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CHANNEL RECOVERY FROM RECENT LARGE FLOODS
IN NORTH COASTAL CALIFORNIA: RATES AND PROCESSES

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ABSTRACT

Stream channel recovery from recent large floods in northern California involves a sequence of processes, including degradation of streambeds to stable levels, narrowing of channels, and accentuation of riffle-pool sequences. Most channels have degraded but remain widened because hillslope encroachment and establishment of riparian groves conducive to sediment deposition have not yet caused streambanks to accrete. The deepening of pools depends on streambed degradation, channel narrowing, and introduction of scouring agents, such as large organic debris, that were removed by floods. The treatment of riparian vegetation and organic debris may be the most effective and economical means of hastening channel recovery.

INTRODUCTION

Recent floods and accelerated mass erosion in north coastal California have caused substantial changes in stream channels--changes that have persisted for many years. The consequent alteration of anadromous fish habitat is considered to be partially responsible for the decline in fish populations over the last two decades (Rankel, 1979). The duration of these channel changes is determined by the rate at which channels recover to their former condition. To plan for the future management of fish habitat, managers need to know and understand the changes stream channels have undergone. A better understanding would enable them to suggest ways to hasten the recovery process.

This paper describes changes in the condition of stream channels in north coastal California as a result of recent floods--particularly the destructive flood of December, 1964. It details changes in the characteristics of channels, including bed elevation, channel width and riffle-pool sequences.

CHANNEL BED AGGRADATION AND DEGRADATION

Large storms caused regional flooding in northern California in 1953, 1955, 1964, and 1972, and 1975 (Harden, et al., 1978). The flood of 1964, in particular, resulted in great volumes of hillslope material being eroded and delivered to channels, causing widespread channel aggradation (Waananen, et al., 1971; Hickey, 1969). Excess sediment in stream channels can harm fish habitat by filling pools and widening channels. Channels can begin to recover only after excess sediment has been removed and the bed degrades. The

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rise and fall of bed elevation marks the downstream passage of flood debris through a particular reach of channel.

An episode of aggradation consists of an initial period of relatively rapid channel filling, followed later by progressive scour or degradation to a nearly constant bed level (Figure 1).

Streamflow measurements at permanently located stream gaging stations provide an annual record of bed elevation changes from which the period of episodes of aggradation at specific locations can be determined (Lisle, 1981). These sections are usually located at the tails of pools in straight reaches. Their consistency of location permits the documentation of changes in channel morphology in a variety of streams.

At some stations bed elevation returned to pre-flood levels at the end of episodes of aggradation--a period lasting a few years or more. At other stations bed elevation stabilized at a level higher than that before the flood. Data from the Smith River show three episodes of aggradation associated with floods in the early 1950's, 1964, and 1972 (Figure 2). An important factor affecting the duration of the aggradation episodes was the post-flood sequence of flows. Moderately high flows are effective in transporting sediment out of main channels. However, large floods which contribute additional sediment to channels may prolong episodes of aggradation. In the Smith River, new episodes of aggradation were started before previous episodes had ended. Recovery of stream channels from aggradation, therefore, depends on long periods without large storms as well as the absence of new sediment. Records from 13 stream sections in northwestern California indicate that most fourth order or smaller stream

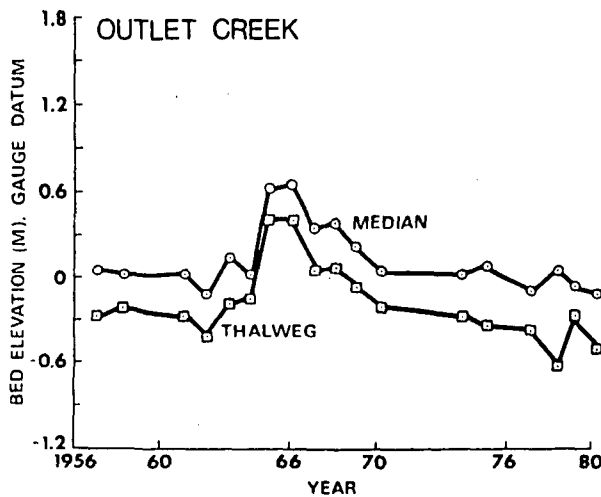


Figure 1--Changes in bed elevations of the Outlet Creek gaging section (Lisle, 1981).

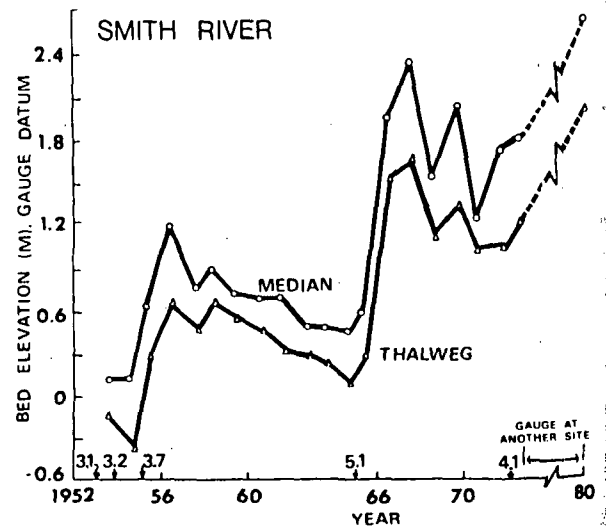


Figure 2--Changes in bed elevations of the Smith River gaging section (Lisle, 1981). The gage was located elsewhere from 1972 to 1979. Numbers above abscissa are runoff values ($m^3/s - km^2$) for floods.

channels have degraded to stable levels since the flood of 1964 (Kelsey, 1980; Nolan and Janda, 1979; Lisle, 1981). Reaches where large volumes of sediment have been stored along main stem channels, such as in Redwood Creek, the Van Duzen River, and the South Fork Trinity River, will however, remain aggraded for one or more decades (Nolan and Janda 1979; Kelsey, 1980; Haskins, 1981).

RECOVERY OF CHANNEL WIDTH

Channel widening often leads to a deterioration of anadromous fish habitat. Food sources are reduced by the destruction of the riparian zone and its isolation from the stream during low flow, and by the seasonal dessication of wide areas of substrate. Channel widening also increases solar insolation, and reduces the number and quality of riffle-pool sequences needed for diverse habitats.

Channel widening was a widespread result of flooding and aggradation (Waananen, et al., 1971; Lisle, 1981). An effect of voluminous bedload sediment is the widening of stream channels; conversely, the onset of channel narrowing depends upon a depletion of sediment. Channel streambeds represent the interface between hillslope and fluvial processes, and their formation is strongly influenced by biological processes. Thus the rate of streambank recovery depends upon the rates of the dominant processes forming streambanks along a particular reach.

Because of rapid tectonic uplift, most stream channels in northern California are contained in narrow valley bottoms bounded by hillslopes. From records of nine gaging sections (Lisle, 1981), it appears that such channels widened no more than 20 percent, but did not narrow along high portions of their banks after degradation of the channel bed (Figure 3). Mass movement contributes material to the channel margins at widely varying rates, thereby contributing to channel narrowing, but mass movement is usually so slow that most channels bounded by hillslopes do not show evidence of narrowing (Figure 4; Lisle, 1981). The processes of channel widening and narrowing in this situation represent a dynamic equilibrium between episodic bank erosion and more gradual bank construction by hillslope encroachment.

Alluvial channels (bordered by river-borne sediment) widened as much as 100 percent (Lisle, 1981). Channel narrowing was accomplished in the Black Butte cross section, for instance, by erosion into flood deposits (Figure 5). This fluvial process coincided with the degradation of the elevated streambed (Figure 6). Streambanks may also be gradually constructed by the deposition and stabilization of alluvium--a relatively slow process that depends largely on the spread and growth of riparian vegetation.

RECOVERY OF RIPARIAN VEGETATION

One of the most crucial problems of channel bank recovery is the stabilization of newly deposited stream bank material. With or without producing large volumes of sediment, large floods characteristically cause channels to widen, although most will narrow afterwards. Rates of bank recovery depend on annual precipitation, which governs the rate of growth and colonization of riparian vegetation (Wolman and Gersin, 1978). In humid climates, channels often narrow within a few months to several years after a large flood; in arid climates this process may take several decades or longer.

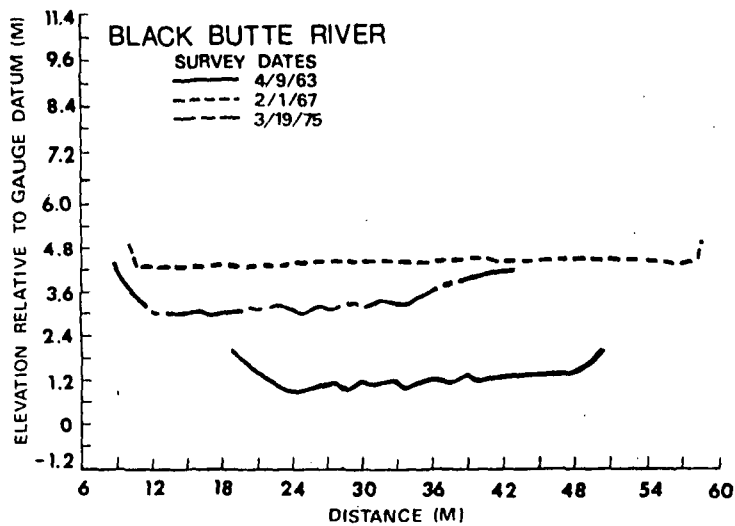


Figure 3--Soundings of the Black Butte River gaging section near Covelo.

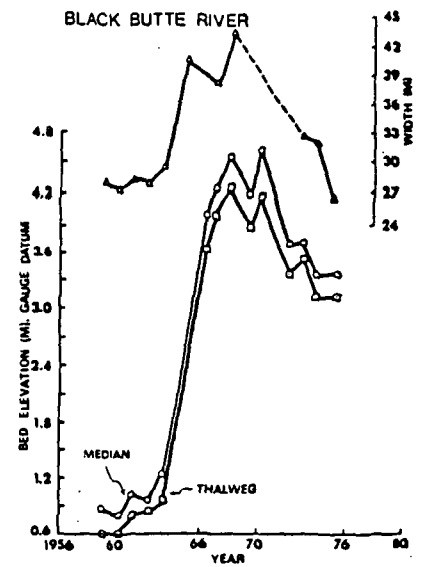


Figure 4--Changes in bed elevations and channel width of the Black Butte River gaging section near Covelo (Lisle, 1981).

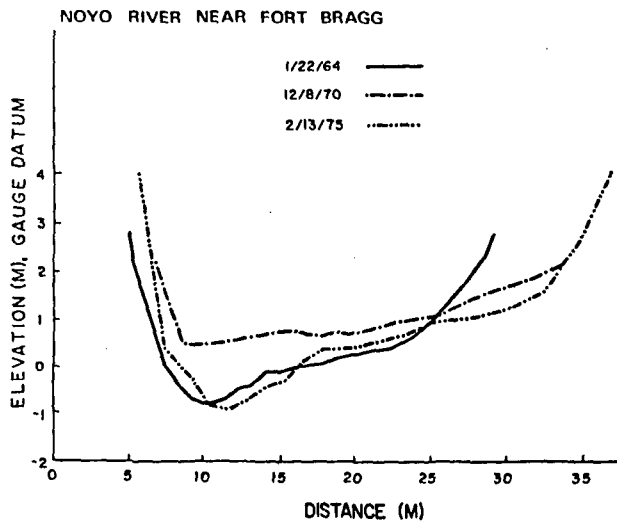


Figure 5--Soundings by the U.S. Geological Survey in the Noyo River gaging section before, during, and after an aggradation episode. After aggradation peaked in 1970, the channel degraded to its pre-flood level by 1975, when it maintained its maximum width.

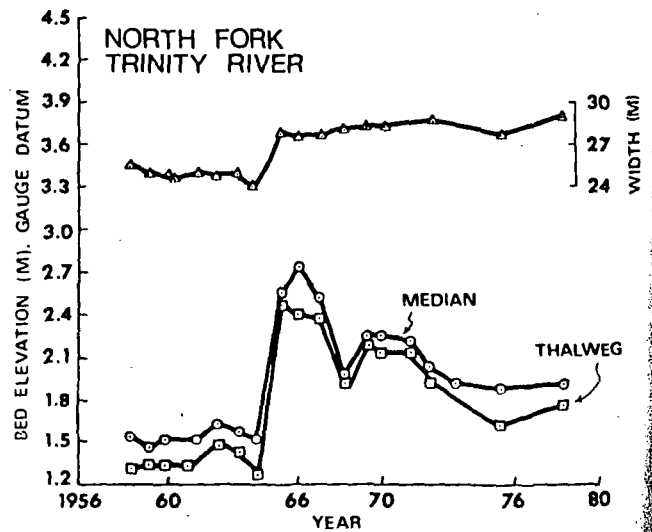


Figure 6--Changes in bed elevations and channel width of the North Fork Trinity River gaging section at Helena (Lisle, 1981).

The following scenario describes the recovery of riparian vegetation along north coastal streams after the 1964 flood. Narrow valley bottoms and a highly seasonal period of runoff have retarded the recovery of riparian vegetation along channels widened by the 1964 flood. Flood bars and streambanks tend to become extremely dry during summer. This dryness retards the growth of riparian vegetation. Newly-established deciduous trees and brush species, such as red alder and willow, are often concentrated along the summertime flow margins of widened channels where moisture is abundant. Vegetation along stream channels decreases the velocity of flows carrying moderately high concentrations of sediment, thereby promoting deposition of silt and fine sand. Rich in nutrients, these new deposits encourage plant growth. Consequently this process is self-perpetuating. During the winter rainy season, however, coarse sediment and large organic debris carried by high runoff contained entirely within channels bounded by valley walls may destroy young plants growing in the active channel.

Because larger trees can better withstand the effect of such flows, the survival of riparian communities and the subsequent growth of streambanks depend on the postflood sequence of flows and the rate of growth of riparian trees. Suppose that a streamside grove of alders established immediately after a large flood could barely withstand (a) at age 4, floods of a size that recur on the average every 2 years; (b) at age 7, floods of a size that recur on the average of every 5 years; and (c) at age 10, floods of the size that recur on the average of every 10 years (Figure 7). On the basis of these assumptions, the rate of increasing stability of the grove would outstrip the likelihood of occurrence of a sufficiently destructive runoff event. The probability of survival of the grove would, therefore, increase with age. Because no large flows have occurred in most streams since 1975, the recovery of riparian vegetation and the growth of streambanks may be well underway.

RECOVERY OF RIFFLE-POOL SEQUENCES

Fishermen lamented the filling of pools after the 1964 flood, but many now have observed renewed scour. The timing of this apparent recovery in relation to bed degradation and possible channel narrowing can be inferred from hydraulic data from 13 gaging stations (Lisle, in prep.) Gaging stations in pools became more riffle-like with aggradation. That is, pools became faster and shallower at a particular flow (Figure 8). Some recovery of pool characteristics accompanied degradation, but full recovery seems to depend on a narrowing of the stream channel. Rifle-pool sequences are accentuated by channel degradation and narrowing. Further scour of pools accompanies the replacement of scour-causing roughness elements, such as large organic debris.

LARGE ORGANIC DEBRIS IN CHANNELS

One of the most important roles of riparian vegetation in the natural recovery of anadromous fish habitat is to introduce large organic debris into stream channels (Swanson and Lienkaemper, 1978). This debris is often swept away by large flood flows and deposited on gravel bars, flood plains, and in large concentrations such as debris jams. It may take a period measured in decades for higher concentrations of debris to become relatively evenly distributed along a stream course. In many north coast streams, future sources of large

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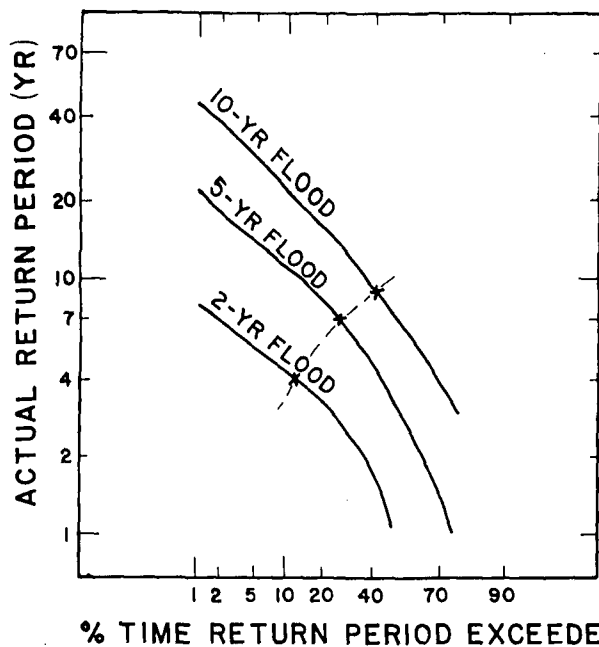


Figure 7--Probability of having a given time period ("actual return period") pass between the recurrence of a flood of a given magnitude or greater (Linsley, et al., 1949, p. 550). Flood magnitudes are given by their average return period.

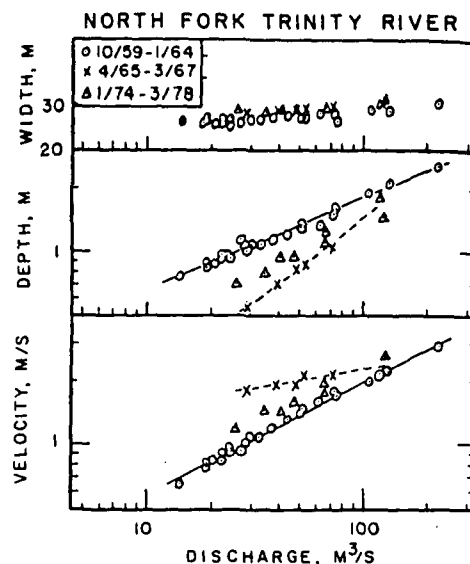


Figure 8--Variations in width, depth and velocity with discharge for periods before and at the peak of aggradation, and after degradation in the North Fork Trinity River gaging section near Helena.

organic debris have been depleted by widened channels, by timber harvesting in the riparian zone, and by present management policies that call for the removal of debris from stream channels.

Large organic debris usually enters stream channels along eroding banks. As a principal pool forming agent in forested streams (Keller, these proceedings), debris offers roughness elements to the flow which, in turn, cause scour. Therefore, the natural replacement of debris in stream channels may constitute a third phase of the recovery of riffle-pool sequences. The introduction and manipulation of large organic debris, as well as other natural roughness elements, such as boulders, offer numerous opportunities for enhancing stream channels for fish habitat. Favorably located elements may be tied in, unfavorably located elements may be relocated, new material may be added, and riparian vegetation may be managed to ensure a continuous steady supply of large organic debris. The trade-off of introducing or manipulating organic debris is often a short term mobilization of sediment. An overall lessening of pool volumes is probably caused more by absence of scour than by the displacement of minor quantities of sediment.

CONCLUSIONS

The recovery of stream channels from recent floods involves a sequence of many processes. Excess sediment has been transported out of most stream channels since the 1964 flood, and fluvial, hillslope, and biological processes may now

begin to shape stream channels to their pre-flood condition. Channel narrowing, for most channels, is a slow process because of the gradual movement of hillslope material to channel margins, the vulnerability of streambank deposits to erosion, and the difficulty of establishing riparian vegetation. Methods for rehabilitating stream channels are most effective when they mimic natural processes and are carried on along with the sequence of recovery processes. The mechanics of recovery suggests that the greatest potential for economical stream enhancement lies in the protection and reestablishment of riparian vegetation and in the introduction and manipulation of organic debris and other natural roughness elements.

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