M e m o r a n d u m

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From: **Department of Forestry and Fire Protection**
Sacramento Headquarters

Subject: **Clearcut Adjacency Rule—Petition to the California State Board of Forestry and Fire Protection dated September 10, 2003 (Microclimate Rule Petition)**
Erosion and Sediment Yield

Abstract

This brief review was conducted to evaluate the potential effect that increasing the time and size requirements for adjacent harvest units before new clearcuts are permitted would have on reducing hillslope erosion and sediment yield potential. Most landslides occur in areas that can be determined in advance, such as inner gorge and headwall swale areas. These are specifically addressed in the existing FPRs. Data collected to date in northwestern California areas with sprouting coast redwood does not show a clear relationship between clearcutting under the current FPR regime (sometimes in combination with requirements included in landscape level documents) and landslide rates. Most of the recent mass wasting features are related to roads and landings. Improved Forest Practice Rules, mass wasting avoidance strategies, and requirements for professional input appear to be substantially reducing rates of mass wasting from northwestern California recent clearcuts. Changing the adjacency rule, as proposed, does not, in itself, address slope stability, and may give a false sense that extending the time between clearcutting of adjacent blocks will provide adequate protection from landslides. However, data collected at the Caspar Creek watershed, indicate that total sediment yields (including surface and channel bank erosion in addition to mass wasting) could be decreased if the time to completely harvest a planning watershed were greatly increased, because the effects of multiple clearcut disturbances on suspended sediment loads were found to be approximately additive. Modeling efforts also suggest that very rapid rates of clearcutting (approximately twice as rapid as is currently allowed by the FPRs) can concentrate the timing of sediment impacts. It is impossible to know exactly how much benefit would be derived with a 25 year—25 foot tall clearcutting rule from the existing literature, but the preponderance of evidence suggests that the benefit would be relatively small related to landsliding. Further data collection is needed before more definitive conclusions can be reached.

Background Information

At the request of Mr. Dennis Hall, Acting Chief of Forest Practice, we have prepared this brief review regarding whether a proposed change in the adjacency requirement of the Forest Practice Rules (FPRs) would likely reduce the potential for hillslope erosion (including mass wasting) and sediment yield.

The FPRs currently require that proposed evenaged regeneration units, including clearcut blocks, be separated by at least 300 feet in all directions (ref. 14 CCR § 913.1[933.1, 953.1](a)(3)). The rules also state that logging units contiguous to an existing evenaged management unit may not be harvested using an evenaged regeneration method unless the dominant and codominant trees average at least 5 years of age or average at least 5 feet tall, and 3 years of age from the time of establishment on the site, either by planting or by natural regeneration (ref. 14 CCR § 913.1(a)(4); with a slight variation in the Northern and Southern Districts). The FPRs provide further restrictions on operations on unstable areas or in watersheds with threatened or impaired values (ref. 14 CCR § 914.2 [934.2, 954.2](d), (f)(1), (2); and § 916.9[936.9, 956.9]).

The petitioner requests that the five year requirement of 14 CCR § 913.1(a)(4) be increased to 25 years and the five foot tall rule be elevated to 25 feet, so that the rule would state: logging units contiguous to an existing evenaged management unit may be harvested using an evenaged regeneration method when the dominant and codominant trees average at least 25 years of age or average at least 25 feet tall. The petition also states that "in addition to cooling air temperature, so vital for amphibians and the water temperature for threatened and endangered fish, this rule would reduce erosion and slow down habitat loss." A previous literature review examined how changes in air temperatures associated with clearcutting impacts stream water temperatures (Cafferata 2003). This review examines some of the literature regarding erosion and sediment yield associated with clearcutting.

Processes Associated with Hillslope Failure and Clearcutting

Landslides are ubiquitous in the California Coast Ranges as documented by regional geomorphic mapping (see, for example, Brabb and others, 1972; Nolan and others, 1978; Spittler, 1982; Davenport, 1984; Kilbourne and Morrison, 1985; Falls, 1999; Davenport and others, 2002; Fuller and others, 2002). These regional investigations are supported by detailed field studies (Weber and Nolan, 1991; Spittler and McKittrick, 1995). Even in areas where the slopes are considered to be fairly stable, such as the Sierra Nevada, landslides are a conspicuous feature on hillslopes (Wagner and Spittler, 1998). Sidle and Wu (2001) report that steep hillslopes with shallow soils in regions with high precipitation and recent tectonic activity are typically unstable, and shallow landslides are often the dominant erosion process. However, even within an unstable area, such as Bear Creek in southern Humboldt County, most of the watershed was not affected by landsliding during high intensity storms that occurred around New Years Day, 1997 (Pacific Watershed Associates, 1998; Spittler, 1998). Many areas where logging occurs pose virtually no potential for increasing sediment delivery to watercourses from either mass wasting or slope instability associated with timber harvesting.[1]

Landslides are not random events that regularly occur in unexpected areas. Hansen (1984) reports that most recent activity of deep-seated landslides consists of renewed movement of older deposits. Shallow debris flows typically occur in areas of convergent subsurface water on relatively steep slopes (Montgomery and Dietrich, 1994). Swanson and Dyrness (1975) report that the H.J. Andrews Experimental Forest in Oregon can be divided into two zones of approximately equal area, one susceptible to landsliding and one relatively stable. Following timber harvesting and road building, only two small road-related landslides took place in what they identified as the stable zone during the course of their study. In contrast, 139 landslides failed within the unstable area. In a study on the factors influencing sediment yields from timber harvested lands in California, Peters and Litwin (1983) identified that over 80 percent of the measured yield was produced by less than 15 percent of the plots. These potentially unstable areas can be identified to a large degree through geomorphic mapping, with inner gorges a primary source of landslides and sediment to many watercourses.

Landslides are caused by either a decrease in the resistance to gravitational forces, an increase in the effectiveness of gravity acting on a slope, or a combination of these (Johnson and DeGraff, 1988). When the shear strength of a potential failure surface is exceeded by the shear stresses acting upon it, displacements occur to bring the system back into equilibrium with the conditions at the time. Increases in stresses may occur due to external loads, such as soil or water, increased unit weight by increased water content, undermining of a slope, and shock waves, such as occur from earthquakes or wind coupling with trees. Strength may be decreased by swelling of clays by the absorption of water, buoyancy from a rise in groundwater, breakdown of soil structures, weathering or biochemical breakdown (Sowers, 1979), or by reductions in apparent cohesion resulting from a loss of root biomass. Clearcutting has a potential to affect many of these factors.

Croft and Adams (1950, in Sidle and others, 1985) are believed to be the first to report an increased tendency for landsliding during storms following timber harvesting. Sidle and others (1985) identify that reductions in root reinforcement as root systems die and temporary increases in soil moisture resulting from reduced evapotranspiration are the principal factors that increase landsliding following timber harvesting. Tree roots provide a component of shear strength that may aid in stabilizing slopes through the reinforcement of low-cohesion soils. Root reinforcement, depending upon the tree variety and root density, can increase the apparent cohesion of soil by 50 percent (Ziemer, 1981a,b,c; O'Loughlin and Ziemer, 1982). Following the removal of timber from a site, the roots of non-sprouting species decay, with smaller roots losing strength at a rate of 45 to 75 pounds per square inch per month (O'Loughlin and Ziemer, 1982). For slopes where new trees are planted, a minimum in effective cohesion is determined by the

[1] For example, 1-95-403 MEN logged 17 acres in southern coastal Mendocino County on slopes inclined an average of 10% or less. This ridgetop-harvesting plan included no watercourses and no winter operations were conducted.

volume, size, and strength of new roots compared with losses from the harvested trees. The rate of strength loss varies by species, root size, and activity of decay organisms, with small roots decaying most rapidly. Ziemer (1981b) reports that forests clearcut three years earlier contained about one-third of the root biomass of old-growth forests for non-sprouting mixed conifer species in the Klamath Mountains.

Unfortunately, relatively little work has been completed on second-growth redwood root decay following harvest. Ziemer and Lewis (1984) completed a brief retrospective study of root dieback in coast redwood. Root biomass in several different ages of cutblocks and second growth stands were plotted along with that found in old-growth forests. They reported that for redwood, root biomass dropped 42% in 11 years and thereafter began to increase again. Live root biomass declines, but does not drop to zero, after logging as coast redwood roots come into equilibrium with the drastically reduced above ground biomass. In forested areas, the influence of root reinforcement is limited to the depth of root penetration and the cohesive properties of the parent material. Two of the commercial species in California, Douglas-fir and redwood, have shallow root systems, and the depth of penetration is limited to about 15 feet. Cohesive properties of soils in California are also variable, and where soils are cohesive, roots have little effect.

Trees influence the amount of water in a slope through interception, evaporation, and transpiration. Dunne and Leopold (1978) report that the median canopy interception of rain by coniferous forest for 11 reported studies is 22 percent. Evaporation of this intercepted water between and during storms reduces the amount of water that reaches the soil. Forest vegetation also removes water from slopes through transpiration. Ziemer (1968) found that an isolated sugar pine located in the Sierra Nevada Mountains removed approximately 3,118 cubic feet or 23,300 gallons of soil moisture during the summer. The result of reductions in interception, evaporation and transpiration is an increase in soil and ground water that ultimately reaches stream channels. Following clearcut harvesting of about half of the North Fork of Caspar Creek watershed, Keppeler (1998) reports an increase in annual water yield of 15 percent during the eight years following the logging. This increase in subsurface water in hillslopes following timber harvesting can affect the stability of potentially unstable slopes.

Sidle and others (1985) report that the influence of timber harvest on slope stability depends on the density of residual trees and understory vegetation, rate and type of regeneration, site characteristics, and patterns of water inflow after harvesting. In areas with marginal slope stability, loss of root strength and/or increased soil moisture from reduced evapotranspiration following logging can lead to an increased rate of slope failure (Sidle and others, 1985; Ziemer, 1981a). The influence of timber harvesting on slope stability depends on site characteristics (slope, geologic parent material, past landslide history), the tree species present, density of residual trees and understory vegetation, rate and type of regeneration, and size of storm events that occur after harvesting (Sidle and others, 1985). In the Pacific Northwest where the tree species harvested do not sprout from the root mass, the period of increased landslide frequency after timber harvesting is elevated the most between the time of root dieback from harvested trees and the establishment of stabilizing roots by incoming vegetation (Swanson and Dryness, 1975). This period of time is considered to be from 3 to 15 years after clearcutting (Sidle and Wu, 2001).

Clearcutting and Changes in Landslide Rates/Sediment Generation

Numerous studies have compared erosion rates in clearcut and unclearcut areas for a given location. For example in the slide-prone Mapleton area of the Siuslaw National Forest in the Oregon Coast Range, Ketcheson and Froehlich (1978, in Sidle and others, 1985) found a 3.5 fold increase over a 15 year period in the volume of debris avalanches and torrents in clearcut areas versus forested areas. Similarly, landslide inventories in the Cascade Range in Oregon found 2.5 and 5.6 times greater soil mass movements in clearcuts compared to forested areas (Morrison, 1975; Swanson and Dryness, 1975; Swanson and Grant, 1982; all in Sidle and others, 1985). In the H.J. Andrews Experimental Forest in the Oregon Cascades, most hillslope failures in clearcut areas occurred in the first 12 years after cutting. Both the Oregon Coast Range and Cascade sites in these studies are dominated by non-sprouting Douglas-fir, and modern forest practices were not incorporated, such as vegetative leave areas in high risk locations (e.g., inner gorges, headwall swales).

More recently in Oregon, Robison and others (1999) reported on the erosional consequences of two very large storm events which occurred in February and November of 1996 in western Oregon. Both storms resulted in a large number of landslides, debris torrents, and altered stream channels. A three year monitoring project was undertaken to evaluate the effects of the storms. The majority of the identified landslides were not associated with roads, but were in clearcut units, with the highest hazard area for shallow rapid landslides occurring on slopes of over 70%. Data from this study indicated a higher incidence of landslides between 0 and 10 years after clearcut timber harvesting. At three out of four of the sites studied in very steep terrain, both landslide density and erosion volumes were greater in stands which were clearcut in the previous nine years. Landslides from recently harvested and older forests had similar dimensions, including depth, initial volume, and debris flow volume. However, increased rates of landsliding did not always occur for recently logged sites compared with nearby unlogged sites during the 1996 Oregon storms, and Robison and others (1999) could not document a consistent correlation between debris flows and clearcut sites when compared to mature second growth forest. It must be noted that this study documents the consequences of a single high intensity storm on slope stability. The study results may not be reasonably projected to represent the entire history of landsliding associated with clearcutting.

In California, Bawcom (2003) examined rates of mass failures for redwood dominated clearcuts in western Mendocino County on Jackson Demonstration State Forest (JDSF). For this area, little evidence was found to indicate that vegetation removal associated with clearcutting alone conducted under the modern California Forest Practice Rules (1982 to 1994) was a significant contributor to slope instability or reactivations of dormant landslides. Almost all of the observed landslides that delivered sediment to watercourses were shallow failures that were associated with old roads (particularly low on the slope near watercourses) that were constructed decades before the recent harvesting. Similar conclusions were reached earlier for the North Fork of Caspar Creek on JDSF by Spittler (1995) and Cafferata and Spittler (1998). They reported that the number and size of large landslides were similar in clearcut and unclearcut subwatersheds (up to the spring of 1998), and that road and landing design, placement and construction were the dominant controls on the number of shallow landslides in the Caspar Creek watershed. The two large landslides that did occur in clearcut units in the North Fork of Caspar Creek occurred approximately 9 to 11 years following harvest (Cafferata and Spittler, 1998; Bawcom, 2003).

The observations made on process and changes in landslide rates lead us to conclude that clearcutting, particularly of non-sprouting species, can increase driving forces on potentially unstable slopes through an increase in the unit weight of soil resulting from higher water contents. Clearcutting can also decrease forces that resist landsliding through increases in buoyancy and reductions in materials strengths, and from reductions in effective cohesion due to the loss of root reinforcement. Although the changes occur wherever clearcutting is practiced, only those slopes that are near the limits of their stability are likely to be affected. Even for these areas, there is only an increase in the *potential* for landsliding. If the sites are not affected by a significant storm event or by high total precipitation during the period of increased vulnerability, landsliding will not occur. Alternatively, for some high-intensity storms, perhaps including some of the 1996 Oregon storms, the component of stability afforded by trees may be inadequate to affect the rate of landsliding.

While clearcutting sprouting coast redwood dominated forests in the Caspar Creek watershed was not found to substantially increase the rate of landsliding, erosional impacts from the harvesting were documented. In the North Fork of Caspar Creek, approximately 50% of the area was clearcut from 1985 to January 1992, in 10 harvesting units. Timber was logged using mainly skyline yarding to a largely existing road system (spur roads for cable yarding were added). Sediment yields were documented at 13 gaging stations and three unlogged tributaries served as controls. Annual sediment loads increased 123 to 269% in the tributaries, but in the mainstem stations, increased loads were detected only in small storms and had little effect on annual sediment loads.

The combined effect of multiple disturbances on suspended sediment loads in the North Fork was found to be very similar to the sum of the effects of the individual disturbances. In general, downstream suspended load increases were no greater than would be expected from the proportion of the area disturbed (Lewis and others 2001). Lewis (1998) concluded that: 1) roads were relatively unimportant sediment sources in the North Fork due to their location on ridges away from channels, and 2) sediment increases from channel erosion associated with unbuffered small streams (i.e., Class III watercourses) in burned and, to a lesser degree, in unburned areas, were a significant sediment source in recently harvested areas.

More recent work in the Caspar Creek watershed has also found bank erosion to be an important sediment source. Tributary and headwater valleys show signs of incision along much of their lengths, and Dewey and others (2003) report that ongoing levels of suspended sediment delivery correlate well with total amount of exposed channel bank. On an annual to decadal time-scale, they found that rates of suspended sediment delivery per unit area of watershed area correlate better with the amount of exposed bank area in reaches upstream of stream gages, than with the volume of sediment delivered by landslide events, with total basin area, or with peak storm flow per unit area.

In summary, most areas, within even the most unstable watersheds, are not affected by landslides, whether or not the slopes have been clearcut and/or a major storm affects the area. However, a single large landslide, representing a very small proportion of a watershed, can have serious environmental consequences. For more stable basins, the percentage of the watershed likely to be affected by landsliding following clearcutting would be even lower. If precipitation intensities and durations are fairly low following clearcutting, unstable areas are unlikely to fail. Restrictions in clearcutting are needed to protect slope stability where there are potentials for failure. However, it must be recognized that for very large precipitation events, the influence of trees may have little consequence in stabilizing slopes. Additionally, in some watersheds, processes other than landsliding, such as channel bank erosion, may be more important for sediment generation.

<u>Modeling Scenarios for Varying Clearcutting Rates</u>

Ziemer and others (1991a) state that contemporary field data are not available to effectively test whether reduced rates of logging and dispersion will reduce cumulative watershed effects, due to insufficient time periods for measurement (i.e., several centuries). They used modeling exercises and assumptions about landsliding rates to provide insight into how different rates of clearcut harvesting and roading may impact watersheds over long time frames (Ziemer and others, 1991a; Ziemer and others, 1991b). Two different management regimes, both using a 100-year rotation for 25,000-acre watersheds with conditions similar to that found in coastal watersheds of California and Oregon, were modeled using Monte Carlo simulations. Forests included coast redwood and Douglas-fir in California and Douglas-fir and Sitka spruce in Oregon. In one scenario, one percent of the watershed was clearcut each year by cutting five widely dispersed 50-acre first order basins. In another scenario, 10 percent of the basin was clearcut each year, completing the logging and roading in the watershed in 10 years. [Note that if the BOF petition was accepted, it is estimated that it would take approximately 100 years to clearcut a planning watershed, compared to the current length of time of 20 to 25 years (B. Bush, Simpson Resource Company, Korbel, CA, per. communication). Therefore, the difference between the Monte Carlo simulation

treatments are about 2 times more extreme than the BOF petition requirement

(100% in 10 yrs or 100% in 100 yrs vs. 100% in 20 to 25 yrs or 100% in 100 yrs).]

Only the effect of landslide erosion from clearcut units and roads was considered, since a coastal watershed was being modeled and it was concluded that landslides are the most important process by which logging causes erosion and sedimentation damage to fish habitat. Mass wasting is also more likely to generate particles of a size that will affect stream bed stability than surface erosion (Ziemer and others, 1991a). Loss of root strength was assumed to be the principal factor predisposing clearcut areas to accelerated landslide erosion. The volume of erosion from logged areas was based on storm severity and relative root reinforcement, with maximum erosion occurring about 9 years after harvest. The effect of the varying logging strategies was recorded in terms of the magnitude and frequency of changes in bed elevation, which can directly affect fish spawning success (Ziemer and others, 1991b).

Predicted differences between the 10 percent progressive clearcut and the one percent dispersed logging strategies were much greater in the first century than in the second century. In the first century, model results indicated that the 10% progressive logging strategy produced about twice the frequency of bed elevation changes as did the 1% strategy. In the second century, there was little difference between strategies, when averaged over all reaches. The 10% strategy also predicted a concentration in the timing of stream bed disturbances, temporarily increasing the potential damage to fish populations. In addition, the models predicted that sediment resulting from road building and logging would be initially stored in low order watersheds and then exported downstream during large storms occurring in later centuries. The authors concluded that we may be underestimating the impacts from intensive activities in a single watershed in a short span of time, and that we may be underestimating the duration of effects (Rice, 1994). It is important to note that the practices considered when these papers were written have changed considerably in recent years, particularly in California watersheds with threatened and impaired values. Current FPRs preclude the modeled 10 percent progressive clearcuts. Watercourse and Lake Protection Zones, protection for unstable soils, and buffers for wildlife permanently limit the potential for clearcutting for a minimum of 15 percent of most watersheds. In watersheds with abundant unstable slopes this percentage is substantially higher. For the rest of the watershed, the existing adjacency rules would require 20 or more years for stand replacement, under even the most aggressive management (B. Bush, Simpson Resource Company, Korbel, CA, per. communication).

Sidle and Wu (2001) also conducted Monte Carlo modeling simulations to assess the effects of various timber harvesting scenarios in the Oregon Coast Range with non-sprouting Douglas-fir forests. The simulated temporal distribution of landslides during a 50-year timber harvest cycle that was 50 percent clearcut (randomly with blocking constraints) in year 0 agreed with field data: most landslides occurred in a period from 3 to 15 years after clearcutting. In addition, a scenario was run with vegetative leave areas, a practice used to reduce landslide occurrence in unstable portions of proposed clearcuts (such as headwall swale areas and inner gorges). Vegetative leave areas were found to be an effective control measure for reducing landslide occurrence. The simulations showed that failure potential was highest in sites with low root strength and sites where groundwater concentrates.

Another modeling exercise completed by Sidle (1992) for coastal Alaska revealed that shorter successive management rotations in Sitka spruce-western hemlock (non-sprouting species) forests caused a cumulative increase in the probability of slope failure. This was attributed to the inability of regenerating forests to reach their maximum potential root strength before the next harvest entry. It was concluded that maintaining viable understory root strength during harvesting cycles can greatly reduce the probability of slope failure (Sidle, 1992).

Current Evaluation of Potential Clearcutting Erosional Impacts

Timber Harvesting Plans (THPs) are currently screened by licensed geologists employed by the California Geological Survey (CGS) to determine if the proposed silvicultural treatments will present a high risk of significant hillslope erosion. Field inspections by licensed geologists are undertaken where there is a moderate or high potential. When clearcutting is proposed in the THP, the CGS geologists take into account whether the portion of the landscape in the clearcut unit has been previously clearcut once or twice, and the resulting erosion features that may have resulted from this treatment. In general, if the site has gone through previous clearcutting without producing large erosion features, it is more likely that this treatment will be rated as appropriate for this site again. Confidence in this conclusion would be higher if the field site had been tested by a significant storm event during the first 10 years following clearcutting, when root strength would be at its lowest point (J. Schlosser, Certified Engineering Geologist, CGS, Santa Rosa, per. communication).

In addition to review of proposed harvesting in THPs by CGS geologists, improved Forest Practice Rules (FPRs) to reduce landslide occurrence associated with clearcutting were included in the July 2000 Threatened and Impaired Watersheds Rule Package in California. These practices include: 1) establishment of a special management zone in which evenaged regeneration is prohibited where the inner gorge extends beyond the Class I WLPZ and slopes are greater than 55%, 2) review by a geologist of all operations on slopes over 65% in inner gorge of a Class I or II watercourse, and 3) for evenaged regeneration methods, establishment of a special operating zone that retains understory and mid-canopy conifers and hardwoods within an area that is either 25 or 50 feet wide above the Class I watercourse WLPZ, depending on slope class.

Sediment source area investigations conducted in southern Humboldt County illustrate important principles related to clearcutting and landsliding that occurred prior to current regulatory practices. For example, PWA (1998) reported that most of the landslides in Bear Creek, a highly erodible watershed tributary to the South Fork Eel River, were associated with inner gorge slopes. Both numerically and volumetrically, sediment production in both the pre-management (pre-1947) and post-management (post-1947) periods was dominated by landsliding from steep (greater than 65%) inner gorge and streamside slopes. PWA (1998) also reported that approximately 85% of the 1996/1997 landslide sediment came from 37% of the watershed logged in the previous 15 years. A third of this sediment delivery came during the large storm of 1997 from one slide on a planar slope in a logged unit where the role of tree removal was not clearly evident, and 75% of the slides occurred in inner gorge areas. Roads in this watershed were estimated to produce less than 10% of the sediment. The Bear Creak watershed may be unusual in its susceptibility to inner gorge landsliding, and sediment data derived from this basin cannot be generalized to extend to other watersheds. The major storm that triggered the landsliding produced the flood of record for nearby Bull Creek. This occurred within five years of the Petrolia earthquake (three shocks of M_L 7.1, 6.6, and 6.7). Because of this, it is not possible to determine whether or not the larger landslides would have failed without the recent shelterwood removal harvesting.

Practices now required by the July 2000 Threatened and Impaired Rule Package and that are part of the Pacific Lumber Company (PALCO) Habitat Conservation Plan (HCP) were developed to avoid high risk locations, such as inner gorge slopes. These requirements that are now included in PALCO's HCP for avoiding mass wasting features provide an example of how improved practices can reduce landsliding rates associated with clearcutting. Clearly, practices required in THPs approved since the PALCO HCP was signed in March 1999 have changed considerably. For instance, the HCP interim prescriptions (prior to watershed analysis) for PALCO timberlands prohibit harvesting practices that were associated with much of the earlier landsliding in the Bear Creek watershed—including ridgeline-to-inner gorge clearcuts. A review by Smelser (2001) of three THPs approved in 2001 found that none of them included ridgeline to inner gorge clearcuts, and the proposed harvesting was located on slopes outside of the debris slide amphitheater and far upslope from the inner gorge. Channel impacts observed following the December 2002 storm events (slightly greater than 10-yr recurrence interval 3-day precipitation and streamflow) in lower Bear Creek watershed did not indicate that significant new landsliding took place (Marshall, 2003) and there was no evidence that harvesting within the past three years had adversely impacted the lower part of the Bear Creek channel network (Cafferata and others, 2003).

Similarly, Marshall (2002) conducted an aerial photograph inventory of mass wasting erosion features in areas that were clearcut under PALCO's interim prescriptions for mass wasting avoidance in the Elk River watershed in Humboldt County. This landslide inventory found that "non-road related landsliding within recently harvested areas is minimal." Instead, road and landings were found to be the predominate sources of sediment compared to recently harvested hillslope areas, and that areas where landsliding was occurring were generally in the HCP mass wasting areas of concerns where harvesting is not allowed.

Protection Added by the Proposed Rule Change

The proposed rule changes do not address specific sites with respect to potential changes in slope stability. Areas that could potentially be affected by clearcut logging, such as inner gorges and historically active landslides, need protection that would not be addressed by the proposed rule change. These areas are currently addressed in the Forest Practice Rules. Effective July 1, 2000, the Board of Forestry and Fire Protection adopted protection for Threatened and Impaired Watersheds14 CCR § 916.9 (a) GOAL – "Every timber operation shall be planned and conducted to prevent deleterious interference with the watershed conditions that primarily limit the values set forth in 14 CCR § 916.2 [936.2, 956.2] (a) (e.g., sediment load increases where sediment is a primary limiting factor…).

Particular attention is being paid to identified unstable areas and geomorphic features related to landslides, including highly sensitive inner gorge areas. Furbish and Rice (1983) found that in the Hurdygurdy and Jones Creek watersheds of the Six Rivers National Forest, basal portions of slopes inclined 30^{o} (58%) or more accounted for about 30% of the study area and produced 88% of the landslide volume. These steeply inclined basal slopes are now called inner gorges, which CGS Note 50 describes as a geomorphic feature formed by coalescing scars originating from landsliding and erosional processes caused by active stream erosion. The feature is identified as that area of stream bank situated immediately adjacent to the stream channel, having a side slope of generally over 65 percent, and being situated below the first break in slope above the stream channel. The inclination of the slope associated with an inner gorge varies based upon the strength of the bedrock (Kelsey, 1988; CGS Note 50). 14 CCR § 895.1 Definitions, states: "Inner Gorge" means a geomorphic feature formed by coalescing scars originating from landsliding and erosional processes caused by active stream erosion. The feature is identified as that area beginning immediately adjacent to the stream channel below the first break in slope. 14 CCR § 916.9 (j) states, "Where an inner gorge extends beyond a Class I WLPZ (Watercourse and Lake Protection Zone) and slopes are greater than 55%, a special management zone shall be established where the use of evenaged regeneration methods is prohibited. This zone shall extend upslope to the first major break-in-slope to less than 55% for a distance of 100 feet or more, or 300 feet as measured from the watercourse or lake transition line, which ever is less. All operations on slopes exceeding 65% within an inner gorge shall be reviewed by a Registered Geologist prior to plan approval, regardless of whether they are proposed within a WLPZ or outside of a WLPZ."

Many of the existing Forest Practice Rules exist to limit hillslope erosion and the production of sediment that could enter watercourses. For example, these rules include restrictions on harvesting systems (914.2, 914.3), restrictions on winter operations (914.7) and log hauling (923.6), requirements for adequate watercourse crossings (923.3) and road drainage structures (923.4 (f), 923.2 (h, o, p,q)), proper road and landing location (923.1) and construction practices (923.2, 923.5), maintenance of erosion control measures (923.4), and adequate protection of sensitive riparian zones (916). More information on rules designed to minimize soil erosion is referenced in the final report to the California State Board of Forestry and Fire Protection on the Hillslope Monitoring Program (Monitoring Results from 1996 through 2001; see Cafferata and Munn, 2002).

Summary and Conclusions

- Studies in the literature report that clearcutting on steep, unstable slopes can lead to increased mass wasting in areas without sprouting species (e.g., Douglas-fir), where tree root systems die completely.
- Studies completed in areas with sprouting coast redwood in northwestern California have found much less of an increase in mass failure rates with clearcutting under the current Forest Practice Rules.
- Modeling efforts suggest that very rapid rates of clearcutting (e.g., 10 years to log 100 percent of the basin) concentrates the timing of impacts, temporarily increasing impacts on fish populations.
- If the length of time used to completely clearcut a North Coast planning watershed (typically 5,000 to 10,000 ac) is increased significantly, it is likely that the total amount of surface and mass wasting erosion (both from roads and clearcuts) will decrease, since the effects of multiple disturbances on suspended sediment loads in a North Coast watershed with clearcutting have been found to be approximately additive.
- Where mass wasting avoidance strategies are utilized as well as on-the-ground site review and recommendations by qualified professionals, initial reports suggest that clearcutting can be used without accelerating landsliding above background rates in northwestern California.
- Changing the adjacency rule as proposed does not in itself address slope stability and may give a false sense that extending the time between clearcutting of adjacent blocks will provide adequate protection from landslides. The Forest Practice Rules already contain specific provisions to protect unstable areas.

This brief review was conducted to determine if substantially increasing the length of time required to completely clearcut a planning watershed-sized basin would alter hillslope erosion and sediment yield potential. In northwestern California areas with sprouting conifer species, landslide rates do not appear to be significantly altered with clearcutting under the current Forest Practice Rule regime (sometimes in combination with requirements included in landscape level documents), since most of the recent mass wasting features appear to be related to road and landing features. In the Sierra Nevada, the rate of mass wasting occurrence is much less than that found in the Coast Range (Spittler, 1995), and it is likely that rapid clearcutting would generate much less impact than has been observed in Oregon with non-sprouting conifer species. Western Sierra uplift and downcutting rates are far slower than that found for the California Coast Range and the natural rate of landsliding is lower. However, if the time to completely harvest a planning watershed is greatly increased, it is likely that total sediment yield will decrease, since data collected to date in northwestern California indicates that effects of multiple clearcut disturbances in a watershed are approximately additive. Improved Forest Practice Rules and requirements for added input from professional geologists appears to be substantially reducing rates of mass wasting from northwestern California clearcut areas harvested under the existing adjacency rules. Further data collection in these types of watersheds and elsewhere is needed before more definitive conclusions can be reached.

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