GEOMORPHIC ASSESSMENT OF THE CORTE MADERA CREEK WATERSHED

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EXECUTIVE SUMMARY

Sand and gravel deposition in the flood control channel downstream from Ross creates a common perception that the Corte Madera Creek watershed produces an unnaturally high sediment yield. Channel widening and local bank failures throughout the watershed's alluvial channel network also create a common perception that channel bank erosion produces a significant portion of the sediment yield. Sand and gravel comprise the coarse portion of sediment inflow at Ross, or the 'bedload'. Sand and gravel bedload deposition in the flood control channel significantly reduces its flood control performance. For this reason, estimating the amount and sources of bedload sediment inflow at Ross is of particular concern to this study. This study presents a preliminary estimated bedload sediment budget for Corte Madera Creek at Ross and evaluates whether or not the sediment load at Ross is unnaturally high. To focus possible future remedial efforts, this study also evaluates whether or not channel erosion contributes a significant portion of the sediment yield. The budget accounts for sediment generated by net channel bed and bank erosion along the alluvial channel network, and sediment generated by fluvial transport from unregulated upland areas above Ross (about two square miles of the Ross Creek subwatershed is regulated by Phoenix Reservoir). The budget provides a preliminary, uncalibrated estimate of total sediment yield at Ross that can be compared to published COE sediment yield estimates at Ross and sediment yields measured or estimated for other comparable watersheds in the region.

This study also presents an independent bedload sediment inflow estimate at Ross obtained from a Parker-Klingeman sediment transport model calibrated with available existing USGS bedload transport data. This yield value can be compared to this study's sediment budget estimates, COE bedload inflow estimates, and other regional data.

Sediment Budget Methods

To quantify the upland sediment budget components, the Parker-Klingeman bedload transport model was used to estimate bedload sediment yield from ten major Corte Madera Creek subwatersheds. Seven of the major subwatersheds contribute sediment from 72 percent of the unregulated drainage area above Ross. The study also substituted Parker-Klingeman shear values with USFS shear values to provide a range of estimated values. The sediment budget allows comparison of sediment contribution per unit drainage area for various upland source areas in the watershed. This study also produced qualitative sediment yield classification maps based on existing USGS landslide habitat and slope stability data to provide independent predictions of relative subwatershed sediment yields.

To quantify sediment contribution from the alluvial zone, this study resurveyed 44 historical channel cross-sections and historical channel bed elevations compiled from 1976 FEMA and HUD Flood Insurance Study records. These comparative data combined with extensive field observations provided average values of net channel bed lowering and channel bank retreat from which sediment yield by both channel bed and channel bank erosion in the entire alluvial channel network could be estimated for 1976-1999. Thus, the budget also allows sediment yield by channel bed and bank erosion to be compared to sediment yield by fluvial transport from aggregate hillslope sediment sources in the surrounding upland areas.

Sediment Budget Results

This study's uncalibrated sediment budget estimates that the Corte Madera Creek Watershed supplies about 7,250 tons of bedload each year to the reach above Ross. The calibrated Parker-Klingeman sediment transport model estimated average bedload sediment inflow at Ross is about 6,750 tons/year. Using an average of the two results, the study estimates that about 7,000 tons/year of bedload are delivered to Ross, or about 450 tons/sq.mi./year. This range of estimated values is about 45 percent greater than Lehre's (1982) detailed estimate for the Lone Tree Creek basin (240 tons/sq.mi./year), a comparable basin in southwestern Marin County with fewer upland roads and less precipitation. Due to persistent upland land use impacts, namely increased drainage density caused by 19th century logging and grazing, the Corte Madera Creek watershed's bedload sediment yield can be considered to be unnaturally high. If the natural background rate were estimated conservatively to be 350 tons/sq. mi./year, than the human-induced increase in bedload inflow at Ross would be about 1,600 tons/year.

This study's estimates of bedload inflow at Ross are about 40 percent less than the 11,070 tons/year value the COE's 1989 sediment transport model predicted for average bedload sediment inflow at Ross. It should be noted that this study's bedload sediment yield estimates are expected to be about 10 percent less than the COE's model prediction, because this study's estimate did not include 'very fine' and 'fine' sand size fractions that were included in COE's bedload inflow prediction. Thus, this study's prediction is about 20-30 percent less than COE's estimate.

This study's bedload yield estimates are also about 40 percent less than values estimated in the Eel River watershed, which can be considered upper limit values due to a greater degree of melange deformation and tectonic uplift, and continuing upland land use impacts. Yields from the Eel River basin are among the highest in western North America. The COE's yield estimate is closer to upper limit values measured in the Eel River basin than this study's estimate, or results from other studies in the region.

Sediment Sources in the Watershed

This study's sediment budget estimated that channel bed and bank erosion in the watershed's alluvial channel network generated about 9 percent of the total bedload sediment load at Ross, for 1976-1999. Observed average channel bed incision and bank retreat rate estimates were comparable to average values reported in the existing studies of comparable watersheds (i.e. Novato Creek and Walker Creek). Fluvial transport from upland channel networks generated about 91 percent of the total sediment yield at Ross. This 91:9 ratio of upland/channel bank sediment sources is comparable to results of detailed sediment budgets compiled for other Marin County watersheds and Eel River tributaries.

Total elimination of bank erosion and systemic channel widening throughout the alluvial channel network would probably reduce bedload sediment delivery to Ross by as much as about 430 tons/yr, only 6 percent of the total bedload delivered to Ross. Total elimination of the additional sediment supply by restoration of problem sediment sources and improved hillslope management practices would probably reduce bedload sediment delivered to Ross by as much as about 1,600 tons/yr, or about 20% of the annual bedload inflow.

This study indicates that the San Anselmo Creek and Sleepy Hollow Creek subwatersheds contribute about 29 percent and 26 percent, respectively, of the total bedload sediment inflow at Ross. Detailed sediment budget studies of northern California Coast Range watersheds indicate that the sediment source mechanisms dominating long-term average sediment yield are landsliding and earthflows. Thus, the frequency of mass wasting can probably be considered a suitable surrogate for long-term average bedload sediment yield in the Corte Madera Creek watershed. Available interpretive USGS maps of potential hillslope instability and landslide frequency show that greatest potential hillslope instability and landslide frequency occurs in the San Anselmo Creek and Sleepy

Hollow Creek subwatersheds. Field reconnaissance also provided evidence that these subwatersheds produce relatively large sediment yields.

Other studies have shown that underlying geologic type is one of the strongest influences on hillslope and total sediment yield. Kelsey (1980) showed that rolling-to-hummocky grassland and grass-oak woodland-covered Franciscan melange slopes can produce about 30 times more sediment per square mile than steep, forested sandstone and shale slopes. The San Anselmo Creek and Sleepy Hollow Creek subwatersheds have a greater percentage of grassland, grass-oak woodland, and chaparral-covered melange slopes than other Corte Madera Creek subwatersheds. Forested sandstone slopes occur primarily in the Larkspur Creek, Tamalpais Creek, and Ross Creek subwatersheds above Phoenix Lake, and substantial portions of the Fairfax Creek subwatershed.

Present Trajectory of Channel Change

This study also evaluated the present state and trajectory of the channel's natural geomorphic recovery from recent channel entrenchment. Corte Madera Creek's alluvial channel network became moderately to deeply entrenched in the Holocene valley fill in about 1850-1910, abandoning its pre-entrenchment floodplain. Rapid channel entrenchment was evidently in partial response to logging and increasing livestock grazing intensity from the middle to late 1800s, coinciding with a period of somewhat greater than normal precipitation. After about 1910, numerous natural bedrock and human infrastructural grade controls outcropped in the channel bed, slowed the channel incision rate, and accelerated channel widening. Natural geomorphic recovery processes that recover aquatic and riparian habitat lost during channel entrenchment are operating in the Corte Madera Creek watershed, including: progressive upstream channel aggradation in the lower portion of the mainstem Corte Madera Creek, and channel bed level stabilization, channel widening, inset floodplain formation, and pool-riffle development in the middle and upper portions of the alluvial channel network.

Progressive upstream channel aggradation evidently ceased in about 1964. Ongoing channel widening, and inset floodplain formation in the middle and upper portion of the alluvial channel network indicate that natural geomorphic recovery processes are ongoing but incomplete in the Corte Madera Creek watershed. However, constraints imposed by urbanization of the pre-entrenchment floodplain limit the rate of natural habitat improvement both by preventing channel widening with bank protection and flood control structures, and routing storm water directly into the channel network from impermeable surfaces. As a priority, projects intended to improve flood control and/or aquatic and riparian habitat and habitat-supporting processes and flood control should seek opportunities, where possible, to increase active channel width rather than strictly prevent bed incision or bank retreat. This study presents a conceptual demonstration floodplain restoration/construction project design for a hypothetical site in the watershed with sufficient undeveloped land adjacent to the channel. This study also presents a conceptual design for streambank stabilization for a hypothetical site where residential and commercial development prevent extensive floodplain restoration/construction. This study also presents a methodology and preliminary suitability mapping to implement site stormwater retention/drainage best management practices that would increase alluvial groundwater storage and summer low flow discharges in the watershed. Discontinuous surface flow during the summer low-flow season is an important limiting factor for salmonid habitat.