RIVER AND RIPARIAN LAND MANAGEMENT TECHNICAL GUIDELINE UPDATE

NUMBER 3, JULY 2003

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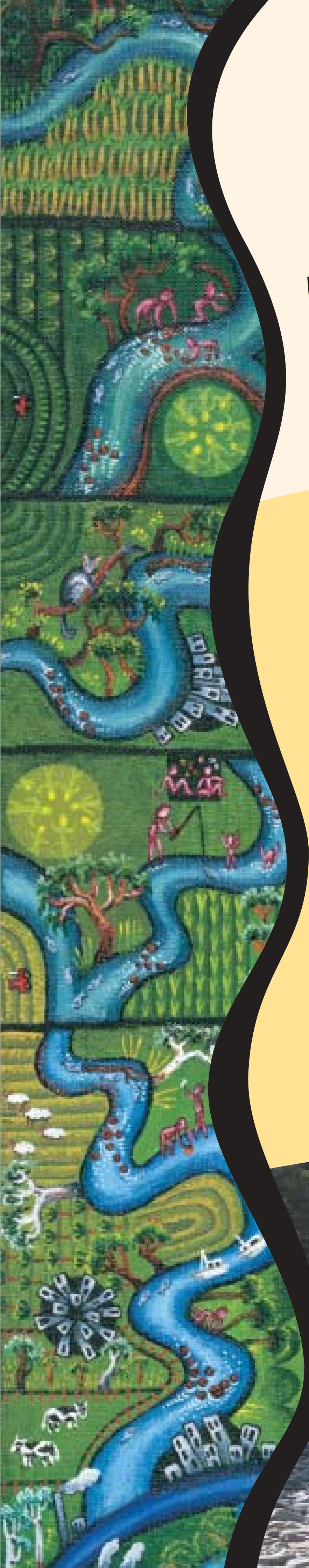
ISSN 1445-3924



Managing wood in streams

Edited by Peter Cottingham, Stuart Bunn, Phil Price and Siwan Lovett

Contributors: Andrew Brooks, Keiran Croker, Peter M. Davies, Alena Glaister, Victor Hughes, Mel Jackson, John Koehn, Sam Lake, Nick Marsh, Simon Nicol, Ian Rutherfurd, Scott Seymour, Simon Treadwell

Summary

- Past river management practices have led to the widespread and systematic removal of logs and branches, yet wood in streams performs many different roles and is a vital component of riverine ecosystems.
- Until recently, logs were thought to be significant contributors to bank erosion and flooding. However, logs can enhance stream stability — their presence can exert significant control on channel complexity in bedrock rivers and channel geomorphology in alluvial rivers.
- With the exception of large wood accumulations, there is little evidence that logs and branches have a dramatic effect on flooding. Rivers will flood irrespective of the presence of wood.
- Logs and branches from Australian riparian zones are relatively immobile. Our streams tend to have a low average stream power, the wood has a high density and many riparian trees have a complex branching structure that ensures they are easily anchored in position after falling into the stream.
- Retention and reinstatement of logs should be a priority for river rehabilitation, instead of removal and realignment. Five key steps should be undertaken when considering the reintroduction of wood into rivers and streams, and these are outlined in this Technical Guideline Update.

Background

The ecological and geomorphological functions and benefits associated with wood in streams were reviewed in *Volume 1* of the *Riparian Land Management Technical Guidelines* (1999). *Volume 2* of the *Riparian Land Management Technical Guidelines* (1999) provided information on the management of wood in order to protect the ecological health of streams. This Technical Guideline Update restates the ecological values associated with wood in streams (upland and lowland), with additional emphasis on associated floodplains and wetlands. These areas are the primary source of the timber that finds its way into streams, and have biological communities that also benefit from the presence of wood. The Technical Guideline Update also provides additional information that will assist those who seek to reinstate wood as part of rehabilitation efforts aimed at improving the ecological health of river systems. These new insights have been collated from recent management experience and ongoing research on the role of wood in the ecology and geomorphology of streams, particularly in southeastern Australia.

Managing or reintroducing wood to streams is often a feature of river rehabilitation. This Technical Guideline Update assumes that practitioners have developed rehabilitation objectives and assessed their stream or river reach to establish that managing or reintroducing wood is likely to contribute to desired rehabilitation outcomes.

Throughout the document we use the terms 'wood' or 'snag' to refer to the logs and branches in streams and rivers that have been derived from riparian and floodplain vegetation. We have deliberately avoided the term 'debris' as we believe it has negative connotations.

Wood in streams and rivers performs many roles and is important for riverine ecosystems. Photo Ian Rutherfurd.

The ecological role of wood in streams

The important role played by wood in the ecology of streams is now widely recognised. Logs:

~ provide a relatively stable physical habitat for biota at all levels of the food chain, ranging from microscopic bacteria, fungi and algae, to macroinvertebrates and fish.

~ provide sites where bacteria, fungi and algae can process carbon and other nutrients such as nitrogen and phosphorus, thus contributing to ecological processes such as productivity and respiration and providing the basis for natural food chains (see Figure 1).

~ contribute to the formation of physical features in streams, such as scour pools and channel bars, that help to provide the range of conditions needed by different instream biota. For example, scour pools formed around large logs are special refuges for stream biota in low flow conditions.

Misunderstanding of how snags affect channel structure and erosion, and overstatement of their contribution to flooding, has seen the broad-scale removal of wood from rivers and streams across Australia. Our rivers and streams now have far less wood in them than was present prior to European settlement. Clearing the riparian zone and desnagging rivers has undoubtedly contributed to channel degradation (Brooks et al. 2003, Brooks 1999a), and the decline of aquatic species that depend on wood for shelter and food (e.g. Koehn et al. 2000, Crook & Robertson 1999, O'Connor 1992). Furthermore, the removal of standing and fallen timber from the riparian zone and floodplains means that future sources of wood are now greatly diminished. For example, preliminary estimates provided by MacNally & Parkinson (1999) suggest that the amount of fallen wood remaining on the floodplains of the southern Murray Darling Basin is approximately 15% of that present prior to European settlement. Wood on the floodplain is likely to play a significant role in maintaining local biodiversity given that fish and aquatic macroinvertebrates are known to utilise this habitat during inundation (e.g. MacNally 2000). The loss of wood on the floodplain and the patchy distribution of that which remains, means that we have also lost potential habitat for birds, invertebrates, reptiles and mammals, in addition to aquatic organisms.

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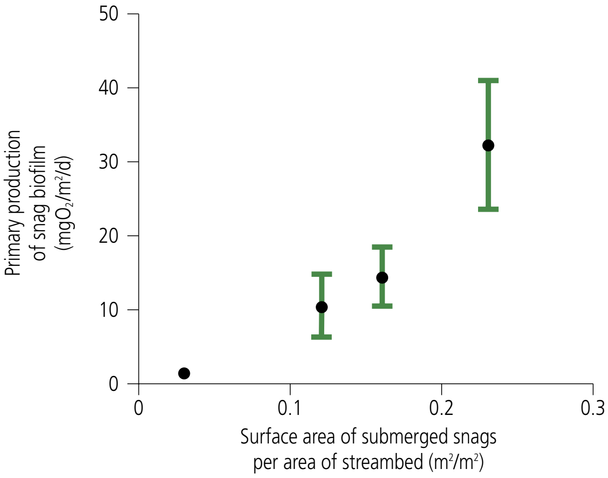

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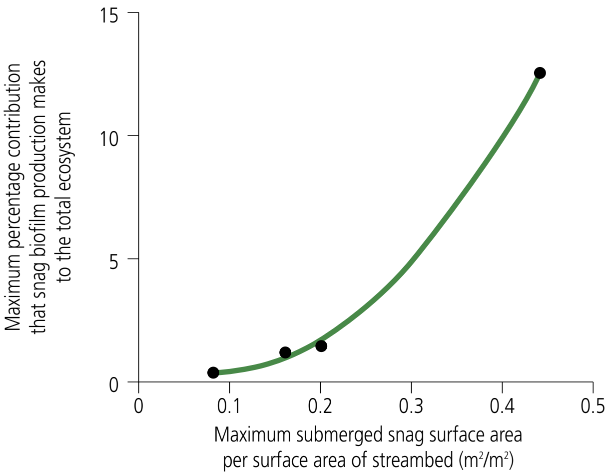

Figure 1: Research shows that primary production by biofilms growing on wood surfaces is an important contributor to total in-stream productivity. (A) In rivers that have low snag surface area, for example rivers that have been desnagged, the amount of primary production by biofilms growing on wood surfaces is low. (B) The greater the snag surface area the higher the overall contribution that biofilm primary production makes to total ecosystem production (S. Treadwell, unpublished data for sites in the Ovens and Murray Rivers).

Main photo Ross Digman. Insect Stuart Bunn. Native Cod John Harris. Frog Hans Wapstra. Grebe Neville Male.

Many different plants and animals rely on wood to provide habitat.

Photo Chris Gippel.

Rivers will flood irrespective of the presence of wood.

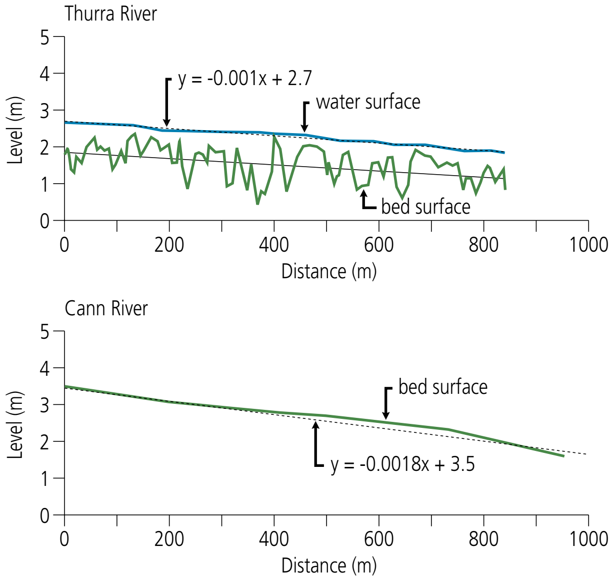

Figure 2: Bed profiles of the Thurra and Cann Rivers showing the profound homogenisation that occurred following wood removal and subsequent channel erosion (the Cann River would have been similar to the present day Thurra long profile [Figure 3] prior to desnagging and riparian vegetation disturbance). (A. Brooks)

It is now widely acknowledged that flooding and erosion are natural components of a healthy riverine ecosystem. Rivers will flood irrespective of the presence of wood, and the minor erosion that occurs around snags is a natural process and contributes to the diversity of habitat available to riverine biota. Thus, the focus of river management over the past decade has moved from one of actively removing snags, to retaining or reinstating them as part of river rehabilitation efforts. At the same time, planning laws and guidelines are beginning to recognise the need for riparian 'set asides' to ensure that valuable infrastructure is not placed where it may be threatened in future as the river meanders and moves across the floodplain.

The geomorphic role of wood in streams

Until recently, many river managers considered that logs were significant contributors to channel instability (e.g. bank erosion) and flooding. We now realise that logs contribute significantly to stream stability and that their role in flooding has been overstated. The presence of wood can exert significant control on channel complexity in bedrock rivers and channel geomorphology in alluvial rivers (see Figure 2), and ultimately the long-term evolution of river channels and floodplains. For example, a comparative study of the Cann and Thurra Rivers in East Gippsland, Victoria, highlighted the importance of wood to stream geomorphology. Europeans settled the floodplain of the Cann River in the 1860s, while the floodplain of the adjacent Thurra River remains relatively undisturbed. Both catchments have been subject to logging and wildfire. The defining difference between the catchments was the widespread clearance of the riparian zone and the removal of wood from the Cann River (Brooks & Brierley 2002, Brooks 1999a, b). When compared with the contemporary Thurra River and paleo-channel condition of the Cann River, the contemporary Cann River has:

~ a wider channel width;
~ deeper mean depth;
~ greater bankfull discharge and velocity;
~ greater stream power;
~ larger median grain size (suggests increased export of fine sediment and greater downstream transport of coarse material);
~ greater likelihood of bank failure;
~ no stable riffle-pool sequences (see Figure 3); and,
~ greater lateral migration.

The data from the Cann and Thurra river studies are just an example of the accumulating evidence that in Australia, wood can play a vital role in shaping and protecting river channels, and should not be removed without a thorough prior hydraulic analysis.

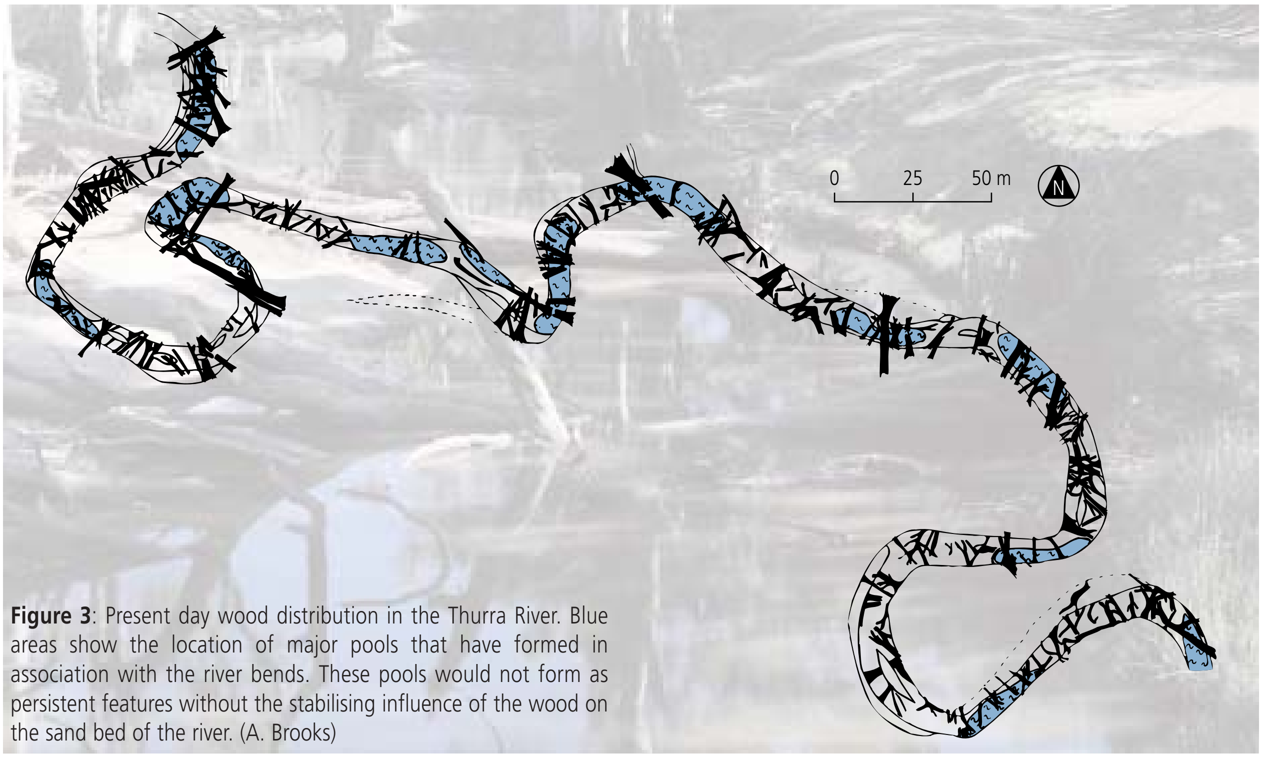

Figure 3: Present day wood distribution in the Thurra River. Blue areas show the location of major pools that have formed in association with the river bends. These pools would not form as persistent features without the stabilising influence of the wood on the sand bed of the river. (A. Brooks)

The significance of wood in rivers and its control on channel geomorphology has also been described overseas, particularly in North America (e.g. Abbe & Montgomery 1996, Montgomery et al. 1996). The control on channel geomorphology provided by in-stream wood can have profound implications for stream ecology and river rehabilitation. For example, the presence of wood can provide macro- and micro-habitat (Figure 3), and affect attributes such as stream power, channel dimensions, sediment transport potential and bed erosion. Bed substrate microhabitat has been shown to be finer and spatially more complex in streams with high wood loads compared to those without (Buffington & Montgomery 1999).

Above right: The present day Thurra River showing the very low capacity channel with a high wood loading and the associated complex channel morphology (see Figure 3). Photo Andrew Brooks.

Below right: The present day Cann River showing a wide featureless sand bed channel that has resulted from wood removal and riparian vegetation clearance upstream. Photo Andrew Brooks.

We now realise that snags contribute significantly to stream stability and that their role in flooding has been overstated.

Busting myths about wood in streams

There has been a systematic removal of wood from our streams based on what were once thought to be sound management principles. However, recent research has shown that our fears of snags are not necessarily substantiated.

Flooding

The presence of snags was thought to create a dramatic increase in flooding due to the increased roughness and decreased conveyance capacity of the channel. This can be true for large log jams, but for the most part individual snags do not increase channel roughness significantly, nor do they significantly decrease channel flow capacity.

Erosion

Snags create erosion. If an entire tree falls into the stream, the upending of the root plate often creates a scar of bare soil, some of which is eroded in the next flood. Large jams sometimes create local channel widening due to the constriction of flow. This local erosion only occurs when wood occupies a major proportion of the channel cross-section. By the time you have visually identified the point of erosion, most of the erosion has already occurred and the area is stabilising.

Infrastructure damage

Australian wood is relatively immobile when compared with international experience. Our streams tend to have a lower average stream power, our wood has a higher density (White 1998) and most critically, eucalyptus trees tend to have a complex branching structure. This complex branching means that the logs are easily anchored in position. For example, Koehn et al. (2000) measured the movement of over 300 snags in the Murray River between Yarrawonga and Tocumwal. They found that only 11% of the snags moved following a one in 20-year flood event, and that the largest downstream movement was only two metres. Hence, the risk to infrastructure from damage by large eucalyptus trees is low; there is greater risk from the accumulation of smaller organic material, such as broken branches, that can be trapped by a bridge or culvert. Smaller material can come from many sources, including wood already in-stream, fallen riparian timber, dead trees and human sources (e.g. pump houses and similar structures on the floodplain) and is very difficult to control. An active maintenance schedule where material is removed from bridges and culverts is required to protect infrastructure. The transport of smaller material may indeed be reduced if there are greater numbers of larger logs to trap this material. In North America, log jams have been constructed upstream of bridges for the express purpose of trapping drift material and preventing its build up. (Abbe et al. in press)

If you are contemplating the removal or realignment of a snag, ask yourself — do I really need to? Sources of advice to help you answer this question are listed in later sections of this Technical Guideline Update.

Wood in a variable landscape

Australia's rivers have highly variable flows, particularly when compared with rivers in the northern hemisphere. The trees that grow in the riparian zone of Australian rivers tend to be hardwoods that have a higher density and are stronger than the softwoods often occurring along northern hemisphere rivers. For example, tree species from southeastern Australian are, on average, 65% denser and approximately three times the hardness of tree species from the Pacific northwest of North America (White 1998). The biological communities of our river systems have adapted to survive in highly variable conditions and in association with the denser and less mobile wood found in Australia. Differences in hydrology, geology, geomorphology and biological communities means that many of the lessons learnt and approaches used overseas to reinstate wood may not be directly transferable for use in Australia. However, this is not to say that we cannot learn from this research, for example, when fundamental physical and hydraulic principles are considered.

Riparian trees and wood loading in streams

Recent research has highlighted the relationship between the density of vegetation in the riparian zone and wood loading in streams. Although wood varied widely both within and between rivers, Marsh et al. (2001) found there was a linear relationship between

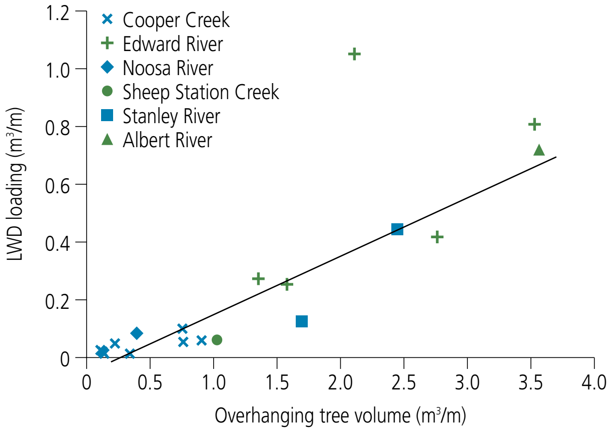

Figure 4: Stream wood loading and fringing riparian overhanging tree volume along six south-eastern Australian streams (from Marsh et al. 2001).

riparian tree volume and wood loading in streams across eastern Australia (Figure 4). This relationship was described by the following equation:

Stream wood volume (m^3/m) = 0.2 x Overhanging tree volume (m^3/m) – 0.05 (R^2 = 0.91)

NB: Overhanging tree volume was calculated as the diameter at breast height (DBH) of all stems larger than 10 cm DBH, multiplied by their height. It was used to provide a relative measure across sites rather than an absolute measure.

This not only provides a potential benchmark for re-instatement of wood in de-snagged rivers, where the overhanging tree volume is considered to be 'natural', but also reinforces the importance of the riparian zone as the long-term source for this material.

Wood distribution in Australian streams

The nature and distribution of wood in streams depends on factors such as the make-up of riparian vegetation, stream power (governed by the gradient of the channel and discharge) and geology.

The distribution of wood along a stream will in part be governed by stream power, which is a measure of the stream's ability to move coarse material. Stream power is a function of both the gradient of the stream and discharge; and increases with increasing stream gradient and higher flows. Stream power is usually greatest in the upper to middle reaches of rivers in southern (temperate) areas, and in some tropical (northern) rivers is affected by cyclonic discharges. Stream power tends to be lower in lowland reaches, as the gradient of the stream is low, although during floods stream power can increase markedly.

An investigation of the distribution of wood in the Murray River between Yarrawonga and Tocumwal (Hughes & Thoms 2002, Nicol et al.

Undisturbed riparian area with overhanging trees providing wood for the stream, Upper Latrobe River, Gippsland. Photo Ian Rutherfurd.

2002, Koehn et al. 2000) concluded that processes such as channel erosion can play a large role in the distribution of fallen timber. For example, snags were found to be up to seven times more common in eroding areas than in depositional areas. Snag numbers were greater along straight reaches and outer banks than along inner banks. The distribution of wood along each bank in straight sections of the Murray River was similar, consistent with the even distribution of energy in the river. However, the distribution of snags in meander bends varies. Snag numbers were generally highest in the inner 1st and outer 3rd and 4th quarters (Figure 5) of a meander bend, where channel migration rates are usually higher. Distance of snags from the bends related to the tightness (radius) of the bend. These and other observations on the nature of log jams in the Murray River were used by Nicol et al. (2002) to produce a template of wood distribution.

In-stream log jams

High stream power or shear stress can result in the downstream transport of wood and, in some instances, the formation of log jams. A study of eastern Australian rivers examined the distribution of in-stream wood (Marsh et al. 2001) and found that while a number of factors are likely to govern how wood is ultimately distributed, reach average shear stress (calculated from channel cross section and reach slope) can play a major role in formation of log jams (Figure 6).

Log jams can be hotspots of biodiversity and material cycling in streams (Treadwell et al. 1999, Masser & Sedell 1994) and a source of colonisation for other reaches of the stream. The photo at the bottom of this page shows the Williams River where log jams are being artificially created to diversify the river channel and increase biodiversity. The key ecological role played by log jams means that they should not be removed from the streams in which they occur.

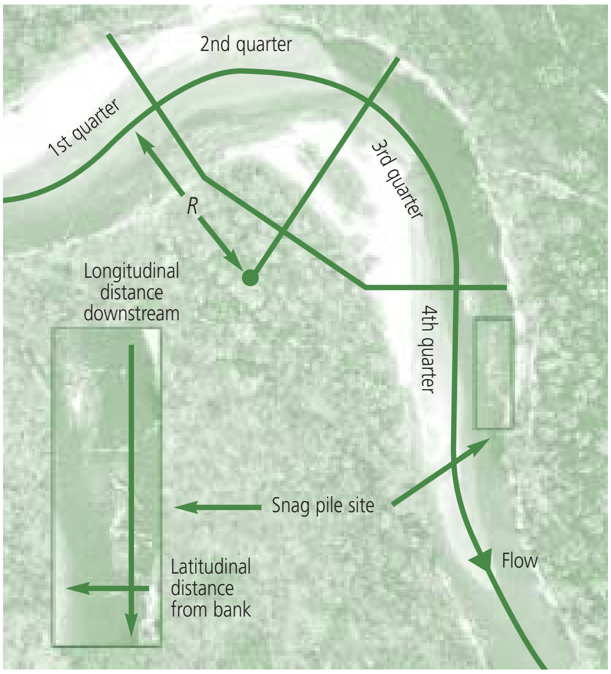

Figure 5 (left): Aerial photograph of a meander depicting the quarters, radius (*R*), latitudinal and longitudinal lengths at the log jam site (from Nicol et al. 2002, Koehn et al. 2000).

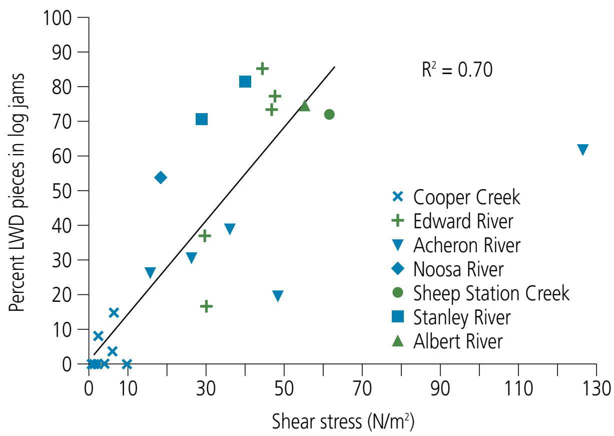

Figure 6 (above): Percentage of wood in log jams as a function of shear stress for selected eastern Australian rivers (updated from Marsh et al. 2001).

Constructed bank deflector jams at the Williams River experimental site, Hunter Valley NSW. Note the scour on the bar opposite the structures, and the bar that has formed upstream of the first structure. The riffle here was raised about 0.5 m due to the downstream effect of the log jams. Photo Andrew Brooks.

Reintroducing wood to streams

There are five key factors to consider when reintroducing wood to streams.

1 Identify geomorphic and ecological rehabilitation objectives →
2 Establish rehabilitation project design and targets (supported by pilot studies) →
3 Consider the likely response of the stream to rehabilitation measures →
4 Locate an appropriate source of wood →
5 Monitor and evaluate the success of the project

Key steps associated with the design and evaluation of wood reinstatement. Although presented as a linear process here, planning for the reintroduction of wood should be an iterative process.

1 Identify geomorphic and ecological rehabilitation objectives

Setting clear ecological objectives is a critical step in the river rehabilitation process (Stewardson et al. 2002, Lake 2001, Rutherfurd et al. 2000, Ladson et al. 1999). A key question to be answered by stakeholders in stream rehabilitation is 'what are the ecological objectives being sought with the reinstatement of wood?' Stakeholders should set clear and agreed objectives after considering catchment or regional stream management goals. Objectives will often centre on increased in-stream biodiversity or processes such as in-stream production. Some examples are presented in Table 1.

Table 1: Examples of the relationship between rehabilitation objectives and wood in streams

Rehabilitation objective	Relevance to wood in streams
Increase the breeding habitat available for native fish	Do the endemic native species have adhesive eggs that require a stable substrate such as wood?
	Do the target species preferentially use hollow logs for spawning?
Create permanent shaded pools to provide habitat or refuge for native fish	Formation of scour holes around wood in sand and gravel-bed streams.
Increased diversity of native fish species	Will the addition of wood increase habitat complexity in the reach?

2 Establish rehabilitation project design and targets

Aspects such as the pattern, distribution and alignment of snags are important considerations when reintroducing wood to streams. Reference patterns or templates, for example those based on knowledge of prior condition or of relatively intact river reaches, are useful when considering the distribution and density of wood required to rehabilitate degraded reaches. For example, patterns of wood distribution (see Figure 3) reported in some reaches (e.g. Nicol et al. 2002) could be used as a template for resnagging other meandering lowland rivers.

An important consideration when using a template approach is how the contemporary river channel to be resnagged has changed since European settlement. Recent changes to channel dimensions might mean that the best rehabilitation template comes from a substantially bigger river. For example, the dimensions of the Cann River have increased by 700% over the last 140 years, increasing bankfull discharge 45 fold and average stream power 35 fold (e.g. Brooks et al. 2003, Brooks 1999b). Appreciating the dynamics of how wood might behave when reintroduced to a larger higher energy channel can be crucial when framing rehabilitation strategies.

Very high wood loadings will often be required if the hydraulic resistance of a degraded river is to be reinstated. For example, Brooks (1999b) estimated that between 3.5 and 7 times the pre-European wood volume would be required to recreate the equivalent hydraulic resistance that existed in the Cann River prior to channel expansion. This is not to suggest it is achievable or desirable to recreate the pre-disturbance unit wood loading. The widespread artificial

Tree planting along river banks to develop new sources of timber for the stream. Photo Andrew Brooks.

reintroduction of wood to streams is unlikely due to a number of practicalities (e.g. cost, logistics). This means that the protection and augmentation of wood in the riparian zone and floodplain should be part of long term rehabilitation strategies. Planting the outside of river bends should be a high priority for riparian revegetation programs, as this is where rivers are most likely to erode naturally and where natural recruitment of snags would be most beneficial. However, depending on the size of river you are working with, some sense of how rapidly the channel is migrating should first be ascertained, as it may be that the river removes all the planted trees before they reach a functional size.

Stream power is an important determinant of where log jams may form. The size and shape of the logs is also important. While a log jam is likely to contain a range of log sizes, a number of big (key) logs will be required as anchors in high energy streams. These logs are often big 'old growth' trees that are increasingly rare along many rivers and their floodplains (MacNally & Parkinson 1999). The absence of large key logs might be the principal reason why log jams do not form.

The density of many Australian timbers means that logs falling into rivers are likely to sink and remain where they fall. Results from the Murray River suggest that 'green' logs can remain immobile, even after large floods (Koehn et al. 2000). However, reintroduced logs that are sourced from the floodplain are likely to have dried over time and may be more buoyant or prone to movement than green timber when placed in a river. Burial is often considered to be the best anchoring technique for Australian conditions. This approach has been successfully tested in gravel bed rivers (Brooks et al. in press, Gerhke & Brooks 2002, Brooks et al. 2001) and trials for sand bed streams are under way (e.g. Stockyard Creek, Hunter Valley NSW; Granite Creeks, Central Victoria; North Dandalup, WA). It is also recommended that burial in sand bed streams should be accompanied by the use of brush and/or geotextile to help prevent outflanking and undercutting. The excavation associated with burying logs can be costly and result in short-term disturbance to the banks and bed. A long-term strategy for reinstating wood in streams should consider revegetation of the riparian zone to provide a natural source of logs in the future, supported by the strategic reinstatement of logs to achieve short-term rehabilitation goals.

> The protection and augmentation of wood in the riparian zone and floodplain should be part of long term rehabilitation strategies.

3
Consider the likely response of the stream to rehabilitation

Reinstating wood in rivers is likely to require approval from relevant natural resource agencies, local government or local landholders. Negotiations with approval authorities will be aided by completing an environmental impact plan and risk assessment to outline the anticipated response of the stream and address public liability issues.

An environmental assessment will consider the geomorphological and ecological changes expected with the reintroduction of wood and the spatial (geographic) and temporal (time) scales at which they are likely to apply. For example, Cohen (1999) examined the metamorphosis and recovery of a 3.5 km reach of Jones Creek, a forested tributary of the Genoa River in East Gippsland, between 1967 and 1998. Floods between 1971 and 1978 significantly increased channel width, depth and reduced sinuosity. The creek bed has been in recovery since 1992, following a process of sediment deposition largely facilitated by log jams and the establishment of within-channel and riparian vegetation.

Successional patterns associated with the reinstatement of wood may be expected to occur over periods ranging from weeks (e.g. biofilm, macro-invertebrates), to seasons (e.g. macroinvertebrates, aquatic plants), years or even decades (e.g. fish, riparian vegetation, channel morphology). How plants and animals in a river respond to the reintroduction of wood will depend on the interplay between geomorphic responses and attributes of colonising organisms, such as reproductive biology and habitat preferences. It will also depend on whether or not there is a source of colonising organisms to provide dispersal and recruitment.

The following are examples of important factors to consider when undertaking a risk assessment to account for potential adverse outcomes and liability issues.

1. The risk of log mobilisation to specific rehabilitation objectives, in-stream ecological values and downstream infrastructure.
2. The risk that future river rehabilitation efforts are abandoned if log reintroduction programs fail due to poor planning.
3. The risk to river users (e.g. canoeists) associated with cabled logs.

4
Locate an appropriate source of wood

Decades of clearing the riparian zone and floodplains of timber mean that the logs available for reintroduction to rivers are in short supply. Sourcing logs from the riparian zone or the floodplain is not recommended as these play an important ecological and geomorphological role in their own right. Where possible, logs should be obtained from alternative sources such as from development sites, road construction and bridge realignments. A key message to be promoted is that timber from such sites should not be burned or sold. Local councils, roads departments and others should be encouraged to stockpile logs whenever clearing is done so that these logs can be used in future river rehabilitation projects.

The following are features to be considered, where possible, when sourcing logs:

~ select logs with intact root balls that will assist with anchoring;
~ select tree species that are representative of the region and are dense;
~ avoid introduced species as many do not last long and may pose long term threats to stream condition (e.g. willows, camphor laurel and poplar); and,
~ if large logs are not available, consider matting smaller pieces of timber into rafts. Be aware that the decay rate of the raft will be significantly greater than that of a similar sized single log due to the increased surface area, and hence the structural characteristics of the raft will often be compromised over time.

Ultimately, we should plan to rehabilitate the riparian zone so that it will in the longer term, provide an ongoing supply of wood.

5
Monitor and evaluate the success of the project

Millions of dollars are spent on river rehabilitation works every year. The benefits of this investment will be maximised if the effectiveness of the works is assessed, and the lessons learnt used to inform others dealing with similar issues. Unfortunately, there are few Australian reports of the ecological outcomes of rehabilitation projects that included resnagging. All too often the monitoring component of projects is ignored, or only considered once the rehabilitation activity is under way (Lake 2001). This makes it difficult to determine if any ecological change was due to the rehabilitation activity or some other factor. Describing the design of suitable monitoring and evaluation programs is beyond the scope of this Technical Guideline Update, but two guiding principles should be kept in mind:

1. It is essential to plan monitoring as part of any rehabilitation project (i.e. what needs to be done before, during and after rehabilitation), with special thought given to how the monitoring will be funded long after the actual works are completed.
2. Monitoring needs to be relevant. It is important that the indicators chosen are either of direct interest (i.e. related to the specific rehabilitation objectives set for the project) or are surrogates of something of direct interest.

Where to seek advice

Referral/approval agencies

Getting approval for reintroducing wood to streams can be complex. Depending on the location, waterway management responsibility may be spread across a number of authorities and agencies. The following are organisations that should be contacted to ensure the proper approval is received:

~ state/territory natural resource and environment agencies;
~ state/territory parks and wildlife agencies;
~ catchment or river management authorities;
~ local government planning and environment departments; and,
~ local landholders.

Further sources of advice

~ Land & Water Australia www.rivers.gov.au
~ CRC Freshwater Ecology http://enterprise.canberra.edu.au
~ CRC Catchment Hydrology www.catchment.crc.org.au

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River and Riparian Land Management, Technical Guideline Update No. 3. Managing wood in streams. Edited by Peter Cottingham, Stuart Bunn, Phil Price and Siwan Lovett.

Published by Land & Water Australia

GPO Box 2182 Tel: 02 6257 3379 E-mail: public@lwa.gov.au
Canberra ACT 2601 Fax: 02 6257 3420 Website: www.rivers.gov.au
www.lwa.gov.au

July 2003

ISSN 1445-3924 ISBN Print 1 920860 00 2 Web 1 920860 01 0
Product code number PR030531

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Publication data
Cottingham, P., Bunn, S., Price, P. & Lovett, S. (eds), 2003, 'Managing wood in streams', River Management Technical Update No. 3, Land & Water Australia, Canberra.

Cover photo A. Brooks. Cover illustration 'River Landscapes' painting by Annie Franklin.
Design by Angel Ink, Canberra. Printed by Goanna Print, Canberra.