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HISTORY, PHYSICAL EFFECTS, AND MANAGEMENT IMPLICATIONS of Large Organic Debris in Western Oregon Streams

Frederick J. Swanson
George W. Lienkaemper
James R. Sedell

PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION
U.S. DEPARTMENT OF AGRICULTURE FOREST SERVICE
PORTLAND, OREGON

Abstract

Large organic debris has historically been an important element in small mountain streams of the Pacific Northwest. The debris serves to slow the movement of water and inorganic and fine organic matter through the channel. Debris may remain in the channel for decades or longer, and tends to stabilize some sections of a streambed and streambanks while destabilizing other areas. The combination of clearcutting and the complete removal of large debris in a channel may deprive a stream of this natural feature of streams for a century or longer. The consequences are likely to be downcutting and "channelization" of the stream, accelerated transport of fine organic and inorganic sediment, and a possible decrease in biological productivity of the stream ecosystem. Therefore, stream debris management during logging operations should include leaving undisturbed the natural, stable organic debris in the channel.

The principal factors controlling the concentration, stability, and functions of stream debris are the history and condition of the surrounding timber stand, flushing history of the channel, stability and abundance of bedload material, steepness of the channel and adjacent hillslopes, and slope stability in the drainage. Because of this complexity, each stream presents a unique situation which should be inspected in the field and considered on an individual basis before a debris management decision is made.

KEYWORDS: Stream environment -)debris, mass movement, residue, western Oregon.

Authors

Frederick J. Swanson is Research Associate, School of Forestry, Oregon State University, Corvallis. George W. Lienkaemper is a graduate student, Interdisciplinary Studies, University of Oregon, Eugene. James R. Sedell is Research Associate, Department of Fisheries and Wildlife, Oregon State University, Corvallis.

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Contents

TABLE OF METRIC CONVERSIONS

1 foot	= 0.305 meter
1 yard	= 0.914 meter
1 ton	= 0.907 tonne
1 ton/100 foot of channel	= 2.976 tonne/100 meter
1 acre	= 0.405 hectare
1 event/mile^2	= 0.386 event/kilometer^2
1 yard^3	= 0.765 meter^3

Introduction

Determining optimum amounts of large debris in streams is difficult. The situation is complicated by the complexity and variability of the stream environment and the variety of ways resource managers view stream debris. Fisheries biologists, stream ecologists, water quality experts, and road design and maintenance personnel would all probably set different standards for stream debris concentrations. Much of the present indecisiveness about management of stream debris may stem from lack of understanding of the biological and physical functioning of debris in small mountain streams. The theme of this paper is that streams and their biota developed through a long history of high concentrations of debris and that perhaps a closer look at the history of natural debris in stream environments will help in managing these streams in the future.

The following comments are the result of a reconnaissance study of large debris in streams which is being carried out by the authors along with hydrologist R. L. Beschta (Oregon State University). We are attempting to assess the origins and history and biological, hydrologic and geomorphic impacts of stream debris in both undisturbed and man-influenced streams in western Oregon. The results of this work are still in a preliminary form.

Background

The streams of western Oregon and Washington are commonly littered with tree tops, limbs, root wads, and whole trees (fig. 1). Debris greatly

Figure 1.--Large organic debris in Lookout Creek, H. J. Andrews Experimental Forest. Note figure in left center of picture.

influences stream biology, hydrology, and sediment transport. Therefore, it is surprising how little study there has been of the origin, fate, and consequence of large organic debris in streams.

The only published work on quantities of organic matter in Pacific Northwest streams is that of H. A. Froehlich and his students (Froehlich 1971; Froehlich, McGreer, and Sedell 1972; Lammel 1972; Froehlich 1973). Their studies have been designed to assess volume and weight of coarse and fine debris in streams flowing through various types of stands. They sampled streams before and after falling and after yarding in units harvested with various logging systems and stream protection procedures. The measured quantities of organic debris in undisturbed streams were both very large and extremely variable. Measured concentrations range from 0.9 ton up to 26 tons/100 ft of channel. They also observed that, following logging, the volume of debris in the streams had been modified to levels ranging between 60 and 360 percent of prelogging debris concentrations, depending on the management procedures used.

The biological consequences of large debris have been reviewed by Narver (1971), Brown (1974), Hall and Baker (1975), Triska and Sedell (1975), and others. Excessive large debris may form jams which block fish passage, cause spawning areas to be flooded with gravel, and increase streambank cutting. Movement of debris may shift gravel, possibly destroying eggs and alevins. Large debris also has beneficial functions in the stream environment. In many situations large debris tends to stabilize the streambed and banks. The presence of stable debris slows the routing of fine organic matter through the stream, allowing greater opportunity for biological processing of fine organic detritus. Bustard and Narver (1975) also cite the importance of logs and roots as overwinter cover sources for salmon and warn against "overzealous stream cleaning."

Geomorphic consequences of large debris in streams have been studied even less than the biological effects. In small New England streams, Zimmerman et al. (1967) observed that channel width in forested stream sections tended to be wider and more variable than streams cut through sod covered banks. Forest vegetation may have a variable effect on the stability of the banks and bed. Stability is enhanced and the channel is narrowed where root systems extend through the banks and channel bottom. The channel may also be destabilized and widened above debris dams and where trees are tipped over. In drainages larger than several square miles, stream width is more uniform than in smaller basins. Zimmerman and others believe that in small streams living and dead vegetation is important in shaping channel geometry, but this influence drops off sharply in larger streams where hydraulic capabilities of the stream become dominant.

Several unpublished USDA Forest Service reports and Colman (1973) note that large debris in streams tends to destabilize the streambed and banks. This is particularly common in gravel-rich streams where natural and man-caused hillslope instability has accelerated sediment supply to the channel. In these settings, large organic debris may slow sediment transport, cause braiding or meandering of the channel over its widened bed and lead to stream bank cutting. Increased bank erosion aggravates the stream problems by introducing more sediment to the channel and possibly causing more extensive instability of adjacent hillslopes.

Although the biologic and geomorphic consequences of debris in streams cannot yet be quantified in terms of fisheries productivity, sediment yield, or other impacts, there does seem to be a growing recognition of the importance of large organic debris in the stream environment. Past recommendations for stream debris management state a need to maintain moderate, premanagement levels of large stream debris (Heede 1972a, b; Brown 1974; Bustard and Narver 1975; and others).

Movement of Large Organic Debris Into Streams

Large organic debris enters the the stream channel by a variety of mechanisms. Several of the mechanisms are interrelated, allowing debris to enter the stream by a chain reaction of events.

A high percentage of stream debris is comprised of tree tops, large limbs, and whole trees blown into streams by strong winds. These pieces may land directly in the creek or on the adjacent hillslopes and then slide into the creek. Therefore, streams in narrow, steep walled valleys may tend to receive more large debris than streams flowing through similar timber stands on broad, flat flood plains.

Undercutting of streambanks may also cause trees to tip into the channel. This process is particularly effective in getting massive, stable root wads and tree trunks into streams. In western Oregon this process is most important on the larger streams which can rework their flood plain. The small first-, second-, and third-order channels are commonly cut on bedrock so the streams have limited ability for lateral cutting. (Stream order is defined by Harr (1976) and Leopold, Wolman, and Miller, 1964).

In a variety of ways the slow encroachment of deep-seated slumps and earthflows on stream channels leads to heavy loading of limited reaches of channel (up to hundreds of yards) with both large organic debris and inorganic sediment (Swanson and James 1975). Earthflow movement tips trees, making them highly sensitive to windthrow. Earthflows also constrict a stream channel until a high discharge event undermines the toe of the earthflow and the opposite streambank, causing a series of small slumps and slides which carry organic matter, including whole trees, into the channel. The continued closing of the channel and instability of the streambanks result in the formation of high stacks of loosely structured debris.

Debris slides and avalanches from adjacent hillslopes, but well above the influence of any streambank cutting, also introduce large organic matter to stream channels. As discussed in the following section, these events commonly result in debris torrents, or "sluice outs", which pick up organic and inorganic material along the channel as they move rapidly downstream.

It is often difficult to pin-point a single mechanism as the means by which an individual piece of large debris has entered the channel. For example, at the toe of an earthflow, the combined forces of bankcutting, windthrow, and deep-seated earth movement may work together--the earthflow tipping the tree and aiding streambank erosion, both of which render the tree highly susceptible to blowdown.

Movement of Large Organic Debris Along Streams

Large pieces of organic debris are moved through a stream system by a variety of mechanisms ranging from episodic flushing during extreme flood events to the everyday release of dissolved or finely divided material as a result of decomposition and physical breakdown by wood processing invertebrates. In many cases, streams bypass debris accumulations, leaving the debris buried in the flood plain to decompose for long periods until the stream cuts back to rework the deposit. These slow, persistent processes of debris decay and breakup are probably dominant mechanisms of movement of large organic debris out of many western Oregon streams. It is the violent flushing events, however, which present the greatest concern to land managers. Flushing occurs either by flotation during high water or by transport in debris torrents as large volumes of organic debris, soil, rocks, and water are "sluiced out" of channels.

The ability of a stream or river to float large debris depends on both the size of the free-flowing part of the water course and the size of debris. In large rivers such as the main branch of the McKenzie, nearly any piece of organic material that enters the river can be floated and transported downriver. Of course, smaller streams can float only small debris. Floated debris, especially in small streams, usually does not travel far before it is stranded on streambanks at high flow levels or against obstructions in the channel. Culverts and stream crossings are particularly troublesome obstructions which may sustain heavy damage from floated debris and associated drainage problems (Rothacher 1959; Rothacher and Glazebrook 1968).

Very large debris can be transported through small channels only in debris torrents such as those described by Fredriksen (1963, 1965). Such highly destructive events are of great concern to land managers. Torrents damage roads, denude significant areas of timber growing land, and severely disturb the stream environment.

Debris torrents may be triggered by the breakup of debris jams in a channel, the collapse of a road fill in a channel way, or a slide entering the channel from the adjacent hillslope. Slides and debris avalanches from hillslopes may trigger debris torrents in several ways. Slide debris may enter the channel and temporarily block it, backing up a small lake until the dam is saturated or undercut, releasing a surge of debris down the channel. In many cases slide debris probably moves directly down the channel, maintaining the momentum picked up coming down the steep slope at the side or head of the stream.

Regardless of the triggering mechanism, once a debris torrent has begun, it moves rapidly down channel, entraining sediment and debris in the channel and soil, organic detritus, and living vegetation from adjacent hillslopes as it scours the streambed and banks. Decreasing stream gradient and channel obstructions, including heavy stands of timber, eventually stop the torrent and create an area of deposition. Such torrents are rare in channels larger than second- or third-order because a steep channel gradient is needed to maintain the momentum of the churning mass of debris.

Torrents commonly scour up to 20 feet on the streambanks, exposing bare soil which is subject to surface erosion and small scale slumping and sloughing for a period of years after the initial event. This material is eventually moved downstream as bedload and collects behind the sediment and debris deposited by the torrent. In low gradient settings the organic matter in the jam acts as a regulating valve, rotting over the course of one to two centuries and slowly releasing the stored mineral sediment to downstream areas.

To develop a feeling for the frequency and significance of debris torrents, we can turn to two study sites in the Cascades. The H. J. Andrews Experimental Forest near Blue River, Oregon, has experienced at least 38 debris torrents since 1950[1]. These events scoured between 50 and 1,650 yd of stream channel each. Morrison (1975) studied 15 debris torrents which occurred in the Alder Creek drainage, a tributary to Fall Creek in the Willamette National Forest. He estimated the debris torrents in the 4,300-acre drainage scoured soil

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[1] Swanson, Frederick J. Unpublished data on file at the School of Forestry, Oregon State University, Corvallis.

from about 17 acres of streamside hillslopes in the past 90 years. About 45 percent of this erosion was the result of management activities during the past 11 years.

The sites where debris torrents were initiated have been analyzed to determine land management history and whether or not slides from adjacent hillslopes appeared to have started the debris torrent (table 1). These data indicate slides from hillslopes are the dominant mechanism of initiating debris torrents, having been a contributing factor in 83 percent of the 53 torrents analyzed. The dominance of roads as slide initiation sites (Dyrness 1967; Morrison 1975; Swanson and Dyrness 1975) is reflected in the high frequency of debris torrents triggered by road-related slides (table 1). Most of the road failures that resulted in debris torrents were fill failures in steep headwall settings where organic debris had no apparent role in triggering the slide. Only nine of the torrents appear to have been initiated in stream channels in forested and clearcut areas. In these settings, mobilization of organic debris in the channels is a likely triggering mechanism for torrents. In six of these cases, slump and earthflow movement into the stream probably contributed significantly to channel instability. In one drainage where the headwaters have been clearcut and there is active deep-seated mass movement, the channel has had three debris torrents in the past 25 years. A large fan of debris at the foot of the watershed indicates debris torrents also occurred frequently before there were any management activities in the area.

Although these reconnaissance studies suggest that debris in streams is not a primary cause of debris torrents in the Cascades, debris is commonly believed to aggravate the destructiveness of torrents once they have begun. As a torrent moves down channel, it picks up debris which had previously collected in the channel. The work of Froehlich (1973) and others indicate this may amount to more than 20 tons of downed organic matter per 100 ft of stream channel. Large volumes of entrained debris, however, may cause

Table 1--*Land-use status of triggering sites of debris torrents in the H. J. Andrews Experimental Forest*[1] *and Alder Creek drainage*

Site	Percent of watershed in 1975	Period of record	Debris torrents			
			Triggered by hillslope slides	With no identified related slide	Total	Per square mile per year
		Years	Number			
H. J. Andrews Experimental Forest (15,860 acres):						
Clearcut	18.7	25	5	6	11	0.10
Road	3.3	25	17	--	17	.83
Forest	78.0	25	9	1	10	.02
Total	100.0	--	31	7	38	--
Alder Creek drainage (4,300 acres):						
Clearcut	26.0	15	2	1	3	.11
Road	3.5	15	6	--	6	1.67
Forest	70.5	90	5	1	6	.01
Total	100.0	--	13	2	15	--

[1]Swanson, Frederick J. Unpublished data on file at the School of Forestry, Oregon State University, Corvallis.

a torrent to stop sooner due to increased friction among the large pieces of debris being churned along and against the adjacent valley walls and vegetation. There may be a trade off of shorter, wider torrent tracks down debris filled channels in comparison with longer, narrower tracks in cleared streams. From observations in the H. J. Andrews Experimental Forest and Alder Creek Watershed, it appears destructiveness of torrents reflects the volume of slide material initially entering the stream rather than the pretorrent debris load of the channel.

Origins of Debris Accumulations

The spatial distribution of debris accumulations in streams is controlled by the stability of adjacent soils and timber, the history of debris movement down the channel, the shape of the channel, and perhaps other processes. Accumulations may form as a result of instream sorting during high streamflow. In larger streams there is greater opportunity for debris transport and sorting to take place; consequently, the debris in intermediate and large streams tends to be concentrated in distinct accumulations. Generally, organic debris in small streams is randomly distributed. Because of this scattering of debris and the large size of individual pieces relative to channel dimensions, it is seldom possible to identify individual accumulations in first- and second-order streams.

Accumulations may also originate from influences outside the channel where several large pieces of debris enter the stream in a single event. This may happen where a group of trees are blown down in "domino" fashion, where streamside or hillslope slides enter a stream, or where deposition occurs at the end of a debris torrent track.

The mode of origin of an accumulation determines its structure and function. For example, the large accumulations at the toes of earthflows tend to be high, open stacks of debris which are very inefficient at trapping sediment and diverting water movement. On the other hand, debris torrent accumulations are typified by tight networks of organic debris with the upstream portion flooded with inorganic sediment. Such a structure efficiently traps sediment transported from upstream.

Most debris accumulations are formed by a variety of interacting mechanisms operating intermittently throughout the history of the accumulation. For example, in a second- or third-order channel, an initial accumulation may be formed by several pieces of blowdown. This channel obstruction may then trap finer floated debris, further closing off the channel and deflecting the stream against the bank. The resulting erosion may undermine the bank and cause large pieces of streamside vegetation to fall into the stream. Such a historical sequence may span several decades marked by periodic shifts in the configuration of the accumulation as large storms change the stream channel and the amount of trapped sediment.

Case Studies

It is useful to examine case studies of several streams to illustrate how these generalizations about the origins, history, and consequences of pieces and accumulations of debris apply in real streams. For this reason, we have studied large organic debris in several western Oregon streams. These streams have been the subject of other biologic and geomorphic research; and they were selected to represent a variety of drainage areas, stand types and ages, management histories, and geologic and geomorphic settings. In each study area, at least 800 ft of stream channel were mapped. Here we present observations on sections of five channel reaches: clearcut and old-growth sections of an intermediate size stream, Mack Creek; an old-growth reach of a smaller stream, Zog Creek; and two unnamed streams flowing through young stands developed after wildfires 75 and 135 years ago. All streams drain areas of volcanic bedrock of the western Cascade range in land managed by the Willamette National Forest.

The study section of Mack Creek, located in the H. J. Andrews Experimental Forest near Blue River is a third-order channel which drains about 1,500 acres. The channel gradient is about 10 percent. Where streamflow is not influenced by organic debris, the bed is made-up of large boulders up to 6 ft in diameter.

Zog Creek is located 30 mi east of Eugene in the Alder Creek drainage which has recently been the subject of erosion studies by Morrison (1975). The study section drains approximately 160 acres. The mapped channel has an average gradient of about 30 percent; and where there is little influence of organic debris, it flows over a series of bedrock chutes and patches of gravel.

The unnamed streams flowing through young stands are tributaries of Blue River just north of the H. J. Andrews Experimental Forest. These boulder dominated streams drain watersheds of less than 40 acres.

Methods

In each of the study reaches the stream channel and all pieces of organic debris longer than 5 ft were mapped using a tape, range-finder, and compass. For each significant piece of debris or debris accumulation, data were collected describing the size of principal pieces of debris, its stability, origin, and degree of decomposition; the volume of trapped sediment; height of debris-influenced drop in water level; and, channel characteristics. Since most large pieces in the study area had not been transported by the stream, the origins of most pieces of debris more than 20 to 30 ft in length could be determined by careful inspection of the position of the root wad or nearby snags or topped and downed trees.

The time of emplacement of individual pieces in the Mack Creek section was estimated by dating small trees, commonly western redcedar and western hemlock, which were growing on the debris. These estimates are clearly minimum values because a period of perhaps 5 or more years may have elapsed before establishment. In some cases, it was possible to date scars on living trees damaged by the large debris falling into the channel. Where dated debris overlies other material, it was assumed that the underlying material was older than the dated log.

Results

ZOG CREEK

The 200-ft reach of Zog Creek mapped in figure 2 is typical of many small western Oregon and Washington streams flowing through a steep walled valley (average sideslopes about 90 percent) and an old-growth Douglas-fir, western redcedar, and western hemlock forest. The abundant large organic debris has a great influence on the stream--31 pieces of debris 5 or more feet in length have some influence over the movement of sediment and water through the 200-ft section. Deeply scoured pools are formed at falls or areas of convergent flow below obstructions. Approximately 32 percent of the drop of the stream is influenced by debris. The debris has trapped an estimated 25 yds of sediment in small bars and shallow pools above obstructions. All of the large debris appears to be very stable. Several trees of about 1.5-ft dbh have grown on old, rotten pieces of debris in the channel, suggesting that as the old debris was losing strength during decomposition, it was also being anchored and reinforced by the developing root system of the living tree. This also indicates that the channel has experienced no violent flushing event in the past 60 plus years.

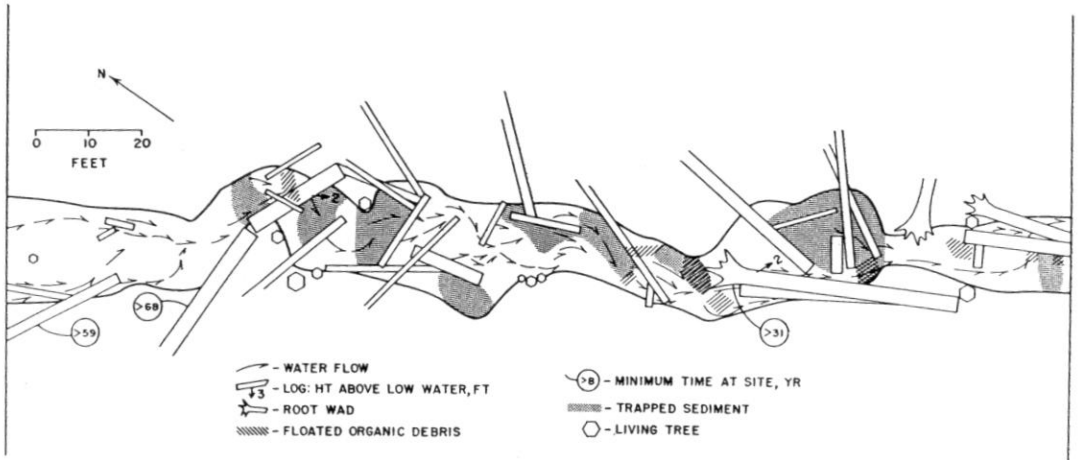

Figure 2.--Map of large organic debris and other material in a 200-ft forested section of Zog Creek.

MACK CREEK - FORESTED SECTION

Maps of two adjacent 200-ft sections of Mack Creek are shown in figures 3 and 4. This stream reach is probably representative of steep channels 20 to 30 ft in width flowing through old-growth stands in the Pacific Northwest. As in the case of Zog Creek, Mack Creek contains abundant coarse organic debris. The study area is part of a stream section in which Froehlich et al. (1972) measured 11.7 tons of large debris (greater than 4 in) per 100 ft of channel.

The large debris in the forested section of Mack Creek forms a series of distinct accumulations which play a variety of roles in the stream environment. Accumulations MA-14 and MA-18 (figs. 3 and 4) converge the flow into a scoured pool near the center of the channel; MA-13 and MA-15 deflect the stream away from one bank, forming scour pools against the far bank; MA-16 and MA-17 effectively intercept sediment and floatable fine organic matter across the entire channel and develop broad, shallow, depositional pools upstream and deeper, narrower plunge pools at the base of falls; MA-12 is mainly floated debris thrown up on the bank on the outside of a bend, thereby offering some protection from streambank undercutting. These accumulations have trapped and temporarily stabilized over 300 yd^3 of sediment. The debris also influences about 50 percent of the drop of the stream through this 400-ft reach. A variety of data on each accumulation is shown in table 2.

Most pieces of debris more than 30 ft in length have not moved since they entered the stream as windfall. Only a few trees appear to have been undercut by the stream prior to toppling into the channel. The accumulations are composed of 10 to 60 percent floated debris up to about 25 ft in length.

Minimum dates on the emplacement of major pieces of debris indicate they have had surprisingly long histories of stability in the channel (table 2 and figures 3 and 4). Five of the seven accumulations originated more than 20 years ago, and MA-13 appears to be in part more than 100 years old. This indicates that flushing of major pieces of debris through this channel has not occurred in the past century.

In the mapped stream reach, organic debris has greatly modified gross

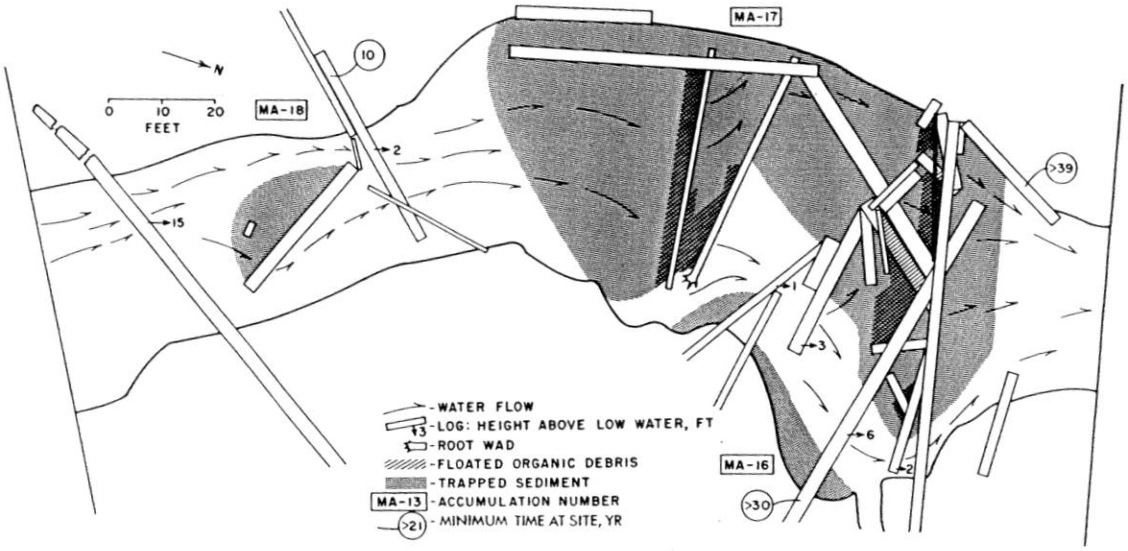

Figure 3.--Map of large organic debris and other material in a 200-ft forested section of Mack Creek immediately upstream from the section in figure 4.

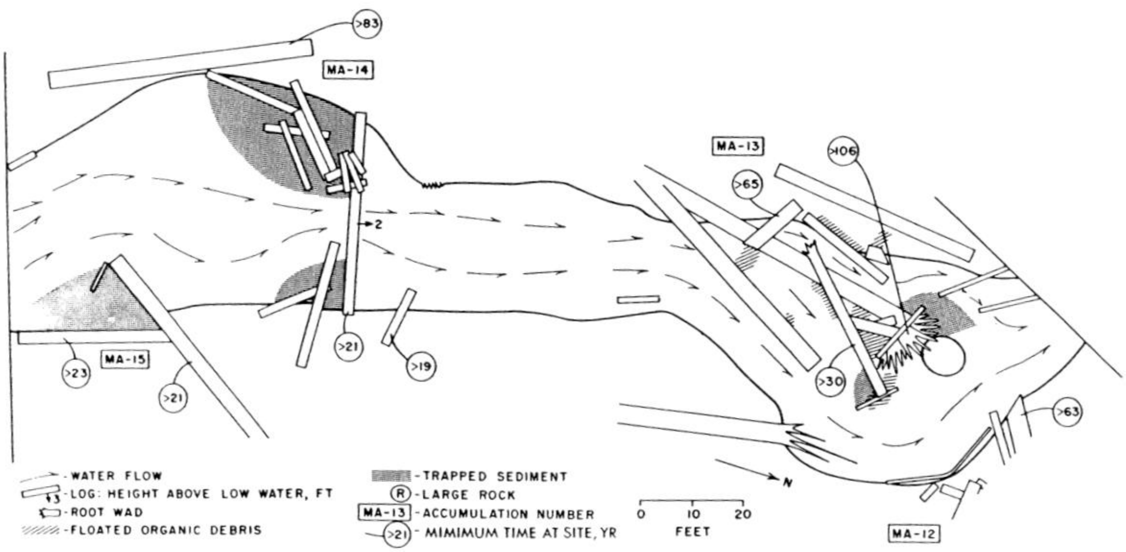

Figure 4.--Map of large organic debris and other material in a 200-ft forested section of Mack Creek immediately downstream from the section shown in figure 3.

Table 2--*Data on debris accumulations in 400-foot section of forested Mack Creek. Shown in figures 3 and 4. Ages were determined in 1975.*

Debris accumulation	Debris influenced stream drop	Trapped sediment	Channel width affected	Floated debris	Age of core of accumulation
	Feet	Cubic years	Percent	Percent	Years
MA-12	0	15	30	60	63+
MA-13	3	45	60	10	108+
MA-14	0	40	100	50	21+
MA-15	0	5	30	10	21+
MA-16	8	120	100	25	30+
MA-17	5	50	75	50	11+
MA-18	4	30	80	40	9 to 10
	20	305			

channel morphology in two cases. Accumulations MA-16 and MA-17 have caused a pronounced widening of the channel by developing overflow channels along the east bank. The history of MA-13 began over 100 years ago when the central piece of the accumulation, a massive western redcedar, fell diagonally up the channel, perhaps as a result of streambank cutting. As other organic debris collected against this obstruction, the channel was more effectively diverted into the eroding streambank; so now most of the streamflow goes around the accumulation.

MACK CREEK - CLEARCUT SECTION

A 200-ft section of the clearcut portion of Mack Creek is shown in figure 5. The area was cut but not yarded before the winter of 1964-65. Extremely high stream flows during winter moved logs, slash, and roots downstream and lodged them behind a massive, pre-existing debris jam in a stand of old growth at the base of the unit. Froehlich et al. (1972) found the clearcut section contains only about 4 percent of the large debris observed in the forested section immediately upstream. They also found

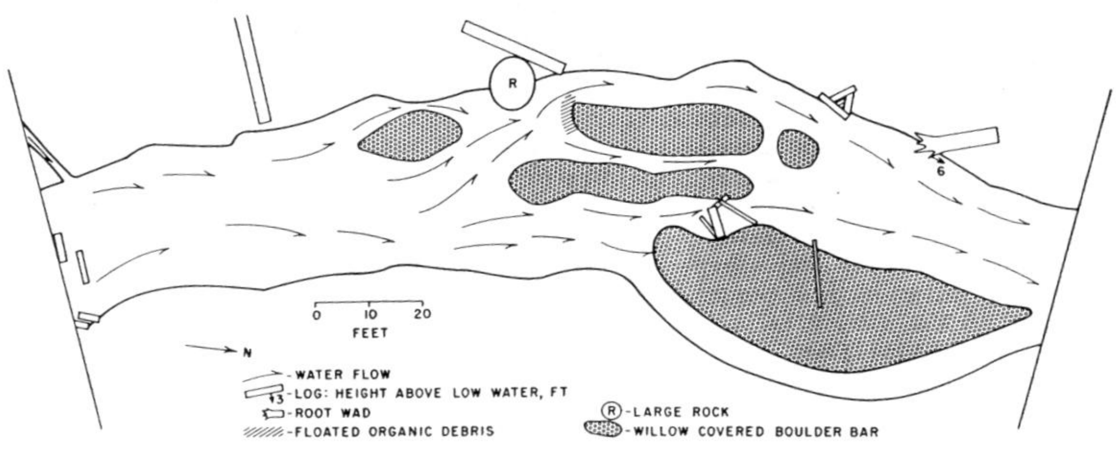

Figure 5.--Map of large organic debris and other material in a 200-ft clearcut section of Mack Creek downstream from sections shown in figure 3 and 4.

the fine debris in the clearcut area was 44 percent of the concentration in the forested stream reach 7 years after logging. The large debris present has practically no influence on sediment storage and the pattern of pools, falls, and riffles. All of the debris in the channel appears to be floatable at high streamflow. Although we do not know channel conditions before logging and roadbuilding, the present appearance and distribution of the debris indicates none of the prelogging debris is in its original position.

Streams in Young Stands

The stream flowing through the 75-year-old stand contains numerous pieces of large organic debris derived from the previous old-growth stand as well as smaller diameter pieces from the postfire stand. The older debris still has an important influence on the movement of sediment and water through the channel. The stream in the 135-year-old stand also contains abundant debris, but pieces from the prefire stand are highly decomposed and have less influence on the stream than debris from the postfire stand. Large organic debris is an important factor in these stream environments even after severe wildfires.

Discussion

The quantity of debris in a stream channel at any time reflects a balance between the processes controlling the debris inputs and outputs of the stream system. Factors which control the input of large debris are age and condition of the surrounding timber stand, the stability and steepness of banks and adjacent hillslopes, and the ability of the stream to transport in new material from upstream channel areas. The export of large organic debris is determined by the ability of the stream to float debris downstream, rates of decomposition and physical breakdown of debris in channels, and the probability of debris torrents flushing out the channel. In many instances input and output take place in sporadic events occurring every few decades or centuries. These include major episodes of blowdown, extreme discharge events, debris torrents, and stream cleanup following logging. In most streams, however, it is a continual give and take situation, with one debris accumulation slowly growing as it traps floated material while the next accumulation along the stream may be collapsing and breaking up into small, floatable pieces after a long period of rotting. It is, therefore, important to view the status of stream debris in a historical perspective.

Several lines of evidence suggest that during premanagement time, small streams have had high concentrations of debris throughout most stages of succession of the surrounding vegetation. Rotting of logs in or above streams is appreciably slower than where they are lying on the ground. Therefore, debris may have a long residence time in the stream environment, possibly remaining in channels well into a second-growth stand developed after wildfire. Flushing of channels appears to be controlled more by slope stability factors (debris slide and earthflow activity within the drainage) than by cycles of debris accumulation in the channel that are terminated by periodic cleaning. These observations indicate small streams draining moderately stable watersheds have contained abundant large organic debris for much of the past few thousand years.

Many of the basic elements of the history and function of large stream debris are clearly seen in the study sections of Zog and Mack Creeks. On the basis of these field studies, we conclude that (1) large concentrations of debris in streams occur naturally; (2) debris may have residence times to more than a century; (3) debris increases the "roughness" of the channel, causing sediment and floated organic matter to be trapped and slowing the movement of these materials through the stream system; (4) a large proportion of the stream drop is in fall over debris, thereby dissipating much of the stream's energy at a few points along the channel rather than more uniformly along the channel as is the case in similar streams which are debris-free; and (5) the impact of large debris on channel morphology is complex because debris causes widening and narrowing, deepening and shallowing, and stabilization and destabilization at different points along the channel bed and banks. On larger streams which can float most of the debris which enters them, the debris plays a rather minor role in the stream environment.

In addition to stream size, the role of debris in streams also varies in response to some factors which change in a roughly systematic fashion from one geographic area of the State to another. For example, many streams in the Klamath Mountains carry heavy gravel loads, but streams draining the sandstones of the Coast Ranges generally contain little gravel. Plant communities also vary between the two areas. Consequently, the concentration, stability, and function of stream debris is likely to vary significantly, necessitating different management strategies. In Coast Range streams, debris might profitably be managed at somewhat higher concentrations to slow bedload movement and enlarge spawning areas; but in sediment-rich Klamath Mountain streams lower levels of debris may facilitate the movement of gravel and reduce aggradation and bank cutting. Such generalities clearly require more study, but they may eventually be useful in developing regional guidelines for debris management.

Clearcutting and cleaning of the stream corridor will have differing impacts under different stream conditions; but, in general, these alterations have three important effects on stream debris: (1) removing large, pre-existing stable pieces of debris from the stream; (2) possibly increasing the concentration of small, unstable debris both by fresh input to the channel and by release of material previously stored behind large debris; and (3) eliminating the source of fresh, potentially stable pieces by removing the timber stand. Consequently, a cleared stream is deprived of coarse organic matter until it is supplied by debris transport from forested sections upstream or until the second-growth stand begins to supply fresh inputs of large debris. This second factor is a long-term proposition which may be short-circuited by frequent cropping of the trees.

What are the long-term consequences of eliminating large organic matter from streams? Of course, it is impossible to answer with certainty; but it seems likely many small streams will undergo downcutting and become effectively "channelized" on bedrock or a stable boulder pavement. A stream which had previously flowed over a series of steps formed by debris will assume a more uniformly steep profile and experience other changes in channel geometry. There will be a resulting decrease in diversity of stream habitat as biologically productive, debris-related depositional pools are eliminated. Increased water velocity will also contribute to the accelerated transport of fine organic matter through the channel system, thereby decreasing the opportunity of stream organisms to process the material. Consequently, the removal of large debris from streams may reduce long-term biological productivity and increase the rate of sediment transfer from headwater streams to downstream areas.

Progressive design and management of logging operations and/or buffer strips (Froehlich 1973, Brown 1974) will help to minimize the impacts of both long- and short-term alterations of the stream environment. Some generalized guidelines, now practiced in many management circles, are:

1) Minimize or eliminate any input of new material to the stream,

2) Base stream cleaning decisions on biological considerations. Money for cleaning to minimize debris torrent hazards in channels might be better spent on improved roads and logging layout,

3) Leave pre-existing, stable pieces of large debris in the stream without disturbing them. This could be done by cruising the channel and marking large stable pieces to be left by the logger. If floatable logging slash does enter the stream, the presence of stable pieces may help minimize the the type of flushing problems described by Rothacher (1959).

4) When considering the trade-offs of buffer strips, recognize them as future sources of large stable debris for the stream. Maintaining buffer strips may help to keep some stream management options open if further study demonstrates in certain situations streamside stands are important as sources of large organic matter for the stream.

The management of massive debris jams presents a special set of problems. There presently seems to be a strong concern to remove jams because, although they do occur naturally, many stand as monuments to past management mistakes. Where jams have trapped large volumes of mineral sediment containing abundant fine material, as is often the case in depositional areas of debris torrents, there are distinct advantages to not removing the large organic debris. The question is often one of releasing a large volume of sediment over a few years or allowing it to be naturally, slowly routed downstream over much longer periods of time.

With both moderate and excessive debris loads in streams, there is no single, simple set of rules which can be applied indiscriminately throughout western Oregon. Each site presents a different set of conditions of stream biology, channel gradient, status of stream debris, conditions of surrounding timber stand, abundance and size of bedload, and slope stability in the drainage. The great complexity of the stream environment means each site must be inspected in the field and treated on an individual basis. Debris management problems call for a high degree of cooperation between specialists and administrative personnel.

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Mailing address: Pacific Northwest Forest and Range Experiment Station
P.O. Box 3141
Portland, Oregon 97208

GPO 997-616