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EFFECTS OF LARGE ORGANIC MATERIAL ON CHANNEL FORM AND FLUVIAL PROCESSES

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SUMMARY

Stream channel development in forested areas is profoundly influenced by large organic debris (logs, limbs and rootwads greater than 10 cm in diameter) in the channels.

In low gradient meandering streams large organic debris enters the channel through bank erosion, mass wasting, blowdown, and collapse of trees due to ice loading. In small streams large organic debris may locally influence channel morphology and sediment transport processes because the stream may not have the competency to redistribute the debris. In larger streams flowing water may move large organic debris, concentrating it into distinct accumulations (debris jams). Organic debris may greatly affect channel form and process by: increasing or decreasing stability of stream banks; influencing development of midchannel bars and short braided reaches; and facilitating, with other favourable circumstances, development of meander cutoffs.

In steep gradient mountain streams organic debris may enter the channel by all the processes mentioned for low gradient streams. In addition, considerable debris may also enter the channel by way of debris avalanches or debris torrents. In small to intermediate size mountain streams with steep valley walls and little or no floodplain or flat valley floor, the effects of large organic debris on the fluvial processes and channel form may be very significant. Debris jams may locally accelerate or retard channel bed and bank erosion and/or deposition; create sites for significant sediment storage; and produce a stepped channel profile, herein referred to as 'organic stepping', which provides for variable channel morphology and flow conditions.

The effect of live or dead trees anchored by rootwads into the stream bank may not only greatly retard bank erosion but also influence channel width and the development of small scour holes along the channel beneath tree roots. Once trees fall into the stream, their influence on the channel form and process may be quite different than when they were defending the banks, and, depending on the size of the debris, size of the stream, and many other factors, their effects range from insignificant to very important.

KEY WORDS Channel morphology Fluvial processes Large organic debris

INTRODUCTION

Channel form, a major dependent variable in fluvial systems, is a function of several independent variables including peak and mean annual water and sediment discharges. Most research in fluvial geomorphology has focused on interactions among flowing water, sediment concentration, and channel morphology. Where streams flow through forested areas channel form is also a function of the nature and extent of large living and dead organic material on stream banks and in the channel. Large organic debris in channels occurs on scales ranging from scattered individual pieces and small accumulations to massive organic debris jams up

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to hectares in extent. Little information is available concerning the effects of various types of large organic material on channel form and process.

This paper is a preliminary report on ongoing studies of the effects of large organic material (logs, limbs, and rootwads greater than 10 cm in diameter) on stream channel form and fluvial processes. We argue that large organic debris in stream channels may greatly affect erosional and depositional processes that locally control channel geometry, development of meander cutoffs and midchannel bars, and in-channel sediment storage. In order to demonstrate this we compare and contrast low gradient meandering streams in Indiana and North Carolina with steeper mountain streams of western Oregon.

Published information concerning the role of organic material in contributing to the modification of stream channels is rather limited but does include early reports such as Lobeck's (1939) discussion of a huge debris jam on the Red River in northern Louisiana and Bevan's (1948–49) discussion of organic debris associated with significant changes in channel morphology of the middle fork of the Willamette River in Oregon. In fact, Bevan concluded that large organic debris in rivers causes more channel changes than any other agent. More recently interest in forest ecology, forest geomorphology and riparian habitat has resulted in increased study of relationships between organic debris and streams (see, for example, Hack and Goodlett (1960); Heede (1972a, 1972b); Bilby (1977); and Meehan, Swanson and Sedell (1977)). Recent research has also dealt with relationships between logging practices and large organic debris in streams (see, for example, Sheridan (1969); Froehlich (1973); Swanson and others, (1976, in press); and Janda (1977)). In addition, several authors (Maddock (1972); Wilson (1973); Smith (1976); and Zimmerman, Goodlett and Comer (1967)) have discussed the effects of organic material on channel width, bank stability and flood capacity.

PRINCIPAL FACTORS CONTROLLING DEBRIS CONDITIONS IN STREAMS

The amount and arrangement of large organic debris in a particular stream reach reflect the balance between input and output processes. Debris transfer into and through stream channels occurs by complex sets of interacting processes. Many of the key relationships among external driving variables, input and output transfer processes and the standing crop of large organic debris are depicted in Figure 1.

Numerous natural processes are responsible for transfer of large organic debris to stream channels. In low gradient meandering streams the common processes include bank failure, blowdown, and in northern latitudes, collapse of trees due to ice loading (icing). Of the three, bank failure caused by lateral stream erosion probably delivers most of the organic material into low gradient streams. However, icing during winter storms and blowdown due to tornadoes, hurricanes and other types of high winds also add considerable debris to streams. In steep forested mountainous terrain debris is also delivered to stream channels by snow avalanches and soil mass movement processes. Particularly important are debris avalanches from adjacent slopes and debris torrents from tributary channels. Encroachment of slumps and earthflows on stream channels leads to increased bank instability and tipping of trees, making them more susceptible to falling in response to other processes such as blowdown (Swanson and Swanston (1977)). At high flow, floating large debris and river ice batter and even uproot streamside vegetation, thereby entraining large debris (Sigafoos (1964)). Steep hill-slopes adjacent to channels allow large debris generated by events operating well away from the channel to slide downslope to the channel. Commonly several of these processes act in concert to move large organic debris to a channel. A common chain of interacting events occurs when blowdown of one or two large streamside trees bares the stream bank, making it more susceptible to stream erosion followed by undercutting of additional streamside trees.

Large organic debris is redistributed in stream channels and ultimately carried out from them by a variety of processes (Figure 1). Large debris may be moved *en masse* by debris torrents in steep headwater streams and by flotation at high flow in wider, deeper channels. Breakdown of large debris occurs throughout physical abrasion and by consumption by invertebrate and decomposer organisms. The products of biological breakdown include dissolved and fine particulate excretory products, CO_2 released by animal and microbial respiration, and fine particulate organic detritus dislodged by feeding activities. In addition, dissolved organic matter is leached from large organic material and carried downstream in solution. During

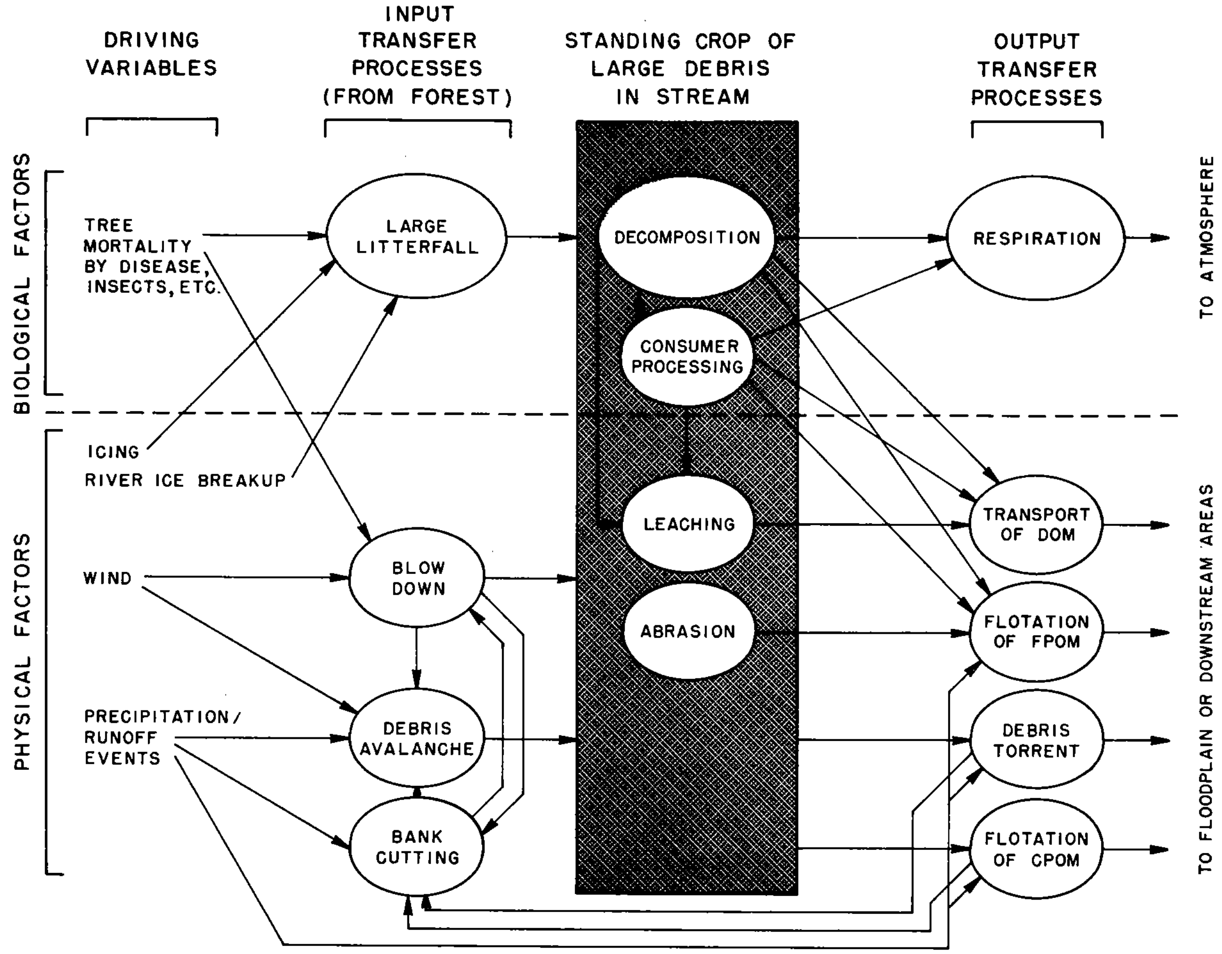

Figure 1. Dynamics of woody debris. DOM = dissolved organic matter; FPOM = particulate organic matter <10 cm in diameter; CPOM = coarser particulate organic matter

periods of overbank flow large debris may be carried out of the channel and deposited on the floodplain where it undergoes decomposition in the terrestrial environment with little influence on the fluvial system.

Stream size ~~is a~~ key factor in determining stream debris conditions. Debris concentrations are highest in small headwater streams and generally decrease downstream, due to increased stream area per unit length and greater ability of wider streams and rivers to carry large debris to floodplains and downstream reaches. For example, in old-growth Douglas fir forests in the McKenzie River system, western Oregon, coarse (>10 cm diameter) debris concentration is 48 times higher in a first-order tributary than in the sixth-order mainstem river (Table I). A series of five sample points alongstream reveals a systematic decrease in coarse organic debris loading (kg/m^2) in the downstream direction.

The relative importance of debris input and output processes changes from headwater areas down through a stream system (Figure 2). Using the Lookout Creek–upper McKenzie River system, western Oregon as an example, blowdown as a debris input process in a particular reach affects all streams, but decreases in importance downstream relative to transport from upstream and bank cutting. Input processes related to soil mass movement are generally restricted to upstream areas where steep tributary channels and hillslopes abut the channel. Snow avalanches may carry debris into the channel only in the high elevation, headward areas. Among large debris output or down channel transfer processes only debris torrents are restricted to steep headwater channels. The physical biological and leaching processes that break wood

Table I. Coarse (>10 cm diameter) debris loading in sampled sections of five streams flowing through old-growth Douglas fir forest in McKenzie River system, western Oregon. Specific gravity of wood assumed to be 0·50 g/cm^3

Stream	Coarse debris loading (kg/m^2)	Length of sampled section (m)	Channel width (m)	Channel gradient (%)	Stream order	Watershed area (km^2)
Devilsclub Creek	43·5	90	1·0	40	1	0·2
Watershed 2 Creek	38·0	135	2·6	26	2	0·8
Mack Creek	28·5	300	12·0	13	3	6·0
Lookout Creek	11·6	300	24·0	3	5	60·5
McKenzie River	0·5	800	40·0	0·6	6	1024·0

down to small, readily transported material operate throughout the river system. Flotation is an important process in streams of third- to fourth-order and larger.

The arrangement of debris also varies along streams in response to the ability of the stream to redistribute debris. In small streams large debris will be located randomly where it initially fell, because even at peak flow these streams are too small to redistribute the relatively large pieces of debris. In western Oregon these conditions prevail in first- and second-order channels (Figure 3). Intermediate-sized channels are large enough to redistribute debris, frequently forming distinct accumulations that may directly affect the entire channel width (Figure 4). Large rivers (>fifth-order in western Oregon) generally have scattered large

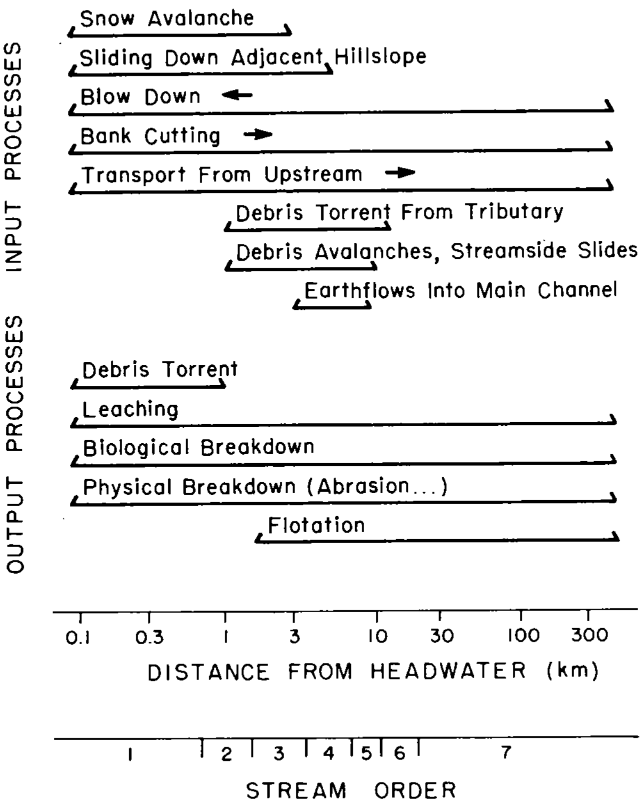

Figure 2. Stream distribution of input–output processes associated with organic debris in the Lookout Creek–McKenzie River System, Oregon. Arrows indicate direction of increasing importance

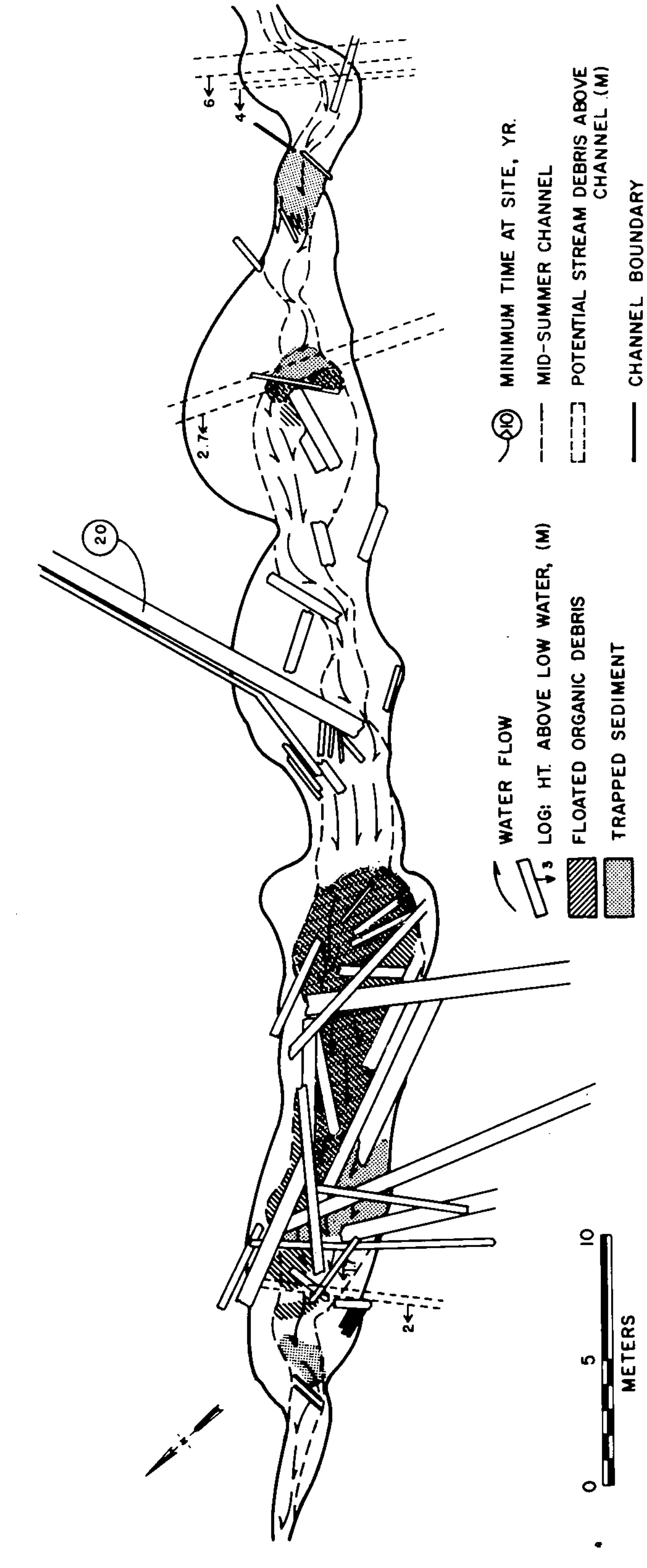

Figure 3. Map of large organic debris in second-order Watershed 2 Creek, H. J. Andrews Experimental Forest, Oregon

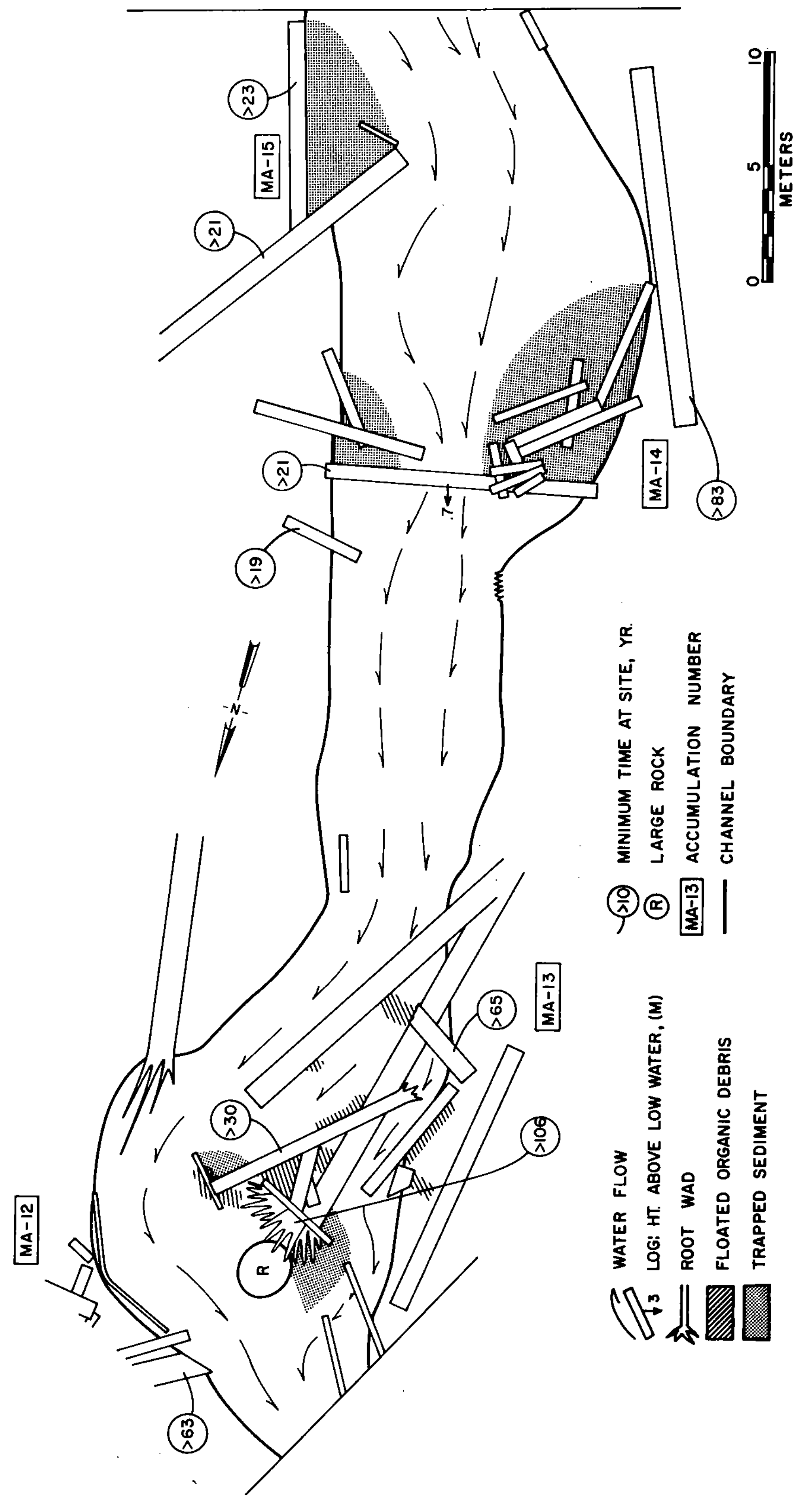

Figure 4. Map of large organic debris in third-order Mack Creek, Oregon

debris in the high water zone on banks (Figure 5) and large accumulations of debris set up on obstructions in the channel and on the outside of river bends. In these situations organic debris has little influence on a channel except at high flow conditions.

These examples are taken from western Oregon, an area typified by large trees and high gradient streams that carry high annual runoff and flood flows. However, the principles described apply in general to any forested stream system. The relative importance of debris input, redistribution and output processes will vary in response to climate, physiography and vegetation conditions with consequent variation in stream debris characteristics. For example, in stream systems receiving smaller sized organic debris the along-stream sequence of debris conditions (random distribution → numerous, distinct channel-wide accumulations → scattered, high-water zone accumulation) will be shifted upstream. Although concentration of debris is lower in most forest types than in old-growth Douglas fir forests, observations in spruce–hemlock (Alaska), spruce–fir (New Hampshire), ponderosa pine (Idaho), mixed hardwood (North Carolina, Indiana, Tennessee) and other forest types indicate that debris concentrations from other forests are also of sufficient magnitude to substantially effect morphology of small and intermediate sized streams.

EFFECTS ON CHANNEL MORPHOLOGY

Effects of large organic debris on stream channel form and process varies (in specific instances) from insignificant to exerting nearly complete control of channel morphology. Of particular importance is the development of debris jams which may partially or completely block the stream channel. Development of a debris jam is a type of autodiversion, that is, a channel diversion triggered in part by fluvial processes. In meandering streams,the formation of debris jams often results in: (1) erosion which locally may scour the stream bottom or increase channel width by more than 50 per cent as water is diverted around the obstruction; (2) deposition that initiates development of midchannel bars immediately downstream from a jam; and (3) a backwater effect upstream that may, in favourable situations, facilitate development of a meander cutoff. On the other hand, in steep mountain streams the effects of debris jams are often considerably different. In many steep streams with little or no valley-flat, sediment storage behind obstructions to flow becomes significant; as does development of plunge pools immediately downstream from organic debris dams.

STUDY AREAS

Determining the effects of large organic material on stream channel morphology is facilitated by studying streams in contrasting environments. Therefore we will examime low gradient meandering streams in Indiana and North Carolina and compare these with high gradient streams of mountainous areas in western Oregon. The low gradient streams include Wildcat Creek near Lafayette, Indiana, Campbell Creek near Charlotte, North Carolina and Mallard Creek near Harrisburg, North Carolina. All three are meandering streams with gradients on the order of several meters per kilometer. Wildcat Creek and Mallard Creek are intermediate sized streams with channel widths on the order of several tens of meters. Campbell Creek is a small stream with average channel width of a few meters.

The steep mountainous streams studied have gradients ranging from 6 to 400 meters per kilometer. These streams are in the Lookout Creek drainage in the H. J. Andrews Experimental Forest, and the McKenzie River, western Cascades, Oregon. These steep gradient mountain streams vary in width from a few meters to several tens of meters.

Low gradient meandering streams and organic debris

The effects of large organic debris on stream channel morphology in low gradient meandering streams varies with size of the stream and size distribution of the debris. For very small streams the effect of organic debris is quite variable and potentially very important (Zimmerman, Goodlett and Comer (1967)). For example in Campbell Creek near Charlotte, North Carolina, the effect of one large tree falling in the small channel was quite pronounced (Figure 6). The series of cross-sections for Campbell Creek from September

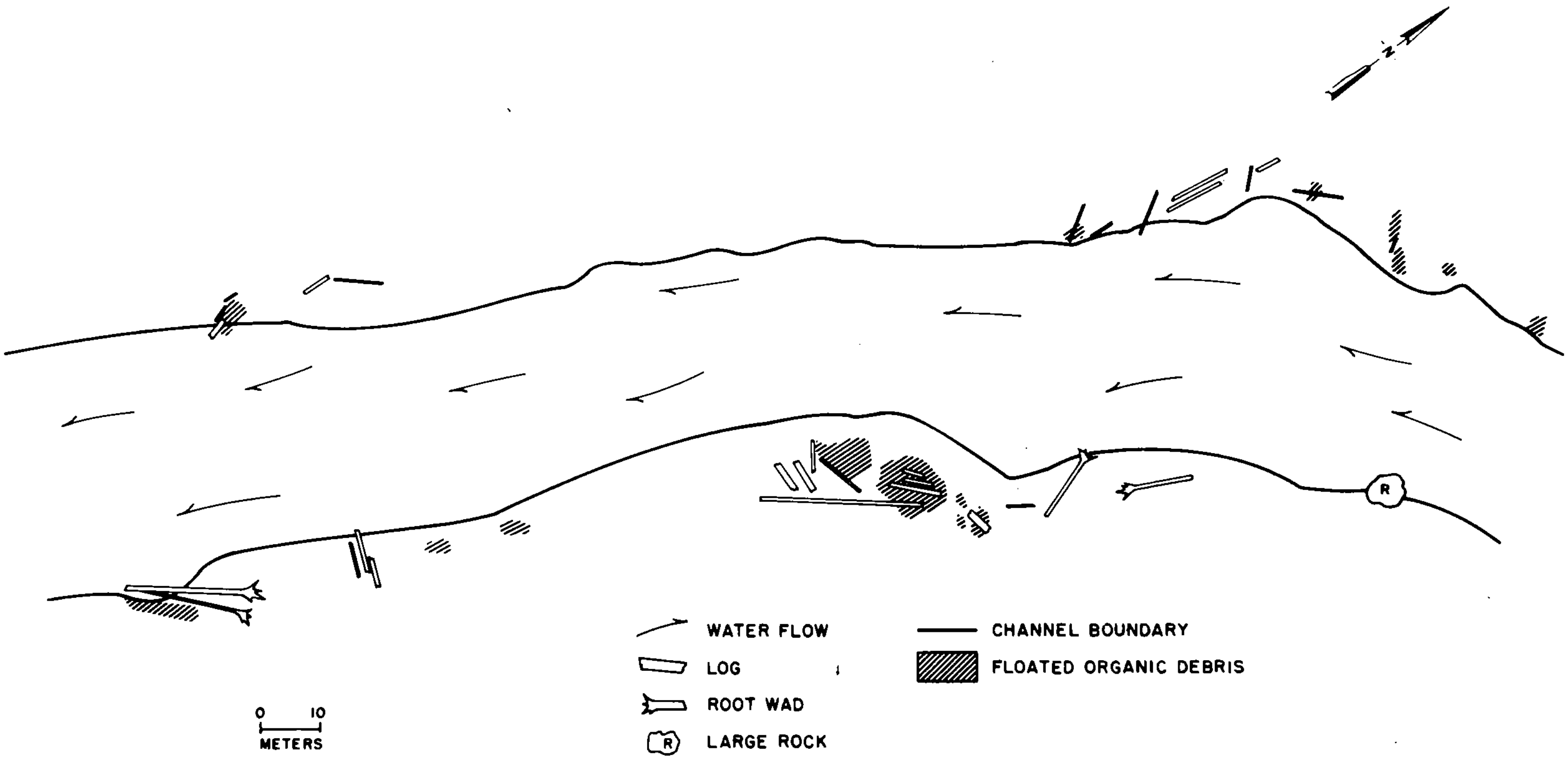

Figure 5. Map of largest organic debris in and adjacent to sixth-order McKenzie River at Rainbow, Oregon

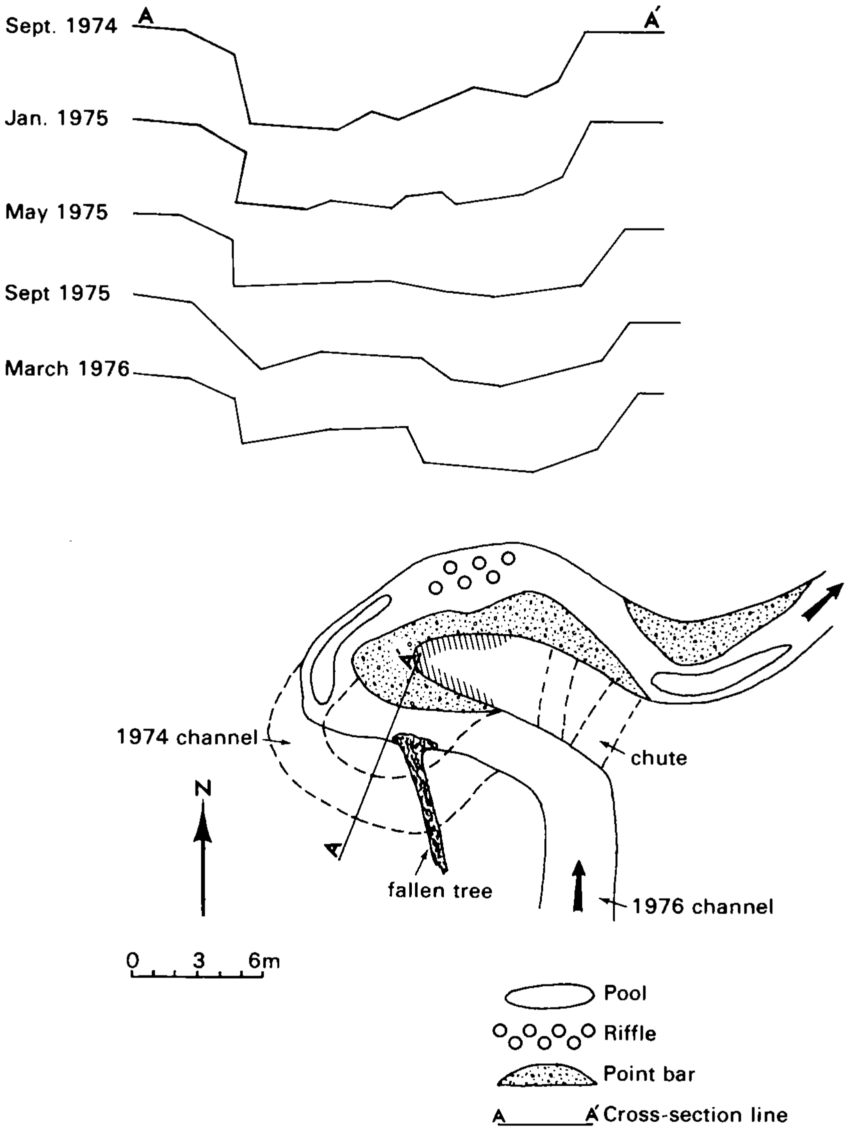

Figure 6. Changes in morphology resulting from large organic debris in Campbell Creek near Charlotte, North Carolina (1974–76)

1974 through March 1976 clearly show that the channel shifted by approximately two channel widths as a result of a single fallen tree which caused local streambank erosion. The tree also backed up water which probably facilitated the development of chutes across the meander bend.

Observations on Wildcat Creek near Lafayette, Indiana suggest that large debris may contribute to the development of a meander cutoff. As of 1968 a large logjam of undetermined age (Point A, Figure 7) was backing up water on a meander bend and diverting it across the floodplain. A braided reach of channel (Point B) had developed immediately downstream from the debris jam and at Point C a high water chute connecting the upstream and downstream ends of the meander bend had formed. In 1971 a meander cutoff formed suddenly when the stream occupied the course of the chute (Figure 7). Keller and Melhorn (1973) hypothesize that the debris jam partly caused the meander cutoff by facilitating overbank flows across the meander bend. Furthermore, several other recent meander cutoffs in Wildcat Creek were also observed to be associated with debris jams but a definite cause and effect relationship is difficult to establish.

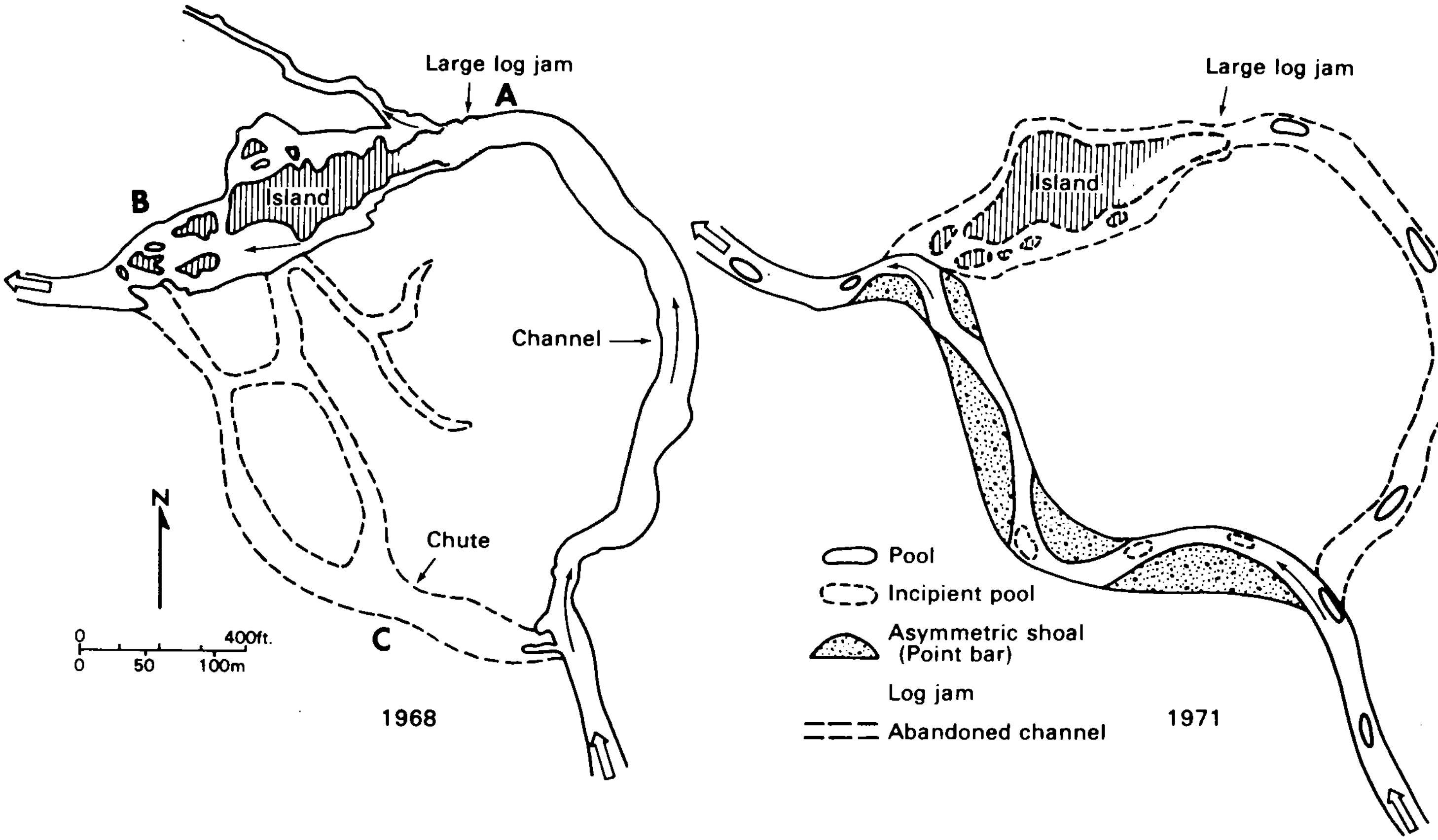

Figure 7: Meander cutoff in Wildcat Creek near Lafayette, Indiana. See text for explanation

Relationships among large organic debris, meander cutoffs, erosion, deposition, and development of midchannel bars in a meandering stream channel were examined in Mallard Creek near Harrisburg, North Carolina. The stream, in the study reach, has a width of approximately 12 meters, a slope of approximately 1 meter per kilometer, and a well developed floodplain, vegetated, in part, by a mixed hardwood forest.

A large debris jam (Figures 8 and 9) associated with a complex series of bars, scour areas, and depositional areas that produce a variety of channel forms was studied. This large debris dam, located on the outside of a meander bend, has resulted in: (1) a 230 per cent increase in stream width due to bank erosion caused by the jam; (2) development of scour holes and midchannel bars in the vicinity of the debris jam; (3) recent development of a high water channel downstream from the jam (produced by diverted flood water) which may eventually cut off the downstream meander bend; and (4) downstream development of smaller jams as the larger one breaks up. The thalweg through the debris jam has pronounced scour holes formed in the vicinity of the jam and in several downstream areas. The water surface delineates a backwater effect where the surface of the water actually slopes upstream just upstream of the jam.

Midchannel bars on the downstream side of debris jams may become islands if they become vegetated and protected from erosion (Kellerhals, Church and Bray (1976)). Sediment accumulating around the large debris is forming the island just downstream from the large jam in Figure 8, and as of 1976 establishment of vegetation has been stabilizing it. Development of midchannel bars due to diversion of water around debris dams and resulting deposition may be important in development of short braided reaches in otherwise meandering stream channels. Development of a braided channel is clearly evident in our Wildcat Creek example. Actual braiding is due in part to development of midchannel bars and in part to islands that were produced when water was diverted around debris jams to form several smaller streams that eventually reunited with the main channel. A similar mechanism has apparently produced short braided reaches downstream from several other debris jams investigated by the authors.

Study of debris jams such as the one in Mallard Creek suggest criteria whereby previous jams might be recognized by relic morphology. Two indications of former jams are: (1) a pronounced local increase in channel width; and (2) the presence of midchannel bars not otherwise common. The presence of both features strongly suggests that a debris jam was in that portion of the channel in the recent past. Based upon these criteria three sites of old jams were identified in a 6·4 kilometer reach of Mallard Creek. One site of an inferred debris jam and recent meander cutoff is shown on Figure 10. The inferred site of the debris jam has a bank scour area on the left side of the channel as well as a well developed midchannel bar. As of February 1976 the abandoned channel still carried a small amount of the low-flow discharge. Remnants of the old debris jam include a down but living sycamore tree which has a shoot growing vertically at the site of the inferred jam. Coring of this shoot and counting annual growth rings suggest a minimum age for the midchannel bar of approximately 18 years. A local resident stated that he remembered that a large debris jam had formed at that site 15 to 20 years previously. The stream makes an abrupt 90° bend at the site of the alluvial plug, and as the new stream channel cuts across the forested floodplain numerous trees have fallen or are leaning into the channel and it is in the process of being blocked by debris. The stream channel may eventually shift back to its old course. Nevertheless this example clearly demonstrates that if a debris jam is in a favourable location on a meander bend, it may locally increase the recurrence of overbank flows and facilitate eventual cutoff of the meander. The length of time required for this meander cutoff in Mallard Creek, is about fifteen years, and the meander bend was abandoned slowly rather than suddenly as in Wildcat Creek.

Further upstream on Mallard Creek on a complex, compound meander bend (Figure 11) a complex set of chutes and floodplain drainage is developing. The former existence of a debris jam, is inferred from the increase in channel width and development of midchannel bars. Associated with this site is a chute which may eventually cutoff part of the compound meander loop. Thus in low gradient meandering streams the tendency to form meander cutoffs may be strongly influenced by large organic debris in the stream channel.

Large organic debris in steep mountain streams

Large organic debris is also important in steep mountain streams although its role differs somewhat from that played in low gradient streams. Morphology of steep mountain streams is commonly controlled by

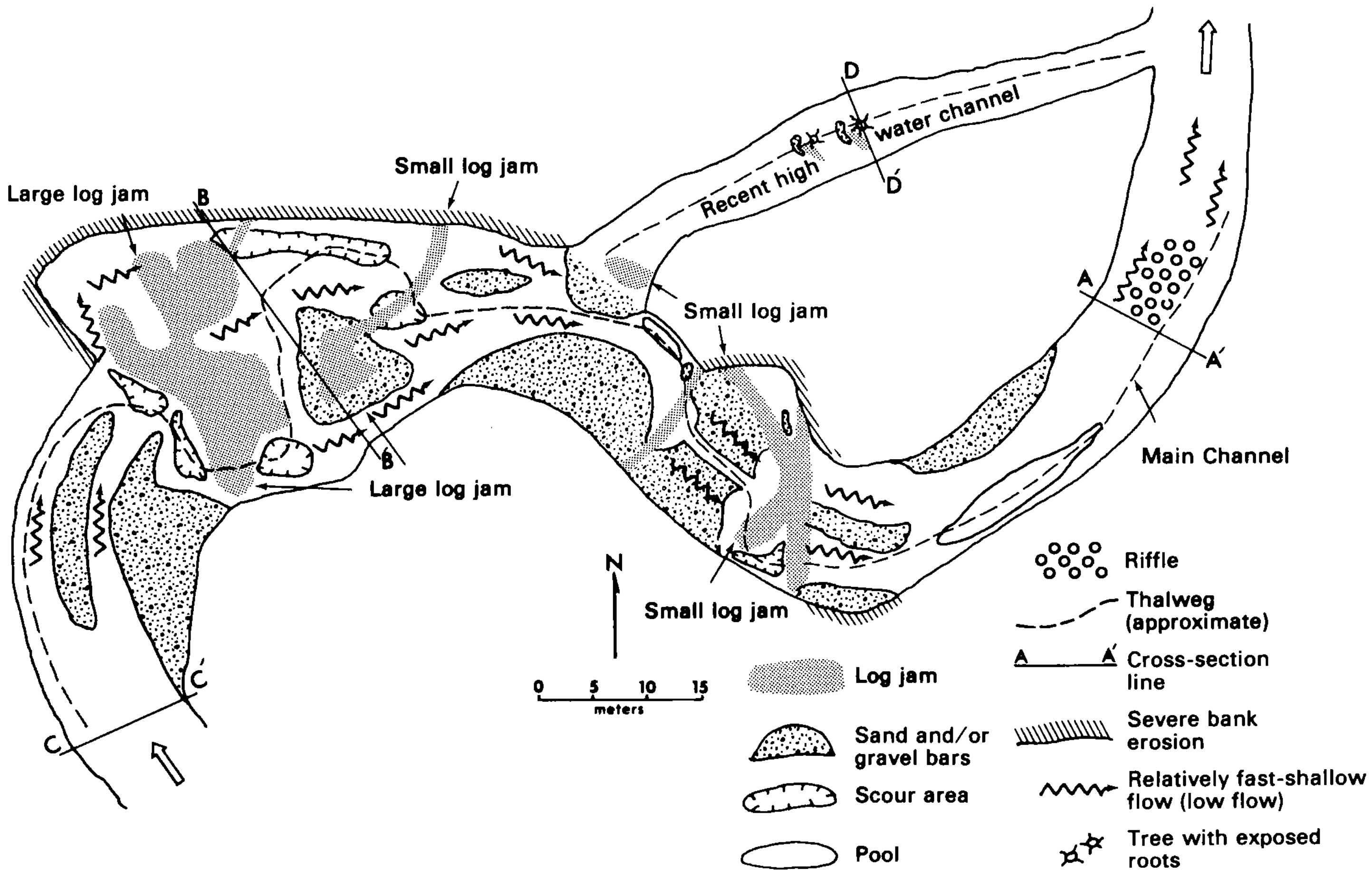

Figure 8. Morphology of a large logjam in Mallard Creek near Harrisburg, North Carolina, 1976. See text for explanation

Figure 9. Downstream view of the large logjam (Mallard Creek) shown in Figure 8

bedrock, boulders and large organic debris, whereas hydraulic factors that cause channels to meander are dominant in shaping low-gradient streams incised in easily eroded substrates.

Watershed 2 Creek in the western Cascades of Oregon is typical of many small steep streams in the Pacific Northwest (Figure 3). The stream flows through a very steep walled valley with valley slopes averaging about 40°. The channel gradient is approximately 15°; and where not influenced by organic debris, bedrock is exposed in the stream bed. The surrounding vegetation is an old-growth Douglas fir, western red cedar and western hemlock forest. This forest type produces large quantities of large debris that may reside in streams for more than a century (Swanson, Lienkaemper and Sedell (1976)). Large debris in the channel has formed plunge pools downstream from logs and has trapped sediment upstream from obstructions (Figure 3). This is the opposite of conditions in the examples of low gradient meandering streams where the scour was in a similar location but stored sediment was primary in midchannel bars downstream of the obstruction. Large debris in Watershed 2 Creek produces a stepped stream profile similar to that discussed by Heede (1972a). The water surface is relatively flat upstream of obstructions and steep going over them (Figure 12). Commonly in such small western Oregon streams 30 to 80 per cent of the drop of the stream is influenced by debris and 20 to 35 per cent of the stream area is occupied by woody debris. A stepped stream profile may result in dissipation of much of the stream's energy at debris-created falls and cascades which occupy a relatively small percentage of stream length.

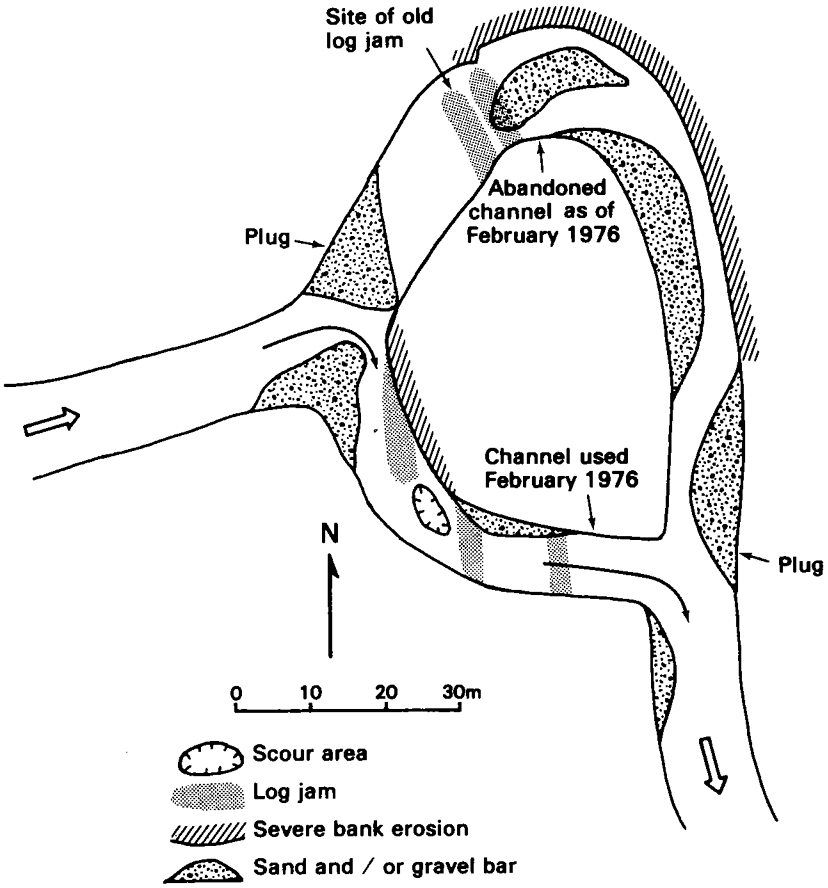

Figure 10. Morphologic map showing the site of an inferred logjam and a meander cutoff in Mallard Creek (winter 1976). See text for explanation

Figure 13 is an idealized diagram showing a debris created stepped channel profile (organic stepping) with plunge pools and areas of sediment storage. The water surface profile of the stream at low stage is somewhat analogous to that of a pool–riffle sequence. However, debris created stepping is probably more analogous to the stepped-bed morphology of channels in arid regions (Wertz (1966) and Bowman (1977)) than to pool–riffle morphology. The average spacing of debris accumulations that deflect flow in five third-order Oregon streams have spacings of one to two channel widths. This is similar to the spacing of Bowman's stepped-bed morphology, but is considerably less than the spacing of pools and riffles, which tend to average 5 to 7 times the channel width (Keller and Melhorn (1973)).

Debris which obstructs flow acts as a dam creating a diversity of habitats for aquatic organisms. Without the presence of the large debris such streams could be effectively 'channelized' with more rapid transfer of sediment through the channel system and a reduction in stable substrates and depositional sites upon which much of a forested stream's invertebrate community is dependent.

The relative importance of large organic debris in affecting sediment storage and energy dissipation in streams decreases with channel slope. In low-gradient streams much in-channel storage occurs in point bars, riffles and floodplains. In steep streams these storage sites are often not present, and thus the large organic debris may account for a much larger portion of total sediment storage.

Stored sediment in small steep streams is subject to catastrophic flushing by debris torrents, masses of soil, alluvium and organic debris moving rapidly down channel (Swanston and Swanson (1976)). These

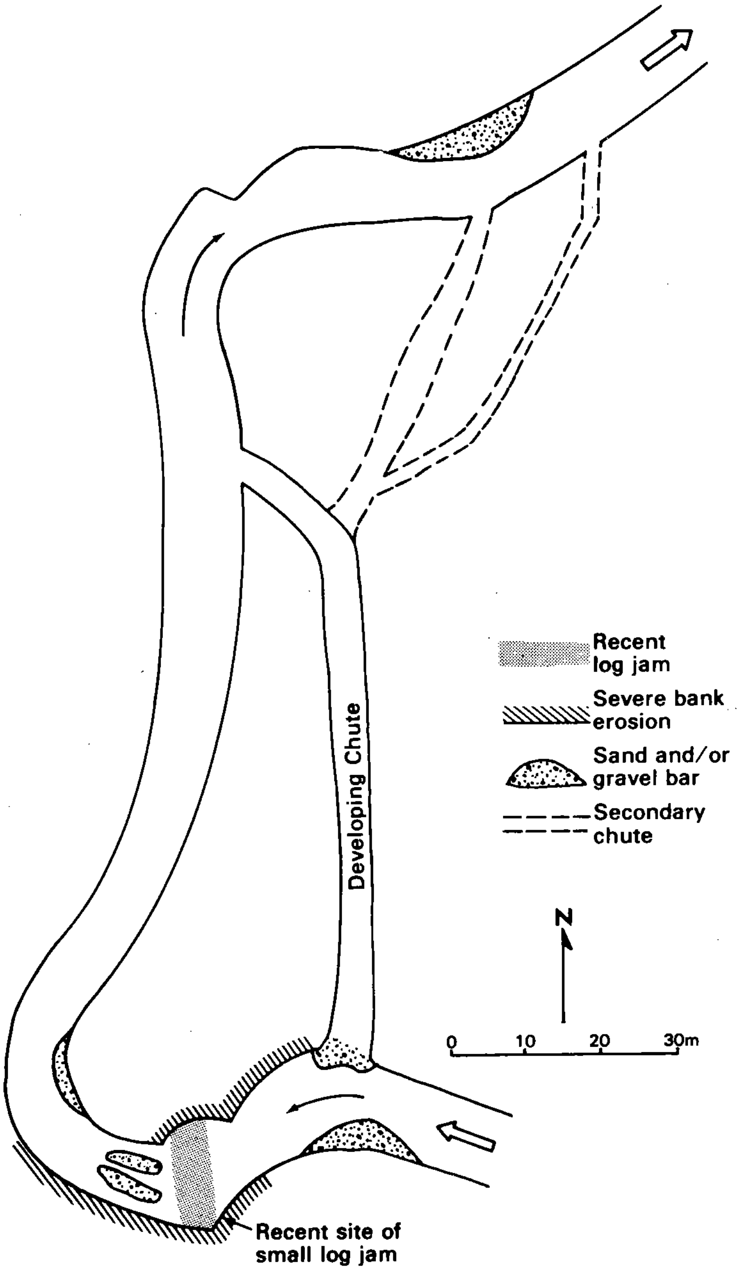

Figure 11. Complex meander bend Mallard Creek (winter, 1976). See text for explanation

events are commonly triggered by extreme precipitation, possibly associated with snowmelt, that leads to shallow soil mass movements from steep hillslope areas. As such hillslope mass movements enter channels, they may maintain their momentum and move rapidly down channel. The mass of a torrent increases as alluvium and large debris is entrained along the channel. This process leaves channels with initial debris loading similar to Watershed 2 Creek (Figure 3) scoured to bedrock (Figure 14) along the course of the torrent track. Passage of a torrent scours the valley bottom and adjacent slopes of small, steep channels, contributing to the formation of a U-shaped cross-profile. As the gradient of a channel decreases, the debris

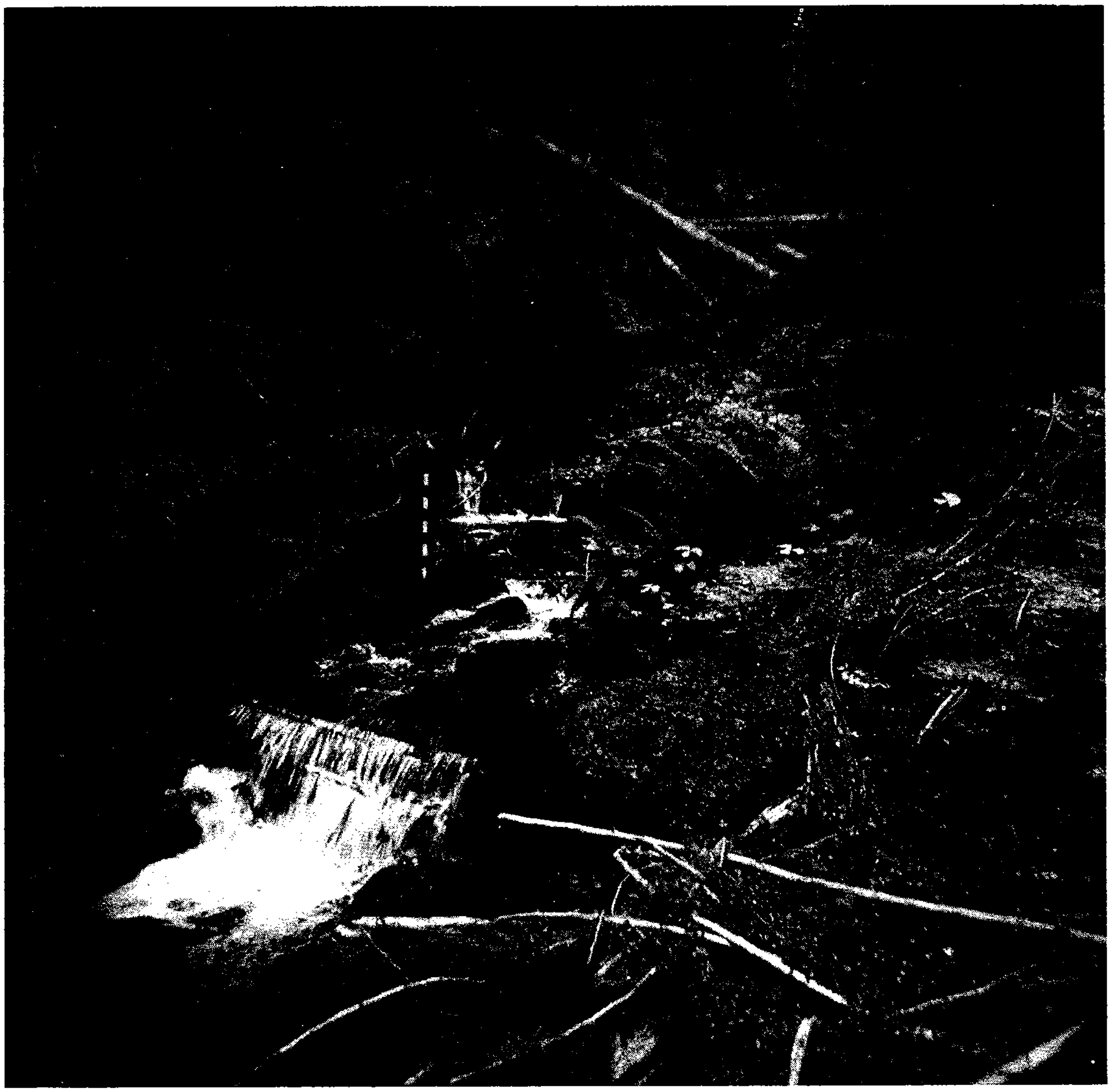

Figure 12. Debris created channel stepping in a small Oregon stream

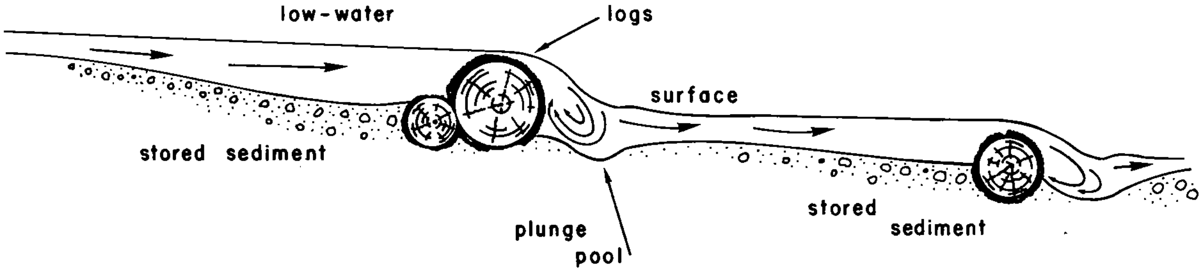

Figure 13. Idealized diagram showing concept of organic stepping

Figure 14. Channel scoured by debris torrent, Oregon Coast Range

torrent finally stops, piling transported material in a massive jam of tightly interlocking pieces (Figure 15). This type of debris jam forms an effective sediment trap that persists for decades, often until the debris is decomposed and flushed downstream or the area is by-passed by lateral cutting of the stream.

EFFECTS ON BANK STABILITY

Living and dead organic matter has variable effects on bank stability. Large dead organic debris in channels generally increases bank stability by creating small falls, runs, hydraulic jumps and other zones of concentrated turbulence where stream energy is dissipated. Organic debris may also be buried in stream banks or positioned against banks, thereby protecting them from erosion. Living vegetation rooted in streambanks is particularly effective in increasing bank stability. The aboveground portion of vegetation contributes to channel roughness, thereby reducing water velocity at streambanks. However, under very extreme flow conditions when vegetation is uprooted channel roughness may abruptly decrease (Baker (1977)).

Organic debris also contributes to bank instability where it directs streamflow against banks, increasing lateral migration of the channel. At high flow conditions, floating large debris batters banks and living streamside vegetation, thereby increasing bank erosion during the flood and reducing the protection of streambank and bed by living vegetation for several years following the event. Therefore, in channel systems where vegetation is important the sequencing of major floods influences the erosional consequences of a particular flood. A flood of a particular magnitude will have different consequences depending on streamside vegetation conditions determined in part on the magnitude and time since previous floods.

Figure 15. Debris dam in a third-order channel, Oregon Coast Range at downstream end of torrent track shown in Figure 14 (note figure in upper centre)

Root systems, where exposed by streambank cutting, are more resistant to erosion than soil and alluvium. The ability of root mats to protect streambanks was investigated by Smith (1976), who observed that streambanks with a five centimetre thick root mat retard erosion up to 20,000 times more effectively than streambanks lacking vegetation. Smith observed an inverse relationship between erosion rate and percentage of vegetation roots in the bank sediments.

In order to evaluate the effectiveness of trees in protecting streambanks from erosion the percentage of bank protected by rootwads of hardwood trees was measured in a 320 m reach of Mallard Creek. A secondary objective was to determine the relationship between size of tree and width of rootwad protection for hardwood trees. In the study reach tree roots protected 73 per cent of the length of streambank. This is considered to be representative for Mallard Creek, and is probably representative for other streams which flow through a hardwood forest. The nearly linear relation (power of $x \equiv 1$) between tree size (x) and rootwad size (y) protecting the streambanks, was expected and suggests that for hardwood trees the length of bank protected by tree roots is approximately five times the diameter of the tree ((Figure 16). Tree root systems exposed along streambanks extend along and into the banks. Therefore, trees may be undermined considerably by bank erosion before they fall into the stream channel. Thus undercut stream banks are commonly found in association with tree root protected streambanks.

Average channel width and slope are also affected by streamside vegetation. Maddock (1972) noted that vegetation reduces the erodability of banks with the result that tree lined channels should be narrower and steeper than alluvial channels with unvegetated banks which transport the same amount of sediment and water. Furthermore different types of vegetation may have contrasting effects on channel geometry. For example, Zimmerman, Goodlett and Comer (1967) observed that different reaches on the same stream varied in width depending upon whether the banks were lined with trees or sod. They found that the mean

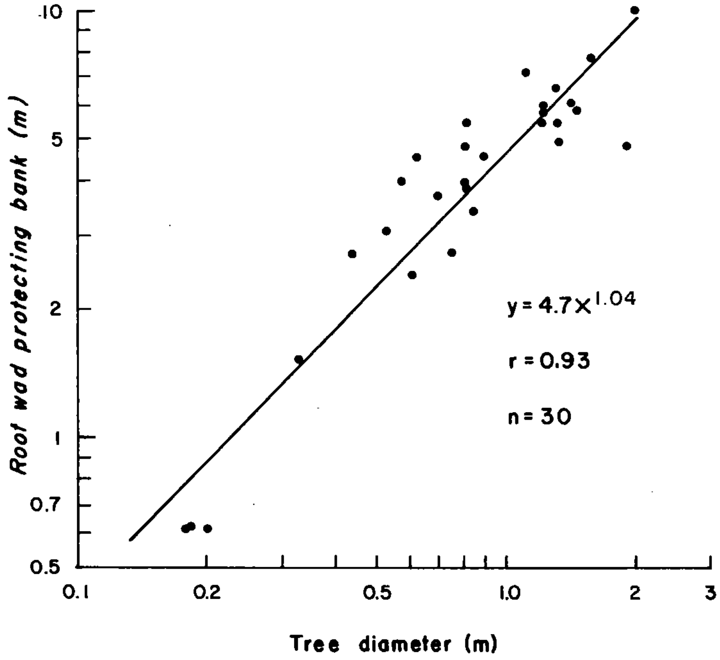

Figure 16. Relationship between rootwad protecting bank and tree diameter for a mixed hardwood forest, Mallard Creek, North Carolina

width of stream reaches with forested banks was significantly greater than that of reaches with sod banks. However, these differences decreased with increasing drainage basin area.

CONCLUSIONS

1. The nature and extent of the influence of large organic debris on stream channel morphology and process is primarily a function of source factors delivering debris to the channel; stream size; and hillslope and valley morphology.
2. Large organic debris dams in low gradient meandering streams of moderate size are often associated with streambank erosion and in-channel deposition which locally may greatly increase channel width; may in specific instances facilitate the development of meander cutoff; and may produce midchannel bars and thus a short braided reach in an otherwise meandering channel.
3. Debris jams in small to moderate size steep mountain streams locally may control channel morphology and processes by increasing or decreasing channel bed and bank erosion and/or deposition; providing for significant in-channel sediment storage for long periods of time; and producing an 'organic stepping' that creates a variable channel morphology somewhat analogous to pools and riffles in low gradient meandering streams or stepped-bed morphology in arid gravelly channels.
4. Living or dead trees anchored by rootwads into a streambank may greatly retard bank erosion. Once a tree falls into the channel it may reside there a long time and depending on the size of the stream and other factors may greatly affect channel form and process.

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