

## Appendix 5: Calculation of cutting rate for Bear Creek watershed

Adapted from a report prepared for the California Regional Water Quality Control Board

### **Objectives:**

Calculate the rate of cut that would provide a hillslope landsliding rate that is <20% over background  
Calculate the effect of no-cut zones on inner-gorge slopes, stream-side slopes, and headwall and swales

### **Information used:**

85% of the landslide-derived sediment originates on the 37% of the area cut within the previous 15 years (PWA 1998a, p.18 ph.4)

69% of the hillslope landslides are on inner gorges, 13% are “streamside” failures, and 9% are on headwalls and swales (PWA 1998a, p.13, Table 2)

Not many of the Bear Creek units were clearcut: “Most logging during the period resulted in the removal of large conifers and the retention of understory vegetation and 20 year old conifer regeneration” (PWA 1998a, p.12, ph.3)

The Basin Plan calls for an increase in turbidity of no more than 20% above background levels

### **Assumptions:**

Landslide rates on areas cut >15 years earlier are the best available estimate of background rates

An increased landslide rate of <20% provides an average turbidity increase from landsliding of <20%  
15 years is sufficient to return to background landsliding rates after logging

Land-use activities upslope of a landslide-prone site do not affect the landslide rate at that site

### **1. Maximum rate of cut that would provide a hillslope landslide rate of <20% over background, assuming no areas are protected by no-cut buffers**

Since 85% of the landslide-derived sediment came from the 37% of the watershed that was recently cut, and the remaining 15% came from the 63% that was cut more than 15 years ago, the rate of landslide sediment production on <15-yr-old cuts is  $(.85/.37)/(.15/.63) = 9.6$  times higher than the rate on older cuts.

Under “background” conditions (i.e., the entire watershed cut more than 15 years previously), the annual sediment delivery per square mile from hillslope landsliding is denoted as  $R$  ( $\text{yd}^3 \text{ yr}^{-1} \text{ mi}^{-2}$ )  
If a proportion  $N$  of the watershed is cut within a 15-year period, that proportion will be producing hillslope landslide sediment at a rate of  $9.6R$ , and the total average hillslope landslide sediment delivery per square mile ( $S$ ,  $\text{yd}^3 \text{ yr}^{-1} \text{ mi}^{-2}$ ) from the watershed will be the sum of the background rate from the  $(1.0-N)$  of the watershed not recently cut, plus the increased rate from the proportion recently cut:

$$S = (1.0 - N) R + N*9.6 R \quad (1)$$

The value of  $S$  is to be kept at no more than 1.2 times the original value ( $S_o$ ), as calculated assuming the entire watershed remains uncut:

$$S_o = 1.0 R \quad (2)$$

Thus, the ratio of equations (1) and (2) must equal 1.2:

$$\frac{S}{S_o} = 1.2 = \frac{(1.0 - N)R + 9.6NR}{1.0R} \quad (3)$$

R can then be canceled out, and the equation rearranged to solve for N:

$$N = \frac{0.2}{8.6} = 0.023 \quad (4)$$

This result indicates that if 2.3% of the watershed is cut in a 15-year period, the resulting landslide rate will average 1.2 times the background rate. This cutting rate is equivalent to 0.15% of the area per year, or a rotation cycle of 645 years.

This rate assumes that no areas are protected by no-cut buffers.

## 2. The effect of no-cut zones on inner-gorge slopes, stream-side slopes, and headwall and swales

Inner gorges, stream-sides, swales, and headwalls were identified as the major sources of hillslope landslides; together, these landforms account for 90% of the total number of slides identified by PWA (1998a). The maximum rate of cut that would provide a hillslope landslide rate of <20% over background can be recalculated assuming that these areas are not logged.

In this case, the initial landsliding rate can be expressed as the sum of two components: 90% of the slides are from the area of inner gorges, streamside slopes, swales, and headwalls, and 10% are from the remaining area<sup>1</sup>:

$$S_o = 0.9R + 0.1R \quad (5)$$

Any areas recently cut would not include the protected areas, so the rate on those landforms remains the same as before, while the rate on the remaining area is substituted in from equation (1):

$$S = 0.9R + 0.1 [(1.0 - N)R + N*9.6R] \quad (6)$$

The value of S is again to be kept at no more than 1.2 times the original value ( $S_o$ ), as calculated assuming the entire watershed remains uncut, so the ratio of equations (5) and (6) must equal 1.2:

$$\frac{S}{S_o} = 1.2 = \frac{0.9R + 0.1[(1.0 - N)R + 9.6NR]}{1.0R} \quad (7)$$

As before, R can then be canceled out, and the equation rearranged to solve for N:

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<sup>1</sup> It should be noted that Dr. Daniel Opalach of Pacific Lumber Company, in a letter to Mr. Lee Michelin of the California Regional Water Quality Control Board dated 12 November 1998, expressed concern that equation (5) was in error and should be replaced by the expression,  $S_o = aR + (1-a)R$ , . The suggested replacement, however, is inappropriate as the rate variables  $S_o$  and R had been defined to represent a rate per unit area. Analysis of units for Dr. Opalach's equation demonstrates the problem:

$$\begin{aligned} \text{yd}^3\text{-yr}^{-1}\text{-mi}^{-2} &\neq \text{mi}^2 \times \text{yd}^3\text{-yr}^{-1}\text{-mi}^{-2} + \text{mi}^2 \times \text{yd}^3\text{-yr}^{-1}\text{-mi}^{-2} \\ \text{yd}^3\text{-yr}^{-1}\text{-mi}^{-2} &\neq \text{yd}^3\text{-yr}^{-1} \end{aligned}$$

The mis-match of units suggests that the definitions of the variables had not been clearly understood. Part of the reason for confusion, I believe, is the fact that equation (5) is simple enough that it begs for a more subtle interpretation. None is necessary. It was simply necessary to partition 90% of the slides per unit area ( $0.9R$ ) into the sensitive sites and 10% of them ( $0.1R$ ) into the rest of the sites as a lead-in to equation (6). The partitioning had to be on the basis of the proportion of slides on the site types rather than on the rate per unit area of the site types, since no information about the area represented by each site type was provided in the PWA report.

$$N = \frac{0.2}{0.86} = 0.23 \quad (8)$$

This time, the result indicates that if 23% of the watershed is cut in a 15-year period, the resulting landslide rate will average 1.2 times the background rate. This cutting rate is equivalent to 1.5% of the area per year, or a rotation cycle of 64.5 years.

This rate assumes that the full area of inner gorge, streamside slopes, headwalls, and swales is excluded from the area logged. Decreased levels of protection would require increased duration of the cutting cycle to compensate for increased rates of landsliding on unprotected or less-protected slide-prone areas. Because little of the recent logging in the area was reported to be clearcutting (PWA 1998a p.12), even selective cutting is assumed to be capable of increasing landsliding rates on the sensitive portions of the landscape.

### Example

This calculation may be easier to follow through the use of a more concrete example. Consider a watershed in which landsliding rates are 9.6 times higher on recently logged land than on land logged more than 15 years previously. If that watershed had remained uncut over the past 15 years, let it be characterized by a landslide count of 10 for a hypothetical storm. If that watershed had been completely cut within the past 15 years, it would then be characterized by a landslide count of 96 for the same storm.

Now, consider that 90% of the landslides were identified to occur on inner gorges, streamside slopes, swales, and headwalls. Under conditions with forests older than 15 years, there would thus be one landslide on the hillslopes outside of these areas, while under recently cut conditions, there would be 9.6 landslides outside of these areas.

If all areas of inner gorge, streamside slopes, swales, and headwalls are left forested, and thus assumed to experience the rate present for forested conditions, there will be 9 landslides in these areas under either cut or uncut conditions.

The total number of landslides under uncut conditions would then be 10, and under recently logged conditions, 18.6 (9 in the protected areas and 9.6 outside of those areas).

If the objectives of the Basin Plan were to be attained, management would be designed to reduce landsliding rates to less than 20% over background, so a target number of 12 slides or less would be desired (assuming that landslide sizes are distributed randomly among the site types). To achieve this level, an excess number of 6.6 slides would need to be prevented. Thus, 6.6 / 8.6 (equal to 77%) of the area outside of the protected areas would need to be covered by forests older than 15 years at any time. This means that 23% of the watershed (exclusive of the protected areas) can be cut over a 15-year period, which is equivalent to 1.5% of the unprotected area of the watershed per year.

### Discussion

These results indicate that cutting cycles on the order of those described by the SYP/HCP can be maintained only if the logging is dispersed through time in any given watershed and only if the areas most susceptible to landsliding are well-protected. If the cut is more intensive than 1.5% of the watershed area per year, then the likelihood of sediment inputs of more than 20% over background from landsliding is relatively high, as storms capable of generating landslides have a recurrence interval of about 10 years (Reid 1998b). If landslide inputs are substantially higher than background rates for a particular storm of a given size, then the likelihood of persistent aggradation—and long-term habitat degradation—is significantly increased. In other words, it is important that the average increase in sediment input in any given year is not large, since it may require many decades for a

system to recover from one year's sediment overload (e.g. Madej and Ozaki 1996). Maintenance of sediment input levels at rates below those that might trigger pervasive aggradation could result in the maintenance of tolerable habitat in perpetuity, while several years' input at very high rates could result in prolonged periods of inadequate habitat, even if the long-term average input rates are the same in both scenarios.

Note that the assumptions used to calculate these values may not sufficiently conservative from the point of view of protection of public trust resources. In the first place, rates of landsliding on cuts older than 15 years are expected to remain significantly higher than rates in old-growth forests on similar rock-types. This assumption could be tested by evaluating rates in areas on similar rock-types that have remained undisturbed for longer periods. Second, field observations by T. Spittler (personal communication, 21 August 1998) suggest that upslope logging can contribute to destabilization of uncut inner gorges downslope of the logged areas; rates of sliding on uncut inner gorges may thus remain higher than background rates. Third, the proportional increase in turbidity for landslides in managed basins is likely to be higher than in unlogged basins because woody debris loadings are expected to be lower, over the long-term, due to selective logging of trees that would otherwise have fallen into streams and provided storage for landslide-derived sediment. This effect will be particularly important in small, intermittent channels.

In any case, the report prepared by PWA (1998a) provides the information required to estimate the logging intensity required to meet the objectives of the Basin Plan for sediment derived from non-road-related landslides. To the extent that other sediment sources are also accelerated by logging, the rate of cut might need to be further decreased to provide mitigation for other sediment sources, such as surface erosion and road-related erosion.