

## Introduction

### 1.1 Purpose of this Guideline

Community perceptions regarding the benefits of both retaining and reintroducing wood into rivers and streams have fundamentally changed since the early 1990s. In large part this has been brought about by a raft of research into the role that trees and branches falling into our rivers (variously described as snags, large woody debris (LWD), coarse woody debris (CWD), woody debris, wood, log jams or structural woody habitat (SWH)) play in aquatic ecosystem health and channel morphodynamics. We now know that in many respects wood in rivers is akin to the coral reefs in our oceans, as it provides substrate for invertebrates and biofilms, and provides complex habitat that supports a wide range of aquatic species. In addition, it also performs a critical geomorphic role.

Research funded by Land & Water Australia (LWA) has been at the forefront of this rethink, and in particular the communication of the new insights to river managers

and the broader community. Over the last seven years LWA has published a number of reports and technical guidelines that have highlighted the role in-stream wood plays as aquatic habitat, as a long-term source of carbon, and as an agent inducing channel complexity and stability. Volume 1 of the *Riparian Land Management Technical Guidelines* (Lovett & Price 1999), and the updated version *Principles for Riparian Lands Management* (Lovett & Price 2007) reviewed the ecological and geomorphological functions and benefits associated with wood in streams, while Volume 2 provided information on how wood can be best managed to protect aquatic ecosystem health. The *River and Riparian Land Management Technical Guideline Update no. 3, 'Managing wood in streams'* (Cottingham et al. 2003) provided an update of the ecological and geomorphological functions of wood on streams contained in the earlier guidelines, with new scientific insights developed since the publication of the original guidelines.

**Photo 1.** Natural log jam — Allyn River, NSW.





**Photo 2.** Bank deflector jam under construction — Williams River, NSW.

This Guideline builds on the earlier publications, focusing more on the technical and practical aspects of reintroducing wood into streams, and incorporating insights from recent field trials. Over the last five years there has been considerable research and development into methods for reintroducing wood into streams, focused primarily around a number of field experiments in which wood reintroduction strategies have been designed and tested from an engineering, a geomorphic and an ecological perspective. The outcomes of some of these field trials are presented here, along with the methods employed for their design, construction and monitoring. New insights from additional experimental work under the Upper Hunter River Rehabilitation Initiative will come on line over the next few years. It should be noted that most of the structure designs outlined in this Guideline tend to have a geomorphic or engineering role as their primary function, with the ecological/habitat functions secondary. Nevertheless, the basic physics still apply for the stability analysis, although different designs and anchoring techniques may be required if the objective is purely one of direct habitat augmentation. If your intention is to reintroduce wood purely for fish habitat, there is still a need to develop an understanding of the reach geomorphic conditions as part of the project design process. Geomorphic changes to your stream reach may completely override any measures undertaken on the assumption that the wood is purely for habitat.

The main purpose of this Guideline is to help river managers design a wood reintroduction strategy that will survive for a sufficient period of time to enable natural wood recruitment to take over and reduce the need for artificial reintroduction of wood to streams. In-stream structures often fail because our ability to predict the future behaviour of streams is limited and because the structures have been poorly or inappropriately designed. This Guideline does not deal with predicting stream



**Photo 3.** Constructed bed control log structure — Stockyard Creek, NSW.

behaviour, but aims to avoid poor and inappropriate structure design. We have incorporated the most up to date knowledge and experience on wood reintroduction, with a view to improve the likelihood of implementing a successful wood-based stream rehabilitation strategy.

## 1.2 Who is this Guideline for?

By necessity, this Guideline requires some technical understanding of channel hydraulics and geomorphology and, as such, is aimed more at the specialist river manager, than at community groups. It is intended primarily to assist staff of government agencies, Catchment Management Authorities and Boards, waterway managers or fisheries officers, to plan and construct a wood based river rehabilitation project. It will, however, also be of value to community groups in helping to conceptualise and plan river rehabilitation projects, to develop costings, and to understand the logistical issues that must be considered before implementing a wood reintroduction project.



### 1.3 Why bother with planning and design — why not just throw them in?

Many artificial instream habitat structures “fail” or are structurally compromised within their first few years of service (Frissell & Nawa 1992, Bisson et al. 2003). While a fish or a biofilm might not care much if a log structure disintegrates somewhat over time — after all they have coped well for millions of years with trees simply falling into the river in a random fashion — council engineers and farmers, for example, tend to get a bit concerned about “failed” structures, and “logs on the loose” in streams. So the first reason for worrying about proper design and planning is that the community expects nothing less. After all, in the mid 1990s, desnagging was still a widespread practice throughout Australia, and it is only in the last few years that research into the benefits of wood in rivers has caused community attitudes to shift towards thinking about returning wood to streams. While there are now some very enthusiastic proponents of wood

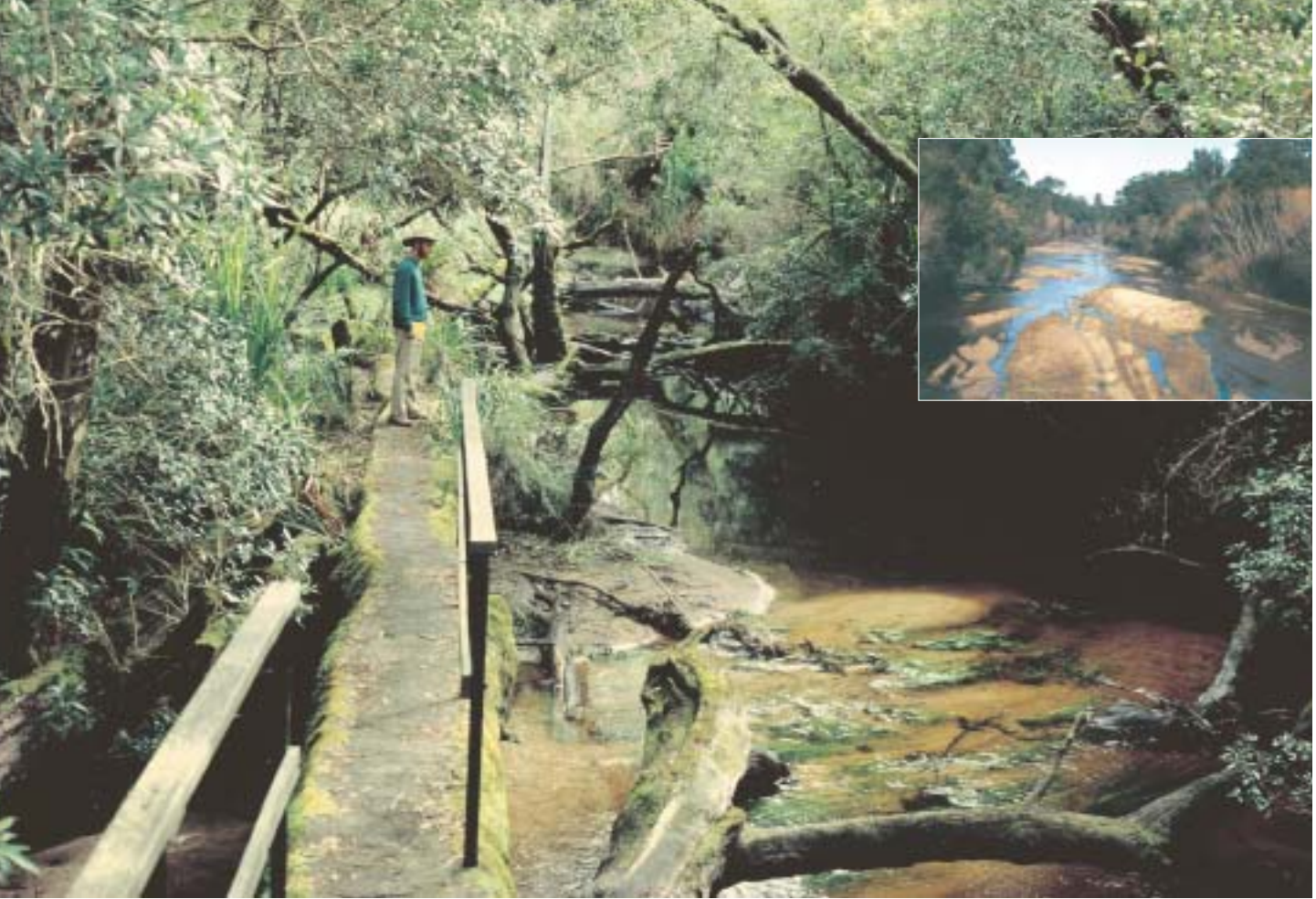
reintroduction, after 150–200 years of pulling logs out of rivers there is still a broad cross section of the community who are yet to be convinced of the wisdom of this approach.

At the other end of the spectrum, there is now an increasing chorus of people asking; “why not just throw the logs into the river as nature has done for millennia — why bother with all this expensive design and anchoring?” While there are very good grounds for undertaking some controlled experiments in the right location of just such an approach, on the whole, society is probably not quite ready for such a radical method. Another key reason for proper design and planning is that at many locations where wood reintroduction is being contemplated, river channel dimensions and, hence, in-stream hydraulics have changed dramatically in historical times. Channel capacity has often increased, and roughness decreased, leading to channels with much higher unit stream power than they would have experienced under pre-disturbance conditions. Under these conditions, logs that might have been stable under pre-European river conditions, are now much more likely to move. As a result there is a need to consider how local stream power conditions might have changed and to design structures with appropriate anchoring that can withstand the forces applied to them.

Another reason to not just throw them in is that large pieces of wood suitable for rehabilitation projects are in short supply and, hence, we cannot afford to waste them. It is an unfortunate fact that the millions of pieces of wood pulled out of rivers over the years were mostly burnt on-site. Furthermore, many riparian areas have been cleared and no longer provide natural inputs of wood to their adjacent streams, let alone act as potential sources of wood for rehabilitation programs. Even where trees have been replanted, it will be decades at least, if not centuries, before these plantings begin acting as natural sources of wood recruitment. This means wood will generally need to be sourced from approved clearing sites, will be in relatively limited supply, and likely to be a considerable distance from where it is needed. Transport costs will be high, so every piece counts, and we cannot afford to just throw them in and hope for the best.

### 1.4 Not the last word

It must be stressed that the science and art of wood reintroduction as a river rehabilitation strategy is still very much in its infancy and these guidelines are not intended to be the last word on this topic. Rather, presented here is the experience gained to date, with some principles for safely designing and implementing a wood reintroduction strategy. There is an obvious bias in the strategies outlined here towards the higher energy coastal rivers, given that

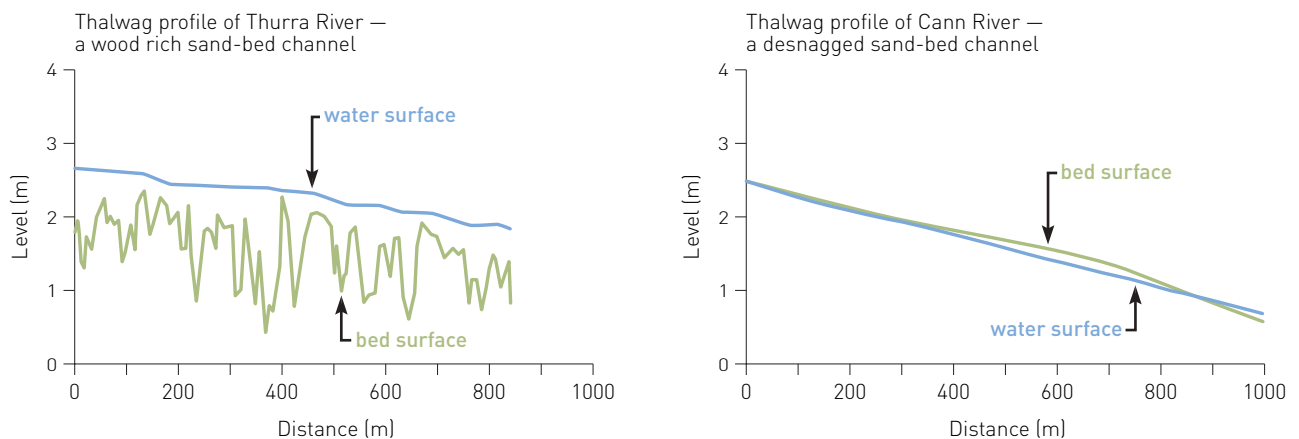


**Photo 4.** Natural sand-bed river with a high wood loading and high morphologic diversity — Thurra River, Victoria. Inset: A desaggged sand-bed channel — Cann River, Victoria.

experience to date is predominantly derived from these areas, and structural stability tends to be more of an issue in these rivers. It must be stressed that this is not a recipe book, and there is no standard log structure that is suitable for all situations. Indeed, it is hoped that by encouraging practitioners to understand river processes and dynamics, and by learning from natural analogues, that they will be spurred to develop new designs and new strategies. In many respects, the experience gained to date is coloured by the circumstances of the day in which

we were attempting to turn around the centuries of bad press that wood in rivers has received. Consequently, the initial structures employed within the experimental reaches (summarised in Section 3.3) were extremely conservative, constructed with considerable factors of safety. We fully expect that as community concerns about wood in rivers are allayed, less conservative designs can be developed with lower factors of safety. Some examples of approaches used by others are included in Appendix A.

**Figure 1.** Bed morphological variability with and without in-stream wood. The thalweg profile is a survey of the deepest point at each survey cross section down the channel. Note the base flow water level in the Thurra (left) provides extensive, diverse aquatic habitat. In contrast, the Cann River (right) under similar flow conditions provides very little usable aquatic habitat, as most flow is sub-surface and there are no pools to provide refugia.



## The functions of wood in rivers

### 2.1 Summary

A considerable body of research has built up over the last few decades highlighting the important functional role of wood in rivers. A detailed review of much of this literature is contained within Chapter 7 of the *Principles for Riparian Lands Management* (Lovett & Price 2007) and for this reason will not be repeated in detail here. The following is a summary of the primary functional attributes of wood from the above reference. The full version can be found at the following website <http://www.rivers.gov.au/publicat/guidelines.htm>

- Riparian vegetation increases stream channel complexity and directly contributes to aquatic habitat through inputs of logs and branches. In turn, the provision of complex habitat has a major influence on aquatic biodiversity.
- Logs and branches can enhance stream stability, regulate sediment transport and exert significant control on channel complexity in bedrock rivers, and channel geomorphology in alluvial rivers.
- Logs contribute to the formation of physical features in streams, such as scour pools and channel bars, which serve as habitat for in-stream biota.
- Logs provide physical habitat for biota at all levels of the food chain, ranging from microscopic bacteria, fungi and algae, to macroinvertebrates, fish and turtles.
- Logs also provide sites where bacteria, fungi and algae can process carbon and other nutrients such as nitrogen and phosphorus, thus contributing to ecosystem processes such as productivity and respiration.
- In alluvial rivers, logs can modify surface water/ground water exchange and enhance nutrient processing.
- Logs 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 a stream.
- Although vast amounts of wood have been removed from many Australian rivers, what does remain provides important habitat for microbes, invertebrates, fish and other animals.
- Retention and reinstatement of logs should be a priority for river rehabilitation, instead of removal or even realignment.

**Photo 5.** Natural log jam — Allyn River, NSW.



In NSW the removal of woody debris (wood) from rivers is now listed as a key threatening process under the *Fisheries Management Act 1994*. Under this act, a threatening process is defined as a “process that threatens, or that may threaten, the survival or evolutionary development of a species, population or ecological community of fish”.

## 2.2 New research: Using wood to restore hyporheic processes

Following the initial trials of engineered log jams at the Williams River experimental site (Section 3.3), subsequent collaboration with Professor Andrew Boulton, Sarah Mika and co-workers from the University of New England, highlighted the potential for using log structures to help rehabilitate the hyporheic zone. The following Section provides an overview of this emerging field in river rehabilitation research by those leading the research. As this work is not covered in the updated version of the *Principles for Riparian Lands Management* (Lovett & Price 2007) a brief explanation of the “hyporheic zone” is included here along with some of the ideas on how wood can help to rehabilitate this important, and seldom considered, part of the riverine ecosystem.

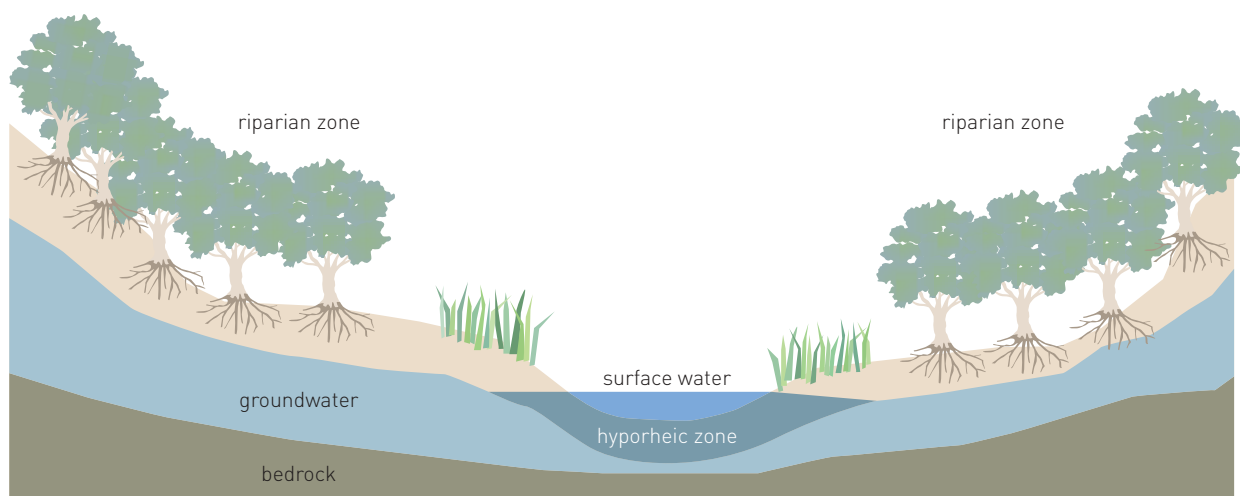
### Can we use wood introductions to restore hyporheic processes?

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Virtually all studies of the ecological benefits of introduced wood focus on processes or biota in the surface stream. However, scientists are beginning to understand more fully the fundamental ecological significance of the hyporheic zone to surface ecosystem processes (reviews in Boulton et al. 1998, Dent et al. 2000). The hyporheic zone is the saturated sediments lying below and alongside river channels, and in many rivers it directly links surface water to permeable alluvial aquifers below the riparian zones and ‘true’ groundwater further below (Figure 2). Exact

boundaries of the hyporheic zone are difficult to identify and these fluctuate in response to variations in the depth and volume of water exchange with the surface stream (White 1993), which are in turn affected by surface river discharge and channel shape (Thibodeaux & Boyle 1987, Boulton 1993).

The main ecological role of the hyporheic zone is the alteration of water chemistry and the generation of nutrients that potentially limit productivity in the surface stream (Coleman & Dahm 1990, Valett et al. 1994). Much of the decomposition and microbial processing of organic matter occurs in the sediments, and the hyporheic zone serves as a storage and processing site for this material (Marmonier et al. 1995). The hyporheic zone is also a potential refuge for surface stream invertebrates from flooding and drying (review in Boulton 2000a) and even surface water pollution (Jeffrey et al. 1986). The significance of the



**Figure 2.** The central location of the hyporheic zone linking surface water, groundwater and the riparian zone.

hyporheic zone for successful recruitment of gravel-spawning fish has long been known in the northern hemisphere (Vaux 1962) and probably holds true for Australian native fish such as freshwater catfish.

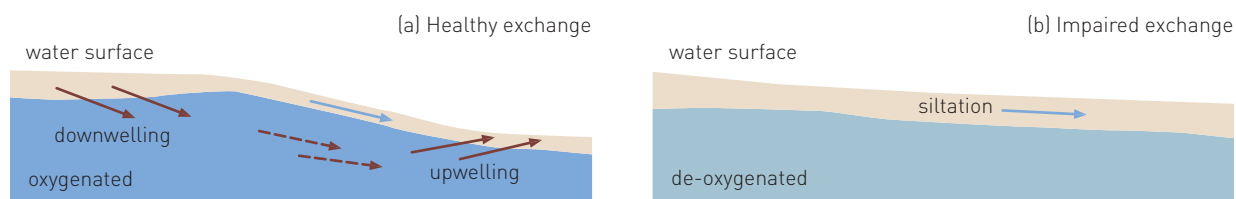
Hydrological exchange drives interactions between the surface stream and hyporheic zone. However, sedimentation and the loss of geomorphic complexity smooths out the longitudinal profile of the stream bed (Brooks 2004), reducing hydrological exchange between the surface stream and hyporheic zone by several mechanisms. Firstly, there is reduced convective exchange arising through pressure differences between the topography of the streambed, surface flow, and the groundwater table. A stream flowing over a bedform, such as a crest of sediment, results in a pressure distribution that drives flow into the bed (Thibodeaux & Boyle 1987). Alternating high and low pressure areas along an undulating streambed generates a ‘pumping exchange’, and advective porewater movement that promotes hydrological exchange of stream and subsurface water (Packman & Bencala 2000, Figure 3a). Interaction of the stream and porewater flow produces a slip velocity at the bed surface and a gradient of exponentially decreasing flow velocities within the bed (Packman & Bencala 2000). Streamflow at the bed surface ‘drags’ the porewater upwards, and this process is largely a response to turbulent flow in gravel-bed rivers. In sand-bed rivers, the smaller pore spaces restrict stream-driven turbulence to a thinner layer near the surface of the bed, substantially reducing the amount of hydrological exchange (Packman & Bencala 2000).

A second means of disrupting surface and subsurface water exchanges is through siltation and deposition of inorganic fine sediments along the channel (Schälchli 1992, Figure 3b). Fine sediments percolate deep into the streambed (colmation) and, because hydrological exchange has been weakened by the loss of topographic relief, there is progressively less flushing until the hyporheic zone is clogged with fine, inorganic silt. This surface deposition and resultant colmation, effectively severs the surface stream from the subsurface zone (Figure 3b). Colmation arising from uncontrolled sediment release into streams and

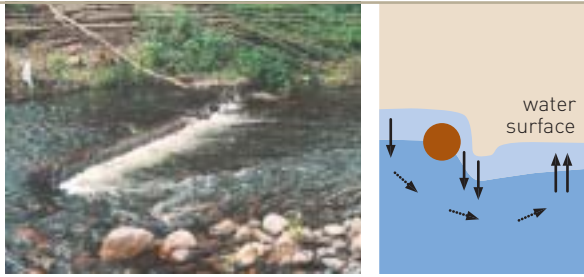
rivers causes many of the serious impacts of human activities upon the hyporheic zone (Boulton 2000b, Hancock 2002). Deeply ingrained fine silt appears remarkably resistant to most flushing flows and floods unless bed material is moved substantially. Frequently, the deposition of fine silt on the streambed promotes dense mats of filamentous algal growth. When light levels and nutrient concentrations are high; these mats trap additional silt and further exacerbate the loss of surface/sub-surface flow connection.

Given that the main impact of human activities on the hyporheic zone appears to have been the effects of sedimentation, siltation and colmation in severing the hydrological linkages (Boulton et al. 2000, Hancock 2002), the most common suggestion for restoring these linkages has focused on the use of environmental water allocations to provide flushing flows (Hancock 2003). Early indications seem to be that very large flows may be needed and the bed material may have to be shifted so that flushing can occur properly (Hancock & Boulton 2005). It is also likely that silt will rapidly infiltrate the interstices after the flushing flows and, therefore, may only be a short-term solution that shifts the problem downstream. Obviously, silt inputs must be controlled to resolve the issue properly, but in areas where rehabilitation is planned or underway, the severe impacts of sedimentation (Wood & Armitage 1997) may neutralise the process.

Another alternative to renewing hydrological linkages with the hyporheic zone may be to reintroduce topographic relief into the stream channel by using wood to create a physical bedform, or induce changes in patterns of sediment deposition within the channel or along the lateral bars. When a log lies across the path of flow and is partially embedded in the sediment (‘log sill bed controls’ (LSC) sensu Brooks et al. 2004, Figure 4), water moving over it would be expected to enhance hydrological exchange (Figure 4). At the leading edge of the log, downwelling may occur in response to the stepped relief while at the ‘plunge pool’ downstream, further downwelling may occur in a localised region. The displacement of porewater by these two downwelling zones is hypothesised to generate a more diffuse upwelling



**Figure 3.** This longitudinal schematic of an idealised streambed illustrates the direction and strength of hydrological exchange between the hyporheic zone and surface stream in response to natural geomorphic complexity (a), and the loss of this exchange when the bed profile is smoothed and sedimentation occurs (b).



**Figure 4.** A log (LS) lying half-buried in the streambed across a channel in the Williams River is capable of inducing localised upwelling and downwelling of streamwater, represented by arrows in the schematic diagram.

zone downstream of the LSC (Figure 4). Furthermore, sediments may pile against the leading edge of the LSC and ‘dunes’ may form downstream of the plunge pool so that there is a cascade effect of the creation of topographic relief (Figure 4).

More complicated is the potential effect of logs anchored to the bank and extending into the channel (‘deflector jams’ (DFJ) sensu Brooks et al. 2004, Figure 5). Plausibly, water may be forced to downwell upstream of the bank jam, but it is more likely that the majority of flow will be deflected. If there is a gravel bar on the opposite side of the channel, ‘scalping’ occurs that increases the complexity of the bar’s edge and potentially enhances the exchange of water laterally into the parafluvial zone (Figure 5). This creation of a series of ‘mini-bars’ could substantially increase the total area for biological and physical filtration (Malard et al. 2002, Boulton et al. 2004).



**Figure 5.** This constructed deflector jam (DFJ) extending into the channel in the Williams River caused scalloping of the edge of the gravel bar across the channel, enhancing the surface area for lateral hydrological exchange, represented by arrows in the schematic diagram.



**Photo 6** (right). Constructed hyporheic-jam (log step) — Hunter River, NSW.

**Photo 7** (below). Constructed hyporheic jam (i.e. log step with paired abutment jams) — Williams River, NSW.

