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Hazard Tree Identification and Mitigation

Forest Health Protection Technical Report
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INTRODUCTION TO HAZARD TREES

Hazard trees[1] have a risk of falling, in whole or in part, and injuring people or damaging property. Responsibility for managing hazard trees on National Forest System (NFS) lands is with the Agency or delegated through signed, written agreements to others such as concessionaires or special use authorization holders. Refer to Forest Service Manual (FSM) Chapter 2330, Publicly Managed Recreation Opportunities; FSH 2309.13, Chapter 50 for specific hazard tree procedures and responsibilities in recreation sites; and FSM Chapter 7733, Safety Measures On NFS Roads and FSH 7709-59 Chapter 40, Road System Operations and Maintenance.

The purpose of this technical report is to provide procedural information on hazard tree identification and mitigation for Pacific Southwest Region (R5) USDA Forest Service employees and is available for use by other forest management practitioners. The document elaborates on a hazard tree identification process including a streamlined approach to use after catastrophic events and another to use along National Forest System roads. A range of hazard tree mitigation options are presented and described for the line officer's decision in consideration of risks, unit priorities, available resources and timing. This report also includes hazard tree documentation suggestions, references for further assistance, and appendices with forms and data collection tools.

This report provides criteria to help inspectors identify trees that are likely to fail and injure people or damage property. These criteria apply to trailhead areas, campgrounds, and other recreations sites, and NFS lands adjacent to state or private lands infrastructure. The criteria provide a rationale for hazard tree identification and mitigation and is fully supported by R5 Forest Health Protection (FHP).

Under the best of circumstances and with the highest standard of care, it is impossible to predict all tree failures. The Forest Service cannot find and mitigate every hazard tree. By exercising good professional judgment and using this report, the Forest Service can significantly reduce, though not eliminate, the risk of trees injuring people or damaging property (Figure 1).

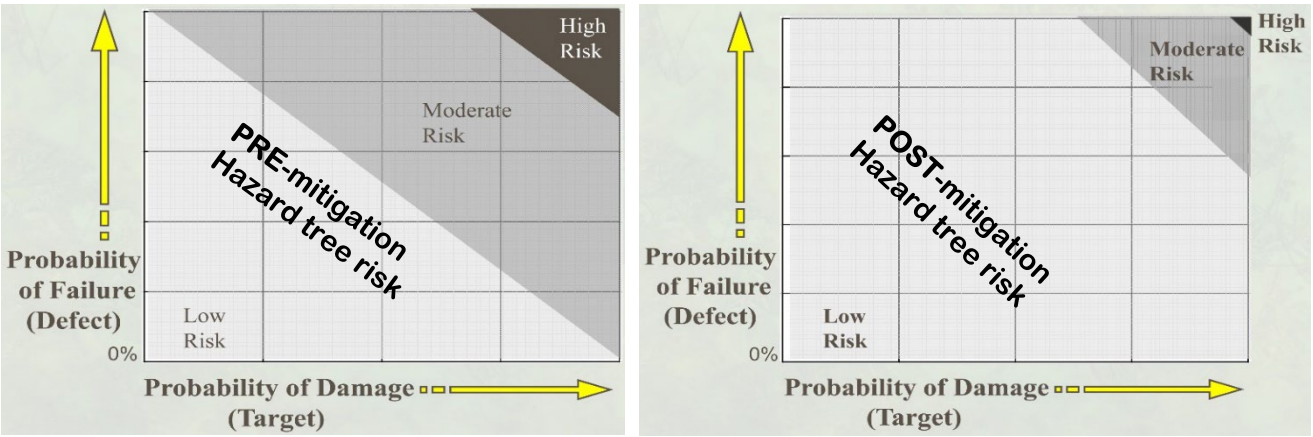


Figure 1. Hazard tree risk related to probabilities of failure and damage, PRE- (left) and POST- (right) mitigation.

[1] Hazard trees are sometimes referred to as danger trees; on federal lands in California, the term hazard tree is used most consistently. This document uses the two terms interchangeably.

When rating trees for their potential hazard, one attempts to determine whether a loss from failure of a tree will occur before the next inspection. Inspection frequencies may vary. Campgrounds are usually inspected each year prior to opening while roadway tree inspections may occur at longer intervals. Line officers decide hazard tree inspection frequencies for facilities and roads considering level of public use, past tree failure history, local conditions (e.g., insect, disease, and fire impacts), and program priorities.

Definitions

- Defects are flaws in a tree that reduce its structural strength. Trees may have a single or multiple defects which may or may not be detectable.
- Failure is the mechanical breakage of a tree or tree part. A failure results in a loss only if someone is injured or something is damaged.
- Hazard rating, or potential failure risk, summarizes the effect of damage that defects may cause to targets on a nominal scale.
- Hazard tree rating system is a tool to assess and categorize targets and detectable defects to describe a hazard tree rating, which are used to prioritize mitigation.
- Loss is defined as personal injury or monetary property damage.
- Targets are people or build infrastructure near hazard trees. Targets can be:
    - Stationary, e.g., buildings, utilities, parked vehicles or sleeping people.
    - Mobile, e.g., moving vehicles or people.

INDIVIDUAL HAZARD TREE ASSESSMENT

Line officers and land managers must balance hazard tree management with other required work. The hazard tree management process offered here can be used at the line officer's discretion as priorities and resources allow. Line officers may (1) designate trained hazard tree inspectors, (2) identify and prioritize sites to be examined, (3) ensure hazard tree inspections with documentation are completed as needed, (4) determine acceptable risk levels for each site, (5) ensure all trees with high hazard potential are removed or mitigated, (6) maintain records of inspection and actions taken, and (7) document tree failures.

Identifying And Prioritizing Sites To Be Examined

According to the Forest Service Manual, periodic safety inspections in developed recreation areas and administrative, special use and other high use sites should be conducted as necessary to identify and correct hazard tree situations using reasonable measures within the limits of available resources (FSM 2330.6a). Inspections are best done prior to the primary use season, with sufficient time allowed for corrective actions. R5 FHP specialists generally recommend inspecting sites once a year, with supplemental inspections after storms or fires. Local conditions (i.e., the site's level of use and the species, age, health, and condition of the trees) should influence inspection priorities and frequencies. Some sites may need to be fully inspected twice a year, while other sites may only need to be fully inspected every few years with cursory inspections in the intervening years. The reasons for adopting or adjusting inspection intervals should be documented and supported by local conditions.

Condition surveys, including hazard tree inspections, should be conducted on NFS roads "subject to availability of funding and other resources" (FSH 7709.59_41.7). The referenced Handbook also states that NFS roads which have been closed should be checked for obvious hazards prior to being re-

opened. Additional checks may be required following major storms. Because it is not feasible to intensively survey all roads every year, a system to prioritize roads for intensive or cursory inspection is recommended. When establishing priorities for roadside hazard tree inspection and mitigation, it is recommended that land managers consider the Road Maintenance Level[2], amount of public use and potential for trees to strike the road. The intensity and frequency of hazard tree inspections may also depend on tree failure history and the species, age, health, and soundness of trees present on the site; and impacts following insect, disease, weather, and fire events. The rationale for prioritization decisions should be documented and supported by local conditions.

Performing The Inspection

When an inspection is being performed, all trees with a target should be identified and rated for hazard potential using an accepted rating system. At minimum, an acceptable rating system should include an assessment of each tree's defect and target potential. Exceptions exist for situations that require a faster, more streamlined approach such as identification and mitigation of large numbers of hazard trees after catastrophic events, e.g., wildfire or bark beetle outbreaks, or along National Forest System roads. The protocols for assessing risks in these catastrophic situations are outlined later in this document and detailed in Appendix 4. Various rating systems exist for many state and federal agencies and other USFS regions, often tailored to local forest conditions. Here, we present and recommend a modified version of the "7-Point System" of Mills and Russell (1980).

The hazard tree inspection form (Appendix 1) and tatum guide (Appendix 2) are designed to help inspectors record the data needed to determine hazard ratings. This information is also available through the R5 Hazard Tree Survey123 Application (Appendix 3). Tree number, species, diameter (at breast height; DBH), and mapping information are recorded as appropriate. It is best if an area is covered in a logical sequence, such as by campsite number or road segment. To gain better and varied perspectives of the trees, it is also best if the assessment area is approached from different directions on each inspection during optimal lighting conditions. The hazard tree inspection process involves the following three steps.

1. **Assess the target potential for each tree**. If the tree would not hit a road, trailhead, structure, parking area, campsite, or other target, it can be ignored. Desirable sleeping areas near campsites that are used by campers should be assessed. A line tape and a clinometer (to measure tree heights) are useful in determining target zones, as are forestry laser measuring devices. The following values are used to rate targets and are described in the 7-Point System section.

   1 point = low failure impact

   2 points = moderate failure impact

   3 points = high failure impact

2. **Assess the tree defect potential**. When first learning to evaluate hazard trees, it helps to consider all possible defects and decide if any apply. It is best to look at trees from 2-3 perspectives, close, at a distance and all around. Diameter tapes, hand lenses, binoculars, sounding mallet and insect and disease field identification guides are all helpful tools. Based on

[2] NFS roads are classified by maintenance levels 1 to 5 (FSH 7709.59, sec. 62.3). Level 5 roads are maintained for high use and comfort and are normally paved double lane roads. Levels 4 to 2 are maintained less frequently for decreasing amounts of use with few improvements. Level 1 roads are closed to vehicle traffic.

indicators and experience, it may be advisable to follow up initial visual observations with more invasive methods using a Pulaski, hand axe, increment borer or drill to look inside the tree. Because wounding can lead to further damage by decay organisms, drilling or cutting into a tree is not recommended unless other indicators, professional experience, or knowledge of the area, leads one to believe that additional useful information will be gained. All tests and observations, both positive and negative, should be documented. The various kinds of defect one may likely encounter are outlined later in this document. The following values are used to rate defects and are described in the assessing defects and the 7-Point System section.

1 point = low failure potential

2 points = moderate failure potential

3 points = high failure potential

3. **Calculate the hazard rating score and determine hazard potential.** This hazard tree evaluation system combines target and defect scores into an overall hazard rating for the tree. The "Notes" column in the hazard tree assessment form provides space to record additional details, such as the target that is involved or the defect source, e.g., root pathogen, canker, conk, insect pest, etc. In some cases, the inspector may feel that the rating does not accurately reflect the hazard potential of the tree. Because tree inspection and hazard rating involve combining science and experience, it is sometimes reasonable to adjust the final rating to reflect what the inspector's experience and sound judgment deems to be correct. In such cases, it is helpful to use the "Notes" space provided in the hazard tree form (Appendix 1) or a supplemental notebook to fully document the reasoning behind the assignment of the final hazard rating.

Assessing Targets

Target potential (sometimes referred to as "failure impact" or "damage potential") incorporates the potential for a tree or tree part to strike a target ("potential failure zone"), the potential for damaging a target, and the value of the target. Moving targets are less likely to be struck than stationary targets because their duration of time in the target zone is usually shorter. When a tree or tree part fails, it may fall apart as it is descending and/or strike other trees or debris on the ground and fling large woody projectiles a considerable distance. For this and other reasons, the recommended potential failure zone of a tree on level ground is generally one to one-and-a-half times the height of the tree, depending on local conditions and judgment (Figure 2). On sloping ground where the tree or dislodged part may slide or roll downhill, the failure zone may need to be extended (Figure 3). When only a branch, top or other tree part fails, the recommended potential failure zone would generally be one to one-and-a-half times the length of the tree part that becomes dislodged (Figure 4) unless carried a somewhat further distance by wind. A tree's direction of lean can give an indication of where it may fall, thereby narrowing its potential failure zone and targets; the zone and targets may further be impacted by the type of slope on which a leaning tree may fall (Figure 5).

When considering the target potential along roads, special attention may be needed for areas following blind curves, where a driver will have limited time to react to fallen trees or tree parts in the roadway.

Once the potential failure zone is determined, the tree is assigned a "Failure Impact Rating" (sometimes referred to as a "Target Rating") that integrates both impact potential and target loss value. Impact

potential considers both the likelihood that a target will be hit in the event of a failure and the amount of damage that would likely occur, and includes such factors as distance between the target and the defective tree, the "exposure duration" of the target, and the size of the tree or tree part that will do the damage. Target loss value is exactly that, and is expressed in terms of degree of injury or monetary value of the target that is hit. Exposure duration refers to how long or how often a target is expected to be in the target zone, which may be *long* (e.g. permanent structure, car parking area), *short* (e.g. people or cars are occasionally passing through), or *intermittent with high frequency* (e.g. several people or cars per minute are passing through). It is also influenced by factors such as road maintenance level, traffic/site volume, site occupancy/use, and degree to which people stop and congregate. Generally, a

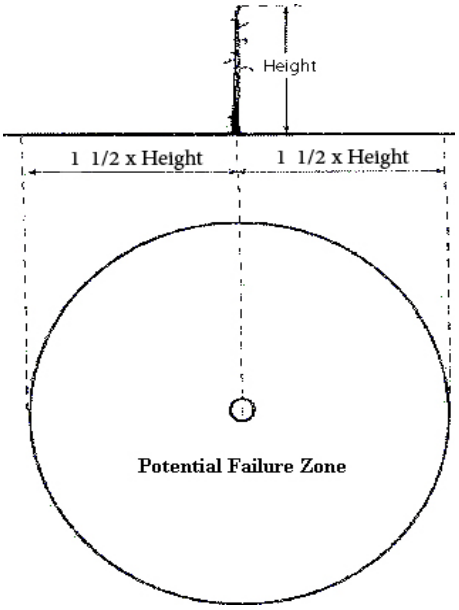


Figure 2. Failure zone at 1.5-times tree height on level ground.

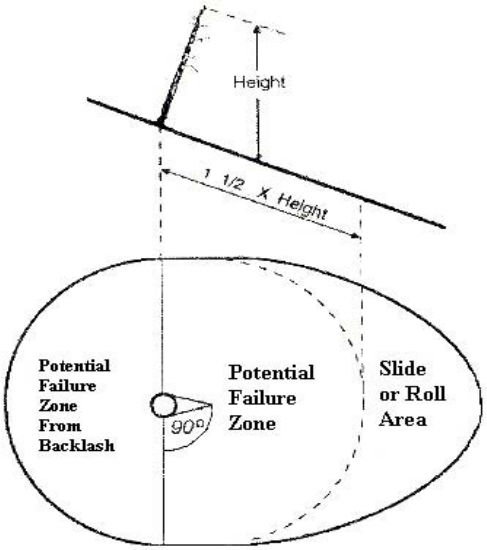


Figure 3. Failure zone at 1.5-times tree height on slope.

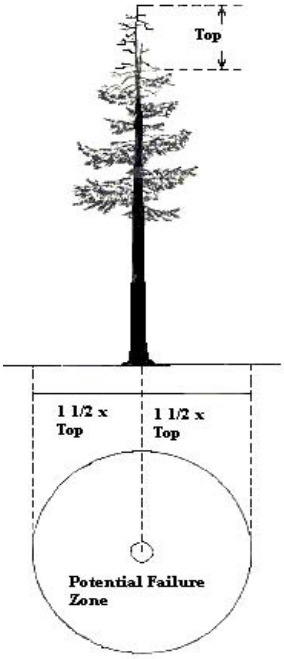


Figure 4. Failure zone for 1.5-times dead portion of tree on level ground.

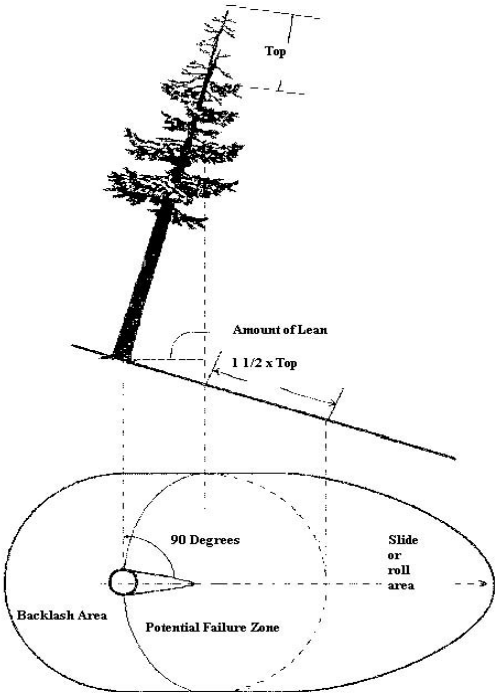


Figure 5. Failure zone for 1.5-times dead portion of tree on slope and considering tree lean.

tree that is rated with a high potential failure (target) rating has a high likelihood of impacting a high value target in the event of a failure, resulting in a high degree of damage or injury. Although assignment of potential failure (target) ratings are ultimately up to the judgement of the person who performs the hazard tree assessment, specific examples are presented in the description of the 7-Point Rating System later in this document.

Assessing Defects

Common indicators of defect are cracks, weak branch unions, stem or branch decay, cankers, dead tree parts (top, branches or bark), bark and woodboring beetles, root damage and root disease, tree lean, and poor architecture. Multiple and connected defects often increase failure potential. Information on the biology, identification and management of many of the biotic and abiotic agents that can contribute to tree defect is detailed in the 2009 USFS/CALFIRE California Insect and Disease Training Manual (http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fsbdev3_046410.pdf). The unique signs, symptoms, and probabilities of failure for the above defects are presented below:

A. Cracks

Vertical cracks in the trunk often indicate that some tree failure has already begun. Cracks most commonly arise from short-term mechanical injury but can also be from improper wound closure. Cracks need to be evaluated carefully. When they form as a tree buckles from the wind they may or may not be accompanied by substantial amounts of internal wood decay. Cracks near major branch unions can also indicate that trees have begun to fail, sometimes without associated heart rot. In other cases, bark cracks are caused by frost or other weather extremes such as lightning and may or may not indicate decay or immediate failure. Careful evaluation using an increment borer or other tools (such as a resistograph, carbide tipped drill bit or tomograph) will help indicate the extent of any associated decay.

Cracks that indicate HIGH failure potential include:

- crack that goes completely through the stem or branch.
- stem that has two cracks on the same segment with a cavity or extensive decay on the inside.
- stem that has a crack in contact with another defect (canker, decay, weak branch union) or is at the base of a leaning tree.
- branch (4” or larger) with any crack.
- conifer stem with a single crack with inrolled bark and a cavity or decay inside.

Cracks that indicate MEDIUM failure potential include:

- hardwood stem with a single crack with a cavity or decay inside (decay should also be evaluated based on the criteria listed below).

Cracks that indicate LOW failure potential include:

- trees with a single frost or lightning crack and no internal decay.

B. Branch unions and forked tops

A branch union is a fork in the stem or a place where two or more branches join the stem together. Strength of the union is determined by whether the wood is well connected between the branches or has entrapped ("included") bark (Figure 6). If bark becomes entrapped by the expanding wood of the branches at the union, it acts as a wedge, preventing the wood of the branches at the union from fusing together. As the branches continue to grow, more and more bark becomes included in the bark wedge inside the tree, while pressure of the expanding wood against the bark wedge increases. Eventually, the remaining woody connections between the branches are no longer able to support the weight of the branch, and the weak union fails.

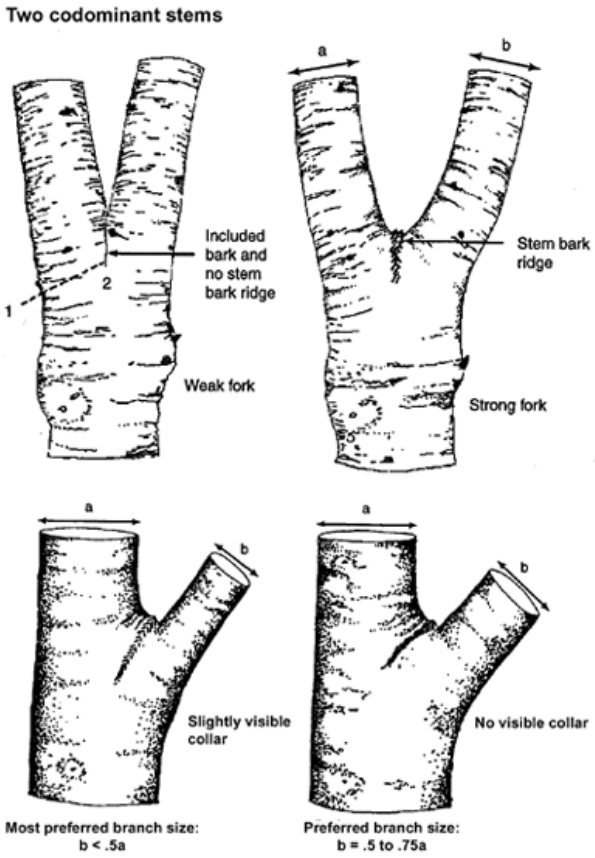


Figure 6. Illustration of how included bark gets formed.

Bark that curves inwardly into a branch union ("inrolled bark") indicates that included bark is present within the branch union. Strong branch unions are characterized by a U-shaped connection with branch angles approaching 90 degrees. Bark at this type of union is usually raised, with a roughened bark ridge over a slightly raised patch of "stress wood" from the branch union. Weak unions have an acute (V-shaped) angle with included bark in the junction between the stems. V-shaped unions with a raised bark ridge at the connection (and no other defect) are generally strong. Narrow branch angles are more likely to have included bark, particularly when one branch is not clearly larger than the other (as with a forked top).

Forked tops need to be evaluated carefully because they may or may not have high failure potential. Forked tops may be weak because they contain included bark as described above. Forked tops may also form when two or more of the lateral branches take over as a new leader when the old leader is broken or killed. When one lateral branch takes over, the old top is often referred to as a "sucker limb". Because they are associated with broken or dead tops, these new leaders, which are usually U-shaped, often have internal decay near the point of attachment with the old top. These new leaders become prone to breakage as they become heavier or are exposed to high winds, ice, or snow. However, this breakage is less common in pines and incense cedar.

Epicormic branches (also called water sprouts) are new branches that replace injured, pruned, or declining branches. They typically form in response to injury or environmental stress. By their very nature, epicormic branches form weak unions because most of their attachment to the main stem is just at one point. As they grow they become heavy very quickly and the wood being formed near the union may no longer have sufficient strength to support their weight. Old, large epicormic branches growing on decaying stems and branches are likely to fail.

Branch unions (including forked tops) that indicate HIGH failure potential include:

- weak branch union (V-shaped with inrolled, included bark) that is also cracked, cankered, decayed or streaming pitch. Strong branch unions (U-shaped) with these defects, except as listed below, should be assessed on the basis of the associated defects.
- heavy U-shaped branches of all species except for pines and incense cedar that form when side branches turn up to become leaders. Pines and incense cedar receive a high rating only if an associated defect (cracked, cankered, decayed or streaming pitch) is also present at the branch union.
- large epicormic branches on decaying stems and branches.

Branch unions (including forked tops) that indicate MEDIUM failure potential include:

- weak (V-shaped) union with inrolled, included bark, but no other associated defects.
- heavy U-shaped branches on pines that form when side branches turn up to become leaders that are also heavily infected, and heavily weighted, by live dwarf mistletoe brooms.
- heavy U-shaped branches on pines and incense cedars or bends in the bole caused by old dead tops and dead upper limbs, "sucker limbs," protruding out of the bole (no additional defect in the bole/sucker limb area). Note: these sucker limbs may be hazards if they meet failure criteria found in Section F (dead tree, top or branches).

Branch unions (including forked tops) that indicate LOW failure potential include:

- heavy U-shaped branches of pines and incense cedar that form when side branches turn up to become leaders (no additional defect in the branch union).

C. Decay in stem or branches

Decay is a leading cause of tree failure but is difficult to observe in some trees because the health and vigor of the crown is not a reliable indicator of internal decay. Decay is usually concealed inside the bole, roots and/or branches. Indicators of internal decay include hollow knots, wounds, broken or dead tops, cracks, wildlife cavities, conks, mushrooms and the presence of carpenter ants or termites. "Sounding" a tree by hitting it with a mallet or the back end of a hand axe and listening for a hollow sound may also give an initial indication of internal decay.

Decaying trees can be prone to failure, but the presence of decay alone does not indicate that a tree is highly defective. Some decay, especially in the interior, is tolerable. Most of the strength of a tree, like a pipe, is on the outside, so interior wood can be decayed without greatly reducing strength. Thus, when decay is discovered in a tree, it is important to determine its extent and the amount of remaining sound wood. Drilling into the tree or taking core samples with an increment borer can help assess the amounts of sound and decayed wood. High-tech tools, such as a resistograph or tomograph, can also help detect and assess internal decay.

Decay conditions in stems or branches that indicate HIGH failure potential include:

- less than one-third of the tree's radius is sound. This is the One-Third Rule for evaluating failure potential. Additional sound wood is needed if the tree is leaning, if the decay is off-center in the bole or present between four feet above the groundline and the lowest live branch, or is associated with an open cavity.

- a cavity, decay or fruiting body is associated with an open crack or weak branch union.
- decay in a horizontal branch.

The One-Third Rule: Trees are rated in the highest failure potential category if the remaining undecayed, sound wood shell is less than one third of the radius (radius is one-half of the diameter, as measured with a diameter tape). This is known as the "One-Third Rule." For example, if a tree has an 18-inch diameter (9-inch radius), then a minimum of 3-inches of sound wood should be present around the whole circumference to pass the One-Third Rule.

Keep in mind that the One-Third Rule is only a general guide, and there are many exceptions. Local knowledge, conditions and experience must always be considered. For example, if the tree is leaning, or if the decay column is not in the center of the tree or is in a horizontal branch, or if there is a cavity or crack that opens to the outside, then additional sound wood is needed to support the tree or tree part and the amount of sound wood needed to pass the One-Third Rule must be increased. Failure potential is also considered high when there is canker-rot in the main stem or the decay is associated with a weak branch union or open crack.

Decay conditions in stems or branches that indicate MEDIUM failure potential: trees with greater than one-third of the tree's radius in sound wood may or may not have medium failure potential, depending on the extent of the decay, species of decay fungus and position within the tree. At the very least, trees with identified decay should be closely monitored on a regular schedule and after significant weather events.

Decay conditions with special cases: if decay is detected in a tree that has a LOW failure impact (target) rating, such as one located along a low-use road, but the extent of the decay (whether it meets the One-Third Rule) cannot be determined because of limited time, access and/or proper equipment, then assessors can use the following as a general guideline:

- True fir and hardwoods with known, but unmeasured decay, especially if a cavity is open to the outside, should be considered as having a HIGH failure potential. An exception would be that in areas with little or no history or evidence of decay-related failure, true fir that meet this condition but otherwise appear to be healthy (with a 50% or greater live crown ratio, no new or old branch dieback and no other defects), which may be given a MEDIUM failure potential rating.
- Douglas-fir, incense cedar and pine species with known, but unmeasured decay, especially if a cavity is open to the outside, should be considered as having a MEDIUM failure potential.

Note: Subject to staff and resource availability, all trees with MODERATE or HIGH failure impact ratings should be thoroughly evaluated for decay with the proper equipment and/or mitigated regardless of the species.

D. Fungal Fruiting Bodies

The following fruiting bodies, or conks, may or may not indicate high failure potential depending on the species, size, and number of conks. **When fruiting bodies are present, it is best to assess associated decay using the decay guidelines above.**

Examples of fungal fruiting bodies that indicate HIGH failure potential:

- *Phaeolus schweinitzii* conks (also known as Schweinitzii root and butt rot, velvet top or cow pie fungus) with associated butt swell on Douglas-fir.
- one paint fungus or "Et" (*Echinodontium tinctorium*) conk on true fir or hemlock (see note below for exception).
- five or more red ring rot (*Porodaedalia* (*Phellinus*) *pini*) conks on Douglas-fir, ponderosa pine, Jeffrey pine, lodgepole pine, or more than one on true fir or hemlock.
- one quinine (*Fomitopsis officinalis*) conk on Douglas-fir, pines, spruce, or hemlock.
- one sulfur fungus (*Laetiporus sulphureus*) conk (also known as "chicken of the woods") on a wide range of conifers and hardwoods**.**

Examples of fungal fruiting bodies (conks) that indicate MEDIUM failure potential:

- *Phaeolus schweinitzii* conks without associated butt swell on Douglas-fir.
- fewer than five red ring rot (*Porodaedalea* (*Phellinus*) *pini*) conks on Douglas-fir, ponderosa pine, Jeffrey pine, lodgepole pine, or one on true fir or hemlock (see note below for exception).
- incense cedar pecky rot (*Oligoporus amarus*) conks on incense cedar greater than 150 years old.

Examples of fungal fruiting bodies (conks) with special cases: if a paint fungus conk is detected on a tree that has a low failure impact (target) rating, such as one located along a low-use road, but the extent of any associated decay (whether it meets the One-Third Rule) cannot be determined because of limited assessment time, access and/or proper equipment, then use the following as general criteria:

- in areas with little or no history or evidence of decay-related failure associated with paint fungus conks, true fir with up to four conks but otherwise appearing healthy (with a 50% or greater live crown ratio, no new or old branch dieback and no other defects) may be given a MEDIUM failure potential rating.
- in areas with little or no history or evidence of decay-related failure associated with red ring rot, Douglas-fir, ponderosa pine, Jeffrey pine, lodgepole pine with fewer than five red ring rot conks, or only one conk on true fir or hemlock, but otherwise appearing healthy (with a 50% or greater live crown ratio, no new or old branch dieback and no other defects) may be given a LOW failure potential rating.

E. Cankers

A canker is an area of exposed sapwood or dead cambium underneath the bark and may appear as a flattened or raised area, or wounded area, on the trunk or branch. Cankers often have decayed wood underneath. Cankers can be caused by fungi, insects, weather, fire, or other mechanical damage. Stems or branches often fracture at or near cankers. Cankers caused by fungi can look similar to exposed scars, but depending on the fungal species, fungal cankers can expand over time. Invasion of underlying wood by decay fungi is often the most serious consequence of a canker. However, depending on the tree species, a canker that encompasses more than one-third or one-half of the circumference of the tree is often highly prone to failure, even if the exposed wood appears sound. Trees with cankers should be evaluated for internal wood decay. When applying the One-Third Rule, cankered trees require more sound wood to be stable. In addition, the potential for failure is higher if a canker is accompanied by decay or if it is connected to another defect, such as a lean or crack.

Ramorum canker (also known as sudden oak death) is caused by *Phytophthora ramorum*. Millions of trees have been killed by ramorum canker in California and Oregon since the mid-1990s. Affected species include tanoak, California black oak, Shreve's oak, coast live oak and canyon live oak. Although the foliage of many other plants are infected by *P. ramorum*, tree-killing bole cankers are only produced in tanoak and the oaks listed above. Trees infected by *P. ramorum* are often rapidly colonized by ambrosia (wood boring) beetles, bark beetles and decay fungi soon after they die, making them especially prone to breakage.

In fire-injured trees, cankers are caused by lethal heating of tissues resulting in the death of the cambium. Dead cambium is often indicated by deep charring of the bole, where all the bark is blackened, and the bark characteristics are no longer discernible. When assessing defect in an area with deeply charred trees, the consistency of the relationship between deep char and underlying dead cambium needs to be checked by cutting into the affected area of the bole. If deep char reliably indicates underlying dead cambium, then all areas with deep char may be assumed to be cankered. However, if it does not, then all deeply charred areas must be checked on all trees that are assessed.

Cankers that indicate HIGH failure potential include:

- cankers with associated fruiting bodies of decay fungi.
- cankers with associated internal decay.
- cankers physically connected to a crack or other defect.
- single or multiple cankers without decay that affect more than one-half of the tree's circumference, particularly if the cankers are located between four feet above the groundline and the lowest live branch.
- basal cankers in true fir that affect more than one-third of the bole circumference.
- cankers in oak or tanoak caused by *Phytophthora ramorum* (ramorum canker or sudden oak death) that affect more than one-third of the bole circumference, or have associated decay fungi, ambrosia beetles or bark beetles.
- deep charring in true fir over more than one-third of the bole circumference when the relationship between deep char and cambial mortality has been confirmed.
- deep charring in sugar pine, ponderosa pine, Jeffrey pine, incense cedar or Douglas-fir over half of the bole circumference when the relationship between deep char and cambial mortality has been confirmed.

Cankers that indicate MEDIUM failure potential include:

- for all species other than true fir, single or multiple cankers without decay that affect less than half of the tree's circumference (including fire-caused cankers).
- for true fir, single or multiple cankers without decay that affect less than one-third of the bole circumference (including fire-caused cankers).
- for oak or tanoak, cankers caused by *Phytophthora ramorum* (ramorum canker or sudden oak death) without associated decay, ambrosia beetles or bark beetles (see Section G below) that affect less than one-third of the bole circumference.
- a large old wound or canker with no decay at the base of a leaning tree.

Cankers that indicate LOW failure potential include:

- true fir with bole swelling from dwarf mistletoe infection, but with no bark sloughing or evidence of decay.

- lodgepole pine or ponderosa pine with basal (hip) cankers from western gall rust with no bark sloughing or evidence of decay.
- lodgepole pine or ponderosa pine with elongated stalactiform rust cankers covering less than one-third of the bole circumference.

F. Dead tree, top or branches

Classifying a tree as dead may be obvious if there are no living branches, needles or leaves present during the growing season, though it can also be challenging if trying to assess deciduous trees in winter or any tree that's been effectively killed by insects, disease, fire, drought, chemicals, or other agents, yet retains some living tissue. In areas that have recently burned, criteria provided in *Marking Guidelines for Fire-Injured Trees in California* (Smith & Cluck 2011) can be used to determine the predicted probability of tree mortality with great accuracy.

Reliably predicting when a dead tree will fail is nearly impossible because parts or the whole tree may fall depending on cause and time of death, its structural and genetic characteristics, and site/weather conditions. Therefore, dead trees of any species, size, age, or time since death have a high failure potential. Mitigation for these trees varies depending on risks to targets.

Tops and limbs that appear dead should be checked closely for evidence of rot or instability (e.g., exhibiting indicators of decay, previous breakage, wood destruction by woodpeckers or, in some species, sloughing bark). The dead portion of the tree must have the potential to reach a target. Dead tops of true firs tend to decay very quickly. New dead tops in Douglas-fir, spruce, hemlock, and hardwoods are highly susceptible to attack by decay fungi, and their failure potential is higher than other conifer species on the same sites. However, old spike tops in pine, incense cedar, juniper and Douglas-fir that give evidence of long-term persistence are usually dry and resin-impregnated and are generally not any more hazardous than living portions of the tree.

Dead tree, top or branch conditions that indicate HIGH failure potential include:

- all dead trees.
- dead tops greater than ten feet long or shorter ones with associated decay or other defect (note that old dead tops of pine, incense cedar, juniper or Douglas-fir may not have high failure potential).
- dead branches greater than two inches in diameter, especially in hardwoods, broken branches that are hanging or lodged in the crown, branches with large dead dwarf mistletoe brooms or large live dwarf mistletoe brooms with associated decay or defect.

Dead tree top or branch conditions that indicate MEDIUM failure potential include:

- dead tree tops less than ten feet long with no associated decay or other defect (note that old dead tops of pine, incense cedar, juniper or Douglas-fir may have lower than medium failure potential).
- any branch greater than two inches in diameter and with more than two-thirds of its foliage dead as exhibited by bare branches or dead/flagging needles/leaves.
- live dwarf mistletoe brooms with no associated decay or other defect (monitor closely).

- long-lived tree species such as juniper, redwood, sequoia, and high-elevation pines (e.g., bristlecone, whitebark, foxtail) with dead branches in excess of two-thirds of the foliage-bearing crown where remaining live branches appear stressed.

Dead tree top or branch conditions that indicate LOW failure potential include:

- old spike tops in pine, incense cedar, juniper or Douglas-fir that give evidence of long-term persistence.
- long-lived tree species such as juniper, redwood, sequoia, and high-elevation pines with dead branches in excess of 50% of the foliage-bearing crown where live branches appear strong and unstressed.

G. Trees attacked by bark and/or woodboring beetles

Bark beetles can attack and rapidly kill trees, especially those that are under stress from other agents such as drought, root disease or fire injury. Woodboring beetles typically attack heavily stressed, dying, or dead trees. Non-native beetles can attack and kill otherwise healthy trees directly. Bark, woodboring and invasive beetles can introduce or provide entry ways for wood decay fungi and hasten the rate of decay and failure. Because the progression from advanced infestation to failure can be rapid, it is important to identify and mitigate the hazard of heavily infested trees within striking distance of high value targets.

Green trees that possess any of the following bark and/or woodboring beetle-associated factors over a continuous area covering at least one-third of the bole circumference are considered dead and indicate HIGH failure potential:

- pitch tubes with pink or reddish boring dust associated with them (in contrast to clear pitch streamers that indicate successful defense against attack).
- pouch fungus conks and/or current woodpecker activity (holes into the sapwood and/or bark flaking, specifically excluding injury caused by sapsucker feeding).
- boring dust or frass (in bark crevices, webbing along the bole, or that accumulates at the base of trees). More details on trees that can be "considered dead" are provided in Smith and Cluck (2011).

Notes: This specifically excludes basal attacks by the red turpentine beetle (large pitch tubes associated with coarse boring dust generally restricted to the lower two to three feet of the bole or woodpecker activity restricted to this area) and when the above indicators are only associated with wounds, old fire scars, etc. (Smith and Cluck 2011). Some non-native beetle species can weaken limbs and main stems causing structural defects and mortality in hardwood species including the Mediterranean oak borer (*Xyleborus monographus*), ambrosia beetles of the genus *Euwallacea,* and the goldspotted oak borer (*Agrilus auroguttatus).* Specific information and identification aids are available online at: https://www2.ipm.ucanr.edu/Invasive-and-Exotic-Pests/

Green trees are also considered dead and indicate HIGH failure potential if they have significant bark and/or wood boring beetle activity or exhibit 50% or more of the foliage-bearing crown is actively fading, as indicated by a uniform change in color over the affected part of the crown. Dead tops that have no foliage are not part of the living crown and do not count toward this 50%, nor does drought-induced needle cast (non-uniform fading restricted to the older needles), fire-killed or scorched foliage or branch mortality ("flagging") caused by dwarf mistletoe/*Cytospora* infections in true fir.

Note: Section F (Dead tree, top and branches) may help inform failure potential as old dead tops or branches meet failure criteria for different conditions or species.

H. Root damage and root disease

Root problems are generally difficult to find and assess since tree roots are underground and out of sight. The two major kinds of root problems are physical and biological. Physical problems include undermined, severed, loosened, cracked, broken, burned, exposed, and stem-girdling roots. A variety of activities can cause root problems, including soil compaction, erosion, fire, flooding or saturation, construction activities, prolonged heavy equipment, or foot traffic, etc. Biological problems are generally caused by root disease and decay fungi. Root problems often only become apparent when large sections or entire tree crowns begin to show symptoms such as chlorosis, thinning, terminal growth loss and production of distress cones, or when signs of root failure become obvious, such as soil cracking or mounding, root lifting or breaking, partial windthrow or increased lean. Additional symptoms or signs of root disease include basal resinosis (patches of resin-impregnated wood and/or resin flow at the base of the tree, not associated with insect attack); for some root diseases, unusual swelling of the butt; root decay or butt rot; mass attack by bark beetles; the presence of nearby fading, standing dead, windthrown or shattered trees; and the production of certain characteristic mushrooms or conks at root collars and in nearby decayed stumps.

Heterobasidion (annosus) root disease is the most widespread and damaging root disease in California, affecting many species of conifers and a few hardwoods. Pines, incense cedar, western juniper, true firs, and giant sequoia are highly susceptible hosts, and failure of these trees in root disease infection centers is common. Other common root diseases in California include black stain root disease in Douglas-fir and in pinyon, ponderosa, and Jeffrey pine; Armillaria root disease in hardwoods, especially oaks (in California, the disease is less damaging in conifers); and a Phytophthora root disease in Port-Orford-cedar. Schweinitzii root and butt rot is another important root and butt decay in many conifers in California.

Presence of root disease in developed recreation areas or along roadways should be carefully evaluated and managed when staff that have been instructed on how to recognize root disease problems are available. When evidence of Heterobasidion root disease is present (as indicated by the presence of uprooted green or chlorotic host trees with roots exhibiting “delaminated” decay or with conks present in old decaying stumps and roots), it is possible that many of the standing susceptible trees in the immediate area are also infected. These infection centers and nearby host trees should be closely examined and considered potentially hazardous. When assessing individual trees in and around known infection centers, it is reasonable to use the condition of the crown as an indicator of advanced decay. Although not always caused by root decay, a thin (declining) crown with a rounded top does indicate poor tree vigor, and often the loss of 80% or more of normal root function. The thinner the crown of a tree in an area where Heterobasidion root disease is present, the more likely it is that the roots have been weakened by decay, and the more likely it is to have high failure potential. However, it is not uncommon for perfectly green, healthy-appearing trees to have the root disease as well.

Root damage and root disease conditions that indicate HIGH failure potential include:

- recently leaning trees, or trees with evidence of recent root-lifting, soil movement, mounding near the base of the tree, or broken/decayed roots.

- inadequate root support, with more than half of the root system within the drip line (outer edge of canopy) severed, broken, undermined, burned, or decayed by excavation, erosion, fire, or decay fungi.
- host tree species visibly infected with root disease fungi, adjacent to visibly infected trees or stumps, or with advanced crown symptoms in the immediate area where Heterobasidion root disease has been identified.

Root damage and root disease conditions that indicate MEDIUM failure potential include:

- less than half of the root system within the drip line severed, broken, undermined, or decayed by erosion or excavation.
- host tree with few or no crown symptoms within 50 feet of a confirmed root disease-infected tree or stump or within 50 feet of a host tree with advanced crown symptoms.

I. Leans and poor tree architecture

Leaning trees deserve special attention because a displaced center of gravity increases the potential for failure and makes other defects of the roots, butt, and bole more hazardous. Lean in a tree can be either due to a tree's long-term responses to light and forces of wind, down-slope soil creep or soil subsidence, or to a recent change that indicates a failure potential. Trees often compensate for a long-term lean by correcting the skyward growth of the leader, giving an upswept appearance. This corrected lean is a sign of a strong root system, indicating that the tree may be stable. In addition, some tree species, such as gray pine and live oak, often grow naturally with a pronounced lean, and are very stable in the absence of other defects. A tree without a corrected lean (not upswept) or recent (uncorrected) leans are strongly indicative of increased failure potential especially when they occur in combination with soil disturbance, construction, saturated soils, lifting of the soil and the root mass behind the leaning tree and cracking in that soil, large fire scars, or other decay, cracks, or defects in the tree. The direction of the lean can often give a strong indication of where the tree will fall. Thus, objects that are underneath a leaning tree might be considered more likely to get hit and at the assessor's discretion, may be given one more point for their target score while objects that are not under leaning trees may be less likely to get hit and may be given one fewer point for a target score.

Bowed trees are leaning trees where the top bends over more than the lower trunk in a down-swept fashion. This condition often results from high winds or loading from ice or snow. Older bowed trees that have increased their stem diameter in the area of the bow are generally stable. However, bowed trees with longitudinal cracks or other associated defects are not. This is particularly true if the tree is subjected to recurrent loads from wind, snow, or freezing rain.

Poor tree architecture may be caused by past breakage or poor pruning. These defects, including acute branch angles, too many branches arising from a single location, and codominant stems with included bark, may take many years to develop. Sharp bends or crooks in branches are naturally weak and prone to failure. If a tree is topped, multiple weakly attached branches may develop just below the cuts.

Lean and poor architecture conditions that indicate HIGH failure potential include:

- uncorrected lean with other contributing defects.

- uncorrected lean with recent root lifting, soil movement or mounding near the base.
- uncorrected lean associated with unstable soils or cracks in the tree.
- uncorrected lean compounded by an unbalanced crown shape weighted in the direction of the lean.
- uncorrected lean at a location with frequent storm or wind injury.
- bowed tree with cracks or other associated defects, particularly if exposed to recurrent wind, snow, or freezing rain.

Lean and poor architecture conditions that indicate MEDIUM failure potential include:

- uncorrected lean without other contributing defects. Monitor for changes in the lean.
- recently bowed tree without other contributing defects.
- branches with a twist, sharp angle, or bend.
- branches that are lopsided or unbalanced with respect to the rest of the crown, especially if nearby trees were pruned or removed within the last ten years.

7-Point Hazard Tree Rating System

HAZARD RATING = FAILURE IMPACT + FAILURE POTENTIAL

Two values are determined for each tree being rated - failure impact (target) and failure potential (tree defect). Both are determined independently and then combined to establish the hazard rating. Point values for failure impact and failure potential are as follows:

Failure Impact (Target)

As discussed in the "Assessing Targets" section above, the first value, failure impact, combines three major factors having to do with targets: likelihood of impact (distance to target and exposure time), the amount of damage if impact occurs (would the object be slightly damaged or destroyed), and the value of the target (high to low injury or monetary loss if the target is impacted). There are many possible permutations of these factors, examples of which are given in the description below for each point value that can be assigned (high, medium, and low):

1 point = **Low failure impact:** minor damage is likely if failure occurs. Factors that may support a "Low Failure Impact" assessment include low probability of target impact due to greater distance between defective tree and target or tree leans away from target; low or limited exposure time (e.g., transitory exposure only); or defective tree or tree parts are small, or target has a low value. Examples include highway corridors or improved NFS roads with little or sporadic traffic, unimproved roads, low-use trails and bicycle paths within developed recreation areas, or structures with sporadic occupancy, such as storage buildings.

2 points = **Medium failure impact:** moderate damage is likely if failure occurs. Factors that may support a "Medium Failure Impact" assessment include moderate probability of target impact due to moderate distance to target, leans near target or moderate exposure time (e.g., daytime use or intermittent exposure only); defective tree or tree part(s) is sufficient size to cause moderate damage; or target is of moderate value. Examples include picnic and other day use areas, interpretive sites such as amphitheaters and kiosks, and moderately used areas within permitted facilities,

including ski areas, marinas, summer home tracts and organizational camps. Moderate to high-use road or trail networks within campgrounds, roadside attractions and permitted facilities, such as vista points or historic stops, information stations, visitor centers, fee collection portals, high use daytime parking areas, designated trailhead parking areas, plazas, staging areas and commercial sites. Roads and intersections with moderate to high traffic volume, haul routes during periods of commercial use, and active projects along roads where work is stationary (such as culvert replacement and bridge construction).

3 points = High failure impact: extensive damage is likely if failure occurs. Factors that may support a "High Failure Impact" assessment include high probability of target impact due to short distance between defective tree/tree part and target, leans directly into target, or high exposure time (e.g., overnight exposure); size of defective tree or tree part sufficient to cause extensive damage; or if the target is of high value (e.g., threatening life or critical infrastructure). Places where high failure impact trees are commonly found include campsites, lodges, hotels, dormitories, residences, ski lifts, 24-hour visitor service and restroom facilities, and above-ground power, gas, water, communication, and other utility infrastructure.

Note: The targets described above are not intended to be an all-inclusive list and may have their failure impact level elevated or reduced depending on local circumstances.

Failure Potential (Tree Defect)

The second value, failure potential, requires the inspector to estimate the likelihood that, prior to the next inspection/mitigation cycle, the defective tree or tree part will fail during the season when the target is present. In general, inspections for campgrounds take place at least once every year in compliance with operating plans, and it is recommended that mitigation of all hazard trees take place before a campground opens. Along major roadways (level 4 and 5 roads), trailheads and parking lots, inspections could be every two years. Level 2 and 3 roads might get inspected every five years and level 1 roads may rarely, if ever, be inspected. Again, prioritization of sites to be surveyed and intensity of surveys are line officer decisions, considering local conditions, results of past hazard tree surveys, available resources, etc.

Determining the tree failure potential requires an evaluation of the defects and the failure potential of the defect for the tree species involved. Failure potentials of the most common tree defects were discussed previously in the section on "Assessing Defects". The following values are applied:

0 points = no defects identified
1 point = low potential for failure: minor defects.
2 points = medium potential for failure: moderate defects.
3 points = high potential for failure: serious defects.

Add 1 point if multiple, interacting defects are present, e.g., leaning tree with other defects (maximum score of 4).

Score 4 points if the tree is dead.

When assessing a tree for failure potential, it is best to record all defects that are present on the inspection form. When a tree has several defects, the highest individual defect value is recorded as

the overall failure potential value for the tree. However, if multiple defects interact to increase the potential for failure, then an additional point is added. For example, a leaning tree may interact with known or suspected root damage or trunk decay, increasing the stresses on the roots and trunk. Because the potential for failure is increased, an additional point is added to the failure potential value. Conversely, because lean does not increase the potential for dead branches to fail, trees with lean and branch decay would not receive an extra point.

Hazard Tree Rating & Potential

The hazard rating is determined by adding the failure impact and the failure potential values. This can then be used to consider what action may be necessary to reduce the hazard.

HAZARD RATING = FAILURE IMPACT + FAILURE POTENTIAL
(Total Score 1-7)

Table 1. Hazard Potential Summary and Suggestion Actions

Hazard Rating Score	Hazard Potential	Suggested Action
1 - 3	Low	No action *OR* Monitor (document and tag or map tree)
4 - 5	Moderate	Monitor (document and tag or map tree) *OR* Mitigate (see mitigation options below)
6 - 7	High	Mitigate (see mitigation options below)

INDIVIDUAL HAZARD TREE MANAGEMENT OPTIONS

Hazard trees are one of many management considerations a line officer must balance along with priorities, resources, staffing, commitments, and constraints. Units rarely have enough resources to meet all the needs and demands. Although line officers often must make difficult decisions about the types of mitigations that are feasible and appropriate and realize that some hazards could cause damage before they can be effectively addressed, the survey results can help the decision-maker direct available resources to where they are needed most and will be most effective. For additional guidance, refer to Forest Service Handbooks:

- Developed recreation areas – FSH 2309.13 Ch 50
- Roads – FSH 7709.59 Ch 60
- High-use trails – FSH 2309.18 Ch 40

Some common actions to mitigate or reduce tree hazard potential include the following:

Removal of Targets

In certain situations, removing targets is the easiest and least costly alternative. Moving picnic tables, fire grates, and portable toilets can often be easily done.

Tree Falling /Removal of Trees

Tree falling or removal may be the appropriate mitigation to eliminate hazard potential. A temporary site or area closure may be necessary until after all hazards are mitigated**.** Careful assessment of the hazard potential is needed before recommending the falling or removal of live trees.

When a tree is felled or felled and removed, care must be taken to prevent worker injury, property damage and wounding of residual trees. Wounds on trees may become defects resulting in future failures. **Contact your FHP staff for current direction on the treatment of conifer stumps to prevent Heterobasidion root disease. This is especially important for hazard tree removal in administrative and recreation sites as well as road and infrastructure corridors.**

Topping

Removing the top of a hazard tree may be the best option in some circumstances. Topping may reduce the height of the tree to where it can no longer reach a target. Topping reduces tree weight and size of crown impacted by wind. A topped tree is usually more aesthetic than a stump, especially if the top is cut to resemble a natural break. Once topped, trees should be periodically monitored for increased failure potential from decay fungi that enter through the cut surface. Large hardwoods may benefit from crown reduction. Pruning wounds usually become infected with decay fungi. Pruned hardwoods may require future pruning to remove new shoots. It is recommended that the crowns of large hardwoods be reduced through a planned branch thinning. A certified arborist should be consulted when local expertise is absent.

Pruning

Healthy trees may be pruned rather than removed when dead branches and dead tops are the hazard. If done correctly, pruning can improve the health of the tree. However, improper pruning can result in an architecture with an even higher probability of failure. Large dead dwarf mistletoe brooms should be removed, while live ones only need removal if they have associated decay or other defect. The hazard potential of a branch or top is determined considering its size, height in the tree, defects, and the amount of human use in the target zone. Moving targets should be considered as an alternative to pruning.

Site/Area Closure

Temporarily closing a site or area with physical barriers might be needed until hazards are mitigated. Permanent closure and/or relocation of the facilities may be needed when a site cannot be made safe.

Warning Notifications/Signing

When physical barriers are not feasible, an unsafe area may be identified by posting warning signs. Closure notifications can be published using websites, local media, user permits or other publicly available resources. While warnings do not abate hazards, warnings may be the only feasible action. Warnings do not completely indemnify the Forest Service in the event of an accident, so they are best implemented in conjunction with other mitigation actions.

Monitoring

Trees with low or medium hazard potential may be monitored, especially after significant weather events. For example, trees with cracks that have low or moderate risk of failure could be monitored until more effective means of mitigation are available. Tagging or mapping trees can be helpful in documenting trees that are monitored.

Specialized Actions

High value trees with defects may merit special mitigation to reduce the hazard potential and retain the tree. This is particularly true if a tree has great spiritual, historical, botanical, or other special significance. Filling decay cavities with concrete and applying wound dressings are considered harmful. Cables, braces, and support poles are sometimes installed on valuable trees to make them safe. Careful evaluation should be done before costly treatments are implemented. Specialized

treatments usually require specialized expertise. When needed, professional arborists should be consulted.

Conclusions: Hazard Tree Mitigation Options

The felling and removal of hazard trees is often the surest way to mitigate a hazard tree problem. However, removal of hazard trees can be complicated and expensive. NEPA documentation, specialized services and special equipment may be needed to remove trees where targets are unique structures. When felling and removing hazard trees is too costly or difficult, another mitigation may be preferable. Line officers must choose the appropriate mitigation(s) for hazard trees on lands they administer. Experts in forest health, watershed management, fire management, archeology, biology, engineering, etc. are available to help line officers with hazard tree mitigation.

HAZARD TREE IDENTIFICATION AND ABATEMENT FOLLOWING CATASTROPHIC DISTURBANCES

Under normal forest conditions it can be expected that about 1-2 percent of all trees will die each year. However, catastrophic events such as intense wildfire, extreme drought, bark beetle outbreaks or strong windstorms can kill millions of trees across large areas.

The urgent need for safe access to forests for employees and the public may require a streamlined approach to identify and abate the hazard trees. There are a few basic steps that are involved with this process:

1. Identify the area that was impacted by the catastrophe.
2. Identify targets within the area that would be at risk from hazard trees (these targets will most commonly include roads, recreation areas or other built infrastructure).
3. Estimate the failure potential threshold (i.e., what post-treatment risk level is desired based on structural defects and/or level of fire-injury).
4. Determine the failure potential zone (e.g., 1 to 1.5 tree lengths).
5. Identify the area around the targets where hazard trees would have to be treated to reduce risks to people and infrastructure.
6. Identify trees that require mitigation (e.g., tree marking or designation by damage).
7. Conduct the mitigation.

A detailed process for conducting these steps is included in Appendix 4. More details about determining the failure potential zone are included in Appendix 5.

In general, it will be impossible to mitigate every hazard tree in high-use areas that have been affected by a catastrophe. Line officers may elect to use a variety of management options described in the previous section.

ROADSIDE HAZARD TREE MANAGEMENT IN NON-CATASTROPHIC SITUATIONS

Forest Service Manuals and Handbooks specify responsibilities for maintaining reasonable public safety conditions along NFS roads, subject to available funds and resources. In addition, FSH 7709, states that NFS roads that have been closed should be checked for obvious hazards prior to being re-opened, and that similar checks may be required following major storms. In general, the procedure for evaluating

hazard trees along roadsides follows the guidance for Performing the Inspection discussed in this document. However, it is recognized that there are many miles of roads that may have hazardous trees adjacent to them. Time and economic constraints play a role in determining how many miles of roads can be reasonably inspected and treated each year.

Although it may not be possible to assess every tree individually along roadsides on a national forest or ranger district at one time, a similar approach to the one described in Appendix 4 for addressing hazard tree abatement after catastrophic events may be adopted. Road segments to be inspected should be prioritized according to level of use (operational maintenance level) and proximity to points of interest (e.g., trailheads, parking areas, scenic viewing spots, etc.), while considering histories of tree failure and insect/disease activity. Once the road segments to be inspected are identified, the process described in Appendix 4, Steps 3-6 may be used to identify, mark, and mitigate trees that pose an unacceptable degree of risk.

DOCUMENTING HAZARD TREE INSPECTIONS AND ABATEMENT

Good records are extremely helpful for a hazard tree inspection program to meet its objectives and be effective. Every public use site or road that is inspected should have documentation, **even if no hazard trees are identified.**

Documenting the hazard tree inspections and abatement is necessary because:

- It provides an assessment of current hazards and a framework for future vegetation management activities.
- It facilitates the detection and tracking of trends in insect, disease, and hazard development.
- It provides a database for the implementation of future monitoring and treatment efforts, as well as a record of their planning and completion.
- It provides a record that inspections and mitigations were performed in the event of tree failure, tort claims or potential litigation.

Use the R5 Hazard Tree Evaluation Form (Appendix 1) or the R5 Survey 123 Hazard Tree Inspection App (Appendix 3) to document mitigations or removals and to track defective trees which require monitoring. Trees without defects and/or have low hazard potential do not need to be recorded.

TREE FAILURE RECORD KEEPING

Regardless of how intensively tree hazards are managed, tree failures will occur. When a tree or tree part fails and impacts a target, the failure should be examined and documented. The details and cause of the failure and loss(es) should be reported and shared as appropriate. Useful information to report includes: 1) reason for failure; 2) loss; 3) nature of the target; 4) distance of tree from target; and 5) relevant site and tree characteristics (e.g., slope, aspect, lean, etc.). Maintaining these records can provide information on the types of trees and conditions that contribute to failures for monitoring.

FOREST HEALTH SPECIALIST ASSISTANCE WITH HAZARD TREES

Hazard tree management assistance is available from R5 FHP staff, including:

- Training in identification, mitigation, and management of hazardous trees (informal site visits to formal instruction).
- On-site consultation to address specific hazard tree situations.

- Helping to draft NEPA documents in support of hazard tree management.
- Assistance with vegetation management planning for recreation areas.
- Financial assistance to treat specific insect and pathogen-related problems, including the development of associated vegetation management plans and NEPA documents.

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APPENDIX 1: R5 HAZARD TREE EVALUATION FORM

Site: _____ Page: ____ of _____

Date: _____ Inspected by: _____

(Each column represents one tree)

Unit (campsite or other)																				
Tree number																				
if used	**Ref. point** (codes on back)																			
	Azimuth																			
	Distance																			
Tree species																				
DBH																				
Height																				
Failure Impact (Target) (Score 1-3, 4 if Dead Tree)																				
Failure Potential (Defect) (Score Each of the Following 0-3): Cracks																				
Branch Unions																				
Stem or Branch Decay																				
Fungal Fruiting Bodies																				
Cankers																				
Dead Tree, Top or Branches (Score 4 If Tree Is Dead)																				
Bark or Woodboring Beetles																				
Root Damage or Disease																				
Lean or Poor Architecture																				
Highest Failure Potential Score From Above																				
Multiple Interacting Defects (1 point)																				
Total Failure Potential (Highest Failure Potential Score + Interacting Defects: Score 0-4)																				
Hazard Rating (Failure Impact + Failure Potential: Score 1-7)																				
Suggested Action																				
Action Completed (Initial and Date)																				
Notes																				

Use of the HAZARD TREE EVALUATION Form

Defective trees are potential hazards to people and property in developed forest areas, Forest Service roads, and where catastrophic events, such as insect or disease outbreaks or wildfire have occurred. Indicators of defects are used to identify trees that may fail. Systematic, annual, documented inspections of trees in developed sites and corrective action are suggested to reduce hazards to the public.

The HAZARD TREE EVALUATION form is more than a hazard rating record. It is a record of the overall structural condition of a tree that can be used to determine progression of defects over time and to document the frequency of certain defects. All defects observed should be checked even though only the highest values are used in the hazard rating.

1. Forms cannot take all situations into account. Trained and experienced evaluation crews are encouraged to exercise judgment in the use of this form. However, if you need to regularly override the form, need training, or have any questions about the process or tree hazard, please contact your local Forest Health Protection staff.
2. Maps of the sites are helpful in planning and performing hazard tree surveys. All structures should be drawn on the maps. These maps used/created during the survey should be included with the HAZARD TREE EVALUATION forms to indicate which sites were surveyed.
3. Trees are easily and accurately mapped on the HAZARD TREE EVALUATION form by selecting reference points, then recording azimuths and distances to all defective trees on the form. Choose reference points that are permanent structures and unlikely to be moved. For large structures, use a more specific reference point such as the most northern/northwestern edge of the structure. Good **reference points to use are:** permanent picnic tables (codes as "T"), fire pits or grills ("F"), campsite number sign ("#"), latrines ("L"), signs ("S"), benches ("B"), water spigots ("W"), and garbage containers ("G").
4. Hazard rating of a tree is determined by Target and Defect Failure Potential:

	Definition	Values
Target	Rating is a combination of the likelihood a target will be hit, and the degree of damage or injury expected, and the value of the target.	Potential targets are rated: "1" (Low), "2" (Medium) or "3" (High). **Automatic 4 rating for Injury or Death**
Defect Failure Potential	A Failure Potential rating is an estimation of the likelihood that a tree will fail based on available indicators.	Defect ratings are "0" (None), "1" (Low), "2" (Medium) or "3" (High). **Rate the worst defect** **Add "1" for multiple interacting defects (maximum defect rating = 4).** **Automatic score of 4 if tree is dead.**

5. More than one type of defect may be identified and recorded for any tree.
6. Calculate hazard rating by adding Failure Impact (Target) and Failure Potential (Defect) values**.**

Possible Hazard Ratings: 7 = Highest and 1 = Lowest

Suggested Actions: 1-3 = no action or monitor(document and tag or map tree); 4-5 = monitor (document and tag or map tree) or mitigate; 6-7 = mitigate

Revised January 2022

APPENDIX 2: R5 TARGET AND DEFECT QUICK LIST (TATUM GUIDE)

FAILURE IMPACT (Target)

3 points = High failure impact: extensive damage expected if failure occurs. Probability of impacting a target (exposure time) high (e.g., overnight exposure); defective tree or tree parts large enough to cause extensive damage; target of high value. Examples include campsites, lodges, hotels, dormitories, residences, ski lifts, 24-hour visitor service and restroom facilities, and above-ground power, gas, water and other utility lines.

2 points = Medium failure impact: moderate damage expected if failure occurs. Exposure time moderate (daytime or intermittent only); defective tree or tree parts of sufficient size to cause moderate damage; target of moderate value. Moderately used trails, picnic and other day use areas, interpretive sites, amphitheaters and kiosks, and moderately used areas within permitted facilities, including ski areas, marinas, summer home tracts and organizational camps, Moderate to high-use road networks within campgrounds, roadside attractions and permitted facilities, such as vista points or historic stops, information stations, visitor centers, fee collection portals, high use daytime parking areas, designated trailhead parking areas, plazas, staging areas and commercial sites. Roads and intersections with moderate to high traffic volume, haul routes during periods of commercial use, active projects along roads where work is stationary.

1 point = Low failure impact: Minor damage expected if failure occurs. Exposure time low; defective tree or tree parts is small; target of low value. Highway corridors or improved Forest Service roads with little or sporadic traffic, unimproved roads, turnouts, or structures with sporadic occupancy, such as storage buildings.

Note: The targets described above are not intended to be an all-inclusive list and may have their failure impact level elevated or reduced depending on local circumstances.

FAILURE POTENTIAL (Defect)

3 points = high potential for failure: serious defects.
2 points = medium potential for failure: moderate defects.
1 point = low potential for failure: minor defects.
0 points = no defect observed

Add 1 point if multiple, interacting defects are present, e.g. leaning tree with other defects. Score 4 points if tree is dead.

Cracks

High (3 points):
- Crack goes completely through stem or branch.
- Stem has two cracks on the same segment with a cavity or extensive decay on the inside.
- Crack in contact with another defect or is at the base of a leaning tree.
- Branch (4" or larger) with any crack.
- Conifer stem with a single crack with inrolled, included bark and a cavity or decay inside.

Medium (2 points):
- Hardwood stem with a single crack with a cavity or decay (the decay should also be evaluated based on the "Stem and Branch Decay" criteria below).

Low (1 point):
- Trees with a single frost crack and no internal decay.

Branch Unions/Forked Tops

High (3 points):
- Weak branch union (V-shaped with inrolled, included bark) that is also cracked, cankered, decayed or streaming pitch. Strong (U-shaped) branch unions with these defects, except as listed below, should be assessed on the basis of the associated defects.
- Heavy U-shaped branches of all species except for pines and incense cedar that form when branches turn up to become leaders. Pine and incense cedar receive a high rating only if an associated defect (cracked, cankered, decayed or streaming pitch) is also present at the branch union.

Large epicormic branches on decaying stems and branches

Medium (2 points):
- Weak (V-shaped) union with inrolled, included bark but no other associated defects.
- Heavy U-shaped branches on pines that form when side branches turn up to become leaders that are also heavily infected, and heavily weighted, by live dwarf mistletoe brooms.
- Heavy U-shaped branches on pines and incense cedars or bends in the bole caused by old dead tops and dead upper limbs, "sucker limbs", protruding out of the bole (no additional defect in the bole/sucker limb area). Note: these sucker limbs may be hazards if they meet failure criteria found in Section F (Dead tree, top or branches).

Low (1 point):
- Heavy U-shaped branches of pines and incense cedar that form when side branches turn up to become leaders (no additional defect in the branch union).

Stem or Branch Decay

High (3 points):
- Less than 1/3 of the tree's radius (or diameter) is sound. Additional sound wood needed if tree is leaning, decay is off-center in the bole or present between four feet above the groundline and the lowest live branch or is associated with an open cavity.
- Cavity, decay or fruiting body associated with an open crack or weak branch union.
- Decay in a horizontal branch.
- True fir and hardwoods with known, but unmeasured decay, especially if a cavity is open to the outside (see main document for exception in low failure impact areas that would result in medium rating)

Medium (2 points):
- Trees with greater than 1/3 of the tree's radius in sound wood may or may not have medium failure potential, depending on the extent of decay, species of decay fungus and position within the tree. At the very least, trees with identified decay should be closely monitored on a regular schedule and after significant weather events.
- Douglas-fir, incense cedar and pine species with known, but unmeasured decay, especially if a cavity is open to the outside.

Note: Subject to staff and resource availability, all trees with moderate or high failure impact ratings should be thoroughly evaluated for decay with the proper equipment and/or mitigated regardless of the species.

Fungal Fruiting Bodies

High (3 points):
- *Phaeolus schweinitzii* conks (also known as Schweinitzii root and butt rot, velvet top or cow pie fungus) associated with butt swell on Douglas-fir.
- One paint fungus, or "Et" (*Echinodontium tinctorium*) conk on true fir or hemlock (see main document for exception in low failure impact areas that would result in medium rating).
- Five or more red ring rot (*Porodaedalia* (*Phellinus*) *pini*) conks on Douglas-fir, ponderosa pine, Jeffrey pine, lodgepole pine, or more than one on true fir or hemlock.
- One quinine (*Fomitopsis officinalis*) conk on Douglas-fir, pines, spruce or hemlock.
- One sulfur fungus (*Laetiporus sulphureus*) conk (also known as "chicken of the woods") on a wide range of conifers and hardwoods**.**

Medium (2 points)
- *Phaeolus schweinitzii* conks without associated butt swell on Douglas-fir.
- Fewer than five red ring rot (*Porodaedalea (Phellinus) pini*) conks on Douglas-fir, ponderosa pine, Jeffrey pine, lodgepole pine, or one on true fir or hemlock (see main document for exception in low failure impact areas that would result in low rating).
- Incense cedar pecky rot (*Oligoporus amarus*) conks on incense cedar greater than 150 years old.

Cankers

High (3 points):

- Cankers with associated fruiting bodies of decay fungi.
- Cankers with associated internal decay.
- Canker physically connected to a crack or other defect.
- Single or multiple cankers without decay over more than 1/2 of the tree's circumference, particularly if the cankers are between four feet above the groundline and the lowest live branch.
- Basal cankers in true fir that affect over 1/3 of the bole circumference.
- Cankers in oak or tanoak caused by *Phytophthora ramorum* (ramorum canker or sudden oak death) that affect more than 1/3 of the bole circumference, or have associated decay fungi, ambrosia beetles or bark beetles.
- Deep charring in true fir over more than 1/3 of the bole circumference when the relationship between deep char and cambial mortality has been confirmed.
- Deep charring in sugar pine, ponderosa pine, Jeffrey pine, incense cedar or Douglas-fir over 1/2 of the bole circumference when the relationship between deep char and cambial mortality has been confirmed.

Medium (2 points):

- For all species other than true fir, single or multiple cankers without decay that affect less than 1/2 of the tree's circumference (including fire-caused cankers).
- For true fir, single or multiple cankers without decay that affect less than 1/3 of the bole circumference (including fire-caused cankers).
- For oak or tanoak, cankers caused by *Phytophthora ramorum* (ramorum canker or sudden oak death) without associated decay, ambrosia beetles or bark beetles that affect less than 1/3 of the bole circumference.
- A large old wound or canker with no decay at the base of a leaning tree.

Low (1 point):

- True fir with bole swelling from dwarf mistletoe with no bark sloughing or evidence of decay.
- Lodgepole pine or ponderosa pine with basal (hip) cankers from western gall rust with no bark sloughing or evidence of decay.
- Lodgepole pine or ponderosa pine with elongated stalactiform rust cankers covering less than 1/3 of the bole circumference.

Dead Tree, Top Or Branches

Dead tree (4 points)

High (3 points):

- Dead top greater than ten feet long or smaller ones with associated decay or other defect (note that old dead tops of pine, incense cedar, juniper or Douglas-fir may not have high failure potential).
- Dead branches greater than two inches in diameter, branches that are hanging or lodged in the crown, large dead dwarf mistletoe brooms and large live dwarf mistletoe brooms with associated decay or defect.

Medium (2 points):

- Dead tops less than ten feet long with no associated decay or other defect (note that old dead tops of pine, incense cedar, juniper or Douglas-fir may have lower than medium failure potential).
- Any branch greater than two inches in diameter and more than 2/3rds dead (remove the entire branch).
- Live dwarf mistletoe brooms with no associated decay or other defect (monitor closely).
- Long-lived tree species such as juniper, redwood, sequoia and high-elevation pines (e.g. bristlecone, whitebark, foxtail) with dead branches in excess of two-thirds of the foliage-bearing crown and where remaining live branches appear stressed.

Low (1 point):

- Old spike tops in pine, incense cedar, juniper or Douglas-fir that give evidence of long-term persistence.
- Long-lived tree species such as juniper, redwood, sequoia and high-elevation pines with dead branches in excess of 50% of the foliage-bearing crown where live branches appear strong and unstressed.

Bark and/or Woodboring Beetle-Attacked Trees

High (3 points): If any of the following exist over at least 1/3rd of the bole circumference (excluding basal attack by red turpentine beetle):

- Pitch tubes with pink or reddish (not clear) boring dust.
- Pouch fungus conks and/or current woodpecker (not sapsucker) activity.
- Boring dust or frass in bark crevices, webbing along the bole, or accumulation of boring dust or frass at the base of the tree.

Note: Be aware of the potential for non-native beetle infestations that can weaken and/or kill branches and main stems of hardwood species.

If tree has significant bark and/or woodboring beetle activity, as indicated by:

- 50% or more of the foliage-bearing crown actively fading, as indicated by a uniform change in color over that part of the crown. Dead tops that have no foliage do not count toward this 50%. Also does not include drought-induced needle cast (non-uniform fading restricted to the older needles), fire-killed or scorched foliage or branch mortality ("flagging") caused by dwarf mistletoe/*Cytospora* infections in true fir. Note: Old dead tops may be considered hazards if the meet failure criteria found in dead tree, top and branches section.

Root Damage and Root Disease

High (3 points):

- Recently leaning trees, or with recent root-lifting, soil movement or mounding near the base, or with broken/decayed roots.
- Inadequate root support, with more than half of the root system within the drip line severed, broken, undermined, burned or decayed by excavation, erosion, fire or decay fungi.
- Host tree species visibly infected with root disease fungi, adjacent to visibly infected trees or stumps, or with advanced crown symptoms in the immediate area where Heterobasidion root disease has been identified.

Medium (2 points):

- Less than 1/2 of the root system within the drip line severed, broken, undermined or decayed by erosion or excavation.
- Host tree with few or no crown symptoms within 50 feet of a confirmed root disease-infected tree or stump or within 50 feet of a host tree with advanced crown symptoms.

Leans and Poor Tree Architecture

High (3 points):

- Uncorrected leaning tree with other contributing defects.
- Uncorrected leaning tree with recent root lifting, soil movement or mounding near the base.
- Uncorrected lean associated with unstable soils or cracks in the tree.
- Uncorrected lean compounded by unbalanced crown shape weighted in the direction of the lean.
- Uncorrected lean at a location with frequent storm or wind injury.
- Bowed tree with cracks or other associated defects, particularly if exposed to recurrent wind, snow or freezing rain.

Medium (2 points):

- Uncorrected lean without other contributing defects. Monitor closely for changes in the lean.
- Recently bowed tree without other contributing defects.
- Branches with a twist, sharp angle or bend.
- Branches that are lopsided or unbalanced with respect to the rest of the crown, especially if nearby trees were pruned or removed within the last ten years.

The hazard rating is determined by adding the failure impact and the failure potential values. This can then be used to determine what action may be necessary to reduce the hazard.

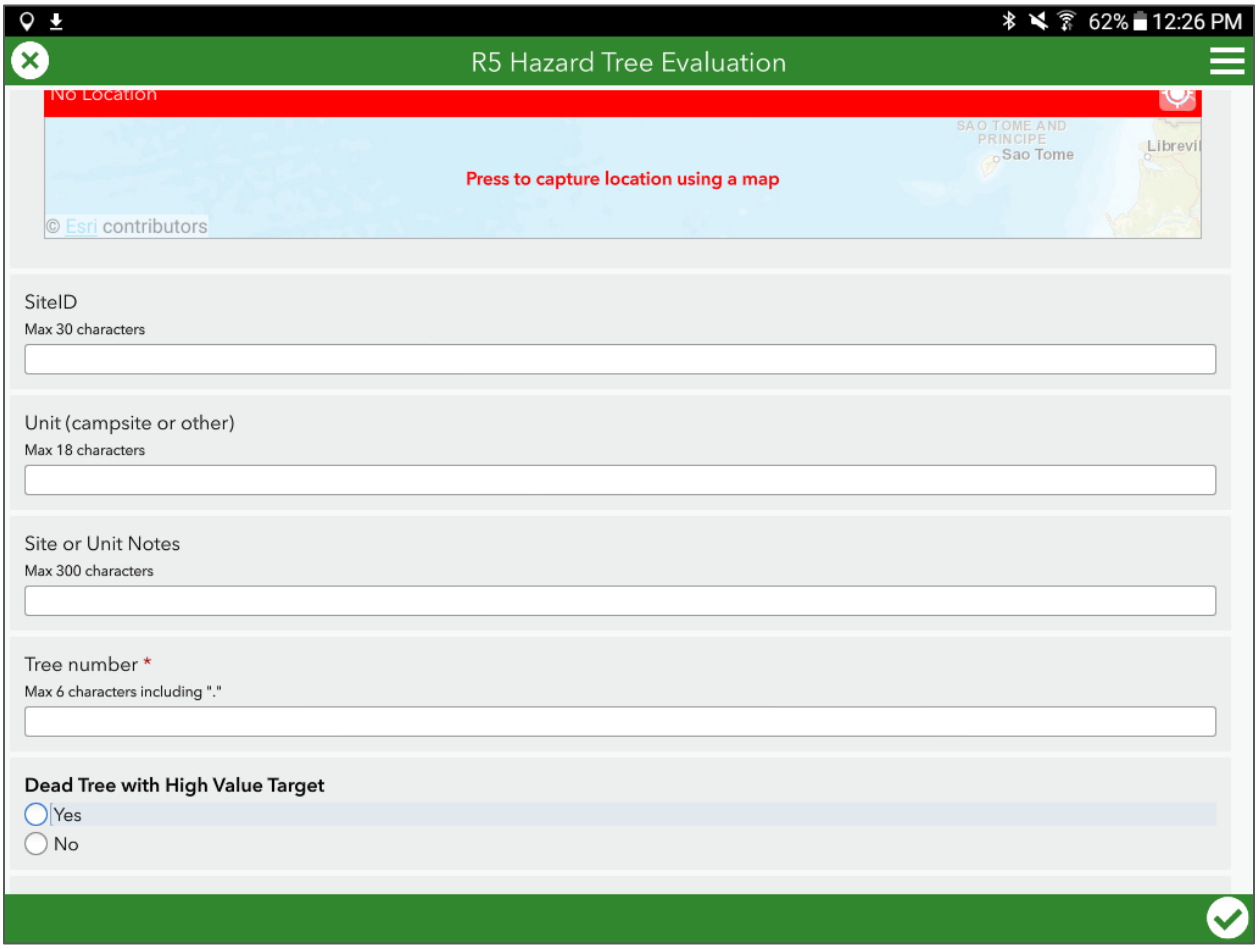
Hazard Rating	Hazard Potential	Suggested Action
1 - 3	Low	No Action or Monitor (document and tag or map tree)
4 - 5	Moderate	Monitor (document and tag or map tree) or Mitigate
6 - 7	High	Mitigate

APPENDIX 3: R5 SURVEY 123 APP FOR HAZARD TREE INSPECTIONS

The R5 Survey123 Hazard Tree Evaluation form is simple to use and includes scoring instructions and descriptions as found in the target and defect quick list. Assessments flow from the form to a GIS feature layer stored on ArcGIS Online (AGOL). The data can be viewed on AGOL or downloaded for use offline in GIS and tabular formats. Forests can create their own user groups at either the forest or district level within AGOL, and users will need AGOL accounts. Request accounts at: https://apps.fs.usda.gov/gtac-tools/AGOL/request_access.php.
Local GIS staff should be able to assist with setup.

Users can copy the Hazard Tree Evaluation form to their local AGOL group and share with the users in the group. The form can be downloaded to devices via the Survey123 mobile application. Survey123 is available for free in the GooglePlay Store, or the Apple App Store. **Assessment data will only be visible to users in the local group.**

Please contact your FHP staff for assistance in accessing and copying the form to your local group.



APPENDIX 4: STREAMLINED APPROACH TO HAZARD TREE ABATEMENT AFTER CATASTROPHIC EVENTS

Since 2012, land managers in Region 5 having been relying on *Hazard Tree Guidelines for Forest Service Facilities and Roads in the Pacific Southwest Region* ("Hazard Tree Guidelines") to help design and implement hazard tree abatement efforts in a wide variety of circumstances. One increasingly common use of the Hazard Tree Guidelines is for hazard tree abatement projects following catastrophic events – such as severe fire, extreme drought, or bark beetle outbreak – which damage or kill large expanses of trees surrounding a road or other potential target. While most of the concepts in the Hazard Tree Guidelines are appropriately applied in such instances, the Guidelines were not drafted with catastrophic scenarios in mind. Because catastrophic mortality events require a special approach to hazard tree abatement, this addendum provides supplemental guidance to be considered in such situations.

The Unique Characteristics of Catastrophic Damage Scenarios

While background mortality in an undisturbed forest may result in 1-2% of trees dying annually in each area, fire, insects, pathogens, drought, and other forest disturbance agents can damage or kill millions of trees across hundreds of thousands of acres in a single event. And, within the affected area of such disturbances may be hundreds of miles of roads, numerous campgrounds, and other public and administrative facilities that are threatened by adjacent hazard trees. Abating hazards in such areas is often an urgent priority for the Forest Service in order to keep large areas of the national forests open and safe.

Appropriate hazard tree abatement guidelines are an essential tool to efficiently and effectively design and implement such abatement projects. There are two characteristics of catastrophic damage situations that require specially tailored guidelines: 1) the scale of the problem, and 2) the uniformity of tree damage or mortality.

The first of these factors – the large scale of catastrophically damaged areas – demands a streamlined approach to both identifying and abating hazard trees, since time is of the essence in hazard tree abatement scenarios. Prompt hazard tree abatement is needed to open affected portions of the national forests as soon as possible following a catastrophe, to reduce the period during which the public and agency staff are put at risk, to remove dead trees while they retain sufficient structural integrity to be safely felled, and, in some instances, to harvest the trees while they still have sufficient commercial value to support their removal.

The second of these factors – the uniformity of tree damage or mortality following a catastrophic event – generally allows for a streamlined approach to identifying and abating hazard trees, since individual tree assessment is less important than in cases of widely dispersed hazard trees affected by a broad array of disturbance agents. Following a catastrophic event, there is generally a high density of trees that possess the same type and severity of defect, such that a thorough, individual tree assessment is often unnecessary. For example, a severe fire or bark beetle infestation may kill all trees (or all trees of a given species) in a particular area, such that the failure potential value (*see* Hazard Tree Guidelines at 19) of such trees is quickly known, and individual tree defect assessment is unnecessary.

Because a detailed individual tree evaluation is neither practical nor necessary in most catastrophic damage situations, the following approach will generally be appropriate in catastrophic damage situations.[3]

[3] The approach laid out in this document is a recommendation, not a strict requirement. Managers may tailor recommended practices to best fit the needs of each situation.

Process for Assessing Hazard Tree After Catastrophic Events

The approach described below is presented in a stepwise fashion, beginning with the initial assessment after a catastrophe and concluding with the identification of individual hazard trees requiring abatement.

1. Identify the area impacted by the catastrophic event.

The first step in identifying hazard trees after a catastrophic event is to identify the boundaries of the area impacted by the event. This can generally be accomplished by remote sensing tools, field visits, or a combination of the two. Because hazard tree abatement is only a priority in areas where there is a target of concern, exact delineation of a catastrophic event's boundaries is generally not needed in areas where there are no targets of concern. Additionally, this step may be unnecessary when a manager already has a clear idea of an area that requires hazard abatement and further detail about the boundaries of the catastrophic event would not be useful.

2. Identify the target(s) of concern.

After the manager has identified the extent of the catastrophic event or a priority treatment area within the catastrophically damaged area, the manager should identify the potential target(s) around which hazard tree abatement is necessary. Such targets could be structures, road segments, trails, recreation areas, or other locations of concern.

Be aware that the approach to identifying hazard trees is reversed in catastrophic damage situations as compared to the standard approach described in the Hazard Tree Guidelines. Under the standard approach, the manager starts with identifying a target of concern and then conducts periodic inspections to determine whether there are trees with high failure potential within striking distance of the target. In catastrophic damage scenarios, the manager starts with the knowledge that there are large areas of trees with high failure potential and then identifies targets of concern within the affected area. Given this difference in approach, many of the survey and inspection protocols set forth in the Hazard Tree Guidelines and Forest Service Directives are generally unnecessary in catastrophic damage situations. *See, e.g.,* Hazard Tree Guidelines at 5-6.

3. Identify the treatment area surrounding the target.

Once a target of concern has been identified, the manager may find it useful to identify a general treatment area around the target to facilitate planning. The treatment area designates the zone within which individual hazard trees will be designated for abatement in subsequent steps; trees within the treatment area are candidates for abatement, while trees outside the treatment area are not (absent unusual circumstances). The purpose of designating a general treatment area is to focus the manager's and/or work crew's hazard tree identification and abatement efforts within a discrete area, accelerating the hazard tree identification process and reducing the amount of time needed to abate the hazards.

Identifying an appropriate treatment area will depend on several factors, such as physical properties (e.g., prevailing tree height, topography), risk tolerances, and the urgency of action. In most cases, the size of the treatment area will be primarily influenced by the prevailing height of the taller hazard trees in the area and the potential failure zone of such trees. For example, if the typical tall tree height along a road is 100 feet, a manager might reasonably designate a treatment area of 150 or 200 feet on either side of the road to account for a tree's potential failure zone of one to one and a half tree lengths, plus additional distance to account for special factors like slope, wind, and the domino effect. The treatment area may be based on a fixed distance from the target (such as 300 feet beyond a campground's perimeter), or a variable distance based on topography or other factors unique to an area.

Identifying a narrow treatment area will accelerate the planning and hazard tree identification process, but risks excluding trees that are genuine hazards. Conversely, identifying a wide treatment area reduces the risk of inadvertently missing hazard trees, but may increase the time, cost, and effort associated with hazard tree identification. In some instances, the manager may choose to take a hybrid approach by delineating a relatively narrow treatment area, while providing the marking crew with the discretion to identify obvious hazard trees outside the treatment area where such outlying trees pose a clear risk.

Ultimately, the identification of a treatment area is a matter of judgment. In some instances, a manager may identify a narrow treatment area, in others, a manager may identify a wide treatment area, in others, a manager may identify a variable-distance treatment area, and in still others, a manager may decline entirely to identify a treatment area.

4. Determine a failure potential threshold.

In most instances, not all trees within a treatment area need to be removed or felled. Rather, abatement is only necessary for those trees that: 1) exceed a defined failure potential threshold; *and* 2) have a potential failure zone that overlaps the target. Therefore, it is essential for a manager to establish a failure potential threshold, as only trees that meet that threshold will be candidates for abatement.

In catastrophic fire situations, the most straightforward way to establish a failure potential threshold is to use *Marking Guidelines for Fire-Injured Trees in California* (2011) ("Marking Guidelines") and select a probability of mortality (Pm) above which all trees would be deemed appropriate for abatement (if their failure zone overlaps the target). *See* Marking Guidelines at 6-7. For example, in a roadside hazard tree abatement project, a manager may select a 0.5 Pm, meaning that all trees for which the probability of mortality is 50% or higher within the treatment zone should be abated, if their failure zones overlap the target. As explained in the Marking Guidelines, selection of an appropriate probability of mortality threshold is a case-specific endeavor that involves balancing multiple factors. As a general matter, Pm levels of 0.4-0.6 are reasonable thresholds in situations where a cautious approach is warranted and maintaining safe conditions is paramount, while higher Pm levels (0.7-0.9) may be appropriate in situations where retention of trees is paramount and safety risks are lower. *See* Marking Guidelines at 6.

In catastrophic insect or pathogen situations, the most straightforward way to establish a failure potential threshold is to use the Hazard Tree Guidelines and select a failure potential value above which all trees would be appropriate for abatement (if their failure zone overlaps the target). For example, a manager might decide that all trees with a "medium" and "high" failure potential, as described in the Hazard Tree Guidelines, are candidates for abatement. Or, the manager might decide that only trees with a "high" failure potential should be felled or removed.

In virtually all instances, dead trees should be identified as candidates for abatement, given their high failure potential.

Once a failure potential threshold has been determined, trees meeting that threshold within the treatment area must be identified on the ground. This will often be done on an individual tree basis by the marking crew (or the logging contractor, in "designation by damage" situations). However, in instances where the catastrophic event results in homogenous conditions across a broad area – such as a severe fire resulting in 100% mortality – individual tree assessment may not be necessary (see step 6, below).

5. Determine the potential failure zone.

Determining the potential failure zone of a tree is the second essential element in ascertaining whether a tree within a treatment area poses a genuine hazard to the target of concern. The potential failure zone is determined by estimating the upper end of the distance a tree or portion of a tree would come to rest after falling, measured from the base of the standing tree. The Hazard Tree Guidelines explain that the default potential failure zone in Region 5 is one to one and a half times the tree's height, but may be enlarged based on site-specific factors, like slope. *See* Hazard Tree Guidelines at 8-9. A more detailed explanation of the potential failure zone is found in *Defining the Hazard Tree Failure Zone* (2020), an addendum to the Hazard Tree Guidelines.

There is a broad spectrum of reasonable approaches to determining a hazard tree's potential failure zone. At one end of the spectrum is a detailed, multi-factor analysis of each tree that attempts to quantify the potential failure zone of that tree, accounting for context-specific factors like slope, wind, and the domino effect. *See Defining the Hazard Tree Failure Zone* at 2-3. At the other end of the spectrum is a single-factor approach, which assigns a reasonable potential failure zone (like one and a half tree lengths) and applies that failure zone to all trees within a treatment area. And, between these two approaches lie many options. Choosing the appropriate approach in the context of a catastrophic event will depend on many factors – the size of the treatment area, the availability of agency resources, the urgency of action, etc. – and is best left to a manager's discretion.

In instances where a manager chooses to rely on a default failure zone to be applied to all trees within a treatment area, the manager and marking crews should, in most situations, apply that default zone on an individual tree basis. That is, each tree within a treatment area that exceeds the failure potential threshold (discussed in the prior section) should be individually examined to determine whether the default failure zone, as applied to that tree, overlaps the target. For example, if the default failure zone is one and half tree lengths and a marking crew comes upon a 100-foot-tall dead tree, the crew would need to determine the distance of that tree from the target – if the tree was less than 150 feet to the target, the tree would be marked for removal, and if the tree was more than 150 feet, the tree would be left. This approach would be repeated for all trees within the treatment area.[4]

There are a wide variety of tools and methods available for managers and marking crews to ascertain whether a tree's failure zone overlaps the target of concern. Some common tools and methods include laser measurement devices, clinometers, and ocular estimates. While managers and marking crews may choose to carefully measure individual trees and their distance to the target, doing so is generally impractical in catastrophic damage situations given the large areas affected, the vast numbers of hazard trees, and the urgency of action. Therefore, in many situations, ocular estimates of a tree's height and its distance to the target will suffice.

6. Identify those trees that require abatement.

Once a treatment area has been determined, individual trees or groups of trees within that area need to be evaluated to see if those trees meet the two abatement screening criteria discussed above, the failure potential and the failure zone. In most instances, both of these criteria should be evaluated on each tree that is considered for abatement. That is, a Forest Service staff member, or a member of a contracting crew should evaluate each tree that is a candidate for abatement and answer: 1) does the tree meet or exceed the failure potential threshold? 2) is the target of concern within the tree's potential failure zone? If the answer is yes to both questions, then the tree

[4] In some limited instances, individual tree assessment is not necessary, such as when a group or stand of dead trees is of uniform height and the most distant of such trees from the target has a potential failure zone that overlaps the target. However, such instances are rare, and most circumstances will warrant individual tree assessment, even if only to quickly confirm that a tree's potential failure zone overlaps the target.

should be felled and, when appropriate, removed. If the answer to either question is no, then the tree should be left standing.

The inspection process described above does not mean that every single tree within a treatment area requires a lengthy, detailed inspection. For example, in an area with high burn severity, it may be clear (from remote sensing images or prior field surveys) that all the trees in that area are dead. Therefore, an individual assessment of each tree's failure potential would not be necessary. Similarly, an individual assessment of a tree's potential failure zone may not be necessary for a group of tall trees directly adjacent to a road, where the target is clearly within the failure zone of those trees. In all cases, though, the marking crew must ensure that that the trees selected for abatement meet both screening criteria.[5]

Given the scale and uniformity associated with most post-catastrophe hazard tree abatement efforts, the individual tree evaluation and documentation processes set forth in the Hazard Tree Guidelines are generally not feasible or necessary. *See* Hazard Tree Guidelines at 7, 23-24, Appendix 1. Rather, tree marking (e.g., through use of a paint gun) or designation criteria, plus keeping a tally, will generally be sufficient for tracking and accountability.

Conclusion

The process described above is a recommended approach to identifying and abating hazard trees following a catastrophic disturbance that kills or damages many trees. The approach tries to balance the urgent need for action, the large areas and high number of trees typically affected, the goal of retaining trees that are not genuine hazards, and the paramount objective of protecting public and agency staff safety. Balancing these numerous, and often competing, objectives is difficult and necessarily imperfect. In some instances, the approach will be overinclusive, resulting in the removal of trees that might not otherwise have caused harm; in other instances, the approach will be underinclusive, leaving trees that pose a genuine hazard. Lacking an ability to see the future, such imperfect forecasting is unavoidable. However, by following the approach set forth in this guidance, consulting other relevant documents (like the Hazard Tree Guidelines and Marking Guidelines), and using local experience and expertise, managers will have a solid platform upon which to design and implement efficient, effective, and reasonable hazard tree abatement treatments following catastrophic disturbances.

[5] In limited instances, a tree that is not itself a hazard may nonetheless need to be removed because it is blocking access to a hazard tree that must be removed, or because it poses a safety issue due to its proximity to a hazard tree identified for removal. The two screening criteria do not apply to such trees.

APPENDIX 5: Defining the Hazard Tree Failure Zone

There are two key factors that determine whether a tree poses a hazard. The first is whether a resource of concern – a target – is within striking distance of the tree. The second is whether the tree is so compromised by a defect that the risk of falling or failure is greater than a threshold of concern. It is the first factor to which this addendum is directed, with a focus on understanding the potential failure zone of a tree.

The "potential failure zone" of a tree is the area within which a tree or portion of a tree is likely to come to rest after falling. As described on pages 8-9 of *Hazard Tree Guidelines For Forest Service Facilities and Roads in the Pacific Southwest Region* ("Hazard Tree Guidelines"), "the potential failure zone of a tree on level ground is generally … one to one and a half times the height of the tree." The potential failure zone of a tree can be enlarged based on site-specific factors like slope and wind, which can add dispersal force, resulting in trees or portions of trees coming to rest two tree lengths or more from the base of the tree.

The setting of each tree is unique, so there is no mathematical formula to calculate a tree's potential failure zone. Rather, managers should use the general guidance set forth in the Hazard Tree Guidelines and this addendum, coupled with professional experience and sound judgment to determine whether a tree or group of trees threatens a target and therefore warrants removal. And, while efforts should be made to retain trees that are not hazards, providing for public safety and the safety of agency employees is paramount, and in cases of uncertainty, potential hazards should generally be abated.

Establishing the Default Potential Failure Zone

Under the Hazard Tree Guidelines, the default radius of a tree's potential failure zone is one to one and a half times the tree's height. *See* Hazard Tree Guidelines at 8, Figure 3. The upper end of this range is greater than a single tree length due in part to the physics of a falling tree and the structural properties of the wood in typical hazard trees. Regarding the physics, a falling tree is akin to an inverted pendulum, with the upper portions of the tree generating tremendous amounts of momentum. This force is not only directed downward, toward the ground, but also outward, lateral to the base of the tree. As a result, it is very common for trees to break on impact (or before), with some of the longitudinal force sending broken portions of the tree a significant distance from the base of the tree.

The risk of wood projectiles dispersing beyond the height of the tree is increased with dead or rotten hazard trees due to the reduced structural integrity common in such trees. Some of the agents that increase the risk of a tree falling – e.g, wood-rotting pathogens and saprophytes, wood boring insects, and fire – also increase the risk that large pieces of a tree will be projected during or after treefall. This is because these agents reduce the structural integrity within a tree, dramatically reducing the tensile strength of wood that might otherwise withstand the longitudinal and shear forces generated during treefall (climatic factors, such as sun-induced checking and cracking, can exacerbate these problems).[6] As a result, when a tree compromised by such agents falls (especially a tall tree), the significant momentum generated by the speed of treefall and the mass of the tree can result in large branches, and even pieces of the trunk, being sent well beyond the tree's height. For these reasons and others, the Hazard Tree Guidelines recommend a default potential failure zone of up to one and a half tree lengths. This benchmark is not meant to suggest that all falling trees will disperse projectiles 50% beyond their height. Nor is it meant to suggest that all dispersal will be contained within this distance. However, identifying a default potential

[6] *See Effects of Fire, Insect, and Pathogen Damage on Wood Quality of Dead and Dying Western Conifers*, PNW-GTR-816, May 2010.

failure zone is needed to ensure a consistent level of safety and ease of field application. And, using either one and a half tree lengths or two tree lengths is common in logger safety standards.[7] For Region 5 hazard tree guidance, one to one and half tree lengths has been selected as the default distance based on the accumulated judgment and experience of numerous forestry experts within the Forest Service and beyond.[8]

Enlarging the Potential Failure Zone

In many cases, a potential failure zone of one to one and a half tree lengths will suffice. However, there are several factors that can increase the dispersal area and warrant an enlarged potential failure zone. *See* Hazard Tree Guidelines at 8-9.

The most important of these factors is slope. If a hazard tree is located upslope of a target, there is a serious risk that the tree, or portions of it, will roll or slide downhill. This risk is particularly significant for portions of the tree that break during treefall, which can move several tree lengths downhill before coming to rest.[9] Therefore, hazard trees that are located upslope of a target may require delineation of a larger failure zone, particularly on steep slopes or in locations where there are no obstacles that would impede a rolling or sliding tree (like other trees, rocks, or topographic features). As stated on pages 8-9 of the Hazard Tree Guidelines, "On sloping ground where the tree or dislodged part may slide or roll downhill, the failure zone may need to be extended on the downhill side for whatever distance is necessary to protect people or property (Figures 5 and 6)."[10] This risk is also recognized in OSHA's logging safety regulations, which state, "A distance of greater than two tree lengths shall be maintained between adjacent occupied work areas on any slope where rolling or sliding of trees or logs is reasonably foreseeable." 29 C.F.R. § 1910.266(d)(6)(ii).

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[7] *See, e.g., Occupational Safety and Health Administration Logging Operation Standards*, 29 C.F.R. § 1910.266 (two tree lengths); Washington Administrative Code § 296-54-513(2)(b) (two tree lengths); *Fallers Logging Safety, Oregon Fatality Assessment and Control Evaluation*, Oregon Health and Science University, 2007 (one and a half tree lengths); *Timber Harvesting Safety Manual*, National Timber Harvesting and Transportation Safety Foundation, 2017 (two tree lengths); *Danger Tree Mitigation Guidelines for Managers*, Forest Service Report 1151-2815P–MTDC, 2011 (two and half tree lengths).

[8] While Region 5 has concluded that one to one and a half trees lengths is an appropriate default potential failure zone, it is not the only reasonable choice, and approaches within the Forest Service vary. *See, e.g.,* Region 6, *Field Guide for Danger-Tree Identification and Response along Forest Roads and Work Sites in Oregon and Washington*, R6-NR-TP-021-2016, 2016 (one and half tree lengths); Region 2, *Guide to Hazard Tree Management*, Technical Report R2-69, 2017 (one tree length); Region 3, *Tree risk assessment and hazard tree mitigation in the Southwestern Region*, TP-R3-16-37, 2020 (one tree length); Region 1, *A Guide to Identifying, Assessing, and Managing Hazard Trees in Developed Recreational Sites of the Northern Rocky Mountains and the Intermountain West*, R1-17-31, 2017 (one tree length); Region 6, *Field Guide for Hazard-Tree Identification and Mitigation on Developed Sites in Oregon and Washington Forests*, R6-NR-TP-021-2013, 2014 (one tree length). The Forest Service regions that designate a potential failure zone of one tree length recognize that the failure zone often needs to be enlarged due to factors such as slope, as discussed below.

[9] During a roadside hazard tree removal effort after the 2014 King Fire, Eldorado National Forest employees witnessed portions of felled roadside hazard trees roll and slide approximately 600 feet below the Eleven Pines Road before coming to rest in the Rubicon River valley bottom.

[10] Trees located downslope of a target do not require an enlarged failure zone on account of slope. However, a failure zone of one and a half tree lengths may still be appropriate, since downslope trees still pose a risk of dispersing projectiles, though the risk declines as the steepness of the slope increases.

Other factors such as wind and "the domino effect" may warrant an enlarged failure zone. Wind not only increases the risk of an individual tree or portion of a tree falling, it also creates the potential for wind-driven projectiles. It is difficult to predict the impact that wind may have in a given instance, and the guidelines do not recommend universally increasing a failure zone based on wind. However, in particularly windy areas or when a tall tree threatens a high-risk target, a manager may reasonably choose to increase the failure zone based on wind.

The "domino effect," where a falling hazard tree strikes another tree and causes it to break or fall, can also enlarge the potential failure zone. However, as with wind, it is difficult to predict whether a domino effect will be triggered. Therefore, managers should not universally assume that the domino effect will come into play. But, in particular instances, such as where a large hazard tree is leaning directly toward a target with a weakened tree in between, an enlarged failure zone may be appropriate.

These are a few common factors that may warrant delineating an enlarged potential failure zone. The purpose of setting forth these factors is not to suggest an across-the-board increase in the potential failure zone, but to identify a partial list of common factors for managers to consider.

Ultimately, the best way to ascertain an individual hazard tree's potential failure zone is to examine the context of the individual tree. However, conducting a detailed examination of every tree may not be practical or appropriate in some situations, such as in broad areas impacted by severe fire or bark beetles, where there may be 100% tree mortality (or close to it) and a detailed examination is not necessary or practical. *See Streamlined Process for Hazard Tree Removal After Catastrophic Events* (2020). Additionally, there are many factors that determine a hazard tree's actual strike location that cannot be predicted by advance tree examination, such as the ground condition and existence of obstacles between the tree and target at the time the tree would naturally fall, the structural condition of the tree at the time the tree would naturally fall, the speed and direction of wind that might topple the tree, etc. Therefore, the best way to ascertain a tree's (or group of trees') failure zone will vary and will always be an estimate. In some instances, it will be appropriate to conduct a detailed, individual tree evaluation that considers multiple factors. In many others, it will be appropriate to simply rely on the default potential failure zone of 1.25 tree lengths (a compromise between the absolute minimal failure distance and a distance that only a very small portion (less than 1%) of all trees should exceed when falling. The goal in all situations is to find an approach that is both practical and provides for public and staff safety.