for the greatest good

Field Guide for Hazard-Tree Identification and Mitigation on Developed Sites in Oregon and Washington Forests

2014

Front cover photo: This Douglas-fir was felled because of high-failure potential due to laminated root rot.

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Suttle Lake, Deschutes National Forest

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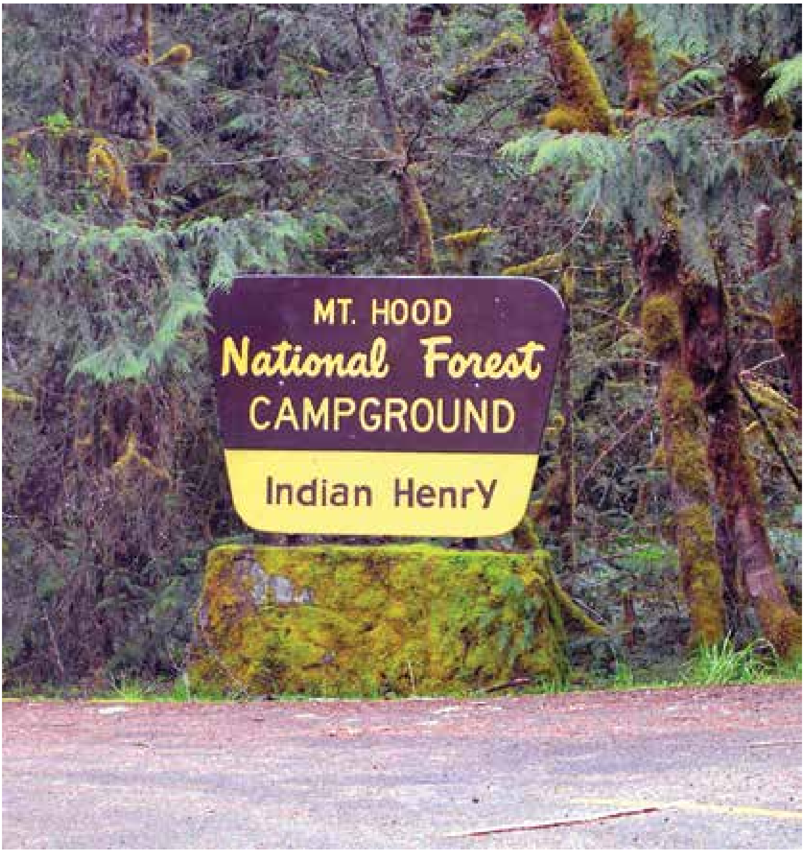
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Cabin on Lake Quinault, Olympic National Forest

Introduction

Hazard-tree management requires unique skills that combine science and intuition. It requires observation, knowledge of the site, experience with tree defects and decays, thorough investigation, and adequate documentation. This guide is intended to aid users in hazard-tree identification, evaluation, and mitigation with an emphasis on native forest trees of the Pacific Northwest.

This guide is for forest-resource managers, recreation staff, pest-management specialists, concessionaires, consultants, and arborists who deal with developed sites in forested areas and need to identify, monitor, and mitigate hazard trees. It is a revision of a similar guide: "Long-range planning for developed sites in the Pacific Northwest: the context of hazard tree management" (Harvey and Hessburg 1992). We recommend that this guidebook be used for identifying and mitigating hazard trees in and around developed sites such as campgrounds, picnic areas, ski areas, boat launches, parking lots, trailhead parking areas, buildings, and administrative complexes. These sites should have a thorough, systematic survey by knowledgeable inspectors due to the long-term exposure and high target values. Such sites should be frequently visited and trees of concern documented, treated or retained, and periodically monitored.

Forest trees, especially large ones, greatly add to the beauty and enjoyment of developed sites. Pathogens, insects, and weather events, however, can cause substantial damage to forest trees in the Pacific Northwest. Reducing this damage is an objective of managers for most forest sites. On developed sites, tree damage may pose a hazard to the safety of people or their property. Developed sites are places where people often congregate and are exposed for longer than intermittent time periods to potentially failing trees. Camp sites and buildings, where breakage from or failure of defective trees could result in damage to people or their property, are examples of valuable targets that need to be protected. Targets that are exposed during the winter, when storms often cause trees or their parts to fail, are particularly vulnerable to tree failure and subsequent damage. The longer the exposure to tree hazards, the greater the potential for property damage or personal injury.

Tree and stand decadence increase with disturbance, advancing age, and forest community succession. With increased decadence comes an increased presence of defective trees prone to failure. In most plant-community types, the result of developed-site use and tree-hazard mitigation has been accelerated succession and increased stand decadence over time. Although trees are a renewable resource, there has been resistance to removing large, old, defective trees from developed sites simply because it takes centuries for them to develop.

Removal or mortality of early seral species increases the proportion of shade-tolerant species such as grand/white fir or hemlock. In community types with these species, repeated hazard-tree removals have promoted shifts in vegetation toward climax conditions and the associated higher susceptibility to insect- and disease-caused damage that typify many developed sites today. Other sites, such as those in dry ponderosa pine communities, tend to remain in pine dominance, even with removals. Trees on these sites are generally more resilient to insects and diseases and usually have a relatively low incidence of damaging agents that could predispose them to failure.

This guide will assist you in appropriately inventorying, documenting, and treating hazard trees. The objectives of this guide are to present:

1) The need to develop long-term management plans for developed sites
2) A standard for evaluating tree hazards in developed sites
3) An up-to-date field aid for accurate identification of diseases, defects, and resulting tree-failure potential
4) A standard for recording developed-site evaluations

Mt. Baker, Mt. Baker-Snoqualmie National Forest

Chapter 1 - Vegetation-Management Planning and Mitigating Tree Hazards

To maintain a balance of benefits in the long term, managers of developed sites must contend with several forest-disturbance agents. The most obvious effects that these agents have on developed sites occur through their influence on forest health and succession. Insects, diseases, and abiotic factors such as wind, drought, and snow cause the deterioration and demise of trees. When removing hazard trees, we may need to consider and plan for replacement vegetation to achieve the desired future condition of the site and the associated vegetation. This, of course, needs to be tailored to the plant community of the site and the silvics of the desired tree species. This constitutes the heart of a vegetation-management plan, which is advisable for documenting both a site-specific and administrative-unit management strategy.

Hazard-Tree Mitigation as a Part of Vegetation Management

Hazard-tree mitigation is one of many management actions prescribed in a vegetation-management plan. Appropriate hazard-tree management complements other management actions to achieve a common set of goals. The primary objective of vegetation-management planning is to develop a description of the desired future condition of the vegetation and the strategy to achieve that goal. Input by various resource specialists should be included.

Older stands with multiple canopy layers generally make highly attractive and aesthetically desirable recreation areas. It may take two or more centuries to develop stand structures that contribute to the most desirable recreation sites. Development and maintenance of desirable older stand structures needs to be a planned objective, and achieving that goal requires management actions that are dependent on the type of plant community and the existing biotic and abiotic disturbance agents. In some situations, it may be difficult or impossible to maintain old-growth structure and keep the area safe. Thus, for future recreation sites it might be more desirable to place them in younger stands because they are often hazard free and more easily managed.

Hazard-tree evaluations, as part of a vegetation-management plan, should involve a systematic, peer-accepted evaluation process that identifies and mitigates hazards and reduces them to acceptable levels. The process needs to be repeatable with continuity over time as personnel change. Record keeping is important, especially documenting trees to be monitored and assuring that hazard trees deemed unacceptably dangerous are mitigated.

Many federally owned developed-recreation sites are being managed by private concessionaires, who may be tasked with the identification and mitigation of hazard trees on those sites. It therefore becomes important that recreation managers work closely with concessionaires on hazard-tree documentation, monitoring, and integration with vegetation-management plans.

What Constitutes a Hazard?

In recreation-resource management, hazard is the exposure to the possibility of loss or harm. With reference to trees, it is the recognized potential that a tree or tree part may fail and cause injury or damage by striking a target. All standing trees within areas occupied by people, property, and structures present some level of hazard. Failure potential by itself does not constitute a hazard. Hazard exists when a tree of sufficient size and mass to cause injury or damage is within striking distance of people, property, or structures (targets). Hazard increases with increasing tree defect, failure potential, potential for damage, and target value. Management actions are taken when the line officer or land manager decides to mitigate the hazard when risks (the product of damage potential and consequences of damage) are unacceptable.

Hazard is defined as acceptable (we will not mitigate) when:

1) All components of hazard have been fully evaluated, and

2) Failure and/or damage probability is estimated to be low

Hazard is unacceptable (we will mitigate) when:

1) The amount of defect indicates failure is likely,

2) The failure potential and relationship to targets indicates damage is likely, and

3) Targets include people, property, or structures

Hazard evaluations assess both failure potential and damage potential.

Hazardous Trees and Associated Liabilities

In this guide, a *hazard tree* is any tree that is within striking distance of a permanent or transitory target of value. Any tree or tree part has some level of failure potential. Biotic and abiotic agents can interact to increase the likelihood of failure. If visitors wish to recreate in forests, they must accept a certain amount of hazard. Land managers and evaluators must learn to recognize the signs of increasing hazard so it can be minimized.

Visitors can be grouped into three distinct classes: invited, licensed, and trespassing. For lands maintained open to the public, visitors are considered invited, and public-land managers are liable to an extent for their safety. The USDA Forest Service Manual (FSM 2309, 2330, 6703, 6730) outlines specific objectives, policies, and responsibilities for managers of recreation sites. These include documented hazard-tree evaluations by "qualified" people and may include corrective actions or treatments. Some liability for injury or loss lies with the landowner or agent for the land. In most states, a Recreational Use Statute or similar legislation provides protection to landowners by holding them free of liability resulting from accidents or deaths occurring on their lands held open for public use. This protection does not extend to landowners when a fee is levied. In this situation, and when gross negligence, intentional wrongdoing, or wanton misconduct is a factor, Federal Tort Claims rules apply. Land managers should carefully consider the benefits of protection afforded by Recreational Use Statutes before applying a user fee.

Informing the public that dangerous conditions exist does not eliminate liability. It is the responsibility of land managers or their agents to discover and correct unreasonably dangerous conditions to minimize the potential for injury to invited users or damage to personal property. Responsibility to actively minimize hazard is roughly proportional to the degree of development of an area. Highly developed sites infer a greater degree of responsibility than undeveloped areas. It is imperative that site managers conduct high-quality, hazard-tree evaluations and, as required, treatments that respond specifically to each unacceptable hazard. If no fee is levied for recreation-site use, posting signs to expose tree hazards and associated risks may reduce liability of the landowner or manager.

The goal in developing recreation sites is to provide facilities that visitors will use. Often, large, old-growth trees are the prime attractions, and those are the very trees that often present the greatest threat to public safety. The goal in managing these sites is to maintain the old-growth appearance while eliminating unacceptable risk to visitors. Similarly, the goal in managing any developed-recreation site is to maintain or improve the characteristics of the site that attracted visitors initially and that promoted formal development, while eliminating unacceptable risk to visitors.

Goal of Hazard-Tree Management

Hazard-tree management historically has been used as a short-term fix to reduce hazard, but this usually does not, by itself, enhance the long-term health or aesthetics of the vegetation in developed sites. Vegetation-management plans should contain strategies to meet long-term goals or desired future condition of the vegetation. Hazard-tree management should be addressed in these plans, and most importantly, so should the strategy for developing or maintaining healthy, resilient, low-hazard trees. The goal of hazard-tree management is to strike a balance between providing healthy trees with low-failure potential and forest vegetation that provides an aesthetically pleasing and natural environment. Hazard-tree management, although based on valid science, is not an exact practice, and mistakes in identifying defects and tree-failure potential unfortunately are made. We provide this guide as a means to minimize these errors.

South Shore Campground, Deschutes National Forest

Chapter 2 - Components of Hazard-Tree Analysis

Hazard-tree analysis involves inspecting and rating trees for their potential to fail and strike targets during the time between examinations. Since it is not reasonable to eliminate all hazards (i.e. all trees) from a developed site, the manager or responsible official must decide what constitutes an acceptable level of risk. Trees near targets and potential targets should be thoroughly inspected. Hazard-tree analysis also involves documentation and record-keeping of trees that have some level of defect but will be retained for the short term and periodically re-evaluated at some scheduled interval.

A Process for Hazard-Tree Evaluation and Action

There are four steps that the evaluator should take when dealing with potential hazard trees in developed sites:

1) Identify tree defects, determine the tree's potential to fail, and assign a numerical score for failure potential.
2) Determine the potential-failure zone and damage potential, and assign a numerical score for damage potential.
3) Document the assessment and recommend treatment options to the manager or supervisor.
4) Document the completed action and the date it occurred.

The degree to which a tree is hazardous depends on two main factors: (1) Potential for failure and (2) potential that property damage, injury, or death will result from tree failure. Low numerical value for either factor implies minimal risk.

What is Failure Potential?

Estimating the potential for tree failure may be difficult because of the many interacting variables: tree size, age, form, species, condition, and location; stand structure; site conditions; and presence and extent of tree defects (Table 1). Failure potential is estimated by examining a tree, determining the factors and conditions that could contribute to failure or weakening, and estimating the likelihood that those factors and conditions will simultaneously occur before the next inspection period. Tree characteristics to be evaluated include:

Table 1. Failure indicators for high, medium, low, and very low-failure potentials for trees in developed sites in Oregon and Washington

	Failure Indicator	High-Failure Potential	Medium-Failure Potential	Low-Failure Potential	Very Low-Failure Potential
		Score = 4	*Score = 3*	*Score = 2*	*Score = 1*
	Dead trees	**All**	**None**	**None**	**None**
Roots	**Live trees in laminated root rot centers** ***Phellinus weirii***	Trees **with** signs or symptoms (ectotrophic mycelium or laminated decay; foliage thinning or yellowing)	**Douglas-fir, mountain hemlock, or true firs** ***without*** signs or symptoms and **≤25ft**. from an infected tree or stump (check for butt rot)	**Douglas-fir, mountain hemlock, or true firs**, ***without*** signs or symptoms and **>25ft.** from an infected tree or stump; **Larch, Engelmann spruce, or western hemlock** ***without*** signs or symptoms (check for butt rot)	**Pine, Sitka spruce, cedar, or hardwoods *without*** signs or symptoms
Roots	**Live trees in Armillaria or annosus root disease centers** ***Armillaria* spp.** ***Heterobasidion* spp.**	Trees **with** signs or symptoms (mycelial fans, resinosis, staining, conks, or wounds with decay; foliage thinning or yellowing) **and** adjacent (≤50 ft.) to windthrown trees with root disease	Trees **with** signs or symptoms but **not** adjacent to windthrown trees with root disease (check for butt rot)	Susceptible tree species **without** signs or symptoms (Table 6) (check for butt rot)	Resistant tree species **without** signs or symptoms (Table 6)
Roots	**Live trees in black stain or Port-Orford-cedar root disease centers** ***Leptographium wageneri; Phytophthora lateralis***	None	None	Trees **with** signs or symptoms (foliage thinning or yellowing; stained inner bark or sapwood)	Trees **without** signs or symptoms
Roots	**Undermined or severed roots**	Trees with **<50%** of the structural roots remaining in the ground	Trees with **50 to 75%** of the structural roots remaining in the ground	Trees with **>75%** of the structural roots remaining in the ground	None

	Failure Indicator	High-Failure Potential	Medium-Failure Potential	Low-Failure Potential	Very Low-Failure Potential
		Score = 4	*Score = 3*	*Score = 2*	*Score = 1*
	Dead trees	**All**	**None**	**None**	**None**
Butt	**Butt rot: *Tomentosus, Schweinitzii, Ganoderma*, or *P. subacida***	Tree with extensive decay: sound-rind thickness **<15%** of stem diameter[1] (Table 3A) or decay in **>50%** of the structural roots	Tree butts with moderate decay: sound-rind thickness **15 to 25%** of stem diameter or decay in **<50%** of the structural roots	Trees with little or no decay: sound-rind thickness is **>25%** of stem diameter and **no** decay in structural roots	None
Butt	**Fire-damaged trees for recent (<5yr) fire damage; use bole wounds for old fire damage**	Trees with **<50%** cross-section of bole with sound wood, or **more than one** quadrant of damaged structural roots	Trees with **50 to 75%** cross-section of bole with sound wood, or **one** quadrant of damaged structural roots except for cedar, ponderosa pine, sugar pine, and larch	**Cedar, ponderosa pine, sugar pine, and larch** with **>50%** cross-section of bole with sound wood; **Other species** with **>75%** cross-section of bole with sound wood	Trees with **100%** cross-section of bole with sound wood, and **no** damaged structural roots
Bole	**Bole wounds**	Trees with sound-rind thickness of **<20%** of stem diameter[1] (Table 3B)	Trees with sound-rind thickness of **20 to 30%** of stem diameter	Trees with sound-rind thickness of **>30%** of stem diameter	None
Bole	**Mistletoe cankers, fungal cankers**	Trees with **<50%** cross-section of bole with sound wood	Trees with **50 to 75%** cross-section of bole with sound wood	Trees with **>75%** cross-section of bole with sound wood	None
Bole	**Frost cracks**	Trees with **weeping** cracks and sound-rind thickness is **<20%** of stem diameter[1] (Table 3B)	Trees with **weeping** cracks and sound-rind thickness is **20 to 30%** of stem diameter	Trees with cracks with **no weeping** and sound-rind thickness is **>30%** of stem diameter	None
Bole	**Bole cracks**	Trees with splits or cracks **with** independent movement, or if decayed, sound-rind thickness is **<20%** of stem diameter[1] (Table 3B)	Trees with splits or cracks **without** movement, and sound-rind thickness is **20 to 30%** of stem diameter	Trees with splits or cracks **without** movement, and sound-rind thickness is **>30%** of stem diameter; callus has formed	None

	Failure Indicator	High-Failure Potential	Medium-Failure Potential	Low-Failure Potential	Very Low-Failure Potential
		Score = 4	*Score = 3*	*Score = 2*	*Score = 1*
	Dead trees	**All**	**None**	**None**	**None**
Conks	**Quinine conks** *Fomitopsis officinalis*	Trees with ≥1 conks	None	None	None
Conks	**Indian paint fungus conks** *Echinodontium tinctorium*	Trees with **multiple large** (≥6 in. wide) conks or **single large** or **multiple small** conks **and** at least one additional indicator of associated defect/decay such as open cracks or exposed rot, or sound-rind thickness at conks **<15%** of stem diameter[1] (Table 3A)	Trees with **single large** (≥6 in. wide) or **multiple small** conks **without** additional indicators of associated defect/decay, or sound-rind thickness at conk is **15 to 25%** of stem diameter	Trees with a **single small** conk, or sound-rind thickness at conk is **>25%** of stem diameter	None
Conks	**Red ring rot conks** *Phellinus pini*	Trees with ≥1 conks **and** evidence of extensive advanced decay[2] such as open cracks or exposed rot, or sound-rind thickness at conks is **<15%** of stem diameter[1] (Table 3A)	**True fir, hemlock, spruce, or hardwoods** with ≥1 conks without evidence of excessive advanced decay; **Douglas-fir, pine, cedar, or larch** with ≥3 **large conks** (≥6 in. wide) **within** a 3-ft.-long trunk cylinder or sound-rind thickness at conks is **15 to 25%** of stem diameter	Douglas-fir, pine, cedar, or larch with ≥3 large conks **not within** a 3-ft.-long trunk cylinder or ≤2 large conks **within** a 3-ft.-long trunk cylinder or any number or location of **small conks**. or sound-rind thickness at conks is **>25%** of stem diameter	None
Conks	**Other heart-rot conks**	Trees with ≥1 conks **and** evidence of extensive decay such as open cracks or exposed rot, or sound-rind thickness at conks is **<15%** of stem diameter[1] (Table 3A)	Trees with ≥1 conks; **without** evidence of excessive decay, or sound-rind thickness at conks is **15 to 25%** of stem diameter	Trees with ≥1 conks, without evidence of excessive decay **and** sound-rind thickness at conks is **>25%** of stem diameter	None
Conks	**Sap-rot conks** *C. volvatus* *F. pinicola* *T. abietinum* *C. purpureum*	**Dead trees** with sap-rot conks	**Live trees** with **>2 conks** on one or more stem quadrants usually associated with wounds	**Live trees with only 1 or 2 conks**; check for extent of dead bark and sound wood	None

	Failure Indicator	High-Failure Potential	Medium-Failure Potential	Low-Failure Potential	Very Low-Failure Potential
		Score = 4	*Score = 3*	*Score = 2*	*Score = 1*
	Dead trees	**All**	**None**	**None**	**None**
Tops and Branches	**Forked or multiple tops or trunks**	Trees with V-shaped forks with embedded bark **and** open cracks, decay, or conks	Trees with V-shaped forks with embedded bark but **no** cracks, decay, or conks	Trees with U-shaped forks or V-shaped forks with **no** embedded bark, cracks, decay, or conks	None
	Dead tops or branches (≥3 in. diameter)	True fir, hemlock, spruce, or hardwoods with indicators of **significant** decay such as open cracks, conks, or exposed rot (tops and branches are high FP, not the whole tree)	**True fir, hemlock, spruce, or hardwoods** with **little** decay; **Douglas-fir or pine** with **significant** decay (tops and branches are medium FP, not the whole tree)	Douglas-fir or pine with **little** decay (tops and branches are low FP, not the whole tree)	**Cedar or larch**; **Pine tops** killed slowly by rust fungi that show **resin** impregnation (tops and branches are very low FP, not the whole tree)
	Detached tops, branches, (≥3 in. diameter) or loose bark (≥1ft.^{2})	**All detatched parts** (parts are high FP, not the whole tree)	**Live and attached** tops or limbs but cracked or split (parts are medium FP, not the whole tree)	None	None
	Dwarf mistletoe brooms	Douglas-fir with **large** (≥10ft. in diameter) **dead** brooms (broom is high FP, not the whole tree)	**Douglas-fir** with **small, dead** brooms; **Other tree species** with **large, dead** brooms (broom is medium FP, not the whole tree)	**Douglas-fir** with **large, live** brooms; **Other tree species** with **small, dead** brooms (broom is low FP, not the whole tree)	**Douglas-fir** with **small, live** brooms; **Other tree species** with **live** brooms (broom is very low FP, not the whole tree)
	Black-cottonwood branches	Trees with large (≥3 in. diam.) live or dead branches with evidence of **decay** and past **breakage**	Trees with large, live branches with evidence of past **breakage** but **no decay**	Trees with large, live branches **without** decay or breakage	None

	Failure Indicator	High-Failure Potential	Medium-Failure Potential	Low-Failure Potential	Very Low-Failure Potential
		Score = 4	*Score = 3*	*Score = 2*	*Score = 1*
	Dead trees	**All**	**None**	**None**	**None**
Whole tree	**Broken or uprooted trees supported by other trees**	All	None	None	None
Whole tree	**Leaning and/or root-sprung trees**	Trees with recent (<5yr) lean ≥15 degrees or old uncorrected lean **with** freshly disturbed soil or root damage	Trees with recent lean ≥15 degrees or old uncorrected lean **without** freshly disturbed soil or root damage	Trees with old corrected lean	None
Whole tree	**Height:diameter ratio[3]**	Trees with **>100%** H:D ratio	Trees with **80 to100%** H:D ratio	Trees with **60 to 80%** H:D ratio	Trees with **<60%** H:D ratio
	Multiple indicators	Two or more **medium-FP** indicators with synergistic effects: one condition (indicator) worsens the other	Two or more **low-FP** indicators with synergistic effects; two or more medium-FP indicators without synergistic effects	Two or more very **low-FP** indicators with synergistic effects; two or more low-FP indicators without synergistic effects	Two or more very low-FP indicators without synergistic effects

[1] To calculate sound-rind thickness as a percentage of stem diameter, divide the sound-rind thickness by the stem diameter and multiply by 100.

[2]Firm wood with white speck or firm wood with red discoloration is not considered advanced decay from *P. pini*. Advanced decay is very soft and crumbly. Sound-rind thickness should include decay caused by *P. pini* that is not advanced.

[3]To calculate H:D ratio, divide the total tree height in feet by the dbh in feet (p. 93).

1. Whether the tree is live or dead
2. Presence of dead, broken, or free-hanging branches
3. Presence or a recent weakening of co-dominant stems or dead, forked, or multiple tops
4. Presence of wounds, injuries, exposed or damaged roots, and associated decay or defect
5. Lean of a tree and factors that contributed to the lean
6. Whether a tree has recently been root-sprung (lateral-root anchorage has been compromised)
7. Whether trees that previously leaned have righted (corrected) their tops subsequently and now have acceptable lateral anchorage
8. Presence and extent of lethal or weakening root, stem, or branch disease or insect infestation
9. Presence and extent of damage caused by human activities

Dead trees are important to identify and mitigate in developed sites. Tree mortality in Pacific Northwest forests often is a complex process involving several related factors. Tree mortality tends to be more common in high-elevation forests where stress from weather, insects, and disease result in higher rates of mortality and in the drier interior forests where mortality from fire, insects, and disease are common. Tree mortality may be directly due to biotic or abiotic causes and may be affected by previous damage, current condition (vigor), and attack by secondary agents such as bark beetles.

Rating Failure Potential

Failure potential is rated on a scale of 1 to 4 in order of increasing severity:

POTENTIAL FOR FAILURE

1 = VERY LOW-FAILURE POTENTIAL
Live trees without visible defects.

2 = LOW-FAILURE POTENTIAL
Live trees with only minor defects.

3 = MEDIUM-FAILURE POTENTIAL
Live trees with moderate defects. Decay extent has rendered the tree at or near the acceptable sound-rind thickness (p. 30-31).

4 = HIGH-FAILURE POTENTIAL
All dead trees; live trees that are highly defective. Decay extent in live trees has rendered the tree below the acceptable sound-rind thickness.

Potential for Striking a Target and Damage Potential

The potential that a tree or tree part will strike a target is determined by evaluating where trees or their parts will likely land in the event of a failure, and whether those places of impact will be occupied by targets at the time. This determination is more straightforward for sites with characteristically high and steady occupancy than where intermediate or low occupancy occurs. Variables that are evaluated include:

- Location of tent pads, fire rings, barbecue pits, water pumps, waste-disposal stations, restrooms, picnic tables, historic buildings, information boards, interpretive stations, trailside rest stops, scenic-viewing areas, ski-lift lines, children's play areas, parking areas, and other potential targets
- Seasonal use patterns
- Day use patterns (day use vs. camping)

Determining the Potential-Failure Zone

The potential-failure zone is the area that could be reached by any part of a failed tree. However, when a tree fails, the tree or its parts may strike other trees and cause them to fail as well. The parts may slide or roll, especially on moderate to steep slopes. Also, when a tree fails, it may strike other trees or debris on the ground and fling material a considerable distance. This is especially true among dead trees. Determining if targets such as toilets, tent pads, or parking areas are within the area where a tree or its parts may fall (Potential-Failure Zone) is an important step in determining if the tree or tree part is a hazard. Therefore, a tree with defect and no target is not a hazard tree. A defective tree, however, whose potential-failure zone intersects a target such as a campfire ring is a hazard, and recommendations for mitigation should be made.

Total-Tree Failure

The failure zone is defined as the area on the ground that could be reached by any portion of the tree that may fail. When determining the failure zone, the following conditions must be evaluated:

- Ground slope
- Direction of lean
- Height of the tree

The failure zone is a circle around the tree with a radius that is the same as the total tree height (Fig. 1). For instance, if a tree is 150 ft. tall, then its potential-failure zone has a radius of 150 ft. On sloped ground, the failure zone downhill of the tree may have to be extended whatever distance is necessary to protect people or property if the tree or part slides or bounces (Fig. 2). For trees leaning more than 15 degrees, the failure zone is an area the same radius as the tree height beginning at

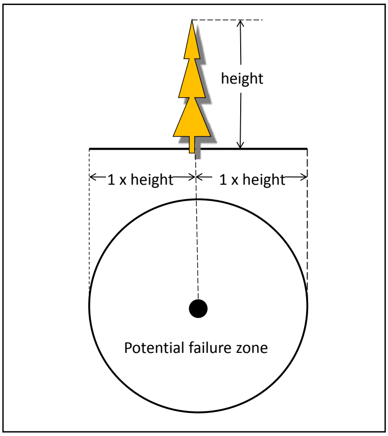

Fig. 1 – *Potential-failure zone for total tree failure with no slope or lean ≥15 degrees*

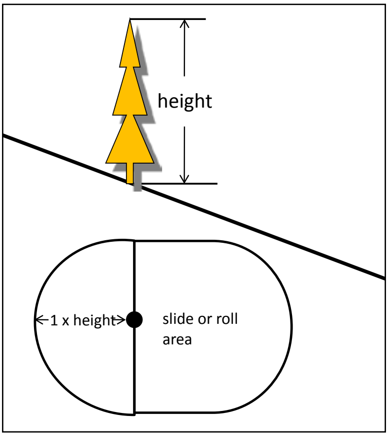

Fig. 2 – *Potential-failure zone for total tree failure on sloped ground*

the tree base then extending towards the direction of the lean and out 90 degrees on either side of the tree from the lean direction (Fig. 3). The area behind the lean is not within the normal failure zone, but storms with high winds could force a backlash opposite to the lean and create an additional danger.

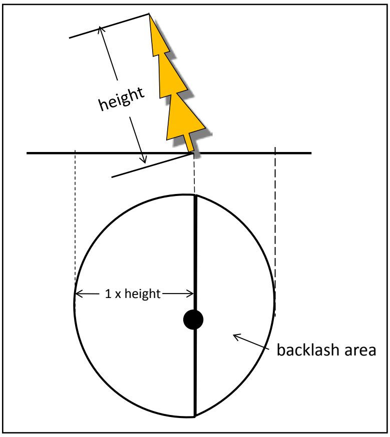

Fig. 3 – *Potential-failure zone for total-tree failure with lean ≥15 degrees*

Tree-Part Failure

The area that could be reached by a dislodged top, branch, slab, or chunk is the potential-failure zone. When determining the zone, evaluate the following conditions:

- Ground slope
- Amount and direction of lean
- Length of the part that could be dislodged

On level or sloped ground where the tree has no discernable lean, determine the length of the part that could be dislodged. The failure zone forms a circle around the tree with a radius equal to the length of the defective part (Fig. 4). For instance, if a dead tree top is 10 ft. long, then the potential-failure zone has a radius of 10 ft. On sloped ground where the dislodged part may slide or roll down hill, the failure zone must be extended on the down-hill side, usually about half the radius of the potential-failure zone (Fig. 5). Dead tops or branches may fail due to high winds that can carry the piece beyond the potential-failure zone.

For tree parts on leaning trees, determine the length of the part that could be dislodged. Determine the amount of lean (horizontal distance from where the part could be dislodged relative to the base). The failure zone is the distance determined by adding the length of the defective part to the lean amount. This distance would be applied to an area beginning at the tree base then extending towards the direction of the lean and out 90º on either side of the tree from the lean direction (Fig. 6).

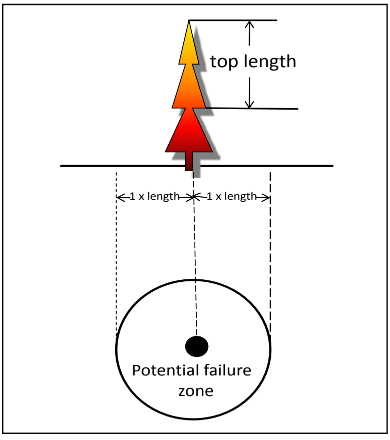

Fig. 4 – *Potential-failure zone for top failure with no slope or lean ≥15 degrees*

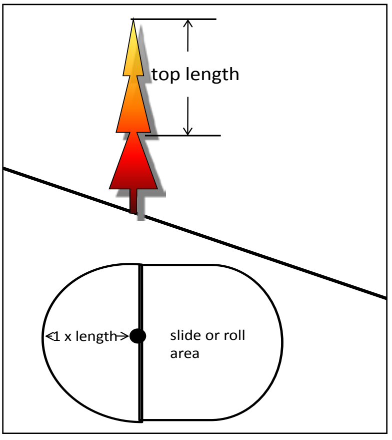

Fig. 5 – *Potential-failure zone for top failure on sloped ground*

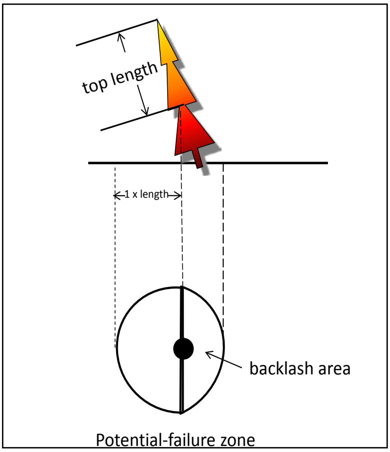

Fig. 6 – *Potential-failure zone for top failure with lean ≥15 degrees.*

Rating Damage Potential

Damage potential is the probability, type, and extent of damage or injury that may result from tree failure. The value of a potential target is estimated by determining the maximum extent of loss in the event that it is struck by a failed tree or tree part. Financial and emotional losses resulting from the death, injury, or dismemberment of a person are far greater than those for the loss of picnic tables, buildings, or vehicles. Values are expressed in relative terms (low, moderate, and high) and are factors considered in evaluating damage potential. For example, if the target is a person or their parked vehicle, then the value would be high. A target of moderate value may be a building or other developed structure or convenience such as a water pump or waste-disposal station. Garbage cans, dumpsters, and information boards may be examples of low-value targets. Roads, trails, and pathways within the developed site should be rated as minor (score=2) or medium (score=3) for damage potential depending on their frequency of use.

Damage potential is rated on a scale of 1 to 4 in order of increasing severity:

POTENTIAL FOR DAMAGE

1 = NO DAMAGE

Target impact will involve only very small tree parts, or there is no chance that failed parts will cause damage when they impact a target.

2 = MINOR DAMAGE

Failure of only small tree parts, and impacts in occupied areas are indirect; or failures will likely occur when area is unoccupied; damage when it occurs, is to low-value targets such as garbage cans, campground signs, or fences.

3 = MEDIUM DAMAGE

Failure involves small trees or medium tree parts, and impacts will likely occur in areas with targets; impacts will be direct, damage will likely be moderate, target value is moderate, such as for water pumps or waste-disposal stations.

4 = EXTENSIVE DAMAGE

Failure involves medium to large tree parts or entire trees, and impacts will be direct in areas with targets; target value is high, and damage to property will likely be severe; or serious personal injury or death is the likely result in areas such as tent sites, parking spurs, or toilets.

A Standard for Hazard Rating

The standard hazard-rating system suggested here incorporates two important components (USDA 2011). The first component addresses the potential for tree failure within a specified time period. The second component of hazard rating addresses damage potential in the event of a failure. This portion of the rating must incorporate the likelihood that a failed tree or tree part will strike a target, the likelihood of damage, and an estimate of target value. The hazard classification for each individual tree is determined by combining the values from the Failure Potential (1-4) and Damage Potential (1-4) components of the rating system. Seven hazard classes ranging from 2 to 8 are possible (Table 2, Fig. 7).

Table 2. Treatment priorities by hazard class:

Hazard Class	*Treatment Priority*
8	**very high**
7	**high**
6	**moderate**
2-5	**low**

Hazard Tree Rating

Damage Potential \ Failure Potential	1	2	3	4
1	2	3	4	5
2	3	4	5	6
3	4	5	6	7
4	5	6	7	8

Fig. 7 – *Hazard-tree rating or hazard class is on a scale of 2 to 8.*

As an example, you determine that a tree has low-failure potential with a rating of 2. You rate the damage potential as minor with a rating of 2. The hazard class is therefore 2 + 2 = 4, and the treatment priority is therefore low. Another tree has a high-failure potential with a rating of 4. The damage potential is medium with a rating of 3. The hazard class is therefore 4 + 3 = 7 and the treatment priority is therefore high. For sites administered by public agencies, the deciding official determines what hazard classes are to be treated or monitored.

How Often Should Hazard Rating be Done?

Timing and frequency of examinations may vary, but all developed sites should be examined for new evidence of hazardous trees at least annually. For USDA Forest Service sites, at the National Direction FSM 2332.1-Public Safety requires annual public safety inspections of these sites before the managed-use season, and trees are to be examined as part of the annual public safety inspection (Region 6 policy, USDA 2011). Sites should be examined once the severe weather season(s) have passed. This usually occurs in the spring in many parts of the Pacific Northwest, because severe weather is most often associated with winter storms. Winter storms often bring attention to the most severely defective trees or limbs, and the portions of stands with severe root disease or stem decay.

Annual pre-season site reviews should be done systematically, normally consist of a walk-through examination, and should be done before opening developed sites with seasonal closures. The expertise required to do annual inspections is less than for formal hazard-tree evaluations, since annual inspection is primarily for obvious winter and storm damage.

A more thorough and formal hazard-tree examination (baseline survey) should be conducted at least every five years, where each tree and all areas of the developed site are observed for new evidence of hazard or defect. More thorough examinations should be done more frequently than five years if the site is experiencing a recent disturbance such as a bark beetle outbreak, flood, fire, wind event, root disease, or the site is in a forest type with a history of many defective trees (i.e. white fir or cottonwood).

All trees within striking range of a target, either fixed or transitory, should be examined. Evaluations should begin at known or established reference points, and all trees in the vicinity of those points be systematically examined. Ideally, a benchmark or baseline hazard-tree evaluation should already be completed for the site, and notes from the walk-through examination can be used to modify or upgrade that information. If no such baseline evaluation exists for a site, one should be conducted.

The development of a baseline evaluation requires a systematic approach that should be organized in planning sessions before going to the woods. The approach described here is one that has been used and modified over the years. It is divided into four stages:

1) Identify and gather the necessary equipment (see Appendix)

2) Determine the information needs and gather those data

3) Record the information and develop a permanent database

4) Mitigate the unacceptable hazards

Where and How to Collect Survey Information

Where to survey

Walk-through and baseline surveys should begin by obtaining a detailed map of the developed site and reviewing any past survey information. Trees should be evaluated adjacent to the roads entering and exiting the site and all travel loops within the developed portion of the site. All trees of a height that if fallen would reach the road should be examined. The width of the survey area adjacent to roads is equivalent to the height of the tallest trees. Concurrently, all trees adjacent to structures, parking areas, restrooms, waste-disposal stations, water pumps, picnic tables, or ski lifts must be inspected. The width of the survey area around these developments is equal to the height of the tallest trees.

Within developed sites, all trees that could potentially reach tent pads, picnic tables, parking areas, ski-lifts, commonly used streamside or lakeside fishing spots, fire rings, barbecue pits, and all other recognized gathering places or focal points of human activity should be carefully evaluated. If these are not known, consult with knowledgeable site hosts or maintenance workers prior to establishing the baseline evaluation. At all times, examiners should be aware of the tree hazards that have potential to impact human targets. These are most important to identify and mitigate to protect the safety of visitors.

How to survey

Begin by evaluating trees from a distance to allow comparison of the vigor and overall appearance of trees relative to their nearest neighbors. The view from a distance allows the examiner to detect dead trees or tops and live crown symptoms of root disease that can include reduced lateral branch and terminal growth, thinning crowns, chlorosis, distress cone crops, and dead tops and branches. Evidence of defoliator activity, dwarf mistletoe infection, stem conks, and bark beetle attack is often initially detected from a distance and involves inspecting multiple trees from different vantage points.

Tree tagging Ideally, each tree with elevated failure potential that will be monitored should be tagged with a numbered, aluminum tag fixed to the tree with an aluminum nail. Nails should be driven through the tag leaving 3/4 to 1 in. of the nail exposed to allow for tree radial growth. Tags should be placed near the soil surface of the litter layer, if present, so they are hidden from view yet easily found. Normally, a cardinal compass direction should be selected, and all tags should be placed facing in that direction. This will simplify the process of tag relocation.

Permanent reference points are essential for generating maps and for documentation and relocation of individual trees. Locate a large object that is a permanent fixture in the site for a reference point. This may be a fire pit in a numbered campground site, an outhouse along a road, or a lift tower in a ski area. Beginning with the first reference point and continuing in order to the last, trees should be evaluated and observations recorded. Samples of evaluation forms are located in the Appendix.

Examine the area in the vicinity of each tree for obvious and subtle evidence of past and current pathogen and insect attack, or other damaging agents. Stand-level clues may be easily overlooked without careful evaluation and consideration. Nearby stumps and old roots should be examined for evidence of advanced decay and conks of root and butt pathogens. Broken-out tops that are lying on the ground, and windthrown or wind-shattered trees should be examined to determine the causal agents. Conks, mushrooms, and other fruiting bodies on and around trees should be identified since these are primary indicators of decay. Their identification often leads to detection and correct diagnosis of problems in adjacent, apparently healthy trees.

During tree inspections, examiners should look for signs and symptoms of disease and evidence of insect attack. In the event that signs and symptoms indicate damage and a potential hazard, trees should be examined more thoroughly to determine the extent to which the damage has compromised structural integrity. Some defects such as frost cracks or broken tops may not demand immediate hazard mitigation but suggest the need for periodic re-examination or monitoring during annual surveys.

Systematic tree examination begins at the ground around the base of the tree, then proceeds to the butt, bole, limbs, and tree top. All sides of each tree should be examined. If basal resinosis, crown symptoms, conks, or evidence of decay indicates a root disease problem, examination of several roots with a drill, ax, or pulaski will be necessary.

Table 3A - Minimum sound-rind thickness[1] at various diameters inside the bark of conifers measured at the defect for trees *without open wounds*. Trees with sound-rind thickness below minimum values have high-failure potential (score=4).

Tree diam. (in.)	*Rind thickness[2] (in.)*	*Tree diam. (in.)*	*Rind thickness[2] (in.)*
4	0.5	44	6.5
6	1.0	46	7.0
8	1.0	48	7.0
10	1.5	50	7.5
12	2.0	52	8.0
14	2.0	54	8.0
16	2.5	56	8.5
18	2.5	58	8.5
20	3.0	60	9.0
22	3.5	62	9.5
24	3.5	64	9.5
26	4.0	66	10.0
28	4.0	68	10.0
30	4.5	70	10.5
32	5.0	72	11.0
34	5.0	74	11.0
36	5.5	76	11.5
38	5.5	78	12.0
40	6.0	80	12.0
42	6.5	82	12.5

[1] Modified from Wagener (1963) by expanding the range of diameters covered
[2] Minimum sound-rind thickness is 0.15 x diameter and rounded to the nearest 0.5 in.

Table 3B - Minimum sound-rind thickness[1] at various diameters inside the bark of conifers measured at the defect for trees *with open wounds*. Trees with sound-rind thickness below minimum values have high-failure potential (score=4).

Tree diam. (in.)	*Rind thickness[2] (in.)*	*Tree diam. (in.)*	*Rind thickness[2] (in.)*
4	0.5	44	8.5
6	1.0	46	8.5
8	1.5	48	9.0
10	2.0	50	9.5
12	2.0	52	10.0
14	2.5	54	10.5
16	3.0	56	10.5
18	3.5	58	11.0
20	4.0	60	11.5
22	4.0	62	12.0
24	4.5	64	12.0
26	5.0	66	12.5
28	5.5	68	13.0
30	6.0	70	13.5
32	6.0	72	13.5
34	6.5	74	14.0
36	7.0	76	14.5
38	7.0	78	15.0
40	7.5	80	15.0
42	8.0	82	15.5

[1] Modified from Smiley and Fraedrich (1992)
[2] Minimum sound-rind thickness is 0.19 x diameter and rounded to the nearest 0.5 in.

Lightly tapping suspect trees with an axe or rubber mallet can be used to detect decay columns, hollows, and dead sapwood under the bark. This is only practical for trees with relatively thin bark. Trees that sound suspicious can then be examined in more detail with drills or increment borers. Binoculars may be necessary to inspect tops and upper boles of suspect or symptomatic trees.

If root disease symptoms are evident or suspect due to proximity to confirmed infection, the root collar, butt, and major lateral roots should be inspected for fruiting bodies, ectotrophic mycelium, mycelial fans under the bark, incipient stain or advanced decay in the wood, or other signs of the causal agent. A pulaski can be used to uncover roots (out to a distance of one yard, if needed) and to chop into them for examination. At least two major roots should be checked for root

Fig. 8 – *Battery-powered drills can be used to check for sound-rind thickness.*

disease if preliminary evidence suggests that it is present. The roots that are most likely infected should be checked first. These include those closest to infected (hollow) stumps, windthrown trees, or obvious root-disease centers.

If a tree has conks, wounds, or cankers, a cordless electric drill or increment borer can be used to check for presence and extent of decay associated with these indicators (Fig. 8). For soft-wooded species such as cedar, spruce, or alder, coring with an increment borer may be more useful than using an electric drill for detecting incipient decay. The first place to drill is directly into the wound, canker, or flattened area. If decay is found, at least three more drillings should be made to the opposite and adjacent sides, to estimate the extent of decay. Tree species that display buttressing or fluted butts (e.g., western hemlock, western redcedar) may require more sampling since the distal portions of fluted areas are often thicker. The thickness of the remaining rind of sound wood (Fig. 9) should be recorded by averaging all measurements. Refer to Table 3A and 3B for minimum sound-rind thickness. When the thickness of the rind of sound wood is insufficient for a tree's diameter, the failure potential is recorded as high (score=4). The determination of sound-rind thickness with an increment borer should be done only during the baseline survey (p. 27) and then no more than every 5 years to minimuze drill wounds.

For trees with open wounds (Fig. 32) (p. 55), minimum sound-rind thickness is 25% greater than indicated in Table 3A (0.19 x diam.). For example, a suspect tree has a diameter of 32 in. at its base and has a large wound near its base. The minimum sound-rind thickness would be 6.1 in. or 0.19 x diam. (0.19 x 32) because of the wound (Table 3B). After

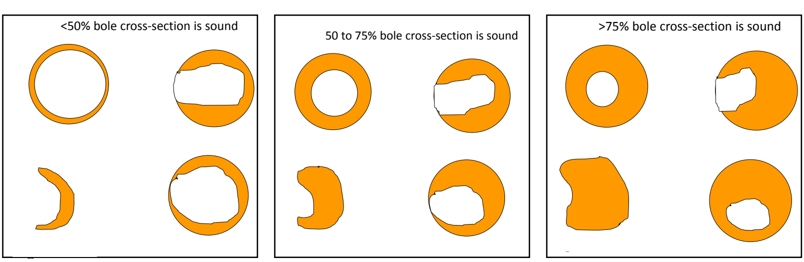

Fig. 9 – *Various bole cross-sectional areas showing percentage of sound wood remaining.*

increment boring at three points at the base, you determine that the average sound-rind thickness is only 4 inches; therefore, the tree has a high potential for failure. All of the examples in Fig. 9 where <50% of the bole cross-section is sound are below the minimum sound-rind thickness. The minimum sound-rind thickness applies primarily to conifers but less so to hardwood species for the following reasons: 1) the difference in basic tree form between hardwoods and conifers, 2) the strong and variant influence of leverage on the breakage potential, 3) the high mechanical strength of the wood of many hardwood species such as oak and maples, and 4) the fact that trunk failures, besides those near the groundline, are relatively rare in hardwoods except in weak-wooded species such as cottonwood, alder, and aspen. In hardwoods the condition of the branches and forks often is more important than the condition of the main trunk.

The minimum sound-rind thickness is just one assessment method for living trees with internal decay. The values in Table 3A and 3B are based on single-stemmed conifers with no lean or other bole defects. Also, the guidelines apply to the bole only and not to the roots or root collar. Although the presence of bole wounds can be compensated for as explained above, other visible and hidden defects associated with the decay column should be considered in the assessment (see multiple defects, p. 94). Allowing trees to reach a threshold of the minimum sound-rind thickness should be done only with evaluation of all other defects.

Drilling all trees is not recommended since it is time consuming and usually not warranted, lacking other indicators of internal defect. Trees in areas known to have a high incidence of hidden defect, however, may warrant close evaluation that may include drilling or sounding. Trees with substantial decay usually bear obvious indication of that defect or produce a hollow sound when pounded with a mallet or axe.

Signs of significant woodpecker activity, such as nest-cavity excavation, often indicate the presence of advanced decay. Woodpecker activity for nest sites should not be confused with sapsucker activity. Sapsucker damage often looks alarming but is only superficial. Chopping the bark or drilling into the wood can confirm the presence and extent of this defect. Be discrete with chopping so as not to suggest to visitors that it is an acceptable activity.

The bole above the lower butt is the next logical section to examine. From this point upward, visual examination can be employed to detect and estimate the extent of defect. Again, signs of past injury or fungal fruiting bodies should be the target of observation.

By the time old-growth trees exhibit fruiting bodies of stem-decay fungi, decay levels often are substantial. Fruiting bodies generally develop at the site of old branch stubs or wounds. Absence of conks, however, does not necessarily mean that a tree is free from decay. Record the presence of all signs of potential defect so that if treatment is not immediately warranted, the loss of a conk or misinterpretation of other signs will not lead future examiners to believe the stem is sound.

Tree tops and branches should be examined thoroughly. Free hanging and dead branches should be evaluated and dealt with as needed. Dead tops should be examined for decay and instability indicated by conks, crumbling sapwood, woodpecker activity, or nesting cavities. Binoculars are useful for this assessment.

Recreation site records covering a 10-year period in the Pacific Northwest revealed the frequency of tree failure by position of the defect on the tree (Table 4). Nearly two-thirds of all recorded failures occurred as a result of root or butt defects. Limb failures occurred more frequently in hardwoods than in conifers.

Documentation

A record that an inspection was done on a site is necessary to provide evidence that a survey was completed. Documenting trees with elevated hazard-rating (e.g. ratings of 6, 7, or 8) can provide evidence that a tree was examined and a decision made to mitigate the hazard or monitor the tree. *A tree record form (see Appendix) should be completed for trees with elevated hazard-tree ratings of 6, 7, or 8*. Healthy-appearing trees will be inspected but may not necessarily have an examination record filled out. Completing a formal report to the responsible official that describes the procedure used, documents the evaluation, and includes a record of trees with elevated hazard and recommended treatment is advisable. Recording results of evaluated trees in developed-site evaluations is necessary for several reasons:

1. The assessment of current hazards and forest health provides a foundation for future vegetation-management activities.
2. It records the predominant defects in each site making the job of future surveys easier.
3. It provides documentation for future hazard management and monitoring efforts.
4. It sets the baseline on which to build other vegetation structures and compositions, and planning and investment horizons.

5. It is the record of performance in the event of litigation.

Table 4. Distribution of failures by position of defect and tree species in Pacific Northwest recreation sites (Harvey and Hessburg 1992).

Tree species	Upper bole (%)	Lower bole (%)	Butt (%)	Branch (%)	Root (%)	Total number
Alder	23	11	30	1	35	154
Douglas-fir	17	11	15	3	54	404
Engelmann spruce	0	3	34	0	63	38
Grand fir	12	18	18	0	53	34
Incense-cedar	14	29	8	4	44	111
Larch	8	26	4	4	58	26
Lodgepole pine	13	8	7	3	69	637
Madrone	10	2	28	42	18	321
Maple	13	4	30	9	47	47
Mountain hemlock	12	77	0	0	12	43
Noble fir	37	11	0	0	53	19
Pacific silver fir	5	48	5	0	43	21
Ponderosa pine	42	6	5	0	47	280
Poplar	15	12	19	31	23	26
Red fir	16	30	13	1	40	87
Sitka spruce	18	27	18	0	36	11
Spruce, unidentified	0	53	0	0	47	297
Subalpine fir	55	3	24	0	17	29
Sugar pine	14	25	17	8	36	36
Tanoak	13	24	18	16	28	1614
Western hemlock	4	18	19	1	58	113
Western redcedar	0	15	12	10	63	41
White fir	6	53	15	0	26	34
Average	15	22	15	6	42	4423

A primary benefit of establishing a baseline survey and permanent database is that future site re-inspections and hazard monitoring are simplified. Hazard and monitoring information can be entered into a database and information generated annually, listing the trees indicated in prior inspections that are to be monitored in a given year. Files can provide the locations of specific trees relative to reference points, their species, size, and type of defect, their prior extent of defect, the appropriate monitoring interval, prior hazard and risk ratings, and recommended treatments. Stem maps can be generated using reference points and azimuth/distance information. Maps of virtually any specification can be generated: tree-removal maps for contractors, annual tree-visitation maps for defect monitoring and periodic re-evaluation, and complete developed-site maps for long-range planning and visual-perspective projections. Over time, annual layers of information may be accumulated and available for trend analyses of vegetation, pathogen and insect populations, and management activities.

For trees with disease or defects, a complete tree record should be developed at the time of the baseline survey and updated with each re-evaluation for developed sites where this is warranted. The tree record should contain all the data needed to discover trends for individual trees. When observed in aggregate, stand-level trends will become obvious. The following information should be recorded (see sample forms in Appendix):

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 (rind)
11. Cause of root or butt disease *(Phellinus weirii, Armillaria* spp., *Phaeolus schweinitzii*, etc.)

12. Stem defects (conks, decay, mechanical injury, fire damage, frost crack, dead top, etc.)
13. Stem-disease cause (*Phellinus pini, Fomitopsis officinalis,* etc.)
14. Failure-potential score and damage-potential score
15. Recommended treatment
16. Date treatment was accomplished

Decisions on the soundness of individual trees can be a matter of life or death to visitors and public employees. Care should be taken to do a thorough job. Adequate time must be allowed to evaluate all trees that have potential targets. An evaluation crew of two people is most effective and efficient. Ideally, hazard-tree inspections are done when weather and lighting conditions are favorable for seeing defects. Trees in developed-recreation sites may have great aesthetic and wildlife value and are difficult to replace. Removal decisions should be based on careful hazard evaluations and should consider other hazard-mitigation alternatives, such as seasonal closures, moving the location of potential targets, pruning, cabling, bracing, and others (Table 10). Sites that are closed for the winter should be evaluated the next spring for any root-sprung trees or recently cracked tree boles that have developed over the winter when high winds and snow/ice loading may have occurred.

Western hemlock with annosus rood disease showing advanced decay and the remaining sound wood (rind)

Determining defects and failure potential on the Mt. Hood National Forest.

Chapter 3 - Identification of Diseases and Defects that Result in Hazardous Trees

This section addresses native tree species and their common defects beginning with the roots and root collar, progressing to the butt and upper bole, and finally the limbs and tops. This is also the progression used in evaluating potentially hazardous trees.

Dead Trees

Tree-failure potential increases proportionately with the number of years a tree has been dead as sap-rotting fungi decay the roots, boles, and tops of dead trees. This decay process is slower for resinous species such as Douglas-fir, pines, and larch, because resin (pitch) inhibits fungal growth and insect attack (Table 5). Decay is also slower in cedars which have decay-inhibiting compounds in their wood. Decay is much faster in the sapwood than in the heartwood of dead trees. Heartwood also has compounds that inhibit decay by some sap-rotting fungi. Smaller dead trees, tops, and branches with proportionately more sapwood, decay faster than larger dead trees or tree parts with proportionately more heartwood.

For recently fire-damaged trees, where green needles may still be present, check the cambium at the root collar to determine if it is alive or dead. For most species, a tree is considered dead when at least three of the four quadrants from around the base of the root collar have cambium, inner bark, or phloem that are discolored and dead. For large ponderosa pines, a dead tree has all four quadrants with dead cambium.

Table 5. Resinous and non-resinous tree species groups in developed sites in Oregon and Washington

Species Group	***Resinous (decay resistant)***
True-fir (*Abies* spp.)	No
Hemlock	No
Spruce	Partially
Douglas-fir	Yes
Larch	Yes
Pine	Yes
Cedar	Non-resinous but decay resistant
Hardwoods	Non-resinous but some are more decay resistant than others

Accurate prediction of the failure of dead trees is difficult and uncertain, and targets in developed sites are stationary and of high value. Therefore, it is USDA Forest Service policy that dead trees of any species, size, age, or time since death have a **high-failure potential,** and the hazard should be mitigated in any developed site (Chapter 4 and Table 1). Dead trees may be retained if their damage potential is very low (score 1).

Wounded Trees

Tree wounds are injuries that break the bark of the stem or branch. Wounds occurring on tree roots and root collars can result in annosus root disease (p. 45), Schweinitzii root and butt rot (p. 55), tomentosus root and butt rot (p. 57), or ganoderma root and butt rot (p. 51). 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. 32) or a hollow interior is visible (Fig. 55). New wounds on living trees can be entry points for stem decay or canker-causing fungi, especially in large and deep wounds. Wounds also can activate dormant spores of decay fungi, such as the Indian paint fungus (p. 74). Wounds on non-resinous tree species (Table 5) generally result in more decay than do wounds on resinous species. Fresh wounds on Douglas-fir or ponderosa pine often are covered with resin.

After a tree is wounded, the wood-infecting micro-organisms may be confined to compartments within the tree through a process called compartmentalization. New wood formed annually after the wound occurs is relatively free of decay-causing micro-organisms, unless another wound occurs. The infected wood within the compartments may eventually become a decayed or hollow cylinder surrounded by healthy-appearing wood. This is referred to as the sound rind, and its thickness determines the failure potential of the affected tree (Table 3B). A wounded tree with a sound-rind thickness $<20\%$ of the tree's diameter inside bark has high-failure potential (Table 1). Over time, the tree may seal the wound with new wood resulting in a scar. The rate of wound sealing is a function of tree growth rate and vigor. Once the decay process starts in a living tree, however, it cannot be mitigated by wound dressings or similar treatments.

Table 6. Root and butt diseases in Oregon and Washington; frequency of occurrence by host species where 1=common, 2=occasional, 3=infrequent, 4=rare, and blank means non-host or unknown occurrence

Host species	Annosus root disease	Armillaria root disease	Black stain root disease	Ganoderma root and butt rot	Laminated root rot	Port-Orford-cedar root disease	Schweinitzii root and butt rot	Tomentosus root and butt rot	Yellow root rot
Alder	4	3		3					3
Aspen		2		3					
Ash				3					
Birch		3		3					3
Buckthorn	3								
Cedar									
Alaska	3	3		3	4		3		
Incense	3	3			4				
Port-Orford	3	3			4	1			
Western red	2	2		3	3		3		3
Cherry		3		3					3
Chinkapin		3		3					
Cottonwood	3	2		3					3
Dogwood		3							
Douglas-fir									
Coast	3	2	1	3	1		1	4	3
Inland	3	1	3	3	1		1	4	3
Hemlock									
Mountain	1	2	3	2	1		3		3
Western	2	2	3	2	2		3		3
Juniper	3	3			4				
Larch	3	3			2		1		3
Madrone	2	3							3
Maple	4	3		3					3
Myrtle				3					
Oak	4	2		3			3		

Table 6. Root and butt diseases in Oregon and Washington; frequency of occurrence by host species where 1=common, 2=occasional, 3=infrequent, 4=rare, and blank means non-host or unknown occurrence *(continued)*

Host species	Annosus root disease	Armillaria root disease	Black stain root disease	Ganoderma root and butt rot	Laminated root rot	Port-Orford-cedar root disease	Schweinitzii root and butt rot	Tomentosus root and butt rot	Yellow root rot
Pine									
Jeffrey	2	2	3	3	3		2	3	
Knobcone	3	3	3	3	3		2	3	
Lodgepole	2	3	3	3	3		2	3	3
Ponderosa	2	2	2	3	3		2	3	
Sugar	3	2	3	3	3		2		
Western white	3	2	3	3	3		2		
Whitebark	3	3	4	3	3		2		
Redwood	3	3			4		3		
Spruce									
Brewer	3	2		3	3		2	1	3
Engelmann	3	2		3	2		2	1	3
Sitka	3	2		3	3		2	2	3
Tanoak		2							
True Fir									
Grand	1	1		3	1		3	3	3
Noble	2	2		3	2		3	4	3
Pacific silver	1	2		3	2		3	3	3
Shasta red	2	2		3	2		3	4	3
Subalpine	2	2		3	2		3	4	3
White	1	1		3	1		3	3	3
Willow		3		3					3
Yew		3			4	4	3		

Root and Butt Diseases

Historically, root and butt diseases have been associated with particularly large numbers of tree failures in Pacific Northwest developed sites (Table 4). Some root mortality may be caused by adverse changes to the root-system environment such as can occur from excesive soil compaction or other disturbance (non-specific root decline). Most root diseases, however, are caused by fungi that decay roots and butts causing loss of anchorage of affected trees. Proper diagnosis is important because tree-failure potential can vary considerably depending on which disease is involved. Also, occurrence of each disease differs by host (Table 6) and often by geographic location. Root and butt diseases can severely weaken infected roots and lower stems and cause substantial loss of tree vigor. The most conspicuous impacts of such diseases on their hosts are predisposition to attack by bark beetles, outright tree death, wind breakage, and windthrow.

Unfortunately, root and butt diseases and the defects that they cause are often difficult to detect, and detection efforts are time consuming. Symptoms can be subtle, and many direct indicators of colonization and decay, especially in the early stages of disease, are located either underground where they cannot be seen without substantial excavation or inside of lower stems where drilling is necessary to evaluate them. Because of this, root diseases often go undetected in developed sites until wind storms blow over infected trees that reveal decayed roots and/or hollow butts. Because many root pathogens can survive for decades or centuries in old, infected root residues, it is extremely important to document presence of root diseases in developed sites, since they will likely continue to be significant tree-hazard concerns in those sites far into the future.

Symptoms and signs of root diseases on a host tree include some or all of the following (also see the appendix):

1. General decline of the entire live crown characterized by chlorosis of foliage, premature shedding of older needles, and terminal and, eventually, lateral shoot-growth reduction (Fig. 10)
2. Distress cone or seed crops
3. Dying branches or thinning crowns from the extremities inward in older trees or from the interior crown outward in younger hosts
4. Butt rot, sometimes extending as much as 30 to 35 feet up the stem from the base

5. Basal resinosis (Fig. 11), and/or bark staining (Fig. 12)
6. Windthrow or wind-shatter (Fig. 13)
7. Bark beetle attack (Fig. 56)

Fig. 10 – *Crown decline can be a symptom of root disease.*

Fig. 11 – *Basal resinosis is often associated with Armillaria root disease.*

Fig. 12 – *Bark staining is sometimes associated with Armillaria root disease.*

Fig. 13 – *Windthrow can be associated with root disease.*

Fig. 14 – *Dead and dying trees often are caused by root disease.*

8. A progression of dead, dying, and declining trees in discrete areas or pockets within the stand (Fig. 14)
9. Mushrooms or conks of root pathogens at root collars (Fig. 15) or in stumps
10. Presence of characteristic mycelia of the fungal pathogens on, in, or under the host bark in the roots and root collar area (Figs. 20, 21, and 23)

Fig. 15 – *Armillaria mushrooms are produced in autumn on infected trees.*

Unfortunately, while some trees may exhibit readily visible signs and symptoms, many more may be diseased but not yet showing above-ground indication of infections. Root pathogens typically spread through a stand at a relatively predictable rate; only a portion of their progress at any given time is manifested by above-ground symptoms.

During extended drought periods, root disease diagnosis becomes even more complex. Drought conditions intensify the effect of disease damage on tree vigor and further lower host resistance to infection and decay. More bark beetle infestation and more tree mortality from the combined effects of root diseases and bark beetles acting together result during and just after periods of drought. It also is often more difficult to confirm the type of root disease associated with tree mortality during droughts, since the trees may be attacked by bark beetles earlier in the progress of the disease before signs of the root pathogen are accessible and apparent.

Major root and butt diseases that contribute to tree hazard in developed sites in the Pacific Northwest include the following:

Annosus root disease is caused by two species of fungi, *Heterobasidion occidentale* and *H. irregulare*. Formerly, these two species were considered to be different forms of the same species, *H. annosum*. These two fungi look alike, have the same life cycles, and can cause the same kind of disease, but they differ genetically and, most importantly, have different host ranges. In the Pacific Northwest, *H. occidentale* primarily infects true firs, hemlocks, and spruces while *H. irregulare* mainly infects pines and junipers. Though one species may occasionally infect stumps of the other, cross over to live trees is negligible and not practically important from a hazard-evaluation perspective.

Annosus root disease, especially that caused by *H. occidentale*, often is encountered in developed sites and is capable of contributing to very substantial tree hazard. Unfortunately, its occurrence appears to be increasing in Pacific Northwest developed sites. *H. occidentale* is distributed throughout the forested areas of Washington and Oregon. *H. irregulare* is found primarily in dry areas east of the Cascades in the two states.

Both *H. occidentale* and *H. irregulare* are spread over long distances by windborne spores that land on and infect fresh wounds and newly created stumps of host tree species (Table 6). Spread by spores can occur over many miles. Once a stump is colonized, the pathogen grows into the roots, and the stump becomes an inoculum source. Spread to additional host trees occurs when their roots contact these previously colonized root systems, and the fungus grows across. Spread across root systems requires actual contact; fungal mycelia grow within and on the surface of roots but do not grow through soil. Spread across root systems occurs at a rate of about one to two feet per year. Fungal inoculum in infected stumps and trees can remain viable for decades after tree death, being especially long-lived in very large stumps or snags.

Annosus root disease can affect hosts in two ways; it can cause a root and butt rot that becomes more extensive with time and can eventually contribute to windthrow or stem breakage, or it can girdle the host by killing the cambium around all or most of the root collar. True firs are frequently killed by stem girdling but also may develop root and butt decay. Hemlocks and spruces mainly experience root and butt decay. Pines and junipers are killed by girdling.

Annosus root disease is often the most difficult of root diseases to diagnose. Hazard-tree evaluators are well advised to seek assistance from experienced forest pathologists in cases where they suspect annosus root disease. Some host trees infected by *H. occidentale* (especially those true firs that are eventually killed by girdling) and *H. irregulare* (pines and junipers) may exhibit crown symptoms similar to those caused by other root diseases, including foliage fading and thinning, needle chlorosis, growth reduction, and appearance of scattered dead branches in the crown in the years before death (Fig. 14). Others trees show virtually no crown symptoms and appear to die without warning. Some infected trees (especially pines) exhibit basal resin flow (Fig. 11). Hemlocks and spruces that develop butt and lower stem decay rarely show crown symptoms. Decay in these species tends to develop rather slowly. Significant decay that is capable of contributing to tree failure usually does not develop until host trees of these species have reached ages of at least 150 years.

Fruiting bodies of *Heterobasidion* are perennial conks with woody or leathery black to chestnut-brown upper surfaces, white pore-less margins and creamy-white undersurfaces with small, round, irregular pores (Fig. 16). Conks may be found in old stumps, just above ground in root crotches of living, infected trees, and below ground on roots of living or dead hosts. Young conks on roots appear as small, white to buff pustules. Presence of a conk on a tree or stump proves infection, but the opposite is not true; many *Heterobasidion*-infected trees do not produce conks. The presence of a conk on a tree or in a stump indicates that adjacent trees of host species also have a high probability of being infected as well as the tree or stump where the fruiting body is actually found.

Incipient decay of *Heterobasidion* is a light-brown to reddish stain in the outer heartwood (Fig. 17). Advanced decay is white and stringy (Fig. 18) or laminated with elongated pits on only one side of the laminations and no setal hyphae (Fig. 19). Pathologists with laboratory facilities can incubate samples of wood with suspicious stain or early decay and confirm or disprove the presence of *Heterobasidion* based on whether or not diagnostic microscopic fruiting bodies are formed.

Clearly, hidden infection by *Heterobasidion* is common. Individual trees with wounds may be infected while showing only the most subtle of indicators or no apparent indicators at all. Annosus root disease can occur in small infection foci centered on old, infected stumps or wounded trees or in large infection centers where tree-to-tree spread has occurred for many decades. Often, many infected host trees in either kind of situation lack indicators.

When annosus root disease is confirmed in a developed site, live trees in and around disease centers vary in failure potential depending on geographic area, tree species, tree condition and age, and the presence of adjacent windthrown trees with evidence of root disease (Table 1). Host trees that have already been killed or will likely die soon, as well as older host trees with confirmed *Heterobasidion*-induced butt rot, will have the highest failure potential. Because the fungi that cause annosus root disease can spread long distances by spores that infect

Fig. 16 – *Conks associated with annosus root disease often form in hollow stumps.*

Fig. 17 – *Stain caused by* Heterobasidion occidentale *in grand fir.*

Fig. 18 – *White-stringy decay caused by* Heterobasidion occidentale *in a western hemlock stump.*

Fig. 19 – *Laminated decay can be caused by* Heterobasidion occidentale.

through wounds and newly cut stumps, it is easy to see why decay occurrence may indeed be increasing in long-established developed sites. Major efforts should be designed to minimize or avoid tree wounding, especially of true firs, hemlocks, and spruces, in developed sites. Treatment of all freshly cut stump surfaces of *Heterobasidion* hosts with registered boron compounds is highly recommended (p. 96).

Armillaria root disease on conifer hosts is caused by the fungus *Armillaria ostoyae*. On hardwoods it is caused by either *A. gallica* or *A. mellea*. Though not as damaging as laminated root rot, Armillaria root disease has a history of frequently causing tree mortality in developed sites in the Pacific Northwest. The fungi that cause Armillaria root disease are extremely common and are distributed throughout all forested areas in Oregon and Washington.

The *Armillaria* species that cause root disease can survive as saprophytes in dead host material for at least 50 years. Spread to new hosts involves mycelial growth across root contacts or for very short distances in soil between old, infected roots and the roots of new hosts, or spread to new roots over greater distances through soil via rhizomorphs (shoestring-like structures that may extend two feet or more from an infected root into the soil). The pathogen then spreads to additional new, living hosts by growing across root contacts or through soil between them. The pathogen forms gradually expanding infection centers that enlarge radially at a rate of one to two feet per year. *Armillaria* species form mushrooms (Fig. 15) that can produce viable spores, but the role of spore spread with the disease-causing *Armillaria* species is not believed to be significant.

Armillaria can infect the roots of most Pacific Northwest tree species (Table 6). *Armillaria* species may function either as weak pathogens of stressed, low-vigor trees or as aggressive killers of susceptible hosts. *Armillaria* species can be quite variable and affect hosts differentially in different areas. As general rules:

1) Infection of stressed or injured conifers is most likely on high-productivity coastal and Westside sites while aggressive tree killing is more common east of the Cascades in Oregon and Washington and in the Cascades in Southwest Oregon,
2) Infection of hardwoods is frequently associated with stress or wounding throughout the Pacific Northwest,
3) In most cases among conifers, the true firs are the most highly susceptible hosts of Armillaria root disease, interior Douglas-fir is intermediately susceptible, and other conifers are usually somewhat tolerant or resistant,
4) Tree susceptibility to Armillaria root disease can in some cases differ markedly by location in ways that are not yet understood; for example there are areas in southwestern Oregon, south-central Washington, and northeastern Washington where pines can be severely damaged, and Douglas-fir is the most severely damaged host in some localized areas in northeastern Washington,
5) The Armillaria species that cause root diseases often occur in combination with other root disease organisms, especially *Phellinus weirii, Heterobasidion occidentale, Leptographium wageneri,* or *Phaeolus schweinitzii.*

Armillaria species generally kill host trees by colonizing the phloem and xylem of the roots and root collar and disrupting movement of water and nutrients in the tree. The cambium around the host's roots and root collar is killed by the fungus, preventing uptake of water and nutrients. Infected trees are frequently predisposed to infestation by bark beetles and wood borers. Trees generally die standing. Though roots may be decayed to a degree, windthrow of trees prior to death is not as common as with other diseases such as laminated root rot and annosus root disease.

Recognizing Armillaria root disease is usually easier than recognizing annosus root disease or laminated root rot. Infected trees show typical root disease crown symptoms, including crown thinning, foliage chlorosis, growth decline, and formation of stress cone crops (Fig. 10). Infected trees also often exhibit resin flow or bark staining at and above the root collar (Fig. 11) and resin-soaked, decayed wood interspersed with straw-colored flecks in the butt and roots. Rhizomorphs may be found under the bark of infected trees, and honey-colored mushrooms are often formed at the bases of infected trees in autumn (Fig. 15). Probably the most certain way to confirm the presence of *Armillaria* is to chop into the root collar of a declining or recently dead tree and observe the white, latex-like mycelial fans that are produced just under the bark (Fig. 20). When these are thick, associated with heavy resin flow, and extend above the ground line, they are considered diagnostic of Armillaria root disease. In the aggressive tree-killing case, dead and dying trees of susceptible host species will be situated in and around disease centers that exhibit evidence of progressive tree mortality over many years (Fig. 14). Infection centers can be very large. In cases where *Armillaria* is affecting low vigor and stressed hosts, infected trees may appear as scattered individuals or small groups of dead and dying trees, often clearly associated with such stress factors as wounding, compacted soils, offsite plantings, drought, infection by other disease organisms, or fires.

Fig. 20 – Armillaria ostoyae *often produces mycelial fans under the bark of infected trees.*

As with annosus root disease or laminated root rot, not all *Armillaria*-infected trees can be easily identified. Apparently healthy trees of susceptible species that are growing close to dead or obviously declining trees with identifiable Armillaria root disease also have a high probability of being infected. The actual extent of an *Armillaria* infection center is larger than indicated by obvious indicators.

When Armillaria root disease is diagnosed in a developed site, trees in and around root disease centers vary in failure potential depending on tree species and condition and the presence or absence of adjacent windthrown trees with root disease (Table 1). Since Armillaria root diseased trees are usually killed standing, such dead trees should be considered to have the same **high-failure potential** as any other dead trees. Live infected and symptomatic trees that occur on sites where trees infected by *Armillaria* have previously been windthrown may also be considered to have **high-failure potential** in the few cases where such a scenario occurs (Table 1).

Black stain root disease is caused by *Leptographium wageneri*. The disease is a vascular wilt that causes tree mortality but not root decay. A characteristic sign is a brown to purplish-black stain in older sapwood that fades with time in dead trees. The disease is spread from tree-to-tree across root grafts and contacts by mycelial growth, and mycelia also grow very short distances in soil. Long-distance spread is via root-feeding bark beetles and weevils that are attracted to stressed trees. Black stain root disease kills all ages of ponderosa pines at some locations east of the Cascade Crest and young Douglas-fir on the westside. Other species besides the pines and Douglas-fir are rarely affected (Table 6). Black stain root disease often is associated with soil disturbance along roads with soil compaction or large numbers of injured host trees. Black stain root disease has been found in a few developed sites in the Pacific Northwest but is not nearly as common as laminated root rot, Armillaria root disease, or annosus root disease. Because black stain root disease does not cause root decay, affected trees die standing and then have **high-failure potential**. Live trees with disease signs and symptoms have **low-failure potential** (Table 1).

Ganoderma root and butt rot or **white mottled rot** affects many conifer and hardwood species (Table 6). It occurs in wounded, live trees and dead or broken trees. The decay is caused by two species of fungi: *Ganoderma tsugae* and *G. applanatum. Ganoderma tsugae* occurs only on conifers and forms a distinctive conk that is annual, stalked, eggshell-like, reddish-brown, and shiny as if lacquered or varnished; hence, the common name, "lacquer fungus" or "varnish conk." *Ganoderma applanatum* occurs on dead or partially dead conifers and on live or dead hardwoods. It produces conks that are perennial, leathery to woody, and may or may not be stalked. The conk undersurface is white to creamy and is easily bruised; hence, the common name "artist's conk." Decay associated with both species is a white spongy rot with black specks. When Ganoderma root and butt rot is diagnosed in developed sites, host trees can have **high or medium-failure potential** depending on the extent of butt decay (Table 1).

Laminated root rot is caused by the fungus *Phellinus weirii*. A proposed new name is *Phellinus sulphurascens*. It is the most damaging root disease of forest trees in Oregon and Washington and one of the most hazardous to people and property in developed sites. It is widely distributed and common in the forests of Washington, western Oregon, and eastern Oregon north of the Crooked River.

The fungus that causes laminated root rot can remain viable and infective for more than 50 years after a colonized host has died. The roots of old stumps and standing, dead trees function as virulent inoculum sources for decades after the trees have been killed or cut. The fungus spreads to new hosts via an ectotrophic mycelium (Fig. 21) that grows onto new host roots when they make direct contact with old, infected, residual roots. Subsequently, the pathogen spreads to additional living hosts by growing across root contacts and grafts between them. Thus the pathogen forms gradually expanding infection centers in stands with major host components. The fungus grows across roots at a rate of about one to two feet per year. Long-distance spread involving spores probably occurs occasionally with *P. weirii*, but appears to be so infrequent that it is not of practical importance.

Phellinus weirii can infect the roots of all Pacific Northwest conifers (Table 6). Highly susceptible hosts are true firs, Douglas-fir, and mountain hemlock. These tree species are readily infected and their roots are extensively decayed by the pathogen. Other conifers can tolerate or resist infection and/or damage to various degrees (Table 6). Though their roots are not as severely decayed as are those of highly susceptible host trees and they are much more tolerant of the disease, larches, spruces, and western hemlock infected by *P. weirii* may develop substantial butt rot over time. Pines and cedars are rarely infected and almost never killed by *P. weirii*; however, even with these species,

Fig. 21 – *Ectotrophic mycelium of* Phellinus weirii *is produced on infected roots of Douglas-fir.*

some root colonization can occur, and the pathogen may maintain itself on the site. All hardwoods are immune to *P. weirii*.

The roots of highly susceptible hosts are extensively decayed by *P. weirii* leading to tree death (often as a result of predisposition to bark beetle infestation) or windthrow. Windthrow frequently occurs among highly susceptible hosts with still-green crowns including some that exhibited little if any evidence of crown symptoms prior to falling. This makes laminated root rot particularly dangerous when occurring in a developed site. More tolerant hosts that develop butt rot may break at the butt or lower stem as decay advances with age.

Recognizing laminated root rot is not always easy but skill in doing so improves with experience. Many infected hosts, especially of the highly susceptible tree species, do show crown symptoms typical of major root diseases (Fig. 14), especially when individual root systems have half or more of their roots affected. These symptoms include crown thinning, foliage chlorosis, growth decline, and formation of stress cone crops. Some infected trees exhibit basal resin flow. *Phellinus weirii* occasionally produces flat buff-colored conks, but these are cryptic, difficult to find, and uncommon enough that they have little diagnostic value. Laminated root rot centers are frequently characterized by an abundance of windthrown trees, with only stubs of roots remaining (Fig. 22). Laminated decay that separates easily at the growth rings and is pitted on both sides of the layers is usually evident in the broken off roots (Fig. 24). It can also be detected in excavated roots of standing infected trees or in the stumps of infected trees that were previously cut.

Diagnostic evidence of *P. weirii* is occurrence of tufts or mats of reddish-brown setal hyphae between the sheets of characteristically decayed wood (Fig. 23). Because of their small size, confirming the presence of setal hyphae is easiest when the evaluator uses a hand lens. On the roots of infected living trees, excavation of roots can reveal the ectotrophic mycelium of *P. weirii* (Fig. 21) as a grayish-buff, crusty sheath of fungal material on the surface of the bark that cannot be readily rubbed off. Close examination shows that this ectotrophic mycelium often contains tufts of setal hyphae. Chopping into roots of infected trees can reveal a reddish stain in

Fig. 22 – *Rootballs with missing major roots, as shown here, are decayed by* Phellinus weirii.

Fig. 23 – *Setal hyphae, the red-brown, fuzzy material shown here, are diagnostic for laminated root rot.*

Fig. 24 – *Laminated decay as shown here is caused by* Phellinus weirii.

the wood in advance of the occurrence of the ectotrophic mycelium. On the cut surface of the stump of an infected tree, stain will often appear in a crescent shape in the wood that is visible for a week or two after the tree is cut. Hollows or crescent-shaped areas containing advanced decay are also encountered on stumps of some infected trees. In long-established recreation sites, a history of frequent removal of dead and windthrown trees can mean that finding *P. weirii* decay in old stumps is particularly useful and important because stumps are the only indicators left of disease in the particular area.

Management of laminated root rot centers is important for long-term prevention of future hazard trees. This is done by determining the boundaries of the root disease center by using crown symptoms and root excavations to identify the disease. Include a buffer around the disease center that extends at least two trees beyond the last tree with confirmed root disease. Many of the trees within this buffer, if of susceptible species, probably will be infected and failure prone. It is recommended that recreation personnel work with silviculturists or pathologists in developing treatment options for developed sites with laminated root rot.

When laminated root rot is diagnosed in a developed site, trees in and around root disease centers vary in failure potential depending on tree condition, size, species, and the location relative to adjacent diseased trees. *Phellinus weirii*-infected trees of highly susceptible host species often represent the highest possible failure potential. Given the history of damaging failures due to laminated root rot in recreation sites in the Pacific Northwest, the often unpredictable nature of these failures, and the difficulty frequently associated with detecting the disease and determining the actual extents of affected areas, laminated root rot should be of particular concern to hazard evaluators and managers of developed sites.

Port-Orford-cedar root disease is caused by *Phytophthora lateralis*. It is an introduced pathogen that causes cambial death and subsequent tree mortality but not decay. The main host is Port-Orford-cedar, although Pacific yew also can be infected on rare occasions (Table 6). The diagnostic symptom is a cinnamon-colored stain in the inner bark of roots and lower stems. The disease is found mainly in southwest Oregon, although it appears in other areas where ornamental Port-Orford-cedars are grown. Port-Orford-cedar root disease is common along roads, watercourses, and in poorly-drained areas. It has been found killing cedar in recreation sites. As with black stain root disease, affected trees die standing and then have **high-failure potential.** Live trees with disease signs and symptoms have **low-failure potential** (Table 1).

Schweinitzii root and butt rot is caused by *Phaeolus schweinitzii*. It vies with laminated root rot as the most common cause of conifer failure in developed sites across Oregon and Washington. On the westside of the Cascade Range, significant butt decay may be indicated by occurrence of the conspicuous fruiting body, referred to as the "cow-pie fungus" or "velvet-top fungus", and often by a swollen butt on host trees (Fig. 26). Fresh conks are velvety to the touch and have brightly colored yellow margins. As a conk ages, it dies, turns brown, and lasts about two years (Fig. 25). On the eastside of the Cascade Range, infection and decay may be as common but are often present without indicators. As such, it is less often discovered until significant wind events and tree failures have occurred. Tree mortality and windthrow are unusual unless associated with Armillaria root disease in eastside forests.

Decay of the butt extending as much as 30 feet up the tree occurs on old trees (>150 years). Butt swell, which develops over many decades, is apparent on trees, especially Douglas-fir with extensive butt defect (Fig. 26). Trees with butt rot often fail under high-wind conditions leaving a characteristic barber chair and shattered butt. Unfortunately, the presence of significant decay in roots and butts is not always indicated by the presence of the characteristic conks, even on the Westside where they are most commonly produced. Also, the presence of conks does not always indicate significant decay in the roots or butts. Therefore, suspect trees (those with conks, butt swell,

Fig. 25 – *Older mushrooms of* Phaeolus schweinitzii *often resemble "cow-pies."*

open cracks, or wounds) should be drilled near the root collar to determine the extent of decay and safe sound-rind thickness (Tables 3A and B). Since decay is commonly found throughout the roots and lower bole, decay found at the base of the tree by drilling should be reason for concern.

Fig. 26 – *Butt swell of Douglas-fir is often associated with root and butt decay caused by* Phaeolus schweinitzii.

The advanced decay is a brown cubical rot. The incipient stain, while distinctive, is rarely observed except on freshly cut log ends. The incipient stain is light green, occurring immediately adjacent to areas of advanced decay. Damage most often occurs in overmature Douglas-fir and Sitka spruce on the westside (Table 6). Douglas-fir, western larch, ponderosa pine, and lodgepole pine are frequently damaged on the eastside. In SW Oregon, Douglas-fir, ponderosa pine and sugar pine are frequently decayed. For all but lodgepole pine, the pathological rotation age is approximately 150 years. For lodgepole pine, that value is a range of years from 100 to 120 depending on site quality, site productivity, and growth history. The high end of the range coincides with the best lodgepole sites. It is important to remember that for lodgepole pine, age becomes a limiting factor in susceptibility to mountain pine beetle beginning at about 80 to 100 years.

Trees are apparently infected by this pathogen at any age. Fresh trunk wounds caused by mechanical injury or fire probably are not infected directly by spores but instead the wounds exacerbate decay in previously infected roots and butts. Many infections, especially on the eastside, also occur by mycelial spread from diseased to healthy roots through litter and organic residues to root tips. Infections are confined to heartwood and are sequestered as relatively innocuous heartwood lesions. When trees are immature, smaller roots with heartwood are decayed. As trees advance in age, larger roots are decayed with increasing deleterious effects on anchorage.

When Schweinitzii root and butt rot is encountered in developed sites, trees should be carefully and thoroughly evaluated rather than automatically removed. This root disease appears to be quite slow to weaken trees to hazardous levels. Evaluations should include examination for obvious leans, recent root wrenching or partial failure, butt swell, shake or cracking of the butt, and evidence of ant or wood borer activity in the butt. Additionally, each of the major lateral roots should be exposed and drilled within 2 feet or so of the root collar to detect any hidden defect in the roots that provide major anchorage. If most of the major root anchorage is not decayed, the tree may be retained and monitored each year or every other year depending on the extent of defect and decay. Trees with seriously compromised anchorage and inadequate sound-rind thickness should be removed or the hazard otherwise mitigated.

On mesic and wetter sites where conks are more abundant, a single fruiting body indicates that the evaluator should take note and examine the defective tree more closely. Once trees with fruiting bodies have been examined, those susceptible hosts immediately adjacent to them should be evaluated in the same way.

Tomentosus root and butt rot is caused by *Inonotus tomentosus*. The infection and spread biology of tomentosus root rot is similar to that of annosus root disease. Inter-tree spread occurs via an ectotrophic mycelium, and spores are involved in infection of new wounds and freshly cut stumps. The importance of spores in local spread is poorly understood. In developed sites, Engelmann spruce is most often affected (Table 6), and damage is manifested typically as windthrow or wind shattering of severely butt-rotted, mature trees. Tomentosus root and butt rot typically does not cause extensive damage in developed sites but is locally important in the Cascade and Blue Mountains. This disease may be completely hidden in trees including some with extensive butt rot. Trees with crown symptoms are not common, making this disease difficult to detect. Also, infection in developed sites usually is not in concise disease centers as occurs with laminated root rot or Armillaria root disease.

Tomentosus root and butt rot is identified in the field by its characteristic fruiting bodies, which are small, yellow to cinnamon-colored, leathery, and may appear in the fall near the bases of defective trees. Even when infection and decay are common, fruiting bodies are seldom produced in some localities, especially in the Blue Mountains. Incipient decay in spruce roots has a distinct pink color that can be detected by drilling (Fig. 27). Healthy wood is cream-white. Advanced decay is a white, pocket rot. Ectotrophic mycelia may occur, but in no instance should ectotrophic mycelia alone be used to diagnose a specific root disease; three of the root diseases discussed in this guide produce surface mycelia, and there is chance of confusion. Other, better indicators are available for each root disease (see Appendix), and several diagnostic clues should be used for each correct diagnosis. Check spruce with potential targets with a drill or borer to detect decay, regardless of external indicators.

When tomentosus root and butt rot is encountered in developed sites it should be addressed immediately. Resistant and tolerant hosts should also be regenerated in tomentosus root and butt rot centers where practical (Table 6). When tomentosus root and butt rot is diagnosed in developed sites, host trees (usually only spruce) in root disease centers can have **high or medium-failure potential** depending on the extent of butt decay (Table 1).

Yellow root rot or **stringy butt rot** is caused by *Perenniporia subacida* which can cause tree mortality or butt rot in suppressed or stressed trees especially Douglas-fir, true firs, and western hemlock as well as many hardwood species (Table 6). Affected trees may be easily windthrown. The 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. Early decay is a light-brown stain that resembles wetwood. Advanced decay is composed of irregularly shaped pockets of decayed springwood that coalesce into masses of stringy fibers with black flecks. Annual rings may separate into a laminated decay. Yellow-white mycelial mats may form between the laminated sheets of wood. Because signs and symptoms are below ground, the disease is difficult to detect in live trees. Host trees can have **high or medium-failure potential** depending on the extent of butt decay (Table 1).

Fig. 27 – *Stain in a spruce root often is caused by* Inonotus tomentosus.

Other Root Problems

Other important root defects include undermined roots that result from erosion, seasonally high waterline or flooding events, and excavation or construction activities. Other root problems include severed roots that are mechanically induced by various construction, road building, and maintenance activities; and loosened, cracked, or broken roots which are caused by high winds and typically result in partial failures. Tree-failure potential is determined by the amount of structural roots remaining in the ground (Table 1).

Undermined roots are often associated with road-building or trail-building activities in and around developed sites. Otherwise, they frequently are observed at waters' edge adjacent to lakes, streams, or rivers (Fig. 28). When soil is eroded away from tree roots by the action of swift current or by waves, anchorage is compromised. Erosion also occurs during and after heavy precipitation, when rainfall intensity, duration, and accumulation exceeds the soil infiltration rate (capacity of the soil to absorb water). The result is high runoff; sheet, rill or gully erosion; and often root undermining. Extreme amounts of undermining can cause tree failure from insufficient anchorage.

Severed roots act as entrance points for decay fungi. They are commonly associated with utility installations, road building, and trail-building activities. Many of the fungi that enter at these points of injury will cause root and butt decay that eventually predisposes trees to windthrow or other types of failure. Other activities that are associated with severed roots are tent-pad construction or ditching to divert runoff in areas where tents are routinely pitched, building construction, and excavation for placement or repair of water or sewage lines or toilet facilities. While severing of roots is not often immediately hazardous, the damage is always detrimental in the long term and should be avoided as much as possible. In addition to providing anchorage and support, roots are essential for water and nutrient uptake. Significant reductions in root system uptake and translocation capacity by root severing diminish tree vigor and resistance to attacks by bark beetles and root pathogens.

Loosened, cracked, or broken roots predispose trees to failure during high winds. Wind events, saturated soils, and soil disturbances occurring singly or in combination, often lead to loosening, cracking, or breakage of roots. Soil saturation is a leading factor in windthrow of shallow-rooted species, or of any

Fig. 28 – *Undermined roots, as shown here, can result in tree failure.*

species growing in high density or in shallow soil. Indicators of root damage include:

- Trees with newly developed or newly accentuated leans (Fig. 29); soil and litter are not in contact with the base of the tree on the side away from the lean (there is a conspicuous gap) and
- Cracks, mounds, or ridges of recently heaved soil adjacent to major lateral roots (Fig. 30).

Roots of trees located in heavily used areas frequently become exposed to the air and are subsequently damaged. This is particularly true in areas where tents are routinely pitched, adjacent to fire rings, barbecue pits, picnic tables, or in any area where protruding roots are an inconvenience to users, such as in hiking or biking trails.

Leaning, Root-sprung, Broken, or Uprooted Trees Supported by Other Trees

Root-sprung trees are likely to fail because their roots are compromised by being partially pulled out of the ground. Such trees are dangerous and are seen as failures in progress. Leaning trees (≥15 degrees) result from root and butt decay, and from high winds that cause root wrenching. Tree leans are either recent or old. All leaning trees should be examined for evidence of severe root and butt rot.

Trees with recent lean (<5 years) may have soil and litter disturbed

Fig. 29 – *Newly developed leans lack tops that point upward (uncorrected).*

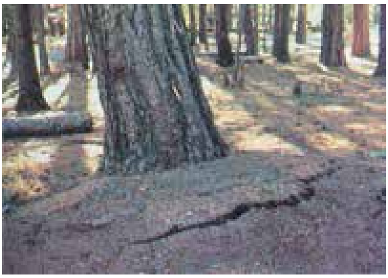

Fig. 30 – *Cracks in the soil around leaning trees indicate that such trees have a high-failure probability.*

and not in contact with the base of the tree on the side away from the lean resulting in a conspicuous gap (Fig. 30). Cracks, mounds, or ridges of recently heaved soil may be adjacent to major lateral roots of leaning trees. Recently leaning trees are tilted over their entire length. Since there is no evidence of subsequent reinforcement of the root system, examiners must assume that such partially failed trees exhibit a **high-potential for failure**. Hazard associated with recently leaning trees should be addressed immediately.

Fig. 31 – *Old leans with righted or corrected tops have low-failure probability.*

Old, leaning trees are those that have been leaning for a considerable time and have grown a vertical top in the time since the lean developed (corrected lean) (Fig. 31). 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, where roots were wrenched, to compensate for prior damages. Unless these roots are disturbed or decay is present, old, corrected, leaning trees have **low-failure potential.** Trees that are uprooted or broken but supported by other trees have **high-failure potential** (Table 1).

Heart Rots

Heart rots are most damaging to mature and overmature trees (old growth), regardless of tree size. By definition, heart rots are confined to the true heartwood. There are some "heart rots" that will affect both the sapwood and the heartwood of living trees. The extent of defect is best correlated with tree age and not diameter. Most of the damage associated with heart rot fungi in most conifer species will occur in trees that are more than 150-years old. Especially decay-prone species such as western hemlock and grand fir, however, may have substantial decay at even younger ages (Table 5). Most fungi that cause stem decay gain access through wounds caused by humans, animals, fire, lightning, snow, high winds, bark beetles, or other agents. Some fungi commonly enter through branch stubs. Wounds, callus tissue, conks, mushrooms, punk knots, swollen knots, old snow breaks, crook, shake, frost cracks, wetwood, bole flattening, or depressions are all potential indicators of internal defect.

In most cases, when stem decay is extensive enough within the bole of a tree to be hazardous, it can be detected by the occurrence of conks, punk knots, and open wounds (Fig. 32). Heart rots, however, may be present when there are few or no external indicators. For example, when conks have fallen from a defective tree and are not observed on the ground, or in dry-habitat types where conks are rarely or not regularly produced. Trees without indicators can be evaluated for the presence of heart rots by several methods.

One way to detect a hollow or decay column is by striking the tree trunk with a rubber mallet or the butt of an axe. To use this method, though, the examiner must develop an ear for recognizing the unique sound of a hollow or decay, and thick-bark species are often difficult to sound. Additionally, detection of a hollow does not mean that the affected tree is a serious hazard to people or property. To evaluate the structural integrity of the suspected tree, the examiner must bore into the tree at the point of defect, either with an increment borer, or a cordless drill, and determine the thickness of the remaining rind of sound wood (Tables 3A and B).

Fig. 32 – *Tree bole with an open wound where the sapwood is exposed*

If the suspected defect is well above the ground, very valuable trees can be climbed and drilled; otherwise, most decay and defect high in a tree should be assessed with binoculars and professional judgment rather than by climbing. Trees that are large and mature or overmature routinely will have the greatest amount of stem decay. Some of that defect will be hidden and inaccessible to the examiner by conventional means of evaluation. Risks associated with defects that have been identified but not directly evaluated by boring, or those that are suspected (based on detection

Table 7. Heart rots in Oregon and Washington; frequency of occurrence by host species where 1=common, 2=occasional, 3=infrequent, 4=rare, and blank means non-host or unknown occurrence

Host species	Ash trunk rot	Annosus stem decay	Aspen trunk rot	Brown cubical rot	Brown cubical rot of birch	Brown stringy trunk rot	Brown top rot	Brown trunk rot	Hardwood trunk rot	Incense-cedar pecky rot	Inonotus trunk rot	Juniper pocket rot	Maple trunk rot	Mottled rot - Pholiota	Red cedar pencil rot	Red heart rot - Stereum	Red ring rot / white speck	Redwood cubical rot	Rust-red stringy rot	White spongy trunk rot	White trunk rot	Yellow pitted rot
Alder						2								3		3	4			3		
Aspen			1	3							2			3						3		
Ash	2								3		3											
Birch		3		3	1				3							3	3			1		
Buckthorn		3							3													
Cedar																						
Alaska																	4					
Incense										2							4					
Port-Orford																	4					
Western red				3											1		3					
Cherry				3					3							3				3		
Chinkapin									3													
Cottonwood		3		3		1			3		2			3						3		
Dogwood									3													
Douglas-fir				3			2	2	4							3	1					
Hemlock																						
Mountain		1		3			3	2			2			3		3	1		1		3	2
Western		1		3			3	2			2			3		3	2		2		2	3
Juniper												2					3					
Larch				3			3	2								3	1					
Madrone		3					4		3													
Maple		4		2		2			3		2		2	3		3	3			3		
Myrtle				2																		
Oak		3		2		2			3		2					3	3			3		

Table 7. Heart rots in Oregon and Washington; frequency of occurrence by host species where 1=common, 2=occasional, 3=infrequent, 4=rare, and blank means non-host or unknown occurrence *(continued)*

Host species	*Ash trunk rot*	*Annosus stem decay*	*Aspen trunk rot*	*Brown cubical rot*	*Brown cubical rot of birch*	*Brown stringy trunk rot*	*Brown top rot*	*Brown trunk rot*	*Hardwood trunk rot*	*Incense-cedar pecky rot*	*Inonotus trunk rot*	*Juniper pocket rot*	*Maple trunk rot*	*Mottled rot - Pholiota*	*Red cedar pencil rot*	*Red heart rot - Stereum*	*Red ring rot / white speck*	*Redwood cubical rot*	*Rust-red stringy rot*	*White spongy trunk rot*	*White trunk rot*	*Yellow pitted rot*
Pine																						
Jeffrey							4	2						3		3	1					
Knobcone							4	4						3		3	1					
Lodgepole				3	3		4	2						3		3	1					
Ponderosa				3	3		4	2			3			3		3	1					
Sugar				3	3		4	2						3		3	1					
Western white				3	3		4	2						3		3	1					
Whitebark							4	4						3		3	1					
Redwood																		3				
Spruce																						
Brewer		3		3			3	3						3			2					3
Engelmann		3		3			4	3			3			3		3	2		3			3
Sitka		3		3			3	3			3			3		3	2					3
Tanoak																						
True Fir																						
Grand		1		3			4	3			3			2		3	1		1		3	3
Noble		2		3			4	3						2		3	2		2		3	2
Pacific silver		1		3			4	3						2		3	2		2		3	2
Shasta red		2		3			4	3						2		3	2		2		3	2
Subalpine		2		3			4	3						2		3	2		2		3	2
White		1		3			4	3			3			2		3	1		1		3	3
Willow				2					3							3				3		
Yew														3			2				3	

clues) but not clearly identified, should be carefully considered. When the potential risks are considered unacceptable if hazardous levels of decay are known to exist, the potential hazard should be more thoroughly investigated or mitigated, but never ignored.

Failure potential of trees with internal decay is directly related to trunk diameter and average thickness of sound wood at the conk or defect. Because living trees can compartmentalize decay within wood infected when stems were wounded, affected trees often have hollows or decayed areas within a cylinder (rind) of sound wood that was added after wounding (Fig. 9). Conifers can lose approximately 70% of the total cross-sectional area to wood decay (which is equivalent to about 1/3 of its strength or resistance to failure) without significantly increasing the level of hazard, as long as the defect is heart rot uncomplicated by other defects. This is equivalent to having a sound rind of 15% of the diameter inside bark (Table 3A, Wagener 1963). If the shell of sound wood is thinner than the thickness displayed in Table 3A for a comparable trunk diameter, failure potential is high. These guidelines are adequately buffered for trees with internal decay but no additional defects.

Trees with wounds or cankers opening to the outside have a much greater failure potential than trees having equivalent rinds of sound wood but no openings (Fig. 32). A hollow tree with an open wound or canker should be considered hazardous if the sound-rind thickness at its thinnest point meets or is below the suggested standard for the diameter. Minimum sound-rind thickness should be increased by at least 25% for hollow trees with open wounds (Table 3B).

Extra caution should be taken when evaluating trees with multiple defects including stem decay, and the sound-rind thickness guidelines should be used with caution since they were developed for trees with a single defect. For example, forked trees with evidence of heart rot, such as a conk directly below the fork, should be evaluated carefully, and the evaluator should assume the fork to be unstable.

The rate of radial growth affects future sound-rind thickness. If growth rate is rapid, strength loss from advancing decay will be partially offset or perhaps even negated by the added strength of new wood. This is because decay is often compartmentalized within a column that is the size of the tree when it was first wounded; new wood formed after wounding usually does not decay unless the tree is wounded again. The condition of callus growth around wounds is an indicator of health and tree vigor. Vigorous callus activity (abundant new wood and wound parenchyma produced over wounds), emergence of a new cambial region and a thin, healthy, new bark indicate rapid growth.

Major heart rots that result in tree hazards in developed sites in the Pacific Northwest include the following:

Ash trunk rot is caused by *Perenniporia fraxinophilus*. Oregon ash is the only host species (Table 7). Trees with one or more conks have **medium-failure potential.** Conks are perennial, woody, shelf-shaped to hoof-shaped with a rough dark-brown to black upper surface and a brownish under surface. Conks can be a width of 1 ft. or more. The incipient decay appears first as a brownish discoloration then developing white spots with time. Advanced decay is straw-colored to white, soft and crumbly, with longitudinal white areas on the radial face.

Annosus stem decay, common in conifers and some hardwoods (Table 7), is caused by the same fungi that cause annosus root disease (p. 45). Infection occurs by airborne spores through wounds that develop into butt or stem rot. Butt and stem decay predisposes trees to windthrow and breakage. Tree-failure potential depends on sound-rind thickness.

Some defect rules for estimating extent of *Heterobasidion*-caused stem decay of true firs, hemlocks, and spruces are as follows:

1) When a *Heterobasidion* conk is visible near the root collar of a tree (not a very common occurrence), the lower 16-foot section of the butt log is defective,
2) Defect extends four feet above and below any stem wound with verified annosus decay that is 10-years old or older,
3) For wounds less than 10-years old, expect internal defect to run the length of the wound.

Aspen trunk rot is caused by *Phellinus tremulae*. A single conk generally indicates considerable internal decay; such trees have **medium-failure potential**. Conks of the fungus are perennial, hard, woody, and generally triangular shaped in longitudinal section (Fig. 33). Conks of *P. tremulae* have an under surface that is brown

Fig. 33 – *Typical conk of* Phellinus tremulae *indicates internal decay in this aspen.*

with small and regular pores. Early decay has a yellow-white zone in the heartwood and is usually surrounded by a yellow-green to brown margin. Advanced decay is soft and yellow-white with fine, black zone lines.

Brown cubical rot is caused by *Laetiporus conifericola* in conifers and *L. gilbertsonii* in hardwoods (both formerly *L. sulphureus*) (Table 7). Decay is usually well advanced before conks develop, so trees with ≥1 conks have **high-failure potential**. The distinctive conks are known as the sulfur fungus or "chicken of the woods." Conks are annual and orange-yellow with multiple brackets, usually found on the butt and lower bole but also commonly occurring on stumps. Older, dead conks may persist for a year or two and are bleached chalky-white and brittle. Conks are commonly observed on dead trees or tree parts. Early decay is a light-brown stain. Advanced decay has red-brown cubes with white mycelial felts.

Brown cubical rot of birch, caused by *Piptoporus betulinus*, is restricted to birch. A single conk generally indicates considerable internal decay, and such trees have **medium-failure potential**. Conks are annual and leathery with short, thick stalks. The upper surface is light brown turning dark brown and scaly with age and a margin that extends below the pore surface. The under surface is white becoming light brown and tooth-like with age. Decayed wood is yellow-brown and breaks into cubes with thin white mycelial fans in the cracks. Advanced decay easily crumbles to powder.

Brown stringy trunk rot is caused by *Spongipellis delectans* and occurs in hardwoods (Table 7). A single conk generally indicates considerable internal decay, and such trees have **medium-failure potential**. The conk is quite distinctive, annual, and emerges from the butt or bole with several shapes but generally is shelf-like. Conks are white- to cream-colored, fleshy to leathery with tawny-colored rounded lips. The underside has small, uniform pores. Decay is initially streaky brown and retains most of its structural strength. As decay advances, it turns a uniform brown and the texture becomes stringy but sometimes laminated. Decay occurs in pockets of various sizes mostly in the main stem, and pockets coalesce as decay progresses. Decay continues after the host dies.

Brown top rot is caused by *Fomitopsis cajanderi* and occasionally damages conifers (Table 7). The fungus causes a brown-cubical heart rot in living trees. It is usually found in trees that had past top damage resulting from wind or ice and snow loading. Conks sometimes form on the lower bole, probably as a result of a very old top-break or bole wound. Wood strength may be moderately affected before any discoloration or texture change becomes evident. A faint brownish or yellow-brown stain, sometimes marked by greenish-brown zone lines, may be seen in the early decay stages. Advanced decay is yellowish to reddish brown, soft, and with irregular cubes. Thin mycelial felts that vary from white to faintly rose-colored may develop in the cracks between the cubes.

The amount of decay is proportional to the diameter of the broken stem with decay progressing downward into the main stem and eventually upward into any new leaders that form after infection. Boles and new leaders on trees with one or more conks at the base of a new leader have a **medium-failure potential**. New leaders and boles on trees with top-breaks but no conks would have **low-failure potential**. Such trees, however, should be monitored for future conks.

The conks of *F. cajanderi* are perennial, woody, bracket-like to hoof-shaped with pink to rose-colored undersurfaces and inner tissue; hence, the common name, "rose-colored conk". The conk's upper-surface is brown to black and usually cracked and rough. Conks often appear stacked in a shelf-like arrangement. Because conks are relatively small, those associated with top breaks may need to be viewed with binoculars. The conks are very difficult to detect, and even highly experienced evaluators easily overlook their presence.

Brown trunk rot is caused by *Fomitopsis officinalis*, the quinine or chalky fungus and occurs in conifers (Table 7). The presence of brown trunk rot, as shown by even one conk, indicates **high-failure potential** for host trees. Damage is 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. The advanced decay is a yellow-brown, reddish-brown, or purple-brown cubical rot (Fig. 34). The decay is crumbly with large, brown cubical chunks, and mycelial felts are conspicuous in shrinkage cracks that form in the cubical decay. Felts may be one-quarter inch thick and may extend several feet in length in one

Fig. 34 – *Advanced decay caused by* Fomitopsis officinalis *is a brown-cubical rot.*

Fig. 35 – *Quinine conks of* Fomitopsis officinalis *are distinctive and indicate considerable stem decay.*

continuous sheet. Mycelial felts are bitter to the taste and resinous pockets or crusts are formed throughout their length. The incipient stain is yellow-green to brownish-green (very similar to that of Schweinitzii root and butt rot). The coloration of incipient stain in ponderosa pine is brown or reddish-brown.

Conks are not common but unmistakable. The conks are usually large, white, hoof-shaped to pendulous, and are perennial (Fig. 35). They have a chalky-white upper surface and a white pore surface. The interior of most conks is soft and crumbly. Conks develop at branch stubs, over old wounds and especially at the site of old top breaks. 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. If a conk is located $\geq$50 ft. above ground, the entire top-half of the tree has decay. If a conk is <50 ft. above ground, then the entire tree has decay. Depending on target location and value, trees with quinine conks should be mitigated in any developed site.

Hardwood trunk rot is caused by *Phellinus igniarius*, the false-tinder fungus and occurs on many hardwood species (Table 7). A single conk generally indicates considerable internal decay; such trees have **medium-failure potential**. Conks are perennial, woody, and generally hoofed-shaped with the lower surfaces nearly horizontal. The upper surface is gray-black to black and rough when old. The under surface is brown with small and regular pores. Early decay has a yellow-white zone in the heartwood and is usually surrounded by a yellow-green to brown margin. Advanced decay is soft and yellow-white with fine black zone lines.

Incense-cedar pecky rot is caused by *Oligoporus amarus* and is common in mature incense-cedar. Unless there are other indicators, trees with conks have **low-failure potential**. Tree failure is not common with pecky rot even when decay is extensive. Decay, which is a pocket-rot of the heartwood, is not limited to the butt log, and it may occur along the entire length of the bole. The advanced decay is a brown cubical rot similar to that occurring in western redcedar with pencil rot. Conks are common but ephemeral. Conks are annual, fruiting at knots in late summer or autumn. They are hoof-shaped to half-bell shaped, tan to buff-colored on the upper surfaces, bright sulphur yellow on the undersides (pore surface) with small tubes that exude clear drops of a yellow liquid (Fig. 36). As conks age they turn brown and hard. Insects, birds, and squirrels destroy conks, leaving "shot-hole cups", which are apparent at and below the knot where conks were attached. Presence of a shot-hole cup also indicates decay. Large, open knots or open branch stubs are also indicative of extensive decay. Woodpeckers like to work around old, punky, open knots, and evidence of old woodpecker work also indicates old conk locations and decayed trees. Dry sides (p. 72) are not typically associated with this decay of incense-cedar. Decay is almost always present in incense-cedar >40 in. dbh with basal wounds or old dead limbs.

Fig. 36 – *Conks of* Oligoporus amarus *on incense-cedar are annual and disintegrate relatively rapidly.*

***Inonotus* trunk rot** is caused by two species of fungi, either *Inonotus dryophilus* or *Inonotus dryadeus*, both of which occur on conifers and hardwoods. A single conk of either species generally indicates considerable internal decay; such trees have **medium-failure potential.** Conks of *I. dryophilus* have buff to reddish-brown upper and lower surfaces. The advanced decay is a white rot of the heartwood of living trees with a conspicuous brown mycelium in the decayed wood. Conks of *Inonotus dryadeus* are annual, firm to woody, and exude amber colored droplets on the upper surface when young and on the outer edge when older; the lower surface is buff colored and becomes dark brown and cracked with age. *Inonotus dryadeus* causes a white rot of the heartwood in butts and roots of living trees.

Juniper pocket rot is caused by *Pyrofomes demidoffii* and is common in mature juniper. Trees with $\geq$1 conks have considerable decay but rarely fail and therefore have **low-failure potential**. Trunk conks are perennial and hoof-shaped with a brown to black upper surface with a buff to black rim. The under-surface is buff-colored with round pores.

Early decay is a light-yellow color. Advanced decay is a white rot with abundant buff-colored mycelial felts in the decayed wood.

Maple trunk rot is caused by *Oxyporus populinus*. This fungus is known as the mossy-maple polypore. Conks generally indicate considerable internal decay, and such trees have **medium-failure potential**. Conks are usually associated with wounds, scars, or cracks. The conk is perennial with multiple shelf-like brackets occurring on the lower butt of decayed trees. The lip and the underside of each bracket are white while the upper-surface is white to gray. Pores on the under-surface are very small. Older conks are distinctive with moss and/or liverworts growing on the upper-surface. Decay is a white heart rot.

Mottled rot is caused by either *Pholiota adiposa*, the yellow cap fungus, or *P. limonella*, the lemon cap fungus and affects both conifers and hardwoods. Failure potential of trees with one or more conks depends on the amount of sound-rind thickness (Table 1). The mushrooms have gills and are annual, fleshy, yellow on their upper surfaces, and sticky when wet. They have a yellow stem and yellowish to brown gills. Mushrooms develop singly or in close groups from a common base and appear in the fall, usually on host stems. Incipient decay is light yellow and is usually confined to small pockets in the heartwood. Advanced decay has discolored areas that enlarge and darken to a honey color. Brown streaks appear, causing a mottled look that the decay is named for. Decayed wood breaks into stringy strands in the last stages after separating at the annual rings. Trunks can become completely hollow. Most decay is in the lower bole but can extend 45 to 60 ft. above ground. Mushrooms are most common on dead trees or on decadent trees with areas of dead stem wood.

Redcedar pencil rot is caused by *Postia sericiomollis*. It is a severe stem decay and butt rot of western redcedar. Failure potential of redcedars with pencil rot depends on the amount of sound-rind thickness (Table 1). In redcedar, decay is usually confined to the butt (first 40 feet) of affected trees. Fruiting bodies are annual, thin, flat, white crusts that are not common and are of limited use in estimating decay presence. The advanced decay is a brown, cubical pocket rot. When decay is minor in affected stems, it appears as long, thin "pencils" of brown cubical decay. As decay becomes more extensive, this pencil rotting is more abundant, and these thin rot columns begin to coalesce. In severely damaged trees, most of the heartwood is decayed and pencil rotting is less obvious, but it can be observed at the outer margins and upper reaches of decay.

No cull rule is defined for this decay. Decayed trees, however, are often used by cavity-nesting birds, and their cavities are a good indicator of advanced decay. Trees with significant decay may display a conspicuous bole flattening at the butt called a "dry side" or "dry face" that resembles a canker. Trees with evidence of a dry side should be sounded with an axe or mallet and drilled to determine the extent of decay and the sound-rind thickness. Dry sides may extend 40 feet or more up the stem. They are normally covered with bark which hides from view an area of decayed wood. The perimeter of the dry side is often humped or folded as if in reaction to injury. In severe cases, the callus fold on the perimeter of a dry side may force the wood of the tree to the outside. Dry sides may be confused with irregularities in the butt associated with butt swell or fluting.

Red heart rot is caused by *Stereum sanguinolentum* and is commonly found in conifers. All dead trees with conks have a **high-failure potential**. Fruiting bodies are found on infected wounds of live trees and on the bark of dead trees. The conks are numerous, annual, and leathery. The upper-surface is gray to light-brown and zoned; the lower-surface is wrinkled, gray to light brown but turning red when bruised (common name of bleeding fungus). Incipient decay appears as a red-brown heartwood stain. Advanced decay is light-brown and soft with thin mycelial felts that may be present.

Red ring rot or **white speck** is caused by *Phellinus pini* and is the most common stem decay of living Pacific Northwest conifers. Failure potential of trees with red ring rot 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). Many stands of old-growth Douglas-fir, pine, larch, hemlock, or true fir exhibit some of this defect. Conks are hoof-shaped and are formed at branch stubs or knots (Fig. 37). Pore surfaces are cinnamon-brown to tan with pores that are irregular rather than round. The interior of the conk has the same cinnamon-brown coloration as the pore surface. On hemlocks especially, but occasionally on other species, conks may be abundant on the undersides of branches (limb conk).

Fig. 37 – *Typical conk of* Phellinus pini *often indicates low-failure potential.*

Fig. 38 – *Wood with decay caused by* Phellinus pini*, commonly called whitespeck, is relatively sound compared to wood decay caused by other fungi.*

Conks are typically higher on trees in older stands. Large conks indicate more decay; smaller conks usually indicate less decay, unless the apparent small conks are remnants of larger conks that have fallen off (see Appendix). Individual limb conks may be 12 to 18 in. long with their long axis parallel to the limb; conks may extend 2 or 3 in. out on either side of a limb. Limbs with conks extending up to 2 or 3 feet away from the main stem are common in some areas.

Punk knots are common on severely decayed trees. They are evidence that a conk is about to form at the site of an old branch stub, or that a conk was once present at the site but has since fallen off. Punk knots and conks indicate the same amount of decay. A true punk knot is observed when the cinnamon-brown "punky" fungal material that occupies the context of the conk is clearly visible to the outside with the naked eye or with the aid of binoculars. Conks are formed at branch stubs or over old knots. Often branch stubs, bark flaps, burls (Fig. 54), and other features can look like conks or punk knots. Close evaluation with binoculars is important to assure the indicator is in fact a conk or punk knot.

The decay caused by *P. pini* is a white pocket rot (Fig. 38) that occurs in rings separated by sound wood until decay becomes very advanced (very soft and crumbly). When this decay is encountered in developed sites, it must be evaluated carefully. Wood decayed by this pathogen maintains some strength against failure. When Douglas-fir, pine, cedar, or larch have ≥3 large conks (>6 in. wide) within a 3-ft. trunk cylinder, the hazard evaluator can expect that damage to the heartwood probably is extensive (Table 1). With many small or separated large conks, these resinous tree species may have adequate strength to withstand high winds. If an evaluator suspects that a tree is marginally safe based on indicators, the evaluation of damage potential, target value, and alternative hazard-mitigation strategies must direct the course of the hazard-management decision. Where damage potential is high, the evaluator should measure the sound-rind thickness at the point of greatest defect, usually near the largest conks. This may require climbing affected trees to drill near the biggest conks. When boring a tree with *P. pini* decay, consider firm (not crumbly) wood with white speck or red discoloration as sound wood (Table 1).

In southern Oregon, red ring rot is more severe in older stands, in pure stands of host trees, on steep slopes, on shallow soils, and on sites dominated by secondary shrub, herb, or forb vegetation (vine maple, vanilla-leaf, oxalis, or rose rather than salal, twinflower, or rhododendron).

Redwood cubical rot is caused by *Oligoporus sequoiae*. The fruiting body develops as a thin, white crust composed of fungal strands and a spore-producing pore surface. The fruiting bodies rarely exceed 2 in. long by 1 in. wide and form in fire scars and bark crevices. Incipient decay is a dark-brown stain that forms pockets of brown, charcoal-like dry rot that shrinks and cracks into cubes when advanced. Redwood is a relatively decay-resistant tree species, so failure potential should be determined by measuring sound-rind thickness.

Rust-red stringy rot is caused by *Echinodontium tinctorium*, the Indian paint fungus. It is the most damaging stem decay of older true firs and hemlocks. The presence of rust-red stringy rot as indicated by conks results in either **high- to low-failure potential** depending on number and size of conks per tree and associated indications of extensive decay (Fig. 39) such as open cracks or weeping frost cracks (Table 1). Trees with a single conk on average have as much as 40 feet of continuous decay within the trunk (see Appendix).

Trees can become infected at a relatively early age through tiny (0.5 mm), dead branchlet stubs. Thereafter, the fungus becomes dormant until re-activated by tree wounding. Infected saplings

Fig. 39 – *Advanced decay caused by* Echinodontium tinctorium, *the Indian paint fungus, can result in tree failure.*

Fig. 40 – *Conks of the Indian paint fungus are distinctive and common on true firs.*

and poles are often released from their suppressed condition, and they resume vigorous radial growth, often encasing dormant infections in heartwood. Following re-activation of the dormant infection by injury near the point of original infection, heartwood is decayed.

Advanced decay is a rust-red stringy rot that may result in nearly hollow stems (Fig. 39). When decay is advanced, large, hoof-shaped conks with a spiny lower surface are produced. Young conks have mostly a light-colored pore surface with a dark top. Older conks have a fissured upper surface and they are rough, dull black, and woody (Fig. 40). The interior of the conk and the cores of infected branch stubs are rusty-red to bright orange-red. Conks appear on the bole at the site of old branches. Where conks appear at multiple, old branch whorls, greater defect is indicated.

White spongy trunk rot, caused by *Fomes fomentarius*, produces conks that are found on dead trees or dead portions of hardwoods. Trees often have multiple conks indicating extensive decay and **high-failure potential**. This decay occurs almost exclusively in hardwoods. The perennial conk is hoof-shaped with a concentrically zoned, smooth, and gray to gray-black upper surface. The underside is brown with small, regular-shaped pores. Early decay is brown and firm. Advanced decay is soft and spongy, yellow-white with dark to black zone lines.

White trunk rot is caused by *Phellinus hartigii* and is found in living conifers and hardwoods (Table 7). Trees with one or more conks have **medium-failure potential**. The decay often occurs in a section of wood radiating in from the sapwood. Incipient decay is straw-colored to purple stain that is irregular in shape. Advanced decay has a bleached look with occasional light-brown areas or streaks. Trees with white trunk rot often fail within 20 feet of the ground. The conks are perennial and, if on the main stem, appear hoof-shaped with a dark-brown to black upper-surface and a brown and poroid lower surface. When formed on the lower surfaces of branches, the conks are flat against the branch and often occur where the branch joins the main stem; hence, the common name, "armpit fungus." The conks are commonly associated with hemlock dwarf-mistletoe infections (p. 83).

Yellow pitted rot is caused by *Hericium abietis*, the coral fungus, and occurs in some conifers (Table 7). Trees with one or more conks have **medium-failure potential**. The fruiting bodies are distinctive, soft, creamy-white, coral-like, annual conks. They occur at wounds on living trees. Incipient decay is a yellow to brown stain with scattered darker spots that give the wood a mottled appearance. Advanced decay is composed of elongated blunt-end pits, about ½ in. long; hence, the old common name, "long-pocket rot."

Sap Rots

Sap rots are decays that occur in the sapwood (Table 8). Most sap-rotting fungi cause rapid decay of dead sapwood only. When these fungi have decayed all of the available dead sapwood, then decay ceases and in most cases no heartwood is decayed. They compete poorly with other fungi that decay heartwood, and are seldom found past the heartwood/sapwood interface. In living trees, sap rots occur on wood tissue killed by other agents, most often bark beetles and mechanical or weather damage. 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. On some true firs and hemlocks, sapwood is fully rotted within 1 to 2 years of tree death. On other conifers, it may take as many as 3 to 5 years for sap-rotting fungi to decay all of the available dead sapwood.

Hardwoods are also subject to sap-rotting, and damage may be significant on live trees. As with conifers, sap-rotting of hardwoods occurs in dead portions of living trees. On many Pacific Northwest hardwood species (poplars, maples, alders), sapwood decays very rapidly once it dies, and there may be few obvious external indicators. When external indicators of sap rot are lacking, testing may be required. Sap-rot depth can be determined by using a cordless drill, increment borer, or axe. Living hardwoods with sap rot in one or more stem quadrants have a **medium-failure potential** (Table 1).

Trees killed with a full complement of foliage, normally develop sap rot at a rapid rate. Trees killed by crowning fire or trees with broken tops, however, exhibit delayed sap rot development. In such trees, the level of xylem sap remains high, and it rather quickly ferments, turning sour.

Table 8. Sap rots affecting trees on developed sites in Oregon and Washington.

Common name	Scientific name of causal fungus	Major hosts
Brown crumbly rot	*Fomitopsis pinicola*	Most tree species
Gray-brown sap rot	*Cryptoporus volvatus*	All conifers
Pitted sap rot	*Trichaptum abietinum*	All conifers and some hardwoods
Silver leaf disease	*Chondrostereum purpureum*	Mostly hardwoods

Bark beetles will rarely attack such trees, and the introduction of sap-rotting organisms will be delayed until bark splitting and sun checking or heart checking occurs. When bark beetles do attack such trees, breeding success is poor. In trees with soured sap, the succession of microorganisms and invertebrates is very different than that occurring in normal trees killed by bark beetles. With any of the following sap rots, dead trees have **high-failure potential** in developed sites.

Fig. 41 – *Red-belt conk of* Fomitopsis pinicola, *the most common decayer of dead wood in the Pacific Northwest.*

Fig. 42 – *Pouch-fungus conks of* Cryptoporus volvatus *often indicate considerable sap rot.*

Brown crumbly rot is caused by *Fomitopsis pinicola*, the red-belt fungus. This fungus causes a sap rot of dead trees but sometimes also a heart rot of living trees, especially those with trunk wounds. Live trees with >1 conks may have low- or medium-failure potential depending on the extent of dead sapwood (Table 1). Bark beetles transport propagules of the fungus to infested trees. Conks are leathery to woody, perennial, and bracket-shaped (Fig. 41). When young, the conks appear white and round. As they mature, the upper surfaces turn dark-gray to black, the lower pore surfaces remain white, and conspicuous reddish margins develop between the two surfaces; hence, the common name "red-belt conk." Conks are often seen on dead and down trees. After tree or tissue death, decay develops rapidly in the sapwood and then progresses to the heartwood. Incipient decay is a faint yellow-brown to brown stain. Advanced decay is light reddish-brown and forms a crumbly mass of rough, small cubes with mycelial felts between the shrinkage cracks.

Gray-brown sap rot is caused by *Cryptoporus volvatus*, the pouch fungus. It is one of the most easily recognized of the sap-rotting fungi.

Table 9. Fungal cankers and stem rusts in Oregon and Washington; frequency of occurrence by host species where: 1=common, 2=occasional, 3=infrequent, 4=rare, and blank means non-host or unknown occurrence.

Host species	*Atropellis canker*	*Ceratocystis canker*	*Comandra blister rust*	*Cryptosphaeria canker*	*Cytospora canker*	*Hypoxylon canker*	*Madrone canker*	*Mistletoe canker*	*Nectria canker*	*Phytophthora canker of golden chinkapin*	*Ramorum canker*	*Redcedar pencil rot*	*Red ring rot canker*	*Sooty-bark canker*	*Stalactiform rust*	*Sterile conk trunk rot*	*Western gall rust*	*White pine blister rust*
Alder					3	3			3							3		
Aspen		2		3	2	3			2					2				
Ash					3				3									
Birch					3				3							2		
Buckthorn									3									
Cedar																		
Alaska																		
Incense								3										
Port-Orford																		
Western red												3						
Cherry					3				3									
Chinkapin										2								
Cottonwood		4		3	3	3			3					2		4		
Dogwood					3				3									
Douglas-fir								3										
Hemlock																		
Mountain								2										
Western								2										
Juniper								3										
Larch								3										
Madrone							1							3				
Maple					3				3									
Myrtle									3		3							
Oak								1	3		3							

Host species	*Atropellis canker*	*Ceratocystis canker*	*Comandra blister rust*	*Cryptosphaeria canker*	*Cytospora canker*	*Hypoxylon canker*	*Madrone canker*	*Mistletoe canker*	*Nectria canker*	*Phytophthora canker of golden chinkapin*	*Ramorum canker*	*Redcedar pencil rot*	*Red ring rot canker*	*Sooty-bark canker*	*Stalactiform rust*	*Sterile conk trunk rot*	*Western gall rust*	*White pine blister rust*
Pine																		
Jeffrey			4					3										
Knobcone			4					3									1	
Lodgepole	2		3					3							2		1	
Ponderosa	3		1					3							3		2	
Sugar	3																	1
Western white	3																	1
Whitebark	3																	1
Redwood																		
Spruce																		
Brewer																		
Engelmann																		
Sitka																		
Tanoak											1							
True Fir																		
Grand					3			2					2					
Noble					3			3					3					
Pacific silver					3			3					3					
Shasta red					3			3					3					
Subalpine					3			3					3					
White					3			2					1					
Willow					3	3			3					3				
Yew																		

The fungus is routinely introduced by tree killing bark beetles and wood borers. Conks are annual, leathery and produced on trees the first year after tree death. Fresh conks are small, round, initially soft and fleshy, yellow-brown to golden brown with pore surfaces covered by a hard membrane; hence, the common name, "pouch fungus" (Fig. 42). Conks bleach to a dirty white after one year. Early decay has gray areas that develop in the sapwood beneath the conks. Advanced decay appears the same and may completely destroy the sapwood.

Pitted sap rot is caused by *Trichaptum abietinum*, the purple conk. The fungus infects its host via airborne spores through openings in the bark. Since this fungus is primarily a saprophyte, conks infrequently form on live trees but are numerous on dead trees and logs. Conks are small, annual, thin, and shelf-like. The upper surface is light gray, fuzzy, and zoned. Old conks become dark gray to black. The under surface is violet to purple when fresh that turns light brown with age. As conks age, the angular pores become elongated and separate into spines or ridges. Incipient decay is light yellow to tan and soft; advanced decay has small pits that become elongated in the direction of the grain, with a honeycombed look.

Silver leaf disease is caused by *Chondrostereum purpureum*. It occurs mostly on dead hardwoods but has been reported on living trees. The conks are annual, shelf-like, and often in groups. The upper surface is grayish-white to purple and zoned with a light margin. The lower surface is usually smooth, bright purple when young and brown-violet when old. Early decay is a reddish-brown stain; advanced decay is white-mottled to pale yellow.

Fungal Cankers and Stem Rusts

Fungal cankers and stem rusts are caused by many species of fungi that infect and kill portions of a tree bole. Cankers and rusts frequently occur on the stems and branches of pines and hardwoods. Canker fungi cause top-kill, branch death, or stem malformation. Stem malformations can be infected and subsequently decayed by other fungi, thus increasing the likelihood of

Fig. 43 –*Atropellis canker is a common disease of lodgepole pine that can result in stem breakage.*

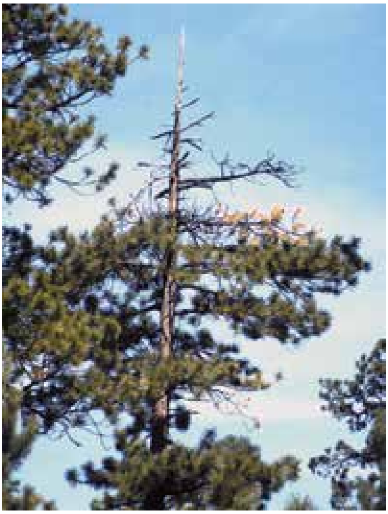

Fig. 44 – *Dead tops of ponderosa pine, caused by Comandra blister rust, often are resin-impregnated, decay-resistant, and therefore of very low-failure potential.*

stem breakage. Cankered areas on true fir, hemlock, spruce, or hardwoods are more likely to be associated with failures than those on resinous species: Douglas-fir, pine, or larch and also decay-resistant cedar (Table 1). Failure potential does not significantly increase until the face of the canker is deeply sunken, or the cross-section of the bole with sound wood is small (Fig. 9). Failure potential increases as cankers develop.

Major cankers and stem rusts that result in tree hazards in developed sites in the Pacific Northwest include the following:

Atropellis canker is caused by either *Atropellis piniphila* or *A. pinicola* (Table 9). It frequently occurs on the boles of pine species, especially lodgepole pine. Resinous wood around these cankers usually remains sound, and failure potential does not significantly increase until cankers become old, long, and wide, and the face of the canker is deeply sunken relative to what would have been the normal circumference at that point (Fig. 43). When the cankers result in <50% cross-section of the bole with sound wood, and the depressions are deep, **failure potential is high** (Table 1). This is most likely to occur in heavily infected stands where trees have multiple cankers and where individual trees have two or more cankers at the same height on the bole.

Ceratocystis canker, caused by the fungus *Ceratocystis fimbriata*, occurs on aspen and cottonwood (Table 9). Ceratocystis cankers are target-shaped with or without bark adhering to the surface of the canker. Infected wood behind the canker usually is stained. Macroscopic fruiting bodies may be produced on the cankers. Most of the cankers on aspen ultimately girdle the bole and kill the upper part of the tree.

Comandra blister rust, caused by *Cronartium comandrae*, occurs on ponderosa pine and sometimes lodgepole pine in Oregon and Washington. Mortality can occur, especially in young, infected trees. Large infected pines exhibit dead tops that progressively die downward

(Fig. 44). Infected and dead tops are relatively decay resistant because of the copious resin associated with infection. These dead tops have **very low-failure potential**, even after several years, and rarely fail.

Fig. 45 –*Dwarf mistletoe bole infections are especially common on grand and white fir, western hemlock, and western larch.*

Cryptosphaeria canker, caused by the fungus *Cryptosphaeria populina*, occurs on aspen and cottonwood. Cankers are elongated with some bleeding at the margins. Several, highly visible, black fruiting bodies form in the bark. Stain and decay may be extensive behind the cankers and determine the degree of failure potential.

Cytospora canker is caused by *Cytospora chrysosperma* on hardwoods and *C. abietis* on true firs. Cankers occur on boles, branches and twigs, forming long, dead areas with well defined borders. Several years after infection, dead bark lifts away from the bole and falls off.

Fig. 46 –*True mistletoe bole and branch infections can cause cankers and subsequent decay in oaks.*

Hypoxylon canker, caused by *Entoleuca* (*Hypoxylon*) *mammata,* is found only on hardwoods, including alder, cottonwood, aspen, and willow. The canker first appears as sunken, yellow-orange areas on the bark that is centered around dead branch stubs or injuries. Older cankers have mottled bark with small, dead patches. Cankers can be 3 ft. in length.

Madrone canker, caused by *Fusicoccum arbuti* and *F. aesculi,* occurs only on Pacific madrone. The causal fungus attacks weakened madrones, especially trees that are drought-stressed, have mechanical wounds, or are suddenly exposed to full sunlight. The fungus causes a stem and branch canker with branch, trunk, or complete tree dieback. Infected branches develop a purplish-black color, appear dry and cracked, and eventually die. Older stem cankers are sunken into the bark. Failures usually are infrequent until branches or stems have been dead for several years.

Mistletoe-bole and branch cankers are caused by dwarf mistletoe (*Arceuthobium* spp.) infection of the bole in conifers (Fig. 45), and true mistletoe (*Phoradendron* spp.) infection in the branches and boles of oaks (Fig. 46), incense-cedars, and junipers. Dwarf mistletoe bole infections are especially common on grand and white fir, western hemlock, and western larch. While bark and cambium tissues are still alive in the area of the initial swelling, boles and branches are not often significantly weakened, and failure potential is not a serious issue. In time, however, the cambium and overlying bark in the oldest part of the swelling die and form a canker that is subsequently decayed by opportunistic fungi and attacked by wood borers. Any of the fungi that function as wound parasites can be found decaying mistletoe-induced bole swellings.

Nectria canker is caused by *Nectria cinnabarina* and occurs on many hardwood species. Sunken cankers are associated with wounds or develop at the base of dying branches. Cankers can girdle and kill stems, and when bark dies, it appears dry and cracked with age.

Phytophthora canker of golden chinquapin is caused by *Phytophthora cambivora*. The disease can cause tree mortality with leaf flagging being a common symptom of infected trees. In the inner bark, the girdling, basal cankers are reddish-orange and extend upward from infected, necrotic roots. The inner bark turns brown when the trees are dead; **failure-potential then is high.**

Ramorum canker is caused by *Phytophthora ramorum*, also the cause of sudden oak death. The causal agent, a fungus-like water mold, was introduced into southern Oregon in about 2000. This disease causes significant mortality of black and live oaks, tanoaks, and California bay in California. Ramorum canker is mentioned in the context of developed-site hazard trees not so much for the bole canker that it causes, but because of the relatively rapid death of its principal host in Oregon, tanoak. Although other tree species can serve

Fig. 47 –*Sooty-bark canker, as seen on this infected aspen, can result in tree failure.*

as foliar hosts in the PNW: maple, madrone, myrtlewood, cascara, and Douglas-fir, none of these species have had bole cankers or have been killed, as yet, by the causal agent in Oregon or Washington. Infected trees are rapidly colonized by decay fungi, and trunk failures can occur even before trees are completely dead. Recently infected and dead oaks and tanoaks in developed sites have **high-failure potential**.

Red ring rot canker is caused by *Phellinus cancriformans* in southwestern and west-central Oregon and occurs on true firs (Table 9). The conks of the fungus are small and numerous with their upper surfaces being rough, dark, and furrowed (butterfly conks). They closely resemble *P. pini* conks (p. 72) but are smaller and occur in groups. The conks grow from a sunken area on the trunk with decayed wood beneath it (a canker). Substantial amounts of stem breakage can occur with this fungus.

Sooty-bark canker, caused by the fungus *Encoella pruinosa,* occurs on aspen and cottonwood. Sooty-bark cankers often have arcs of blackened bark tissue as a result of infection (Fig. 47). Fruiting bodies that form on the cankers are silver gray.

Stalactiform rust is caused by *Cronartium coleosporioides* and occurs primarily on lodgepole pine and less commonly on ponderosa and Jeffrey pine. Older infections form diamond-shaped cankers that can extend to 30 ft. long. Tree mortality may occur if boles are completely girdled.

Fig. 48 –*Lodgepole pine with western gall rust can break if stem cross-sectional area of sound wood is too low.*


Fig. 49 –*Tops of trees killed by white pine blister rust are often resin-soaked with little decay and have very low-failure potential.*

Sterile conk trunk rot is caused by *Inonotus obliquus* and affects some hardwoods (Table 9). Unless there is evidence of extensive decay (cracks or exposed rot), trees with ≥1 sterile conks have a **medium-failure potential**. The sterile conks are conspicuous, perennial, black masses of fungal tissue that erupt from stem cankers. The conk surface is rough and cracked; the interior is yellow- to rust-brown. The tree trunk is often thickened at the conk. Incipient decay is yellow-white in irregular zones. Advanced decay appears as alternating zones of white and light reddish-brown wood. White veins of mycelium are common near the cankers.

Western gall rust is caused by *Endocronartium harknessii* and is common on lodgepole and knobcone pine. It frequently can be found on ponderosa pine, especially near water courses. The disease causes branch flagging, bole breakage, topkill, and mortality of young trees. The galls are small to large, round to pear-shaped swellings on branches and boles. "Hip cankers" are caused when the main stem flattens and broadens as it grows around bole infections (Fig. 48). Trees with galls on the main stem or "hip cankers" develop progressively and increase the tree's failure potential as the percentage of sound wood in the bole decreases.

White pine blister rust is caused by *Cronartium ribicola* and is found throughout the range of 5-needle pines in Oregon and Washington. The fungus causes branch flagging, top-kill, and death usually of pines <8 in. dbh (Fig. 49). Mountain pine beetles often attack older, infected trees. After needle infection in the spring, spindle-shaped swellings form on branches. Bright yellow-orange pustules (aecia) with aeciospores are produced from raised blisters on the bark. Cankers result in dead, roughened bark that has margins that appear greenish-yellow to orange. Heavy pitch flow often occurs with the bole cankers. Infected and dead tops are relatively decay resistant because of the copious resin associated with infection. Blister-rust-killed tops have **very low-failure potential** even after several years and rarely break and fall.

Other Bole Defects

Cracks and splits in the main stem frequently occur and are often overlooked or regarded as insignificant. Cracks usually tell an important story and may reveal to the examiner that a closer inspection of the heartwood is warranted. Cracks and splits can be entry points for decay-causing micro-organisms or activate dormant spores of decay fungi, such as the Indian paint fungus (p. 74).

Cracks and splits are produced in several ways: tension and compression failure associated with older injuries and internal decay, lightning strikes, wind shake, and frost action. Cracks can form by tension and compression failure when trees with extensive heart rot bend back and forth under the stress of high winds. The sound rind on the windward side of affected trees is under great tension when winds are strongest. The side of the tree to the lee of the wind becomes compressed by that same wind force. This difference in forces, when most exaggerated, creates a shearing action in the middle of the bole where the two forces meet, and the bole develops a vertical crack somewhere between the ground and where the extent of heart rot is the greatest. An open crack with independent movement of its sides indicates **high-failure potential** because the trees have already partially failed.

Lightning strikes cause cracks when electrical discharges are grounded through trees. When the discharge is insufficient to explode the tree or its parts, damage can be highly variable, ranging from shallow, spiraling furrows that just penetrate the bark, to cracks that may be several inches wide and penetrate deep into the wood. Often huge chunks of wood may be blown out of the furrow contributing to its depth and impact on subsequent tree vigor and wind-firmness. Occasionally, entire trees or portions will be shattered, severely cracked, or split. The **failure potential** of lightning-damaged trees increases with the length, width, and depth of cracks as well as with the extent of subsequent decay. On the other end of the spectrum, groups of trees may be synchronously killed by lightning without any apparent evidence of mechanical damage.

Fig. 50 –*Frost cracks often indicate low-failure potential unless they are weeping, as shown here, then failure potential is medium to high.*

Wind shake can cause cracks, especially on trees growing at higher elevations. High winds regularly impact conifer forests, and winds are often turbulent and twist trees in different directions. Under the influence of frequent high winds, trees often develop shake in the lowest section of the butt. The twisting action of the wind first causes separations to develop along the growth rings. Later, these develop "legs" which extend radially outward toward the bark. In time, this defect breaches the bark and can be observed from the outside. Shake cracks may occur on any side of the bole and "legs" may extend from a few feet to 20 or 30 feet above the ground. Extensive wind-shake defect indicates partial failure and may be associated with increasing butt rot. Wind-shake cracks also incite dormant Indian paint fungus (*E. tinctorium*) infections to develop active decay (p. 74).

Extreme cold can cause bole cracks. **Frost cracks**, common at higher elevations and in cold-air drainages, appear on bark as raised nearly vertical callus lines that extend to the ground where the air is coldest (Fig. 50). This can be contrasted with wind-shake cracks which need not be vertical, often do not contact the ground, and may gradually spiral up the side of an affected tree. Frost cracks develop under the influence of freezing temperatures when the outer-sapwood growth rings become dehydrated by extracellular ice formation and produce a contraction on the circumference of the bole with no radial contraction. These cracks begin at the tree base, usually from an old wound, and seldom go higher than 15 feet up the bole. Defect is not commonly associated with true frost cracks, and they are seldom associated with high-failure potential unless they are weeping and have sound-rind thickness <20% of the stem diameter (Table 1). Older frost cracks develop "frost ribs," a series of raised vertical ridges parallel to the frost cracks themselves. If frost cracks have exudates (weeping), they indicate

Fig. 51 – *Forked tops, such as this hardwood that is weeping and cracked (A) and this cedar with open cracks (B), have high-failure potential. The ponderosa pine with only embedded bark (C) has medium-failure potential.*

either **high- or medium-failure potential** depending on the sound-rind thickness (Table 1).

Codominant stems, forked tops, or trees with multiple tops that are tightly V-shaped, can split and break from the green weight of foliage, heavy snow loads, or internal decay. Since a broad-angled-branch connection was not differentiated at the time the branch first formed, new radial growth at the point of branch convergence forces the acute angle further apart. Eventually, new radial growth will weaken the crotch to such a point that wind or snow load, or the added weight of new foliage causes a branch failure. This not only occurs in mature, forked conifers but also in conifers with severe ramicorn branching and hardwoods with large, spreading crowns. Tree crotches should be regularly examined with binoculars, because defect indicators such as open cracks, decay, mushrooms, or conks often suggest weakening and predisposition to failure (Fig. 51). Trees with these indicators have a **high-failure potential** (Table 1). Tree crotches with only embedded (included) bark (Fig. 51) without the above indicators have **medium-failure potential**. V-shaped tops without defect indicators or U-shaped tops generally have **low-failure potential** (Table 1). Forked tops of ponderosa pine in central Oregon have a potential-failure-zone radius of 1.5 times the length of the broken fork

Defective Branches

Hazards associated with defective branches are often exaggerated. The incidence of failure in this category is lowest of any listed in Table 4. Table 4 does not indicate the magnitude of personal loss associated with branch failures, but personal injury and property damage are usually less serious than that associated with trees that fail at the roots, butt, or bole. Defective branches fall essentially straight down from the point of failure, and their impact area is considerably smaller than that of a tree failing at the roots, butt or bole. The potential-failure zone is the same radius as the length of the branch. While **failure probability is medium** for attached defective branches, free-hanging limbs should be removed immediately if they hang over a target.

Hardwoods, especially poplars, cottonwoods, maples, and alders, are more susceptible to branch failure than most conifers because their crotches are structurally weaker, the lignin content of the wood is low by comparison, and their long branches are heavily weighted at the extremities with green foliage and fruit. As with conifers, crotches of major branches should be regularly examined for defect indicators such as open cracks, splits, or embedded (included) bark that suggest weakening and predisposition to failure or infection by decay fungi. Forked tops with open cracks have **high-failure potential** (Table

1). Also, heart rots of hardwoods often extend into major branches creating higher potential for failure. Dead branches on resinous conifer species remain attached longer than on non-resinous species, and limbs of hardwoods fail sooner than those of most conifers.

Fig. 52 –*Douglas-fir dwarf mistletoe brooms that are dead and ≥10ft. in diameter have high-failure potential.*

Black cottonwood branches have an increasingly high potential to break from the crown as the tree matures. Breakage will often occur at sound wood, although decay is also common and will increase failure potential. Breakage potential is greatest in the summer season when branches are weighed by foliage and cell structure is weakened by high transpiration. Black cottonwoods are a poor choice for long-term maintenance in developed sites, and location of targets should be well removed from large cottonwoods that will be retained.

Each year, **winter storms** occur in developed sites and often cause failure of the most defective branches, tops, and trees. Severe storms have a sanitizing effect in an overstory that has many defective branches; few remain that are defective enough to fail during the next year under their own weight. This sanitation effect is especially common in the higher elevations. At lower elevations, severe storms may be less frequent or different in kind or abundance, and heavy snow/ice loads may be infrequent or may not occur at all.

Large dwarf mistletoe brooms (≥10 ft. in diameter), especially on Douglas-firs but sometimes on ponderosa pines, that are dead and hanging directly over stationary targets of value or over areas that are routinely exposed to heavy transitory traffic, should be removed by pruning (Fig. 52). In areas of normally high snow loading or violent winter storms, this hazard is often mitigated as brooms break off with snow and ice loading. Brooms with a high-failure probability will often fail in winter when sites are closed or visitor use is limited. Pruning of large, live brooms may improve the vigor of infected trees and may slow the spread of the parasite to the upper crown that eventually results in tree death or top-kill. Candidates for live-branch pruning are trees with dwarf-mistletoe brooms only in the lower one-third to one-half of the live crown, and trees with live-crown ratios that will still be ≥40% after pruning. With Douglas-firs consider using MCH pheromone around trees pruned in spring or summer to prevent lethal attack by bark beetles.

Treat hazardous defective branches by removal (Table 10). Candidates for this treatment are dead, broken, or free-hanging branches (completely loose and lodged), or large, dead, dwarf-mistletoe-broomed branches that are above permanent targets or heavily used areas. Trees in need of treatment are climbed and pruned as needed. Some success has been reported using another pruning technique which eliminates climbing. A line is shot over the distal end of a defective branch via a crossbow or compound bow, and both ends of the line are pulled downward in a sharp movement, thereby breaking off and removing that portion most prone to failure. If the limb does not break readily with pulling, it is unlikely to fail within one season.

Pruning of live branches should be done with care to avoid excessive bole wounding and decay. At the junction of the main stem and a branch, both coniferous and hardwood trees exhibit a folding of bark tissue called the branch collar. This collar is important in the production of a barrier zone of cells that wall-off tissues damaged by wounding and reduce the potential for decay. Pruning cuts should be made flush with the branch collar. A longer stub is a more suitable entrance court for decay fungi and it is less readily overgrown by callus tissues in the healing process. Wound dressings on pruning cuts or other wounds are not only unnecessary, but may even be detrimental. Dressings act as a moisture barrier and maintain for longer periods a suitable environment for decay fungi. Pruning is best done in the late fall and winter when trees are fully dormant. Also, possible insect attack by pitch moths or bark beetles is less likely in the fall and winter than in the spring and summer.

Dead or Broken Tops

Dead tops on live trees eventually break out and fall to the ground (Fig. 53). Before tops fail they often rot in place and are held by little or no sound wood. A gentle bumping or jarring of a top-killed tree may cause top failure.

Fig. 53 – *Failure potential of trees with dead tops depends on whether the tree species is resinous like Douglas-fir or non-resinous like white fir.*

In developed sites, trees with dead, highly defective tops are often jarred by people or their vehicles. When dead tops are encountered in developed sites, hazard should be assessed immediately. Unacceptable hazards should be mitigated.

The failure potential of dead tops of cedar, Douglas-fir, larch, and pines with rust-killed tops is normally very low (Table 1). Dead tops of true firs, hemlock, spruce, and hardwoods are highly susceptible to attack by decay fungi, and their failure potential is normally higher than that of other conifer species on the same sites. Large, heavy pieces of loose bark on dead tops also present a hazard.

Trees with old, broken tops may have rot present below the break. This is especially true of non-resinous conifer species, although resinous species with top breaks are prone to brown top rot caused by *Fomitopsis cajanderi* (p. 67) or brown trunk rot caused by *Fomitopsis officinalis* (p. 68). If the upper branches in the remaining top are thrifty and vigorous in their appearance, additional top failure is unlikely in the near future, though trees with tops broken out should be monitored regularly. The potential that new tops arising from upturned lateral branches will fail is also low unless indications of internal defect are evident.

Burls

Burls are abnormal swellings on stems and branches (Fig. 54). Usually, burls are composed of undecayed wood and, as such, trees with burls have **low-failure potential**. Burls vary in size but can be several feet in diameter. Their cause is mostly unknown, but they are common among high-elevation tree species such as lodgepole pine and subalpine fir. When high in the tree or covered with moss or lichens, burls sometimes resemble conks and therefore require careful examination with binoculars.

Fig. 54 – *Burls are often large woody growths of unknown cause on conifers and hardwoods that resemble conks but indicate low-failure potential.*

Fire-Caused Damage

Fig. 55 – *Fire-damaged trees have failure potentials that depend on the amount of sound wood remaining.*

Fire-damaged tree boles or limbs may be so badly burned with associated wood consumption that they are structurally weakened which may cause the bole or limb to break and fail (Fig. 55). Root systems may be partially consumed by fire, and the entire tree may fall. Before burning, the tree may have had conks or mushrooms that indicated severe decay. These may have burned off, eliminating their value as indicators of root disease or heart rot. Therefore, the tree may be less stable than the visible indicators suggest. Likelihood of failure is determined by tree species (resinous or non-resinous), the amount of sound wood remaining, and if the tree is dead (Table 1). Large pines, cedar, larch, or Douglas-fir with old, basal, fire scars may have compensated for any defect or decay by increasing their butt diameter; such trees have **low-failure rates** unless a subsequent burn causes additional loss of support. Fire-damaged trees may still have green crowns but dead cambium at their bases; essentially they are dead trees. Long lasting and smoldering fires at the bases of large pines usually kill the fine roots and may eventually contribute to death of the tree usually by predisposing it to bark beetles and wood borers. Fire-killed trees are rapidly infested by wood borers that introduce wood-decay fungi. Tunneling by larvae facilitates wood decay.

Substantial damage, especially on ponderosa pine and Douglas-fir, can occur in trees that have old, resin-impregnated wounds that reburn. This seems to be especially true when fires are hot, burn after a long period without fires, and the trees involved have deep mounds of exfoliated bark and duff around their bases at the time of the fire. Trees with old catfaces or firescars should be examined carefully after a fire to determine how much damage to the cross-section of sound wood has been caused by reburning. For recent fire damage (<5-years old), use "fire-damaged trees" in Table 1; for older fire damage, use "bole wounds."

High Height-to-Diameter Ratios

Live trees with a high height-to-diameter ratio (an index of slenderness) may fail depending on the ratio (Table 1). These trees can break or bend permanently usually from snow or ice loading in the winter. Tall, thin trees with dwarf-mistletoe brooms may be particularly prone to bending or breakage. To calculate height-to-diameter ratio, estimate the total tree height in feet and divide by the dbh measured in feet. For example, a tree 100 ft. tall and 1 ft (12 in.). dbh would have a height-to-diameter ratio of 100. Bending or breaking of tall, thin trees is most likely to occur after densely stocked stands or groups of trees are thinned.

Insect-Caused Damage

Forest insects can weaken roots, stems, tops, or branches and introduce fungal spores that result in wood decay and physical degradation. Insects interact with fungal pathogens to cause damage or directly kill trees or their parts. Bark beetles in the family *Curculionidae* are important in the Pacific Northwest in causing tree mortality. The most important beetles are the Douglas-fir beetle, fir engraver, spruce beetle, mountain pine beetle, western pine beetle, and pine engraver. Bark beetles frequently attack trees that are stressed from root disease, bole damage, defoliation, or drought. Symptoms of bark beetle attack include boring dust, pitch streams, galleries under the bark, fading or red crowns, dead tops, or group mortality (Fig. 56).

Fig. 56 – *Bark beetles often kill trees and form pitch tubes on attacked pines.*

Wood borers also are involved in killing trees but usually prefer weaker hosts than bark beetles. They also colonize recently killed trees. Wood borers can significantly lower the structural integrity of infested trees because they bore into the sapwood and even into the heartwood. In SW Oregon, the flatheaded fir borer actively kills low-elevation Douglas-fir. Wood borers and bark beetles introduce decay fungi as trees are being killed. Trees with wood-borer holes in exposed wood need to be closely examined.

Carpenter ants and termites can colonize and further weaken trees that are already decayed. Defoliating insects such as the western spruce budworm and the Douglas-fir tussock moth can kill tops or entire trees. Dead tops of Douglas-fir can remain sound for several decades; dead tops of true firs, however, can fail relatively rapidly. Defoliator-killed trees or parts should be evaluated in the same fashion as other dead trees or parts.

Multiple Defects

Trees are often encountered with two or more (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 worsens another; they interact synergistically. Some examples of multiple defects that indicate increased potential for failure are:

1. Heart rot and cankers, stem injury, or saprot
2. Root rot and lean
3. Cracked forks and heart rot
4. Wind shake and butt rot
5. Leaning trees with hollow stems (Fig. 57)

Fig. 57 – *Multiple medium-failure indicators can imply high-failure potential such as this maple with hollow, leaning stems.*

The sound-rind thickness guidelines (Table 3A and B) should be used with caution when other tree defects that worsen the condition are present. In this case, trees may fail with more than the minimum sound-rind thickness.

Chapter 4 - Hazard-Tree Management

Evaluations Prior to Site Development

Ideally, hazard-tree management begins before there is a final decision on where to locate a proposed developed site. A thorough hazard evaluation of proposed sites prior to capital investment reveals the prudence and feasibility of establishing the site, and it alerts managers to problems prior to the investment of scarce resources. Examination of sites with old-growth trees prior to site development is particularly important because of the predictable decadence of many trees on these sites. Unfortunately, this has seldom occurred, as most current sites were established many years prior to the advent of vegetation management or hazard-tree management.

Old-growth stands, while more aesthetically appealing to many recreationists, are less well suited to developed site recreation. Not only is defect more abundant, but when old-growth stands are opened to establish access, parking, permanent camping spots, and structures, the probability of windthrow will usually increase, and continue increasing with each repeated salvage or hazard removal entry. Young, thrifty stands are more wind-firm, and they respond better and more rapidly to spacing entries. Trees in such stands readily re-establish wind-firmness, and they resist repeated attacks of insects, diseases, and the damage caused by visitors until they reach their pathological-rotation age.

One possible approach is to conduct a two-phase evaluation. The first phase is a thorough evaluation of the stand on the candidate site to determine if the candidacy should be further considered. If root disease is found, the site should be eliminated from further consideration as a developed-recreation site. If the candidate site does not have root disease, the second phase is a detailed hazard evaluation of each tree.

The best time to prepare a complete vegetation-management plan is after an informed decision is made to develop a site. This plan should include a stem map and information on the condition of each tree within striking distance of proposed stationary or moving targets. With this information in hand, the forest-resource manager can finalize designs, taking advantage of openings where hazardous trees will be removed. If it is desirable that the stand be opened in certain areas to introduce more light, or increase visibility, trees with varying degrees of hazard can be prioritized for removal, and treatment can occur during the construction phase.

If a vegetation-management plan has not been developed prior to establishing a developed site, hazard management will be reactive rather than proactive. In these situations, creativity is important in treating hazardous trees. Tree removal may be the least desirable option. If the character value, scenic value, wildlife value, or historic value of a defective tree is high enough, moving a valuable target may be the preferred option. It is always wise to consult with appropriate forest-resource specialists to accurately determine the resource value of some hazard trees.

Management of Existing Sites

Some hazard trees can be treated without their removal. Others must be removed. Trees affected by root diseases and standing, dead trees fall into the latter category (see Table 10 for treatment options by category of damage). Since resistance to failure is related to the amount of sound wood remaining in the butt and stem, many trees with butt defects do not require immediate treatment but must be monitored if they are retained. Treatment likely will be required at some time in the future. Defective trees that present an acceptable amount of risk in the current year should be monitored at regular intervals to track intensification of the hazards.

It is important to avoid creating new hazards while treating others. For example:

- If large, defective trees are to be felled, care should be taken to prevent injury to surrounding trees.
- In sites where stocking levels are high, care should be taken not to create canopy gaps that open the stand up for windthrow.
- Prune defective limbs properly to avoid future stem decay. Prune branches flush with the branch collar, not flush with the stem. Stubs extending beyond the branch collar, both on living and dead branches, can allow decay fungi to enter. After pruning, do not paint cuts; wound dressings have been shown to increase decay in some cases.
- When removing true firs, hemlocks, and, on dry sites, ponderosa pine, consider treating the newly made stumps with an EPA-registered boron compound to reduce the potential for *Heterobasidion* spp. colonization and subsequent incidence of annosus root disease (p. 45).
- During construction and rehabilitation activities, avoid damaging tree boles and roots to prevent future decay and associated hazards.

Table 10. Tree damage and treatment options for developed sites in Oregon and Washington

Defect	Pruning	Topping	Cabling or Bracing[1]	Tree Removal
Root and butt rots				X
Undermined, severed, or broken roots			X	X
Heart rots			X	X
Sap rots				X
Cracked/split boles			X	X
Bole cankers			X	X
Bole flattening			X	X
Forked or multiple tops				X
Dead or broken tops		X		X
Mistletoe brooms	X			
Defective branches	X			
Detached branches, tops, or bark				remove piece
Leaning trees			X	X
Fire-damaged trees			X	X
Dead trees				X[2]

[1]Cabling or bracing only should be considered when retaining defective but highly valuable or historic trees.

[2]Dead trees should always be removed when valuable targets are nearby. Developed sites are poor places to maintain snags for wildlife.

In all cases, site closure, target removal or relocation, and/or exclusion of visitors from the impact zone are treatment options either alone or in combination, so they are not listed above.

Topping trees within striking distance of valuable targets is recommended only to remove dead tops. Topping live crowns is rarely recommended. Removal of live foliage reduces a tree's ability to feed itself through photosynthesis. Topping also creates a large wound that can become an entry court for decay fungi. Topping live crowns may also attract bark beetles and other damaging insects. Topping may eventually lead to forked or multiple tops that may themselves subsequently fail. If topping of living crowns is done to create wildlife habitat, such trees should not be within striking distance of valuable targets.

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For additional information and references about hazard trees, see http://www.fs.fed.us/r10/spf/fhp/hazard/index.htm

Glossary

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

Advanced decay – the later stages of **decay** often characterized by a crumbling wood structure

Aecium (pl. aecia) - specialized **spore**-producing structure formed on trees infected with rust fungi

Aeciospore - type of spore produced in an **aecium** that typically infects alternate hosts

Azimuth - a compass reading in degrees going from 0^0 (north) to 359^0

Bark beetles – a group of often destructive forest insects whose adults and **larvae** make **galleries** in the cambial region of living or felled trees; a subfamily of the Curculionidae

Barrier zone of cells – Cells within a plant or tree that form around injured tissue as a response to wounding and microorganism invasion. These cells restrict the movement of the invading microorganisms

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; seedlings and saplings have stems rather than boles

Boring dust – a mixture of fecal matter and wood debris resulting from chewing and tunneling by bark beetles and wood borers; also called frass

Branch flagging – a disease symptom where some of the foliage on branches, particularly older foliage, is dead or dying

Branch stub - the remnant of a tree branch after it breaks off near the trunk; often an entrance point for decay fungi or a site where fungal **conks** form

Branchlet stub - the remnant of a branchlet (small branch or twig) that breaks off near the main branch; often an entrance point for decay fungi, especially the Indian paint fungus

Branch whorl – a circle of branches developed from one node on a tree

Broom or witches' broom - an abnormal clustering of branches associated with infection by a **dwarf mistletoe, rust fungus,** genetic aberration, or other insect or **disease**

Butt - the base of a bole to a height of 8 feet

Butt log - the first log above the stump

Butt rot - decay developing in and sometimes confined to the butt; originating at **basal wounds** or coming up through roots

Cabling or bracing – cabling is the installation of a cable within a tree between limbs or leaders to limit movement and provide supplemental support. Bracing is the installation of lag-threaded screws or threaded steel rods in limbs, leaders, or trunks to provide supplemental support. Both may be used to extend the time trees or their parts remain intact. Proper cabling and bracing require skill, hard work, and a keen understanding of tree construction. The treatment often wounds trees.

Callus - tissue produced at **wound** sites in response to injury that may or may not overgrow an injured area

Cambium - a layer of living cells between the wood (xylem) and innermost bark (phloem) of a tree

Canker - a lesion on a stem, branch, or root; typically longer than wide; the **cambium** and cortex of which have been killed

Canopy - the more or less continuous cover of branches and foliage formed collectively by the crowns of adjacent trees

Catface – a partially healed or grown-over **wound** on a tree stem resulting from fire or equipment use; similar to a **scar**

Causal agent - a **biotic** or **abiotic** entity that causes a deviation from the normal form or function of a tree; can be biotic entities such as fungi or insects or abiotic entities such as wind or fire.

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

Climax stage - the last stage of natural forest **succession;** a late-successional stage usually containing shade-tolerant tree species

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

Compartmentalization – a process in living trees where wound-infecting microorganisms and subsequent decayed wood are confined to compartments within the tree. At least four interior walls restrict the movement of microorganisms and decay to adjacent compartments. Wall 4, the **barrier zone**, forms at the cambium after wounding and confines decay within a wood cylinder present at the time of wounding. Given enough time, all walls eventually will fail resulting in complete wood decay. Compartmentalization is repeated each time a tree is wounded

Compression strength - a measure of resistance of a body to compressive loading; the force at which failure occurs under a compressive load

Conk - a shelf-like reproductive structure of the type formed by many wood-decay fungi; also called a **sporophore** or **fruiting body**

Crook - an abrupt bend in a tree or log

Crotch - that part of the tree where the main stem or larger branches fork

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

Cubical decay – decayed wood that breaks into distinct cubes

Cull (tree) – a tree or tree part that is so highly defective as to be lacking in commercial value as a sawlog; a tree that is decayed through much of its length

Cull rules – Values of **defect** and **decay** extent that are usually based on tree age, dbh, number of indicators (**conks, punk knots**), or distance of indicators above the ground. Cull rules sometimes provide a crude estimate of tree-failure potential.

Dbh - the **d**iameter of a tree at **b**reast **h**eight; breast height is defined at 4.5 feet above the ground on the uphill side of any tree

Decay - degradation or decomposition of wood by fungi and other microorganisms resulting in the progressive loss of integrity and strength of affected parts; can be **incipient** or **advanced**

Decay column – generally a large section of the tree bole that is internally decayed in the shape of a cylinder or column with tapered ends; a product of **compartmentalization**

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

Delaminate - to separate into sheets as with the pages of a book; wood delaminates at the growth rings; characteristic of decay caused by *Phellinus weirii* and some other decay fungi

Developed forest sites – areas within the forest that contain human-developed structures, such as buildings, ski lifts, boat ramps, parking lots, picnic tables, or campsites that are used for recreation or administration

Disease – a prolonged disturbance of the normal form or function of a tree or its parts; usually caused by organisms such as fungi or mistletoes but not insects

Disease center - a group of dead and dying trees that have developed progressively over time; caused by root pathogens such as *Armillaria* spp. or *Phellinus weirii*; also called a mortality center or infection center

Distress (stress) cone crop – abundant, small cones that are often produced on root diseased trees

Drip line - the maximum radial extension of the tree crown projected to the ground

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

Dwarf mistletoe - a parasitic flowering plant with stems and seeds 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 material, usually white to cream-colored, found on the outside of the root bark that is formed by certain root **pathogens** (i.e. *Phellinus weirii* and *Heterobasidion occidentale*)

Embedded (included) bark – the inner and outer bark that forms between the expanding cylinder of the branch and the trunk or between two trunks. As the branch and trunk cylinders expand, the inturned bark becomes a wedge between the two cylinders that greatly weakens the fork.

Exudate - matter that has oozed out of a stem, branch, or root that may be a symptom of a defect or infection such as root-collar exudates caused by *Armillaria* spp.

Failure - partial or total breakage or collapse of a tree or tree part

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; they originate from old mechanical **wounds**; often called bleeding or weeping cracks if copious **exudates** are present

Frost ribs - parallel ridges of **callus** that form on either side of **frost cracks** which are repeatedly (often annually) aggravated by extreme cold

Fruiting body - conk, **mushroom**, or other fungal reproductive structure that produces spores

Fungal thallus - the entire assimilative phase of an individual fungus

Fungus (pl. fungi) **-** a non-**vascular** plant lacking chlorophyll (therefore it does not photosynthesize), having cell walls with both cellulose and chitin, having a vegetative body composed of **hyphae**, and reproducing by **spores**

Gall - a pronounced swelling or tumor-like body produced on trees parasitized by certain fungi or bacteria, or infested by gall-forming insects

Gallery - a tunnel formed by the feeding of insect **larvae** or adults, particularly by **bark beetles**

Gill – blade-like formation on the underside of some **fruiting bodies** (mushrooms) that bears **spores**

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

Hazard tree or danger tree – any tree that is within striking distance of a permanent or transitory **target** of value

Heart rot - decay usually restricted to the **heartwood** in living trees

Heartwood - the inner, nonliving part of a tree stem that is altered to a protective state as a result of normal, genetically controlled aging processes as cells die; provides mechanical support

Highly defective - trees or tree parts that possess such substantial decay or defect that they are extremely likely to fail

Hypha (pl. hyphae) **-** single, microscopic, thread-like filament made up of fungal cells

Incipient stain/decay - early stages of decay often characterized by discoloration of the wood

Increment borer - an auger-like instrument with a hollow bit and an extractor used to remove thin radial cylinders of wood (increment cores) from trees having annual-growth rings to determine tree age or detect the presence of wood decay or stain

Infection – the act of a **pathogen** establishing itself on or within a host

Inoculum - spores or tissue of a **pathogen** that serve to initiate disease

Larva (pl. larvae) – the immature stage between egg and pupa in insects such as **bark beetles** or wood borers; examples are maggots, caterpillars, or grubs

Lichens – a type of green plant composed of an alga and a fungus that grow in symbiotic association. Lichens often grow on tree boles and branches and can hide conks or cavities.

Live-crown ratio - the ratio of live-crown length to total tree height; usually expressed as a percentage

MCH-pheremone – a natural chemical used to protect down or standing high-value Douglas-fir trees from attack by the Douglas-fir beetle

Mesic - requiring a moderate amount of moisture

Minor defect - damage that does not alter the structural integrity of a tree or tree part in any significant way

Moderate defect - damage that reduces the structural integrity of trees or tree parts but does not render them in immediate danger of failure; trees with moderate defect should be monitored.

Mycelial fan - a mass of **hyphae** that grows under the bark of infected roots and butts and has a "fan-like" appearance. Mycelial fans, especially of *Armillaria ostoyae*, are usually thick enough to peel off like latex paint and are white to cream-colored when fresh and turn brown when old.

Mycelial felt - a dense and expansive mycelium that takes the form of a thick sheet

Mycelium (pl. mycelia) **-** a mass of **hyphae** or fungal filaments

Mushroom - the reproductive fruiting body of any fleshy fungus, usually produced annually. Spores are produced from mushrooms.

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

Old-growth (forest) – usually a late**-successional stage** of forest development that contains large and old live and dead trees (overmature trees), multiple canopies, and down logs

Parasite - an organism that grows part or all of its life on or within another organism of a different species and derives all or part of its food from it

Parenchyma - the soft tissue of higher plants commonly used for food storage

Pathogen - a fungus, bacterium, virus, or other infective agent capable of causing **disease** in a particular host or range of hosts

Pathological rotation (age) - age of a forest stand when **heart-rot** fungi decay more wood than is produced; can also refer to loss of wood due to mortality induced by root diseases

Photosynthesis – the manufacture of organic compounds, particularly carbohydrates, in the chlorophyll cells of plants from carbon dioxide, water, and enzymes in the presence of light as the energy source

Pitch tubes or streams – a tubular mass of **resin, boring dust,** and frass that forms on the surface of the bark at the entrance holes of **bark beetles**

Plant association or community – a plant-group type based on land-management potential, **successional** patterns, and species composition

Pore - a small hole in the undersurface of a fungal **fruiting body** from which **spores** emanate

Prophylactic treatment - action to reduce potential of infection or infestation

Pruning – the removal, close to the branch collar, of side branches (live or dead) or multiple leaders from a standing tree

Pulaski - a chopping and trenching tool that combines a single-bitted-ax blade with a narrow trenching blade resembling an adz hoe; named for the USDA Forest Service ranger who invented the tool for fire-fighting and saved numerous lives during the 1910 fire in Idaho.

Punk knot or swollen knot - a protruding and unhealed knot of a tree with **heart rot**, the surface is not encased fully in the bark, and the knot interior contains highly decayed wood that resembles the interior of the **conk** of the causal fungus

Pustules – very small (<1/2 in. wide) **fruiting bodies** that form on the roots of infected trees especially *Heterobasidion* spp. on saplings or seedlings

Ramicorn branch – a branch that protrudes at an acute angle

Resin - secretions of certain trees, especially conifers, that are oxidation or polymerization products of terpenes, consisting of mixtures of aromatic acids and esters; generally associated with tree resistance to fungi and insects; also called pitch

Resinosis - the reaction of a tree to invasion by certain pathogens and insects or to abiotic injuries that results in the copious flow of resin over the outer bark in the area of injury, or resin-soaking within the outer bark, or in resin accumulation under the bark

Rhizomorph - a thread-like or cord-like fungal structure made up of strands of **hyphae** that are covered with a protective rind; rhizomorphs look like roots, but they are an extension of a fungus that infects live or dead host parts (usually roots or wood); may occur with infection by several species of fungi including *Armillaria* spp.

Rind - the shell of solid wood surrounding a **decay column** in a tree. A rind may be broken and not continuous because of a **wound** or **canker**.

Risk - the proximity to actual damage and loss; the real possibility or chance of damage and loss

Root collar or crown - where the root system joins the bole of the tree

Root graft - the growing together of two or more roots in such a way that their **cambium**, xylem, and phloem eventually fuse, and materials, including fungi, pass from one root to another

Rust or rust fungus – term used for a particular group of diseases or the fungi that cause them; most rusts require at least two host species to complete their life cycles; an example is white pine blister rust on white pine and *Ribes* spp.

Saprophyte - an organism that lives on dead organic matter

Sap rot - wood decay that is characteristically confined to the **sapwood**

Sapwood - the outer layers of a stem, which in a live tree are composed of living cells (xylem) that conduct water up the tree

Scar – a **wound** that shows some evidence of **callus** tissue (sealing or healing)

Second-growth (forest) - a relatively young forest that has been regenerated either naturally or artificially after some drastic disturbance such as extensive felling, wildfire, insect or disease attack, or blowdown; also called young-growth (forest)

Seral stage - the first stage of natural forest **succession**; an early **successional stage**

Setal hypha (pl. hyphae) **-** a thick-walled reddish-brown **hypha** that tapers to a point; it is sub-microscopic and only found in **advanced decay** associated with laminated root rot or cultures of *Phellinus pini*

Shake - a physical defect of trees caused by exposure to high winds; the defect appears in its most advanced stages as deep longitudinal fissures that follow the grain of the butt log and are associated with separations of the growth rings deep in the **heartwood**. More commonly, growth ring separations occur without the external fissures.

Sign - the manifestation of disease by the presence of structures of the causal agent (**conks, mushrooms, setal hyphae, mycelial fans or felts, rhizomorphs**)

Silvics – study of the life history and general characteristics of forest trees and stands with particular reference to environmental factors

Snag - a standing dead tree often classified by different stages of decay

Spore - a microscopic reproductive propagule of fungi (and other cryptogams)

Sporophore - conk, **mushroom**, or other fungal reproductive structure that produces spores

Springwood – that part of the annual ring of wood that is less dense and composed of large-diameter, thin-walled, secondary xylem cells laid down early in the growing season; also called earlywood

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

Stocking (level) – an indication of growing-space occupancy relative to a pre-established standard; common indices of stocking are percent occupancy, stand density index, basal area, relative density, and crown competition factor

Structural roots - major tree roots that significantly add to the support of a standing tree

Succession (forest) - a continuum of forest development where one community of plants is gradually replaced by another

Successional stage - a condition within forest succession; starts with the early **seral stage** and ends with the **climax stage**

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 of a tree or its parts

Topkill – death of the upper crown of a tree; usually caused by insects, **pathogens**, animals, or weather

Topping - removal of some of the upper crown of a tree; not recommended for live crowns

Undermined roots - roots that are no longer firmly anchored due to soil removal or loss, beneath and/or around them

Vascular (plant or system) - Specialized cells (phloem and xylem) within a plant that transport water and nutrients to and from roots and foliage

Vascular wilt – symptom of a lack of water in the plant vascular system whereby foliage loses its turgidity and droops (wilts)

Wetwood - a water-soaked area in the **heartwood** of a tree that is a symptom of infection by certain fungi (particularly yeasts) and bacteria

Windshake - a separation along the grain in a tree stem caused by wind stress

Windthrow – a tree that has fallen to the ground, usually at the roots or butt, due to excessive wind or perhaps without wind because of decayed roots or butt

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 without wind because of a decayed stem

Wound - an injury that usually breaks the bark of branches, stems, or roots of a tree and serves as a possible entry point for many species of fungi. Old wounds may become sealed with new bark and eventually become hidden. **Scars** are wounds that have sealed and have **callus** tissue.

Zone line - a narrow, dark-brown or black line in decayed wood, generally resulting from the interaction of different strains of fungi or the host reaction.

Forked tree, Jubilee Lake campground, Umatilla National Forest

Hazard trees at Biglake Campground, Willamette National Forest

Appendix

Cull rules used to identify the extent of red ring rot in *Douglas-fir west* of the Cascade Crest in Oregon and Washington.

Tree age (yrs.)	Red ring rot extent
< 125	Trees with conks and defects warrant periodic evaluation
125 to 150	4 ft. above/below conks (punk knots); 2 ft. above/below swollen knots
151 to 200	10 ft. above/below conks (punk knots); 5 ft. above/below swollen knots
201 to 250	13 ft. above/below conks (punk knots); 7 ft. above/below swollen knots
251 to 300	18 ft. above/below conks (punk knots); 9 ft. above/below swollen knots
301 to 350	22 ft. above/below conks (punk knots); 11 ft. above/below swollen knots

Cull rules used to identify the extent of red ring rot in old-growth (>125 years) *western hemlock and true firs west* of the Cascade Crest in Oregon and Washington.

Number of conks	Red ring rot extent extent
Single conk	8 ft. above/below conk; 4-ft. above/below swollen knots when accompanying conks
Multiple conks	16 ft. above/below lowest and highest conk or punk knot); 8 ft. above/below swollen knots

Cull rules used to identify the extent of red ring rot in *Douglas-fir, ponderosa pine, and western larch east* of the Cascade Crest in Oregon and Washington.

Tree age (yrs.)	Red ring rot extent
< 125	4 ft. above/below conks (punk knots); 2 ft. above/below swollen knots
125 to 200	8 ft. above/below conks (punk knots); 4 ft. above/below swollen knots
201 to 250	12 ft. above/below conks (punk knots), 6 ft. above/below swollen knots
251 to 300	16 ft. above/below conks (punk knots); 8 ft. above/below swollen knots
301 to 350	20 ft. above/below conks (punk knots); 10 ft. above/below swollen knots
>350	24 ft. above/below conks (punk knots); 12 ft. above/below swollen knots

Cull rules used to identify the extent of red ring rot in *true fir, hemlock, and spruce east* of the Cascade Crest in Oregon and Washington.

Tree age (yrs.)	Red ring rot extent
<200	8 ft. above/below conks (punk knots); 4 ft. above/below swollen knots
≥200	16 ft. above/below conks (punk knots); 8 ft. above/below swollen knots

Cull rules used to identify the extent of red ring rot in *western white pine and sugar pine east* of the Cascade Crest in Oregon and Washington.

Tree age (yrs.)	Red ring rot extent
<200	4 ft. above/below conks (punk knots); 2 ft. above/below swollen knots
>200	8 ft. above/below conks (punk knots); 4 ft. above/below swollen knots

Cull rules for white and Shasta red fir in southwest Oregon used to estimate defect extent caused by the Indian paint fungus (Filip et al. 2009).

Conk age, number, and location:	Rust-red stringy rot extent:
Conk is single, small, and young	8 ft. above and below conk
Lowest conk is 0 to 32 ft. from ground Multiple conks are separated by <25 ft.	12 ft. below lowest conk; 21 ft. above highest conk
Lowest conk is >32 ft. from ground Multiple conks are separated by <25 ft.	20 ft. below lowest conk; 21 ft. above highest conk
Conks are in bottom third of tree	Decay in the middle and bottom third of tree
Conks are in top third of tree	Decay in top and middle third of tree
Multiple conks are separated by >25 ft	Decay in the entire tree

Cull rules used to estimate defect extent caused by the Indian paint fungus for all species in Oregon and Washington.

Tree dbh (in.)	Rust-red stringy rot extent:
<19	18 ft. above and below conks
19 to 26.9	18 ft. below lowest conk; 20 ft. above highest conk
27 to 34.9	21 ft. below lowest conk; 20 ft. above highest conk
> 34.9	22 ft. below lowest conk; 20 ft. above highest conk

Signs and symptoms of damaging agents in developed sites in Oregon and Washington. X = the sign/symptom is routinely evident; O = the sign/symptom is occasionally evident

Sign or symptom	AR	CV	ET	FC	FO	FP	GA	HA	HE	IT	LW	OA	PI	PL	PP	PS	PT	PW	SS
Reduced height growth	X							X		O	X			X		O		X	
Yellow foliage	X							O			X			X				X	
Slow crown decline	X							X		O	X					O		X	
Distress cones	X							O			X							X	
Rapid tree death	X							O			X			X				O	
Basal resinosis	X										X							O	
Windthrown live trees								X		X						X		X	
Live-stem breakage			X	X	X		X	X		X			X		O	X	X	X	
Insect galleries under bark	X	X				X		X			X			X				X	
Mushrooms	X									O						X			
Mycelial fans under bark	X																		
Mycelia in decay				O	X	X		O		O						X		O	O
Rhizomorphs	X																		
Perennial conks			X	X	X	X	X	O					X		X		X	O	
Annual conks		X							X	X		X				X			X
Setal hyphae																		X	
Root pustules								X											
Ectotrophic mycelium								O		O								X	

Damaging agents: AR=*Armillaria* spp., CV=*Cryptoporus volvatus*, ET=*Echinodontium tinctorium*, FC=*Fomitopsis cajanderi*, FO=*Fomitopsis officinalis*, FP=*Fomitopsis pinicola*, GA=*Ganoderma* spp., HA=*Heterobasidion* spp., HE=*Hericium abietis*, IT=*Inonotus tomentosus*, LW=*Leptographium wageneri*, OA=*Oligoporus amarus*, PI=*Phellinus igniarius*, PL=*Phytophthora lateralis*, PP=*Phellinus pini*, PS=*Phaeolus schweinitzii*, PT=*Phellinus tremulae*, PW=*Phellinus weirii*, SS=*Stereum sanguinolentum*

Signs and symptoms of damaging agents in developed sites in Oregon and Washington. X = the sign/symptom is routinely evident; O = the sign/symptom is occasionally evident

Sign or symptom	AR	CV	ET	FC	FO	FP	GA	HA	HE	IT	LW	OA	PI	PL	PP	PS	PT	PW	SS
Delamination pits - 1 side								X											
Delamination pits - 2 sides																		X	
Yellow stringy decay	X																		
White-spongy decay							X	X									X		
Rust-red-stringy decay			X																
Red-brown-cubical decay				X	X	X										X			
White pocket rot							X	O					X		O				
Honeycomb decay									X	X		X							
Conk looks like cow pie																X			
Conk with spines			X																
Conk at branch stubs			X		X							X	O		X				
Conk is rose-colored				X															
Conk bottom is easily etched							X												
Conk is hoof-shaped			X		O								X		O		O		
Conk looks like coral									X										
Conk looks like popcorn		X						O											
Conk has a red margin (belt)						X													
Conks turn red when bruised																			X

Damaging agents: AR=*Armillaria* spp., CV=*Cryptoporus volvatus*, ET=*Echinodontium tinctorium*, FC=*Fomitopsis cajanderi*, FO=*Fomitopsis officinalis*, FP=*Fomitopsis pinicola*, GA=*Ganoderma* spp., HA=*Heterobasidion* spp., HE=*Hericium abietis*, IT=*Inonotus tomentosus*, LW=*Leptographium wageneri*, OA=*Oligoporus amarus*, PI=*Phellinus igniarius*, PL=*Phytophthora lateralis*, PP=*Phellinus pini*, PS=*Phaeolus schweinitzii*, PT=*Phellinus tremulae*, PW=*Phellinus weirii*, SS=*Stereum sanguinolentum*

Equipment recommended for hazard-tree evaluations

Equipment	Intended Use
Pulaski	Exposing roots and checking for decay, signs and symptoms
Axe or rubber mallet	Sounding boles and inspecting stems for sap rot, heart rot, insect attack, or dead sapwood
Binoculars	Examining stems for conks, punk knots, swollen knots and other indicators of stem decay, and for examining tree crowns for hazardous branches, dead or forked tops, and other defects
Diameter tape	Measuring tree or branch diameter
Tape measure	Measuring distances to targets or for stem mapping
Compass	Recording azimuths for stem mapping and relationships to reference points
Laser measurer	Measuring tree heights and distances
Cordless drill/ increment borer	Estimating the rind thickness of sound wood in the bole; detecting root and stem decay
Hand lens(10X)	Examining advanced decay for setal hyphae and other indicators
Field guides	Identifying tree species, diseases, insects, and defects by their indicators
Data forms	Recording data and observations
Tree tags	Providing a semi-permanent numbering system for trees that will be re-evaluated annually (tags are aluminum, numbered in series)
Aluminum nails	Securing tags to trees; steel nails rust
Tree paint or tree flagging	Identify trees to be felled or treated; treatment should be immediate after marking

This equipment list can be modified to suit budgets and individual needs. These items have been routinely used to do a thorough job of recording a baseline evaluation to which subsequent annual evaluations and monitoring exams could be tiered.

HAZARD-TREE DATA FORM

Page___of___

Site name: ________________________ Unit No. or Location:____________________

Date: ______ Recorders:__________

Tree no.	Tree species	Tree dbh (in.)	Tree height (ft.)	Defect height (ft.)	Target distance (ft.)	Root/butt disease symptom[1]	Rind (in.)[2]	Root/butt cause[3]	Stem disease defect[4]	Risk rating[5]		Recommended treatment[6]	Treat-ment date
										FP	DP		

[1]**Root/butt disease symptom:** DEAD=dead tree, REGR=reduced-height growth, DETO=dead top, DEBR=dead branches, THCR=thin crown, YECR=yellow crown, RESN=basal resinosis or weeping, CONK=conk(s) present, FANS=mycelial fans, ECTO=ectotrophic mycelium, WNDS=wound, CRACK=cracks

[2]**Sound-rind thickness** in inches; average of four drillings at defect

[3]**Root/butt disease cause:** PW=*Phellinus weirii*, AR=*Armillaria* spp., HE=*Heterobasidion* spp., PS=*Phaeolus schweinitzii*, IT=*Inonotus tomentosus*, X=unknown, etc.

[4]**Stem disease/defect:** MECH=mechanical injury, FIRE=fire damage, STCR=stress crack, FRCR=frost crack, CANK=stem canker, FORK=forked or multiple top, HANG=detached branch, top, or bark, DMBR=dead mistletoe broom ≥10 ft. wide; for conks, ET=*Echinodontium tinctorium*, PP=*Phellinus pini*, CONK=unknown species, etc.); for dwarf mistletoe in live trees, use DMR5=dwarf mistletoe rating of 5, BB=bark beetle attack.

[5]**Risk rating:** FP=failure potential (rating: 1 to 4) and DP=damage potential (rating 1 to 4) where 1=very low, 2=low, 3=medium, and 4=high

[6]**Recommended treatment:** TOPx=top tree where x is the remaining tree height, PRUN=prune branches, FELL=fell tree, BRAC=bracing or cabling of tree, MOTA=move target, EXPE=exclude people from target area, MONI=monitor tree

HAZARD-TREE EVALUATION

Facility: ______________________ Date: __________ Evaluators: ___________

Location:
Site ID _____Ref. Pt. _______________ Bear _____ Dist.____
Tree ID_______ Species_______________DBH ______Ht. _____

Top:
OK
Dying
Dead Recent/ Old

Branches:
OK
Dying
Dead
Detached

Stem:
OK
Scar Cavity Canker — Open Length______ Closed Ft² __________
Conks _______________
Cracks Old Recent
Forks Splitting Included bark
% Lean ________
Decayed Min rind Thickness Needed Dia. ___ X 0.15 ________
Reading ___________________________________ Av. ______

Ratings:
Failure Pot. ____
Damage Pot. ____
Hazard Rating ____

Photo☐

Roots:
OK
Exposed Wounded Decayed % Impaired___

Targets______________________________
____
____

Comments____

Location:
Site ID _____Ref. Pt. _______________ Bear _____ Dist.____
Tree ID_______ Species_______________DBH ______Ht. _____

Top:
OK
Dying
Dead Recent/ Old

Branches:
OK
Dying
Dead
Detached

Stem:
OK
Scar Cavity Canker — Open Length______ Closed Ft² __________
Conks _______________
Cracks Old Recent
Forks Splitting Included bark
% Lean ________
Decayed Min rind Thickness Needed Dia. ___ X 0.15 ________
Reading ___________________________________ Av. ______

Ratings:
Failure Pot. ____
Damage Pot. ____
Hazard Rating ____

Photo☐

Roots:
OK
Exposed Wounded Decayed % Impaired___

Targets______________________________
____
____

Comments____

Location:
Site ID _____Ref. Pt. _______________ Bear _____ Dist.____
Tree ID_______ Species_______________DBH ______Ht. _____

Top:
OK
Dying
Dead Recent/ Old

Branches:
OK
Dying
Dead
Detached

Stem:
OK
Scar Cavity Canker — Open Length______ Closed Ft² __________
Conks _______________
Cracks Old Recent
Forks Splitting Included bark
% Lean ________
Decayed Min rind Thickness Needed Dia. ___ X 0.15 ________
Reading ___________________________________ Av. ______

Ratings:
Failure Pot. ____
Damage Pot. ____
Hazard Rating ____

Photo☐

Roots:
OK
Exposed Wounded Decayed % Impaired___

Targets______________________________
____
____

Comments____

HAZARD-TREE DATA FORM

PAGE ____ OF ____

SITE: ______________________________
DATE: _______ / _________ / _________
RECORDERS: _______________________

Tree #	Species	Location Memo	Condition/Notes	DBH	Sound Rind	DMR	Stem Decay	Root Disease	Fail. Pot.	Dam. Pat.

HAZARD-TREE DATA FORM

SITE:______________________________ Date:_______________

Examiner:_________________________ Page___of_____

Tree #	Site ID:		Ref. Pt.		
Distance:			Azimuth:		
Species	DBH	Height	Dead	Lean	Top/branch defect
Stem defect/ decay	Butt rot	Open wound/ crack	Diameter inside bark	Sound rind thickness	Root disease
PF +	PD =	RATING	Recommended TREATMENT		
Target(s):					
Date & Treatment completed:					
Remarks or drawing:					

Tree #	Site ID:		Ref. Pt.		
Distance:			Azimuth:		
Species	DBH	Height	Dead	Lean	Top/branch defect
Stem defect/ decay	Butt rot	Open wound/ crack	Diameter inside bark	Sound rind thickness	Root disease
PF +	PD =	RATING	Recommended TREATMENT		
Target(s):					
Date & Treatment completed:					
Remarks or drawing:					

For assistance on Oregon and Washington federal lands:

http://www.fs.fed.us/r6/nr/fid/staffweb/regoff.shtml

Pacific Northwest Regional Office
Forest Health Protection
USDA Forest Service
1220 S.W. Third Avenue
Portland, OR 97204
503-808-2997

Blue Mountains Forest Insect and Disease Service Center
USDA Forest Service
Forest Sciences Laboratory
1401 Gekeler Lane
LaGrande, OR 97850
541-962-6544

Southwest Oregon Forest Insect and Disease Service Center
USDA Forest Service
J. Herbert Stone Nursery
2606 Old Stage Road
Central Point, OR 97502
541-858-6126 or 6124

Wenatchee Forest Insect and Disease Service Center
USDA Forest Service
Forestry Sciences Laboratory
1133 N. Western Avenue
Wenatchee, WA 98801
509-664-9223 or 9215

Central Oregon Forest Insect and Disease Service Center
USDA Forest Service
Deschutes National Forest Headquarters
63095 Deschutes Market Road
Bend, OR 97701
541-383-5591 or 5788

Westside Forest Insect and Disease Service Center
USDA Forest Service
Mt. Hood National Forest Headquarters
16400 Champion Way
Sandy, OR 97055
503-668-1475 or 1474

For assistance on State and Private Lands

Washington Department of Natural Resources
Resource Protection Division
Natural Resources Building
Fourth Floor
1111 Washington Street, SE
Olympia, WA 98501
390-902-1692 or 1309

Oregon Department of Forestry
Forest Health Management
Insects and Diseases
2600 State Street
Salem, OR 97310
503-945-7397
http://www.oregon.gov/odf/privateforests/pages/fh.aspx