for more detailed descriptions of individual tree defects and FP scores. DEAD TREES are always FP4.

Code	**DECAY OR CAVITY:** FP in whole tree or tree part is determined by average sound wood shell (**SHELL;** values in table 2) and conk numbers and sizes (Ch. 4). **SHELL** excludes bark and is measured where the greatest decay is suspected.	Code	**LEAN/SWEEP AND SLENDERNESS:** Fully vertical top growth in a leaning tree is termed "corrected". Slenderness is calculated as height to diameter ratio (H:D ratio): height (ft.) / dbh (ft.).
1D	No decay or cavity detected	**1L**	Lower bole vertical with sweep in upper bole **OR** H:D ratio <60
2D	Some decay but **SHELL** >30% diam.	**2L**	Soil looks intact; corrected lean of any amount **OR** uncorrected lean <15° **OR** H:D ratio 60 to 80
3D	No opening, **SHELL** >15% diam. **OR** opening present, **SHELL** >20% diam. **OR** conks present and FP based on species, conk number and size (Ch. 4)	**3L**	Soil looks intact; uncorrected lean >15° **OR** H:D ratio 80 to 100
4D	No opening, **SHELL** <15% diam. **OR** opening present, **SHELL** <20% diam. **OR** conks present and FP based on species, conk number and size (Ch. 4)	**4L**	Soil cracked or lifted or root breakage **OR** H:D ratio >100
	STEM DAMAGE AND WOUNDS (cracks, physical damage, fire damage): Note different FP criteria for western redcedar and resinous conifers (pines, Douglas-fir, western larch) vs. "other conifers".		**BRANCHES AND TOPS** (forks; dead or damaged parts; dwarf mistletoe and other branch brooms): Note different FP criteria for groups of conifers listed under STEM DAMAGE and aspens, cottonwoods, and birches.
1W	Crack or minor wounds fully callus-sealed **OR** no fire scar	**1B**	Douglas-fir **small, live** broom, **OR** other tree species' large live broom
2W	Small, shallow, partially-callused crack and **SHELL** >30% diam. **OR** minor structural damage, scraped bark, or fire scar <50% circumference and **SHELL** >30% diam. **OR** sound wood remaining after fire >50% for western redcedar and resinous conifers or >75% for "other conifers"	**2B**	V-shaped fork without embedded bark **OR** unbalanced multiple tops **OR** non-decayed dead top <3"diam. **OR** non-decayed dead top >3" in western redcedar or resinous conifer **OR** >3" diam. living branch on cottonwood tree with no evidence of past crown breakage or decay **OR** large living Douglas-fir broom **OR** small dead broom in non-Douglas-fir conifer
3W	Structural crack without movement and **SHELL** >20% diam. **OR** structural damage or fire scar is <50% circumference and **SHELL** >20% diam. **OR** >50-75% sound wood remaining after fire for "other conifers"	**3B**	V-shaped fork with embedded bark **OR** living, cracked top or branch >3" diam. **OR** non-decayed dead top or branch >3" diam. in aspen, cottonwood, birch, or "other conifers" **OR** >3" diam. living branch on cottonwood or birch tree with evidence of past crown breakage but no decay **OR** Douglas-fir with small dead broom **OR** large dead broom in non-Douglas-fir conifer
4W	Structural crack with evidence of movement **OR** wound or fire scar >50% circumference **OR** damage with SHELL <20% diam. **OR** <50% sound wood remains after fire	**4B**	V-shaped fork with embedded bark and crack or decay **OR** detached or dead and decayed branch or top **OR** > 3" diam. dead cottonwood or birch branch without decay **OR** > 3"diam. living branch on cottonwood or birch tree with evidence of past crown breakage and decay **OR** Douglas-fir with large dead broom **OR** broom on cracked branch
	CANKERS (aspen canker diseases, blister rust, dwarf mistletoe, etc.)		**ROOT DAMAGE, ROOT DISEASE, BUTT ROT**
1C	No cankers	**1R**	A few exposed, undamaged roots **OR** no structural root damage in fire-exposed tree
2C	<50% circumference of bole girdled	**2R**	>75% structural roots undamaged **OR** exposed small roots with minor damage and not root-sprung **OR** butt rot with **SHELL** >25% diam. and no aggressive root disease (**ARD**) in tree or proximity
3C	>50% circumference of bole girdled	**3R**	Some roots damaged but 50-75% root system intact **OR** fire damage of structural roots in only 1 quadrant **OR ARD** suspected in proximity (Ch. 4) but **ARD** not obvious or confirmed in tree **OR** butt rot with **SHELL** 15-25% diam.
4C	Tree killed	**4R**	Roots exposed, decayed or substantial damage on >50% of root system **OR** fire damage in >1 quadrant of structural roots **OR** tree has **ARD** symptoms (Ch. 4) **OR** butt rot with **SHELL** <15% diam.

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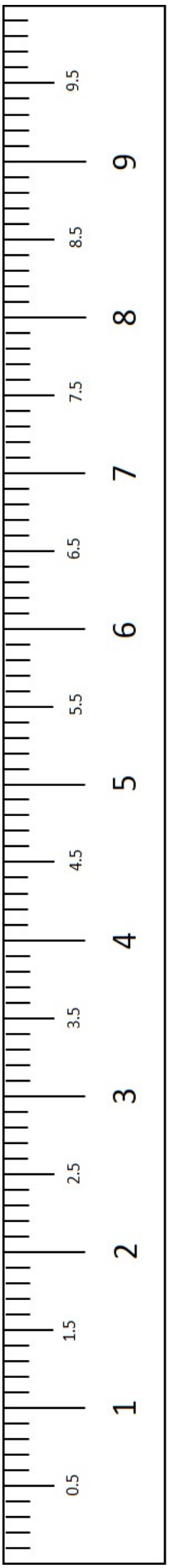
Sound Wood Shell Thickness Values for Stem Diameters

Within-Bark Tree Diameter in Inches	Inches for 15% Sound Wood Shell	Inches for 20% Sound Wood Shell
4	0.6	0.8
6	0.9	1.2
8	1.2	1.6
10	1.5	2
12	1.8	2.4
14	2.1	2.8
16	2.4	3.2
18	2.7	3.6
20	3.0	4.0
22	3.3	4.4
24	3.6	4.8
26	3.9	5.2
28	4.2	5.6
30	4.5	6.0
32	4.8	6.4
34	5.1	6.8
36	5.4	7.2
38	5.7	7.6
40	6.0	8.0
42	6.3	8.4
44	6.6	8.8
46	6.9	9.2
48	7.2	9.6
50	7.5	10