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THE EFFECTS OF INTENSIVE FOREST LAND-USE AND SUBSEQUENT LANDSCAPE REHABILITATION ON EROSION RATES AND SEDIMENT YIELD IN THE COPPER CREEK DRAINAGE BASIN, REDWOOD NATIONAL PARK

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Abstract. The detailed erosional inventory of a 246 hectare tractor yarded clear-cut area in the Copper Creek drainage basin, a tributary to Redwood Creek, indicates widespread management-related sediment production and yield. The most important sources were gullies and enlarged channels caused by stream diversions. These accounted for 83 percent of the total measured erosion of 124,435 cubic meters. Ninety-two percent was attributed to four management-related causes while over 80 percent could have been entirely avoided by better land-use practices. Most of the increased erosion occurred during three major storm periods in 1972 and 1975. The delivery ratio for 91 percent of this erosion is conservatively estimated at 0.85. By 1979, 47 percent of the gully systems were inactive. Erosion control eliminated roughly 80 percent of the continuing and expected future management-related erosion.

INTRODUCTION

A significant problem associated with timber harvesting in mountainous terrain is the degradation of watershed resources resulting from increased rates of soil erosion and sediment yield. Few places in North America display this more graphically than the Redwood Creek basin where physiographic, geologic and climatic factors and complex land-use patterns have contributed to exceptionally high rates of erosion. For example, during six years of record beginning in 1971, Redwood Creek at Orick, California, transported a mean annual suspended sediment load of 2,619 metric tons per square kilometer (7,480 t/mi^2), 32 percent higher than the Eel River at Scotia, California (Janda, 1977), which has previously been characterized as the most rapidly eroding, non-glaciated basin of comparable size in North Amercia (Brown and Ritter, 1969). While Redwood Creek's suspended sediment discharge has been estimated to be 8.6 times greater than the expected normal rate of delivery (Anderson, 1979), some tributary basins displaying severe ground disruption from recent timber harvesting have yielded 17 times as much suspended sediment, per unit area, as nearby unharvested basins (Janda, 1977). One such highly impacted area is the Copper Creek drainage basin, a 7.3 km^2 (2.8 mi^2) watershed

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recently incorporated within the expanded boundaries of Redwood National Park (figure 1).

Prior to timber harvesting, 59 percent (445 hectares) of the Copper Creek drainage was covered with conifer forests dominated by coastal redwood (Sequoia sempervirens) and Douglas-fir (Pseudotsuga menziesii). Vegetation on the remaining 41 percent (314 hectares) consists of Oregon white oaklands (Quercus garryana) on the middle and upper slopes and prairie grasslands along the ridgetop areas. The conifer forest lands were logged between 1955 and 1971 with three years of multiple re-entry selective logging from 1958 to 1961 followed by clear-cutting and tractor yarding of the remaining residual timber in 1970-1971. This final phase of logging was marked by extreme ground disturbance (approximately 80 percent bare soil) over virtually the entire forested portion of the basin. In conjunction with the rehabilitation of the 246 hectare (607 acre) cutover area south of the main channel of Copper Creek in 1979, a detailed inventory of erosion sources was conducted to determine the magnitude and causes of accelerated erosion rates and to identify the extent to which various types of erosion on tractor-logged slopes have contributed to increased sediment yields.

SITE DESCRIPTION

This report deals with data collected on the logged portion of the Copper Creek basin south of the main stream channel and upstream from the K & K bridge crossing (figures 1 and 2). The site, which excludes the oak woodlands and prairie grasslands extending upslope from the boundary of the logged area to the divide, represents approximately 32 percent of the watershed and 55 percent of the cutover area within the basin. Figure 3 depicts a portion of the study area immediately following logging in late winter, 1972. Elevations at the site range from 170 to 730 meters (560 to 2,400 feet) and the average hillslope gradient ranges from 30 to 50 percent.

The Copper Creek watershed is underlain by interbedded graywacke sandstones, mudstones and conglomerates of the Franciscan complex. Hugo soils overlay most of the fractured bedrock found within the basin and study site. The Hugo soil series is widespread in forested areas on Franciscan terrain and represents over half of the forest soils in Humboldt County (Cooper, 1975). It is a fine loam, which typically develops on colluvial material and exhibits a comparatively high infiltration capacity. Soils of the Atwell series also occur locally on the study site and are predominately exposed along the streamside slopes of Copper Creek and its tributary channels. The high clay content of this soil and the highly fractured siltstone and mudstone parent materials on which it forms explain its close association with areas of slope instability.

Annual precipitation near Copper Creek, between 1938 and 1980, averaged approximately 2,032 mm (80 inches). Four major storms (1964, 1972 (2), and 1975) have occurred in Copper Creek since logging activities began in 1959. While the magnitudes of the 1972 storms were probably less than either the 1964 or 1975 rainfall events (Harden et al., 1978), their erosive impact may have been greatest, since clearcutting and tractor yarding was completed the year before. Dendrochronological evidence not presented in this report suggests that timing of the four major storms correlates well with the most active periods of gully development on the study site.

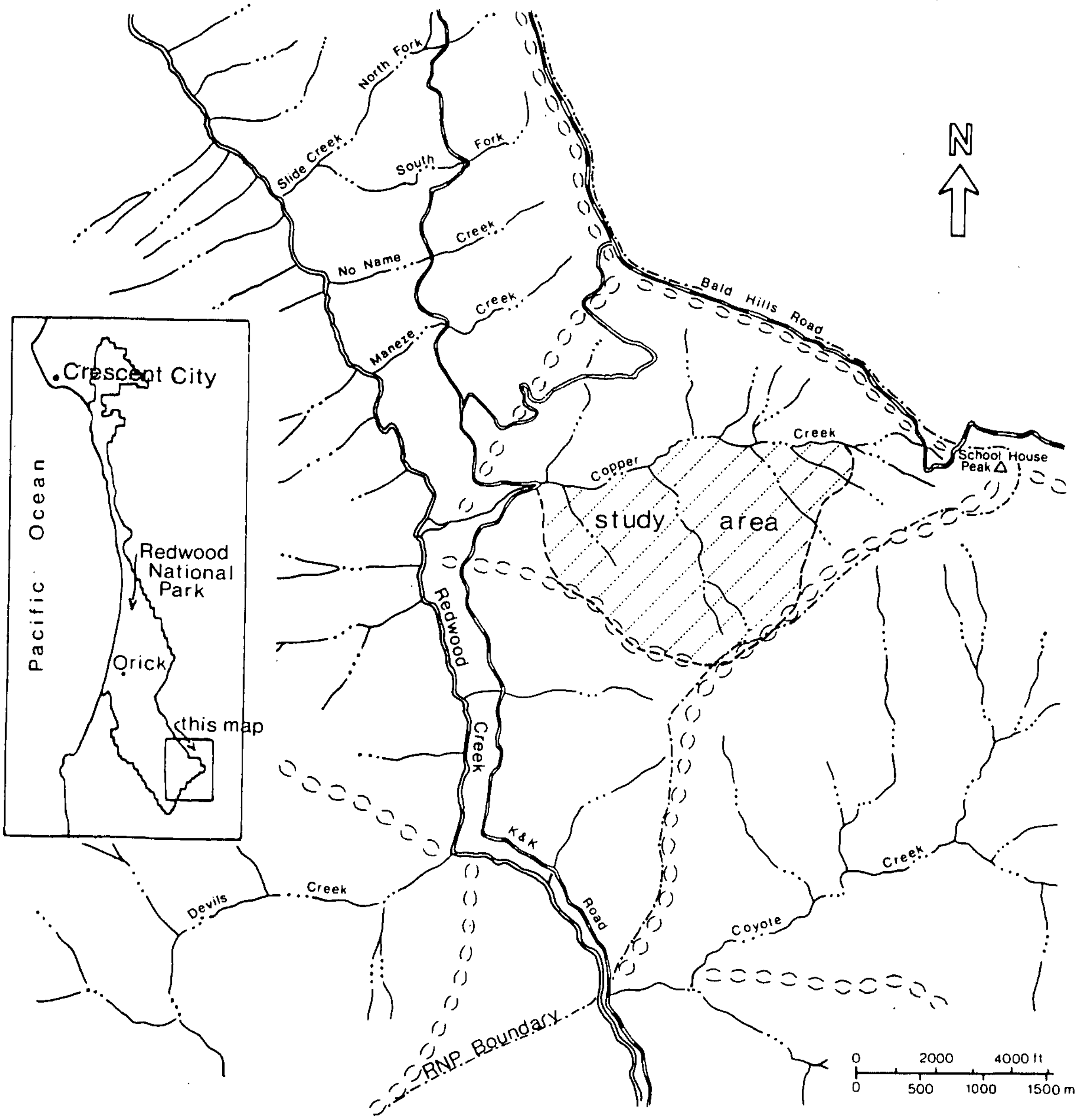
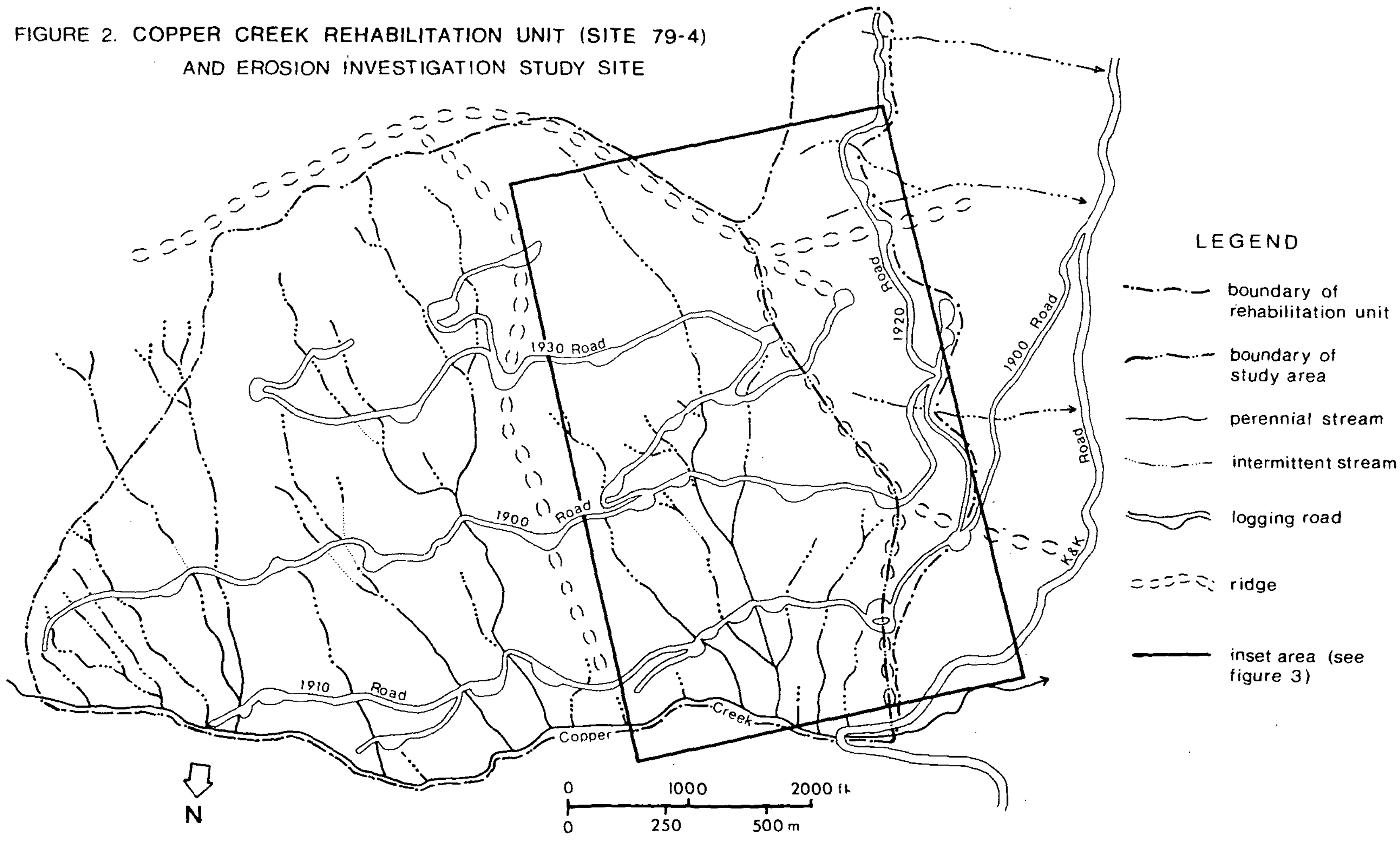


Figure 1. Location of Copper Creek Drainage Basin and Erosion Study Investigation Site

FIGURE 2. COPPER CREEK REHABILITATION UNIT (SITE 79-4) AND EROSION INVESTIGATION STUDY SITE



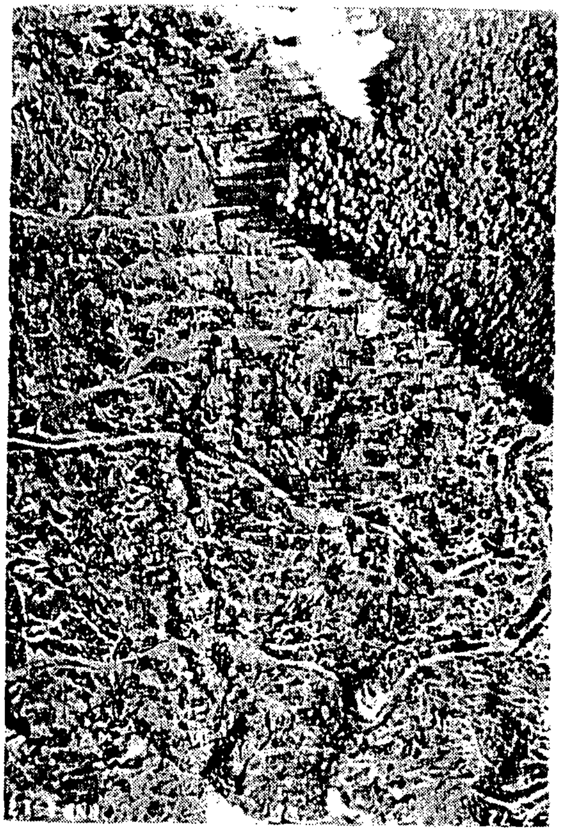


Figure 3. Aerial photograph (3/7/72) of west section of study site (see inset area, figure 2). Photo shows site conditions following 20 year return period runoff event. Note the degree of ground disturbance associated with the clear-cut tractor yarding completed in 1971. Old growth forest (upper right, outside of study area) was logged the following year.

METHODS

As a prerequisite to watershed rehabilitation activities, a detailed geomorphic map of the site was compiled during 2.5 months of intensive field work by several geologists. Active and inactive erosion sources, including all gullies with cross-sectional areas as small as 0.09 square meter (1 ft^2) were located and plotted on enlarged aerial photographs. With this geomorphic base map to guide future work, a two-phase, quantitative inventory of sediment sources was then initiated.

Exclusive of rilling, sheetwash, and small cutbank failures, erosional features on and adjacent to 9.3 kilometers (5.6 mi) of logging road and 27 log landings were numbered and indexed, according to grid coordinates, on the geomorphic base map. The field data sheets include sketches, volumetric measurements, detailed descriptions and causes of the erosional features. Feature lengths and cross-sections were measured with a tape and survey rod. Cross-sections were measured at 6.1 meter (20 ft) intervals or more frequently if a significant change in size or shape occurred. A total of approximately 160 erosional features were described and measured in the roads survey.

In its second phase, the survey focused on erosion features found on slopes adjacent to the major road systems and within the study area (figure 2). These included enlarged or gullied natural stream channels as well as all newly formed hillslope gullies greater than 0.27 square meters (3 ft^2) in cross-sectional area. Interfluve gullies smaller than this were often included in the measurements when they were elements of dicontinuous systems containing larger gullies. The only features excluded from the hillslope inventory were sheet and rill erosion, and isolated streambank failures along otherwise unimpacted watercourses (those not subjected to substantially increased discharges). The field methods defined in the road erosion survey were also used to measure and describe erosional features on the slope. However, the detailed sketches included in the road survey were usually replaced by verbal descriptions in order to facilitate measurements. A total of approximately 180 features representing 15.5 kilometers (9.3 mi) of gullies and gullied natural channels were included in the slope survey.

The analysis described below combines the information from the road erosion survey and the slope erosion survey. The data set consists of approximately 340 features or 3,500 cross-sectional measurements representing the total volume of erosion measured in the field. Locating and determining causes for erosion were often the more time-consuming and difficult aspects of the field study since causes were sometimes obscure and often, more than one cause could be attributed to a single erosional feature. Primary and secondary causes were located and recorded in the field for each erosional feature. This study presents only the primary causes. In a few cases, where two causes seemed to equally influence a feature, both causes were listed as primary and the volume was divided between them.

ACCELERATED EROSION

Gully systems on the site are widespread, complexly interconnected and represent the most dominant erosion process contributing to increased sediment yield. (Table 1). The majority of gully-causing problems are associated with numerous

TABLE 1. SOURCES OF SEDIMENT PRODUCTION FROM THE COPPER CREEK STUDY AREA, 1971-1979

Sediment Source	Total Hillslope Erosion[a] (% by length)	(% by volume)	(% stored locally)	(% transported downslope)	(m^3)	(yds^3)
New gully systems	90	70	0[b]	70	87,104	113,933
Gullied or enlarged stream channels	5	13	0[c]	13	16,177	21,159
Logging road fill failures	1	2	1	1	2,489	3,255
Slumps on logging roads	2	4	4	0	4,977	6,510
Landslides associated with logging roads	1	8	4	4	9,955	13,021
Combined gully/fill failure on logging road	1	3	0	3	3,733	4,883
Totals...............	100	100	9	91	124,435	162,761

a. does not include 12,030 m^3 of landslide erosion contributed from the sideslopes of the study area along the Copper Creek channel; excludes sheet and rill erosion and isolated tributary bank failures.

b. only the voids of gully channels were measured; no attempt was made to measure stored sediment on the gully bed, hence all eroded sediment, represented by void space, had been transported downslope.

c. on-site storage of sediment in the tributaries to Copper Creek is estimated at far less than 10 percent of total hillslope erosion; steep, supply-dependent streams moved virtually all erosional products supplied to them downslope and, eventually, off-site.

diversions of low-order stream channels on the clear-cut hillslopes. These problems reflect widespread tractor disturbance in and adjacent to the natural channel system, the lack of road maintenance between the initial selective harvest and subsequent re-harvesting, and the abandonment of the dead-end logging road system after clearcutting activities were completed in 1972. For example, by 1979, 18 of 23 culverts (78 percent) positioned along the 9.3 kilometer (5.6 mi) road network were totally ineffective and two of the five functioning culverts were partially plugged with sediment and debris. Such failures frequently led to road wash-outs or stream diversions and the creation of hillslope gullies. In addition, logging haul roads crossed 24 ephemeral and intermittent streams where no drainage structures were installed to transport streamflow through the road prism. These, together with numerous skid-trail stream crossings on hillslope areas, also served to divert previously channelized runoff across bare soil areas and resulted in the development of extensive gully networks.

In addition to gullying, accelerated erosion within natural, pre-existing stream channels contributed to sediment production from the tractor-yarded areas. Deterioration of skid-trail stream crossings and tractor disturbance adjacent to stream channels directly introduced soil and organic debris into the streams. Skid-trail crossings commonly diverted streamflow out of one stream, across hillslopes and into another stream system, resulting in the adjustment and enlargement of channel dimensions due to increased discharges. Soil and organic debris perched on steep channel-sideslopes caused slope failures into the adjacent stream channels. This debris, in conjunction with increased surface runoff and sediment delivery from cutover hillslopes, initiated additional channel enlargement and streamside landsliding. As a result of these disturbances, numerous stream channels on the site locally exhibited unstable, vertical sideslopes and enlarged channel dimensions.

Volumetrically, 70 percent of the accelerated erosion measured on the 246 hectare (607 acre) study area was derived from newly-formed gullies, while an additional 13 percent was derived from gullied natural stream channels which were adjusting to increased discharges and sediment loads (Table 1). The remaining 17 percent of measured erosion, by volume, was associated with landslides and slumps. These were almost exclusively derived from unstable logging-road fill slopes and cutbanks located on steep slopes near the bottom of the study site. Atwell soils, steep hillslope gradients and emerging groundwater, all common on the lower slopes, led to the increased susceptibility to mass soil movement in this region.

Of nearly 14.5 kilometers (9 mi) of gullies measured on the hillslopes (exclusive of both erosion on the road prisms and gullied natural stream channels), those with a cross-sectional area exceeding 1.1 square meter (12 ft^2) accounted for 95 percent (64,000 m^3) of the total gully erosion by volume, but only 50 percent by length. Those gullies over 0.5 square meters (5 ft^2) in cross-sectional area explained all but approximately one percent of the total measured volume. Initial results suggest future surveys of hillslope gully erosion on similar terrain may be simplified by inventorying erosional features, and then measuring only those channels in the larger size classes.

CAUSES OF ACCELERATED EROSION

Ninety-two percent of the measured post-harvest erosion, by volume, was

TABLE 2. Primary Causes of Management Related Sediment Production from the Copper Creek Study Area, 1971-1979

Primary Cause	Total Hillslope Erosion[a] (% by length)	(% by volume)	(cubic meters)	(cubic yards)
1. lack of culvert maintenance	17	33	41,063	53,711
2. skid-trail stream crossing or other tractor disturbance in stream channel	36	31	38,575	50,456
3. lack of drainage structures at logging road stream crossings	16	15	18,665	24,414
4. mass-movement associated with logging roads and landings; due to unstable fill-slopes	3	13	16,177	21,159
5. misplaced culvert (placed down road from stream crossing)	4	4	4,977	6,510
6. increased surface runoff, due to harvesting, yarding and road building	18	3	3,733	4,883
7. lack of inboard ditch maintenance	6	1	1,245	1,628
Totals.........................	100	100	124,435	162,761

a. does not include 12,030 m^3 of landslide erosion contributed from the sideslopes of Copper Creek.

attributable to four principal causes (see Table 2): 1) lack of road (especially culvert) maintenance (33 percent); 2) tractor disturbances in natural stream channels principally related to flow diversions originating at stream crossings (31 percent); 3) lack of culverts at logging-road stream crossings with consequent diversion of stream flows into road side ditches and/or across overland areas (15 percent); and 4) oversteepened road fills which subsequently failed (13 percent). Three other identified causes (see Table 2) cumulatively accounted for only eight percent of the total measured volume of increased sediment production.

During road construction, culverts were generally placed on the largest streams. Following abandonment of the road system in 1972, the subsequent plugging of these drainage structures caused the diversion of a number of second-order streams and the development of large hillslope gullies. While this "type" of gully accounted for the greatest volume of accelerated sediment production from a single cause (33 percent), they involved only a comparatively short total gully length (17 percent of total measured length). Thus, large stream discharges developed gully systems with the greatest cross-sectional dimensions (twice the average cross-sectional area compared to gullies from the next leading cause), but these same diverted waters quickly rejoined natural, pre-existing channel systems.

Skid trail stream crossings were frequently constructed on the small intermittent and ephemeral stream channels. Subsequent diversions of these waters caused the development of extensive gully systems on the dense network of skid trails found between the major drainage channels. While gully cross-sections were moderate in size ($\bar{x}$ = 4 m^2 (43 ft^2)), the gullies derived from skid-trail stream diversions accounted for over one-third (36 percent) of the total cumulative length of measured erosion features in the study area and 31 percent of the total volume. In contrast, it is noteworthy that gullies which developed on skid trails or other bare soil areas, and whose source of discharge could only be attributed to direct rainfall or intercepted subsurface flow, accounted for 18 percent of the total length of measured gullies but only three percent of the total volume. This type of erosion feature, although ubiquitous on the study site, produced comparatively little sediment.

SEDIMENT PRODUCTION AND SEDIMENT YIELD

The erosion study documented 124,435 cubic meters (162,761 yds^3) of management-related erosion, most of which occurred on the slopes and in the tributaries to Copper Creek predominately from water years 1972 to 1979. Assuming a bulk density of 1.76 grams per cubic centimeter (110 lbs/ft^3) (Popenoe, 1981, personal communication) this represents an accelerated erosion rate of 11,190 metric tons per square kilometer per year (31,970 $tons/mi^2/yr$). Primarily over the same time period, an additional 61,250 cubic meters (80,120 yds^3) of recent landslide erosion has occurred on the steep sideslopes to the main channel of Copper Creek (revised from Kelsey et al., 1981), 20 percent of which originated from within the study area (12,030 m^3). Thus, including streamside landslides, a maximum of 136,465 cubic meters (178,496 yds^3) of material could have entered Copper Creek from within the study area alone. A quantitative survey of sediment currently in storage along the entire length of the Copper Creek channel indicated 9,700 cubic meters (12,690 yds^3) of sediment is still in residence (Kelsey, et al., 1981, p. 100), most of which is found behind debris jams or in lower gradient reaches downstream of the K & K bridge.

While it is clear that virtually all the landslide debris from slopes adjacent to Copper Creek entered the main channel system, it is much more difficult to determine sediment delivery ratios for those processes acting on hillslope areas upslope from the main stem of Copper Creek. A survey of tributaries within the study area indicates a highly efficient transport system whose rate of sediment discharge is more dependent on supply than on stream power. Sediment storage in these steep channels is insignificant. Delivery ratios in excess of 0.90 are estimated for material which reaches or enters the active stream channels tributary to Copper Creek.

Landslides located adjacent to stream channels, gully systems and gullied natural channels are extremely efficient sediment delivery mechanisms. In the Copper Creek study area, these three erosion sources accounted for 91 percent of the measured volume of hillslope sediment production (Table 1). Including the 12,030 cubic meters (15,735 yds^3) of landslide debris contributed from basal hillslopes directly to the main channel (20 percent of 61,250 m^3), these three comparatively efficient mechanisms of sediment production and delivery generated over 125,265 cubic meters (163,850 yds^3) of sediment from the study areas. Assuming a conservative sediment delivery ratio of 0.85 (5 to 10 percent less than that estimated from field measurements), management related sediment yield from the study area averaged over 9,575 metric tons per square kilometer per year (27,350 $t/mi^2/yr$) roughly since completion of clear-cut tractor yarding and abandonment of the road system in 1971[1]. Given that some non-management related erosion also occurred during this period, total sediment yield may have been, perhaps, 10 percent greater (see Anderson, 1979, p. 3608). This is 3.4 to 3.9 times the total annual yield rate of Redwood Creek from 1971 to 1976 (estimated at 2,450 to 2,800 metric tons per square kilometer per year (7,000 - 8,000 $t/mi^2/yr$)) and 32 times the estimated "pre-disturbance" or prehistoric annual sediment yield from the Redwood Creek basin (Anderson, 1979, p. 3608).

EROSION CONTROL

Rehabilitation and erosion-control work on the Copper Creek study site was completed in 1979-1980. Work primarily consisted of excavating the remaining tractor-constructed stream crossings, re-diverting streams out of gully systems and back into their appropriate natural channels, removing culverts and fills at road crossings of ephemeral, intermittent and perennial water courses, excavating unstable, oversteepened fill slopes located near streams, decompacting previously impermeable road surfaces and outsloping roads or excavating cross-road drains and waterbars to provide for uninterrupted, dispersed hillslope runoff. In addition, a variety of labor-intensive erosion-control practices designed to

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1. It should be emphasized, again, that preliminary data suggests sediment production and yield from the study area was highly "event dependent" and that a significant proportion of the measured erosion occurred during the major runoff events of 1972 and 1975. "Average" sediment yield is thus highly dependent upon the time period selected for analysis. For this reason, the computed rates are for comparison purposes only and likely do not represent the actual sediment discharge rate for any given year.

reduce short-term soil erosion from areas disturbed during heavy equipment rehabilitation operations were also employed (e.g. see Kelsey and Weaver, 1979; Weaver and Madej, 1981).

When rehabilitation was initiated in 1979, eight years following clearcutting, 47 percent of the features measured during the erosion inventory were judged to be inactive and no longer contributing significant quantities of sediment to downstream areas. Erosion-control work corrected roughly 80 percent, by volumetric contribution, of the remaining, currently active sediment sources at a total cost of $250,000. Except for the removal of two main-channel log jams and the associated stored sediment, erosion-control work within the unit was primarily concentrated on hillslopes removed from the immediate vicinity of the Copper Creek channel. Such rehabilitation effectively eliminated a great deal of continuing gully erosion. However, we conservatively estimate that no more than 25 percent of the currently active mass-movement features along the main channel were stabilized by upslope gully dewatering or the removal of unstable or perched road-fill material[1]. In addition, while no estimate has been made of the effect of rehabilitation on reducing the potential sediment yield from currently inactive landslides or from mass-movement features along tributaries to Copper Creek, such reduction could also be substantial if major storms occur in the near future.

Immediately prior to rehabilitation activities, management induced mean annual sediment yield[2] from the 2.46 square kilometer (.95 mi^2) study area of Copper Creek was estimated at 4,690 metric tons per square kilometer per year (13,410 $t/mi^2/yr$), of which roughly two percent, or 100 metric tons per square kilometer per year, was derived from landsliding along the main channel. We estimate that erosion control work effectively reduced sediment yield from management caused hillslope erosion by 80 percent and landslide sediment production by 25 percent to a total of 995 metric tons per square kilometer per year (2,840 $t/mi^2/yr$), far less than the long-term mean sediment yield of Redwood Creek.

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1. The great majority of landslides along Copper Creek occurred during the storms of the early 1970's, while only a few were present (visible) on 1966 aerial photography. Conservative calculations, assuming all mass-movement occurred in 1964, yield a delivery rate of roughly 800 $m.tn/km^2/yr$ while a more realistic assumption, that most occurred in the period after 1971, results in a calculated yield of nearly 1,500 $m.tn/km^2/yr$. For the purpose of this paper, we have used a conservative estimate of 1,000 m.tn/km/yr. Based on field observations and aerial photo analysis, we have also judged that 10 percent of these features were still active at the time of the erosion inventory in 1979.

2. The method of computation assumes hillslope and landslide erosion sources in the study area generate sediment at the mean annual rate (total measured erosion transported downslope divided by the number of years since erosion first began) multiplied by the delivery ratio and percent of features still active in 1979. While this method is frequently used in the literature for general comparative purposes, erosion in the study area appears to have been much greater during the major storm events of the earlier 1970's. Additionally, sediment yield from evolving gully systems are not likely to remain constant through time, even in the absence of fluctuating hydrologic inputs. However, we would have expected <u>at least</u> this yield during years which included storm events comparable to those already documented on the study site.

Over the life of the rehabilitation program, similar relative reductions from other rapidly eroding logged lands in the park will substantially reduce tributary contributions to the sediment supply of the lower Redwood Creek channel. Excessive accumulations of sediment that are stored along many reaches of Redwood Creek represent a secondary source of available debris which will be gradually removed by future winter flows. Successful erosion-control work can therefore reduce accelerated hillslope erosion rates, decrease tributary stream sediment yields, and minimize the potential for increased sediment yields resulting from continued gully diversions and stream captures. In much the same manner as main channel aggradation eventually became a substantial problem, conversely the cumulative effect of many small watershed projects in alleviating sediment delivery from logged hillslopes should result in the net long-term improvement of off-site physical and biological channel conditions.

CONCLUSION

Although current forest practice rules governing timber operations in California are much more comprehensive than they were in the early 1970's, much can still be learned from observing and documenting the long-term effects of past land-use activities.

Most of the identified causes of increased sediment production in Copper Creek (Table 2) could have been addressed through preventive erosion control and careful land management practices. For example, the construction of waterbars on skid trails, a common practice since the enactment of the Forest Practice Act in 1973, might have reduced soil loss by over 3,700 cubic meters (4,840 yds^3), or three percent of the total measured erosion. More significantly, such techniques as excavating or "dishing-out" skid trail stream crossings, installing properly sized culverts wherever logging roads crossed channels of perennial, intermittent or ephemeral streams, and maintaining roads and drainage structures (especially during and immediately following storms) could have prevented nearly ?0 percent of the documented erosion on the Copper Creek study area. To minimize long-term post-harvest erosion from logged areas, roads can either be continually maintained or "put-to-bed" through the conscientious practices of waterbarring, culvert removal, and stream-crossing excavations.

s an example of the potential impact of tractor loggging and road construction n erosion rates, water quality degradation, and downstream sedimentation, opper Creek may represent a worst-case situation. However, preliminary data rom other basins tributary to Redwood Creek also indicate generally high elivery ratios and sediment yields (unpublished NPS mapping, 1979 - 1981; elsey, et al., 1981). In marked contrast, the high rates of erosion and sedi-ent discharge measured in the Copper Creek basin far exceed the computed elivery ratio of .22, an accelerated sediment yield of 208 and a total yield of 33 metric tons per square kilometer per year (594 and 1,696 t/mi^2/yr, respec-ively) measured in the comparably sized Caspar Creek experimental watershed from 967 to 1976 (Rice, et al., 1979). Rather than draw detailed comparisons and ontrasts between these two examples, it is important to note the wide range of ocumented rates of accelerated erosion and sediment yield from steeplands within he same physiographic province.

While factors such as climate, topography, soil type, and geology can affect the erosional susceptibility of logged land, high rates of accelerated erosion are not necessarily inherent to logging activities. Information gathered for this report suggests that the amount of management related erosion often reflects the extent to which those conducting timber harvest accept certain responsibilities during and subsequent to logging activities. These responsibilities include sound road-building and design techniques, minimal tractor disturbance in natural stream channels, and stringent road maintenance standards during and following timber harvest activities. The majority of the erosional problems on the study site (over 80 percent, by volume; see Table 2) could have been prevented by the proper placement of road drainage structures and a regular road maintenance program. Thus, the severity of the erosional problems reflects not so much the harvest methods as the practices employed during and following the conduct of harvest operations. Post-harvest erosion control, while beneficial, is more costly and less effective than careful planning and prevention since many sources of accelerated sediment production become either inaccessible, uncontrollably large, or inactive with time.

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