Forest Health Protection
Pacific Southwest Region

Date: September 23, 2005
File Code: 3420

To: District Ranger, Big Valley Ranger District, Modoc National Forest

Subject: Annosus Root Disease in the Rush2 Planning Area.
(FHP Evaluation # NE05-08)

On July 6, 2005, Forest Health Protection (FHP) personnel examined three typical white fir stands in the Rush2 planning area on the Big Valley Ranger District, Modoc National Forest. The objectives were to assess tree health and provide management recommendations including recommendations regarding stump treatment with SPORAX® to control annosus root disease. John Landoski (District Culturist), and Cheryl Rosel (Student Career Experience Program/SCEP soils student) were accompanied by Sheri Smith (Entomologist) and Bill Woodruff (Plant Pathologist) from Forest Health Protection. The Rush2 project is on the 5-year timber sale plan for the Modoc National Forest and is targeted to be sold in fiscal year 2007. The area is part of the Big Valley Sustained Yield Unit which has annual timber production requirements. Bill Woodruff also conducted a follow-up visit to map suspected white fir annosus root disease areas on September 14, 2005.

The Rush2 planning area is dominated by white fir at the higher elevations and open grown ponderosa pine at the lower elevations surrounding Sweagert Flat. The stand composition grades from fir-dominated stands to pine-dominated stands, as the elevation decreases. Past forest management is evident in and around the Rush2 stands. Numerous healthy-appearing ponderosa pine plantations of various ages, up to approximately 20 years old, have replaced harvested white fir and white pine-fir stands in and around the planning area. Some of the plantations have a few residual healthy-appearing white fir trees of all ages. Naturally regenerated, sparsely-stocked, ponderosa/Jeffrey pine and white fir have replaced harvested ponderosa pine/white fir stands on private land around Sweagert Flat. Here it appears that ponderosa pine seedlings were planted in places to increase stocking.

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Many of the white fir-dominated Forest Service stands appear to be old and/or over-stocked. Reported basal areas generally range in the upper 200's, with one measurement as high as 400 ft^2/acre. Fruiting bodies (or conks) of *Heterobasidion annosum* were found in fir stumps (Figures 1 & 2) and characteristic annosus root disease decay was found in roots of windthrown white fir in various locations throughout the Rush2 area. Declining crowns with numerous dead and dying branches, were present in old white fir. Many younger white fir have stunted growth, as indicated by rounded tops and short leader growth on their crowns. Both of these conditions can be caused by *H. annosum*. In many stands where annosus root disease is indicated by symptomatic trees, healthy-appearing young white fir are also present, indicating that the disease is probably not present throughout or at least has not yet resulted in above ground symptoms. Annosus-like decay can be found in each of the three stands visited. Declining white fir is common in many of the stands, therefore it is likely that fir-type annosus root disease is present in most fir stands in the Rush2 area. No evidence of pine-type annosus was observed.

Figure 1.

Stump and fruiting bodies of *Heterobasidion annosus* inside the stump.

Figure 2.

The follow-up survey to map areas with suspected annosus root disease revealed that the prevalence of fir-type annosus appears to increase as the percentage of white fir increases. This is to be expected due to the increased probability of root contacts between fir trees in stands with higher proportions of white fir and *H. annosum* being commonly transmitted tree-to-tree through the roots and root contacts. In addition *H. annosum* can be transmitted long-distances through spores produced by the disease's fruiting bodies (or conks) which grow on decaying wood of dead and dying fir trees. Annosus spores can infect living fir trees through naturally-occurring wounds. The spores can also germinate on and grow through freshly-cut fir stumps into uninfected roots and eventually spread to adjacent uninfected fir root of surrounding trees.

Annosus root disease in white fir primarily infects the heartwood in the roots and at the base of the bole, sometimes causing hollow cavities where annosus conks can often be found growing. The cambium and phloem are usually not affected and to continue to function, produce wood and keep the tree alive. However, annosus root disease in suppressed white fir can eventually infect and decay enough root tissue to weaken trees

and slow their growth. Many of these weakened trees can be killed by fir engraver beetles, *Scolytus ventralis*, often during prolonged periods of below-average precipitation. Evidence of fir engraver is common on dead and down white fir in the area (Figure 3).

Figure 3. White fir log with fir engraver adult and larval galleries.

In contrast to fir-annosus, pine-annosus quickly colonizes the cambium of ponderosa and Jeffrey pine trees at the root collar and rapidly kills those trees, usually within a year. The fir, or S-type *H. annosum* and pine, or P-type *H. annosum* generally do not cross-infect species. As previously stated, no P-type annosus root disease was observed. However, past experience indicates that both S-type and P-type annosus spores are present year-round in the atmosphere throughout the Modoc NF as well as elsewhere in the Sierra Nevada Mountains of California. As previously stated, these spores can infect healthy root systems through freshly-cut conifer stumps. Whereas S-type *H. annosum* can infect true fir through naturally-occurring and other wounds as well as stumps, P-type *H. annosum* primarily infects pine trees through freshly-cut stumps.

Borate compounds have been successfully used for decades in the United States to prevent *H. annosum* stump infection. Originally, generic granular borax was used to treat freshly-cut conifer stumps to keep *H. annosum* from colonizing the roots. Borax, or sodium tetraborate decahydrate ($Na_2B_4O_7\ 10H_2O$), is a naturally occurring mineral which has been used more than 50 years in household laundry and cleaning, household insect control, hand cleaners and soil amendments for improving plant growth. Boron, a key element in borax, is an essential micronutrient for plant life, however high concentrations can be phytotoxic. Forestry use of borax was supplemented, about two decades ago, with the insecticide TIM-BOR®, disodium octaborate tetrahydrate ($Na_2B_8O_{13}\ 4H_2O$), which was applied to stumps as a liquid. Even though it is effective in controling annosus root disease, TIM-BOR® can no longer used in California because it is not registered for that application. When it became necessary to register a fungicide to control annosus root disease in foretry applications, Wilbur-Ellis Corp., for economic reasons, chose to register only the granular borax as SPORAX®. Essentially, SPORAX® is the same generic borax that has been approved for used in American homes and agriculture for more than five decades. The difference is that SPORAX® has been registered as an approved pesticide for control of *H. annosum* in forestry applications. Only SPORAX® can be used in California for this purpose.

Research has demonstrated that borax (both granular and liquid formulations) prevents the establishment and growth of *H. annosum* in cut stumps of conifer tree species not already infected. The use of SPORAX® has been determined safe by pesticide regulators. Biological agents have been used elsewhere in the world to control annosus root disease, but no biological control has been found effective in California.

Management Alternatives of Annosus Root Disease in the Rush2 Area

Annosus root disease is present in white fir in the Rush2 area. The estimated extent of the disease is shown in Figure 4. The red areas delineate stands where declining or stunted crowns, decayed roots, or annosus conks could readily be found. The yellow areas are stands where the listed conditions are present, but not prevalent. The remaining areas are either non-forest, or have little or no white fir and are dominated by ponderosa and Jeffrey pine.

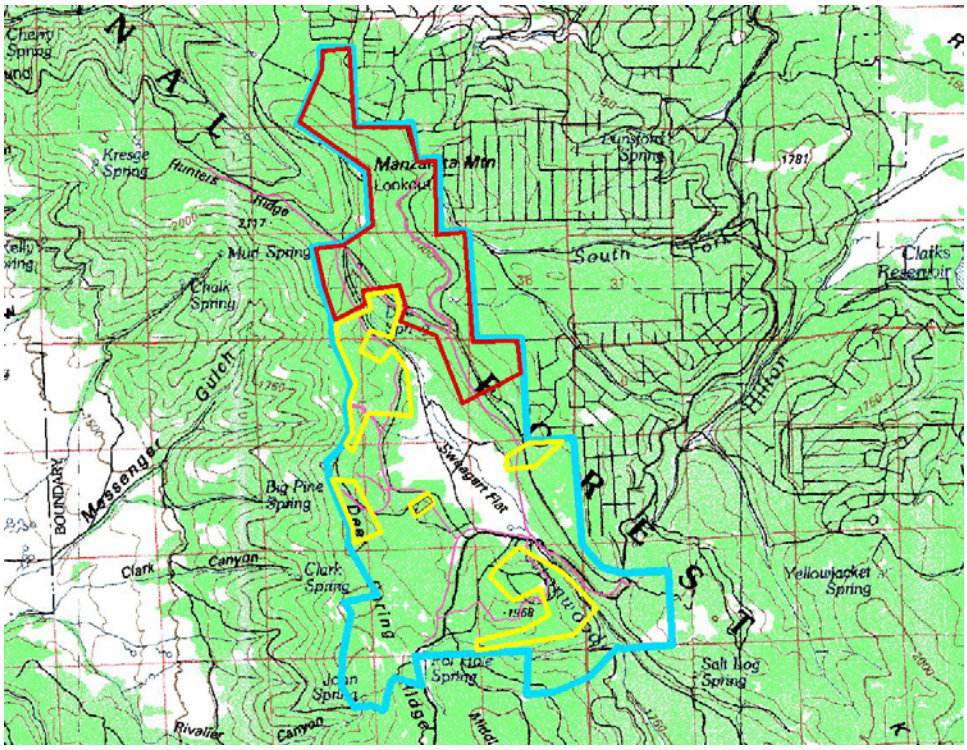

Figure 4. Rush2 planning area (Blue). Red delineates the area where S-type annosus root disease is estimated to be prevalent. Yellow delineates areas where S-type annosus root disease is estimated to be present, yet much less prevalent. The remaining area is either non-forest or dominated by ponderosa/Jeffrey pine.

Alternative 1. No Action.

Without forest management, annosus root disease will persist in the fir-dominated stands that are currently infected (red and yellow polygons). Through spore dispersal from within and outside the Rush2 area, annosus root disease will gradually infect healthy white fir through naturally-caused wounds. Over-crowded and/or annosus-infected fir will continue to be killed by fir engraver events, often associated with precipitation deficits. Eventually, sufficient woody material will accumulate on the ground and in the canopy to provide fuel

which could sustain a stand-replacing wildfire. Prior to the twentieth century, wildfire was the disturbance which normally removed decadent true fir stands from the landscape and initiated the slow process of growing new fir stands. In the absence of fire, older white fir trees will continue to decline and young healthy fir trees will continue becoming infected with *H. annosum*, and annosus root disease will persist.

Centuries ago, areas cleared of diseased or declining true fir forests by wildfire would have most likely regenerated slowly over many decades. During these decades new fir seedlings would gradually inch their way through a dense brush cover until they reached open sunlight. Only then would growth accelerate to produce fir trees to replace the fire-killed conifers. During this long period of stand replacement, with few-to-no mature host trees in the stand, old infected fir roots would have time to completely decay and eliminate the disease. This is probably how annosus root disease cycled in natural fir stands. It should be noted, that even though annosus root disease weakens already stressed fir trees and contributes to their death, *H. annosum* is an effective decay organism which decomposes conifer roots and recycles forest nutrients. This fungus also creates hollows in stumps and roots which are sometimes used by small mammals. Additionally, true fir forests with advanced decline due to annosus root disease will provide openings in the canopy which favor some species of wildlife and early-successional plant communities, including ponderosa pine. For this reason, depending on the management objectives for the Rush2 white fir forests, annosus root disease could be considered beneficial or detrimental to those objectives.

Alternative 2. Thin White Fir infected with Annosus Root Disease.

Thinning over-stocked forest stands removes competing trees and makes soil moisture available to the remaining trees. Healthy white fir, growing on white fir sites, is capable of surviving in relatively dense stands except during severe drought periods during which time the trees are stressed and fir engraver beetles are active. However, white fir infected with *H. annosum* may experience chronic stress which predisposes them to fir engraver mortality, even during relatively moist periods. Annosus-caused stress on infected white fir trees may be reduced by removing competing trees to increase the vigor of the residual trees. The infected fir trees will never recover from the disease, but they may be able to grow new wood at a rate which exceeds the progress of the disease, thereby maintaining the structural integrity of the lower bole and roots. Thinning true fir stands, heavily impacted by annosus root disease (red areas in figure 4), will probably not significantly improve stand growth, but thinning may increase individual tree growth and vigor; and make the released annosus-infected trees more resilient during extended periods of below-average precipitation. Thinning stands infected with annosus root disease will most likely retain white fir on the site longer than if they were left untreated.

SPORAX® treatment of freshly-cut white fir stumps where the roots are already infected with *H. annosum* will have no effect on controlling the disease (ie. in figure 4, most of the red and portions of the yellow areas). Stumps must be treated with SPORAX® before the S-type annosus spores have a chance to germinate and grow into stumps and then into uninfected roots. Once roots are infected with *H. annosum*, the disease will persist until all the available nutrients in the infected roots are depleted by the fungus. In Califonia pine forests, it generally takes about 30 years for annosus root disease to die off in clearcuts where pine roots became infected through stump infections. After 30 years, pines can

again be safely planted after all the infected pine roots have decayed. This is probably similar for true fir roots, as well.

Thinning over-stocked true fir stands or mixed pine-fir stands in Rush2 which are partially affected by S-type annosus root disease (yellow areas in figure 4) will be more beneficial in increasing the stand vigor than in the heavily affected stands (red areas). This is because some of the white fir in the yellow areas are uninfected and more likely to respond to thinning. In the mixed pine-fir stands infected with S-type *H. annosum*, it is wise to favor the pine as leave trees, and cut the fir, since the pine will not be killed by the S-type annosum. In the 'non-red' Rush2 areas, it is recommended to treat both the freshly-cut pine and fir stumps 14 inches and greater in diameter with SPORAX®, even though some of the fir will already be infected. It is impossible to know which fir trees are infected and which are not. Treating all the large fir stumps with SPORAX® will help protect any adjacent uninfected white fir from becoming infected through root contact. However, as previously mentioned, white fir can become infected through naturally-occurring wounds. This is also true for mechanical wounds created near the base of trees during logging. As much as practical, it is always important to protect all leave trees from bole damage to minimize infection by *H. annosum* and other pathogens.

It is recommended to SPORAX® treat all the freshly-cut pine stumps, 14 inches and larger, where the roots of those stumps contact other pine trees. This is true for all P-type *H. annosum* hosts in the Rush2 area (ie. all pine species and incense cedar). Once a ponderosa or Jeffrey pine is infected with P-type annosus, the tree will most likely die within a year. However, mortality in post-thinning residual trees will be delayed by the time it takes for *H. annosum* to grow through the stumps and roots of cut trees and then through the roots to the base of adjacent trees. This process can take more than a decade, depending on many factors. Residual pine tree mortality can continue to occur as long as it takes for the disease to die in all the infected roots, at least 30 years or more, depending on how the disease progresses through the stand. Annosus root disease can continue spreading tree-to-tree in a mature pine forest indefinitely, as long as there are uninfected pines connected by root contacts to infected pines.

Treating stumps with SPORAX® is wise, since a stump surface is an ideal pathway to the roots for *H. annosum*; a pathway that rarely occurs in nature. However, choosing not to treat stumps will probably not totally decimate a conifer stand. As is evidenced in Rush2, where pure fir stands are heavily impacted by annosus root disease, trees continue to grow and forest cover continues. However, the infected stands are growing at a reduced rate, compared to uninfected fir stands. This is evident by observing annual height growth differences. Harvesting healthy fir stands without treating the stumps will introduce annosus root disease to the stand at an increased rate, compared to what would occur naturally. The stand will survive, yet it will begin to decline more rapidly than without annosus root disease.

Where pine trees were planted on Forest Service land in Rush 2, no annosus mortality was observed. This is probably because the stumps were treated with SPORAX® or other borate compound. Stumps on private land were most likely not treated. Most of the planted pine trees on private land within the Rush2 area are too young to have contacted infected roots from harvested trees. Therefore it is difficult to know if annosus root disease

is present at this time. If annosus mortality does occur in untreated plantations, it will happen in trees planted close to infected stumps. Past experience with harvesting pine in California has shown annosus root disease to be more damaging in partial cuts than in clearcuts. This is because the root disease dies out in a clearcut before the planted trees reach maturity. Losing a few seedlings per acre to annosus root disease during the interim may not significantly impact the future stand. However, in selectively thinned stands of large pine trees, survival of the residual pine trees is much more critical since there are so few trees remaining. A stand of mature pine could be significantly impacted by annosus root disease after a thinning where the 14 inch and larger pine stumps were not treated with SPORAX®. This is because each large stump is connected to a large root system which has a high probability of contacting one or more leave trees, thereby transmitting the lethal annosus root disease. Therefore, it is recommended to treat the large pine stumps in the Rush2 area.

Alternative 3. Remove Most of the White Fir and Plant Ponderosa/Jeffrey Pine

There are many plantations in the Rush2 area where most or all of the white fir trees were removed and pine was planted. In mixed pine-fir stands, the pine may have been thinned or totally removed, as well. Generally these plantations appear to be growing well, even where the pure white fir stands were clearcut and pine trees were planted.

Clearcutting the pure white fir stands and planting non-host ponderosa pine is the only way to effectively control the S-type annosus root disease, short of removing white fir for 30 years or mechanically removing all infected fir roots before planting health white fir seedlings. For infected mixed pine-fir stands, cultural treatment, favoring pine as leave trees, can be an effective control for S-type annosus root disease. Removing all infected white fir and planting pine will control the fir annosus. As discussed above, it is highly recommended to treat all 14 inch and larger pine stumps with SPORAX® to prevent introducing P-type *H. annosum* and resulting mortality in large pine leave-trees.

If you need further assistance, please contact Bill Woodruff at 252-6680. A short biology of annosus root disease and a copy of FSH R5 Supplement 3409.11-94-1 are attached to provide more information on annosus root disease.

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APPENDIX

Biology of Annosus Root Disease (*Heterobasidion annosum*)

Heterobasidion annosum is a fungus that attacks a wide variety of woody plants. All western conifer species are susceptible. Madrone (*Arbutus menziesii*), and a few brush species (*Arctostaphylos spp.* and *Artemisia tridenta*) are occasional hosts. Other hardwood species are apparently not infected. The disease has been reported on all the National Forests in California, with incidence particularly high on true fir in northern California campgrounds. Incidence is somewhat higher in older, larger fir stands and in stands with high basal areas (over about 330 square feet/acre).

During periods favorable to the fungus, fruiting bodies (conks) form in decayed stumps, under the bark of dead trees, or under the duff at the root collar. New infection centers begin by aerial spread of spores produced by the conks and subsequent colonization of freshly cut stump surfaces or wounds on living trees. The fungus then spreads through root contacts into the root systems of adjacent live true fir. Local spread of the fungus from a stump typically results in the formation of a disease center, with dead trees in the center and fading trees on the margin. These centers usually continue to enlarge until they reach natural barriers such as stand openings or non-susceptible plants.

In pines, *H. annosus* grows through root cambial tissue to the root crown where it girdles and kills the trees. In less resinous species such as true firs, the fungus sometimes kills trees, but more frequently it is confined to the heartwood and inner sapwood of the larger roots where it causes a chronic butt and root decay and growth loss. Thus, while infection in true fir usually does not kill the host, it does affect its growth and thriftiness. Losses in true fir from *H. annosus* are mainly the result of windthrow resulting from root decay, and reduced root systems which predispose trees to attack and eventual death by the fir engraver beetle. Field observations suggest that vigorous young firs are usually able to regenerate root tissues faster than they are lost to the root disease. But when true firs slow in growth because of stand and/or site conditions, root development decreases to where there is a net loss in roots and the trees slowly decline due to the gradual loss of their root systems. This decline may take 10 to 20 years before tree death occurs.

Occasionally, infections will cross from roots of pine to roots of true fir; however, rarely is the fungus observed to cross from true fir to pine. At higher elevations where pine and true fir are intermixed, *H. annosus* is commonly found only on true fir and mortality rarely includes both species within an infection center.

FSH 3409.11 - FOREST PEST MANAGEMENT HANDBOOK
R5 SUPPLEMENT 3409.11-94-1
EFFECTIVE 5/17/94
CHAPTER 60 - MANAGEMENT OF SPECIFIC PESTS

62 - DISEASES.

62.2 - Other Diseases.

1. Introduction to Annosus Root Disease. This section describes annosus root disease in the Pacific Southwest Region, and discusses the biology and resource management implications of the disease. It also presents guidelines and techniques for its detection, and management strategies available for reducing its impact.

Annosus root disease is one of the most important conifer diseases in the Region. Current estimates are that the disease infests about 2 million acres of commercial forest land in California, resulting in an annual volume loss of 19 million cubic feet. Potential impacts of the disease include: increased susceptibility of infected trees to attack by bark beetles, mortality of infected trees presently on the site, the loss of production on the site, and, in recreation areas, depletion of vegetative cover and increased probability of tree failure and hazard. In recreation areas, annosus-infected trees are often extremely hazardous, causing death or injury to visitors, and damage to permanent installations and property.

The goal of annosus root disease management in the Region is to reduce resource losses to levels which are economically, aesthetically, and environmentally acceptable when measured against the objectives of the resource manager. It is possible to reduce the impact of annosus root disease through detection, evaluation, prevention, and suppression. These activities must progress in a planned, timely sequence for successful reduction of annosus root disease impacts. Detection and evaluation in individual stands are normally necessary before undertaking prevention and suppression action. In developed recreation sites, early recognition and removal of hazardous annosus-infected trees is critical, and will greatly improve chances of preventing future damage with minimal site deterioration. Prevention is the most desirable means of reducing losses. Undertake suppression activities only when needed to supplement prevention measures. The basic guidelines for detection (FSM 3410), evaluation (FSM 3420), prevention (FSM 3406.1) and suppression (3406.2) for any insect or disease also pertain to annosus root disease. However, consider the additional specific guidelines for annosus root disease summarized in this section.

Annosus root disease occurs on a wide range of woody plants. The disease affects all western conifers; hardwoods are generally resistant or immune. All the National Forests in Region 5 have reported finding it. Incidence is particularly high on Jeffrey pine in southern California recreation sites and on Jeffrey and ponderosa pine in eastside pine type forests. The disease, endemic in the Red and White Fir forest types, is associated with one-fifth or more of the true fir mortality in the forests surveyed in northern California.

2. Biology. Heterobasidion annosum (Fomes annosus) causes annosus root disease. The fungus is similar to the common heartrot fungi, and forms fruiting bodies or conks in decayed stumps, under the bark of dead trees, or, rarely, under the duff at the root collar.

Infection centers start when airborne spores produced by the conks land and grow on freshly cut stump surfaces. Infection in true fir may also occur through fire and mechanical wounds on the butt. Fresh basal wounds on species other than true fir are rarely colonized. The fungus grows down the stump into the roots and then spreads through root contacts into the root systems of adjacent live trees, resulting in the formation of enlarging disease centers. These infection centers may continue to enlarge until they reach barriers, such as openings in the stand or groups of resistant plants. In pines, the fungus grows through root cambial tissue to the root crown where it girdles and kills the tree. In true fir and other non-resinous species, the fungus sometimes kills trees, but is more frequently confined to the heartwood and inner sapwood of the larger roots. It then eventually extends into the heartwood of the lower trunk and causes chronic decay and growth loss, or failure at the roots. References that discuss the biology and disease cycle of H. annosum include Otrosina and Cobb 1989, and Smith 1993.

Heterobasidion annosum in western North America consists of two intersterility groups, or biological species, the 'S' group and the 'P' group. These two biological species of H. annosum have distinct differences in host specificity. To date, all isolates of H. annosum from naturally infected ponderosa pine, Jeffrey pine, sugar pine, Coulter pine, incense-cedar, western juniper, Pinyon, and manzanita are of the 'P' group. Isolates from true fir and giant sequoia are of the 'S' group. The biological species infecting other hosts are unknown at this time.

This host specificity is not apparent in isolates occupying stumps, with both the 'S' and 'P' groups recovered from pine stumps, and the 'S' group and occasionally the 'P' group from true fir stumps. These data suggest that infection of host trees is specific, but saprophytic colonization of stumps is not. The fungus may survive in infected roots or stumps for many years. Young conifers of a species that is susceptible to the particular intersterility group established near these stumps often die shortly after their roots contact infected roots in the soil.

Invasion of freshly cut stump surfaces by germinating spores is a critical stage in the disease cycle. Conks produce spores which disseminate throughout the year, but H. annosum is dependent on favorable environmental conditions for successful germination and establishment. Spores are inactivated by ambient temperatures of 113º F (45ºC) and mycelium in wood is killed after exposure for one hour at 104º F (40ºC). Temperatures just below the stump surface commonly reach or exceed the thermal inactivation level (40º C) of mycelium from April to September in the Southeastern United States. In eastside pine on the Lassen National Forest, lethal temperatures reach above 40ºC in the top 6 inches of 6-inch diameter stumps when exposed to direct sunlight for several days in the average summer. Temperatures do not approach the lethal range in larger size classes of stumps.

Stumps are susceptible to infection immediately after cutting. Ponderosa pine, Douglas-fir, and coast redwood stumps remain susceptible to infection for 2 to 4 weeks. The decrease in susceptibility with time is probably a result of colonization of the stumps by microorganisms that compete with and replace H. annosum. Surface area infection of freshly cut ponderosa pine stumps increases with increased photochemical oxidant injury.

Vertical penetration depends on temperature and extent of injury from other sources. After germination, vertical penetration into pine stumps averages 3 inches/month from October through May and 5 to 6 inches/month from June to October. The rate of vertical penetration in stumps from pine trees severely injured by photochemical oxidants is greater than in those from slightly injured or uninjured trees.

Heterobasidion annosum is an important agent predisposing conifers to bark beetle attack. In pines, the fungus weakens trees and increases their susceptibility to pine bark beetles. Infected true firs are predisposed to attack by the fir engraver. White fir mortality from the annosus root disease-fir engraver complex frequently occurs after tree growth decreases because trees are stressed. As a result of the stress, it is suspected that roots grow very slowly and decay faster than the tree can replace them. This predisposes the tree to fir engraver attack, and causes its death.

3. Detection. The general distribution of annosus root disease in the Pacific Southwest Region is known, but information on its location in specific stands may be needed. Based on Region-wide surveys, it is prudent to assume that the pathogen is present in all true fir stands, unless a detailed survey suggests that it is not. Collect location information for stands when planning management activities. Because trees affected by annosus root disease are easily windthrown or fall without visible symptoms that might warn forest recreation managers of impeding failure, the number, size, and locations of annosus infection centers within developed sites or sites planned for development should be determined. Field surveillance and detection surveys will locate occurrences of H. annosum.

4. Field Surveillance. Forest workers and managers, in connection with their regular duties, carry out day-to-day field surveillance (FSM 3411). Stand examinations, inventories and other activities afford excellent opportunities for forest workers to note and record the presence of H. annosum.

A systematic search for diagnostic symptoms of infection and signs of the pathogen, determines the presence of H annosum. Use the following similar symptoms for correct diagnosis:

a. Pattern of Dying Within the Stand. Root pathogens tend to kill trees over a period of years, with oldest deaths at the center, usually around stumps, and recently dead and dying trees at the margin. In contrast, a characteristic of mortality by bark beetles alone is groups of trees dying at about the same time.

b. Pattern of Dying of Individual Trees. Trees with root disease die gradually, with symptoms progressing from the bottom of the crown upwards, and from the inside of the

crown out. Infection of the roots causes: (1) reduced height growth, with crowns becoming rounded; (2) thin and chlorotic crowns, resulting from poor needle retention; and (3) subsequent insect attack of the stressed trees.

c. Symptoms and Signs in Roots and Root Crowns. Use symptoms and signs in roots and root crowns to determine the specific identity of the pathogen. The best evidence of H. annosum is the presence of characteristic fruiting bodies or conks. The annual to perennial, leathery conks vary in size and shape from small button-shaped or "popcorn" conks on the root surface of recently killed seedlings or saplings, to large bracket-type conks. The large conks generally have a light brown to gray upper surface, and a creamy white lower surface with regularly spaced, small pores. Small "popcorn" conks appear as small buff-colored pustules that range in size from a pinhead to a dime. They often have no pore layer. In pines, the conks are found between the bark and wood on stumps, beneath the duff layer at the root crown, and within old stumps. In true fir, the conks are found in cavities hollowed out by the fungus. Conks may be abundant in some stands and scarce or absent in others. Even when present, they can be easily overlooked because of their inconspicuous color and obscure location. Refer to Hadfield, et al. 1986 and Smith 1993 for color photographs of conks.

On pines, additional symptoms may be found by exposing the roots and root crown and examining the inner bark. Choose recently killed or dying trees for examination. Indications of H. annosum infection are: (1) easy separation of the bark from the wood; (2) the separated surfaces are a light brown to buff color, the surface of the wood streaked with darker brown lines; and (3) numerous small silver to white flecks on the surface of the inner bark. Resin often heavily infiltrates infected roots.

Incipient or early stages of wood decay are not very diagnostic. Discoloration may or may not be present and the heartwood remains firm and hard. As the decay progresses, the wood becomes white to straw yellow, separates along annual rings, and may contain elongated white pockets.

If field personnel are unable to identify H. annosum with certainty, or desire confirmation of a tentative identification, the Forest Pest Management Group can assist. Gather specimens of infected root tissue in various stages of decay and any fruiting bodies and send them to FPM pathologists in the Service Areas, or to pathologists in the Regional Office. The specimens must be of tissues in early stages of decay to enable isolation of the pathogen. A completed Forest Pest Detection Report (Form R5-3400-1) shall accompany the samples.

5. Detection Surveys. Personnel may conduct detection surveys (FSM 3412) in areas where no other surveys are scheduled and it is essential that the presence or absence of annosus root disease be known for management purposes. The objective of a detection survey is simply to determine the presence and location of H. annosum.

Because annosus root disease is not always obvious and can be difficult to detect, contact the Forest Pest Management Group with a request to conduct the survey if H. annosum has the potential to adversely affect activities or interfere with resource objectives.

6. Evaluation. The purpose of a biological evaluation (FSM 3421) is to provide information for the resource manager on annosus root disease infestations, their affects on the stand, the management alternatives appropriate in the context of the particular resource management objectives, and the future affects of each alternative. The Forest Pest Management Group or field personnel shall conduct biological evaluations of annosus root disease. Submit requests for a biological evaluation by sending a Forest Pest Detection Report (Form R5-3400-1) or written request to the Regional Forester or FPM Program Leader, or to one of the Service Areas. Field units shall coordinate requests through the appropriate line officer.

7. Management Strategies. Use the integrated pest management (IPM) approach to manage annosus root disease and other pests. IPM involves regulating the pest, the host, and the environment to minimize pest impacts on resource management objectives in ecologically and economically sound ways. Also, use the IPM approach to implement and coordinate activities needed to prevent or suppress pest-related problems. This approach also emphasizes the selection, integration, and use of a variety of tactics on the basis of anticipated economic and ecological consequences. Accomplish control of annosus root disease by prevention of new disease centers, thereby decreasing the risk of stump and wound infection, and through silvicultural manipulation of infested stands to minimize the impact of the disease.

8. Prevention. Prevention (FSM 3406.1) includes activities designed to minimize the impact of a pest before it appears. The objective of annosus root disease prevention is to prevent establishment of the disease in stands. Once annosus root disease becomes established in most forest stands, no economically feasible procedure for directly suppressing the disease is available. Therefore, prevention is the most efficient and economical method of reducing the impact of H. annosum. Prevention of annosus root disease includes treatment of freshly-cut conifer stumps with registered products. Other preventive treatments include carrying out silvicultural activities to lessen stand susceptibility to the disease, and minimizing logging damage and mechanical injuries.

9. Stump Treatment. Personnel can reduce the probability of infection of freshly cut conifer stumps by the use of a surface stump treatment with registered products. Contact Forest Pest Management for currently registered and effective materials. Treatment of freshly cut conifer stumps with two borate products (sodium tetraborate decahydrate and sodium octaborate tetrahydrate) indicate at least 90% efficacy in preventing infection. The borate in the formulations is toxic to the spores of the fungus and prevents germination; it does not have an effect on existing infections. Apply the products according to label directions. For maximum effectiveness, it is imperative to apply the material as soon after felling as practical and that the application cover the entire stump surface and other areas where the bark has been knocked off. The requirement for application in timber sales and other non-force account work shall be part of the contract or cooperative agreement. A Regional C provision is available for inclusion in timber sale contracts.

R-5 FSM 2303 requires treatment of all conifer stumps in recreation sites. The same direction shall apply to other high value areas, such as progeny test sites, seed orchards, and areas of high value trees, such as giant sequoia groves. In eastside pine or mixed

conifer type stands, where surveys have indicated high levels of annosus root disease, treatment of conifer stumps 12 inches ***(Note: Revised to 14 inches: Ref. Kliejunas & Woodruff, FHP Report # R04-01)*** or greater in diameter is highly recommended during chainsaw felling. When mechanical shearers are used, the minimum diameter should be reduced to 8 inches ***(also revised to 14 inches)***. These areas include the eastside pine and eastside mixed conifer types on the Modoc, Lassen, Plumas, Tahoe, Sequoia and Inyo National Forests; the Goosenest Ranger District, Klamath National Forest; and the McCloud Ranger District, Shasta-Trinity National Forests.

In all other areas, consider stump treatments on an individual stand basis. The line officer is responsible for the decision to treat freshly cut conifer stumps, and shall base that decision on information available for the specific situation in the particular stand in question. This information should include:

a. The objectives and management direction for the stand.

b. The level of annosus root disease currently in the stand or in nearby similar stands, determined by an examination of stumps for evidence of H. annosum and indications of infection in living trees.

c. An estimate of the cost-effectiveness of the treatment.

d. A Forest Pest Management biological evaluation or an on-site visit.

10. Avoiding Cambial Damage. In addition to being an aggressive colonizer of freshly-cut stumps, H. annosum can also act as a wound parasite by attacking living trees through injuries that expose cambial tissue. The fungus, as well as other decay fungi, are likely to colonize logging injuries, especially those in contact with the ground. Trees with nonresinous wood, such as true fir and hemlock, are more likely to be infected following injury and to have more extensive decay than species with resinous wood, such as Douglas-fir and the pines. Decay caused by H. annosum is common behind fire scars and other basal wounds in true fir. It may be possible to minimize losses by preventing fires that expose cambium when underburning for fuels reduction, and by reducing mechanical injuries during stand entries.

Other methods of prevention have been suggested, but consider these methods experimental until there is demonstrated efficacy under California conditions. These experimental methods include: (1) thinning during the hotter summer months; (2) creation of high stumps, and, (3) control of stocking density in true fir stands.

11. Suppression. Suppression (FSM 3406.2) of annosus root disease includes the reduction of damage to acceptable or tolerable levels. Direct suppression procedures for H. annosum, such as stump removal, creation of buffer strips, and soil fumigation, are costly and considered experimental. Indirect suppression options, that is, those that alter conditions favoring the pest through the application of silvicultural methods of stand manipulation, are available. These methods include species conversion, thinning in true fir stands, and in recreation areas, thinning and interplanting with hardwoods.

a. Species Conversion. Because of host specificity of the 'S' and 'P' types of H. annosum, favor the non-infected host species (see item 2.a.). In mixed conifer stands with infected true firs, the stand my be converted to pines and incense-cedar with little risk of subsequent infection. If pines are infected, favor true fir. In recreation areas, favor existing hardwoods or the non-infected conifer species. Since hardwoods are resistant, the fungus will eventually die out over a period of 2 to 4 decades, depending on stump size. Then, take steps to regenerate the conifers.

b. Thinning in True Fir Stands. Field observations suggest that removal of slow growing fir and thinning of overstocked stands to increase tree vigor may reduce the impact of the disease, given that the residual trees are capable of responding to release.

c. Revegetate Disease Centers. If consistent with site-specific objectives, resistant species can be used to revegetate active annosus centers. Leaving the centers barren or revegetating with hardwoods will allow the fungus to eventually die out over a period of several decades or more. Favoring hardwoods already present and planting suitable hardwoods provides a barrier of nonsusceptible roots that may limit the spread of infection centers. Thin dense pole-sized stands of susceptible conifers and interplant with hardwoods. Doing this minimizes opportunities for root contact and reduces the risk of further spread. It also increases tree vigor, which reduces risk of bark beetle attack.

d. Stump Removal. Removal of stumps and roots infected with H. annosum would reduce the amount of inoculum of the fungus on the site, and allow for earlier successful revegetation of the site with susceptible conifers. Stump removal as a suppressive method is being tested in several recreation sites, and its efficacy has not yet been demonstrated.

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