FACT SHEET 2

Streambank stability

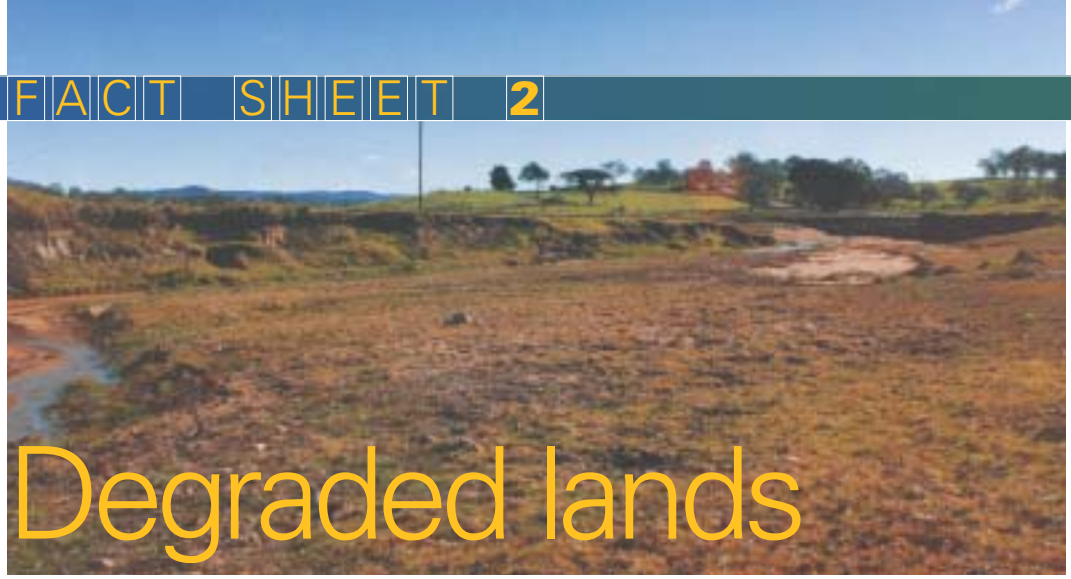
2

RiverLandscapes

This Fact Sheet is the second in a series dealing with the management of riparian land.

Streambank erosion is a dynamic and natural process as streams meander across the landscape. Since European settlement of Australia, however, in many places the rate of streambank erosion has increased markedly. There are two primary reasons for this increase. The first is extensive clearing of deep-rooted, natural vegetation from catchments for agricultural and urban development. This has resulted in rainfall moving off the land surface at a much faster rate. These increased flows put pressure on stream channels that can no longer contain flood peaks, and bank erosion (as well as bed erosion) is one result.

The second factor is the widespread removal of native riparian vegetation from along streambanks, either through deliberate clearing for development, or through the combined effects of stock grazing and fire. The removal of large, woody debris (de-snagging) in many streams, sometimes to assist navigation and transport, and sometimes in the belief that this would reduce flooding, has also contributed to making streambanks unstable. Both these activities have weakened the ability of streambanks to resist the erosive forces of increased flood flows and resulted in eroding streambanks becoming a common feature in Australian landscapes.



Degraded lands

Large scale clearing of vegetation has degraded riparian lands and increased stream erosion.
Photo Siwan Lovett.

Streambank erosion often involves the loss of valuable agricultural and recreational land. As the banks collapse or erode into the stream and are washed away, sediment and nutrient loads increase and water quality is reduced. Expensive infrastructure, such as roads, bridges and buildings, may be threatened by accelerated streambank erosion. This Fact Sheet discusses the processes by which streambanks erode, and the role of riparian vegetation in helping to slow or prevent this process.

Streambank erosion — what it is and why it occurs

There are three main processes at work in streambank erosion. They may occur singly or in combination, in different parts of a river catchment. It is important to identify and understand which of these processes is dominant in a particular location because the management responses are often very different. The three processes are:

- Sub-aerial erosion — This involves processes that loosen the soil of the streambank, which is then vulnerable to being carried away by the water flowing past. Trampling by stock, rain impact, frost and wind acting on bare soil, can all loosen the surface of a streambank, making it vulnerable to being washed away as water levels rise. Protecting the bank surface from the action of the loosening processes, and also reducing the speed and erosive force of the water flowing along the bank, are key actions in reducing this cause of erosion — riparian vegetation can play a critical role in achieving both.

- Scour — This occurs when the force applied to a streambank by flowing water exceeds the resistance of the bank's surface to withstand those forces. This often happens at the toe of the bank (i.e. at the water's edge) where suspended particles in the flowing water scour away the bank soil. It is also common on the outside bends of rivers, where the flow speed is fastest. Again, protecting the bank and reducing flow speed are critical actions to reduce this form of bank erosion.

The stream is scouring the toe of this streambank which has no riparian vegetation to prevent this erosion from occurring.
Photo Andrew Brooks.

The removal of riparian vegetation has resulted in streambank erosion and the collapse of large sections of the bank.
Photo Ross Digman.

- Slumping — This occurs when blocks of the bank collapse as a result of undercutting or other structural weakness within the streambank. The reinforcing effect of plant roots, and removal of moisture through plant use, can assist in reducing slumping processes in many situations.

Each of these processes may occur at different parts of a stream's course, from its upper reaches to its lower floodplain. Careful inspection of eroding banks will often show which of these three processes, whether individually or in combination, is most active. Having worked out which of the erosion processes is dominant, it is then important to ask why it is occurring.

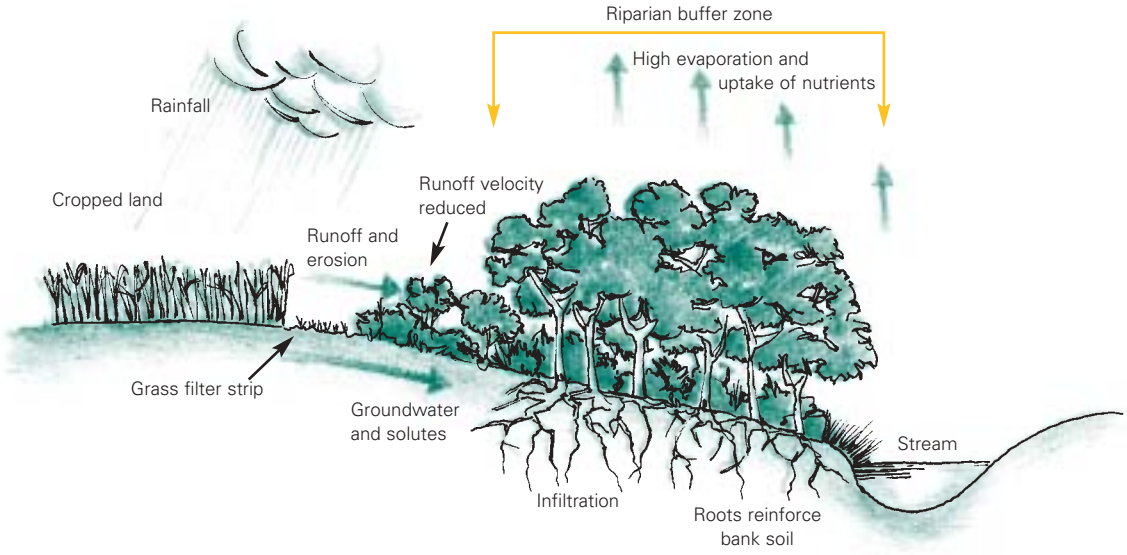
Unrestricted grazing by animals (domestic, feral and native), rapid fluctuation in flow level (e.g. releases from an upstream dam), or other factors preventing the growth of vegetation, are often implicated where sub-aerial erosion is an important component. Scour may reflect increasing flood volumes and frequency, possibly a symptom of clearance upstream, past channel straightening, sand and gravel extraction or other changes in stream flow. Widespread slumping of streambanks may follow removal of natural riparian vegetation, changes in stream flow or rapid changes in water level. By understanding the processes at work in streambank erosion, and the factors that have caused them to increase in magnitude and impact, we can develop a sound management and restoration plan.

Although collapse or slumping is the most obvious and dramatic form of bank erosion, it can be argued that scour is the most destructive process. If collapsed material is not removed by scour, the bank will probably eventually stabilise at a lower angle and become revegetated. It is scour which 'primes' the bank for the next collapse. Vegetation reduces scour by slowing the speed of water adjacent to the streambank. It will also 'ride down' with a collapsed bank and protect its toe from further scour.

How riparian vegetation helps to protect streambanks

Root systems

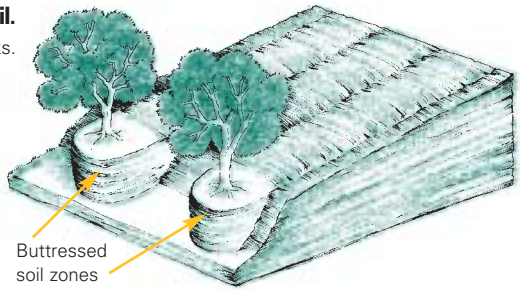
The roots of vegetation reinforce the soil in the same way that steel rods reinforce concrete. Fine roots are more important in this process than thick roots. Root reinforcement by riparian vegetation is usually the most important safeguard against bank collapse. Recent experiments have shown that tree roots can substantially increase soil strength to a depth of at least 2 metres, and to a distance equivalent to the canopy dripline. More-detailed information on the effectiveness of plant roots in helping to stabilise streambanks, and guidelines to calculate the replanted width required, is given in the 'for further information' section of this guideline.



Processes that occur in the riparian zone to assist streambank stabilisation. Illustration The Idea to Here.

Water use

Riparian vegetation is able to use much of the water present in streambanks, and also improves the drainage of streambank soils. Often banks collapse when they are saturated with water, so that riparian vegetation, by helping to use that water and by improving drainage, can help to reduce the risk of sudden collapse. This effect may be important when bank soils are wetted by short-lived events, such as a summer storm or a peak flow release from an upstream dam. The effect is likely to be small during prolonged periods of saturation.



Trees buttressing the soil.
Illustration Carolyn Brooks.

Buttressing

Riparian vegetation, which is present on the face of the streambank, helps to support or buttress the soil above it so that it does not collapse. It is not uncommon to see a block supporting a large tree or group of trees remain stable, when on either side sections of the streambank without deep-rooted vegetation have collapsed.

When sections supporting natural riparian vegetation do collapse, the soil often forms a sloping section at its base, and revegetating this section will help to buttress the upper section and hold it in place.

Reduced flow speed

The speed of water flow in a channel can be decreased by vegetation growing either on the bank or in the water, and by debris or sediment in the stream. If the vegetation is growing on the bank face, it can reduce scour and consequently undercutting and collapse of the upper bank. The extent to which speed is reduced is very dependent on the type of vegetation. For example, grass and dense shrubs with stems able to bend over and lie down in a peak flow are more effective than widely-spaced trees.

In some cases, highly-invasive vegetation may grow into the river channel. Vegetation growing within the channel will reduce scour by decreasing the flow speed adjacent to the bank. However, if the vegetation becomes too dense, for example in the case of reed beds or some invasive exotic grasses, it can direct flow into the banks and increase scour. As well, lower flow speed in channels invaded by vegetation, especially willows in southern Australia, can reduce channel capacity. The result may be an increase in the frequency of nuisance flooding.

Exotic rice grass invading a small creek.
Photo Andrew Sullivan.

Surcharge

Surcharge is the weight imposed on a bank by the vegetation it supports. Large trees can weigh several tonnes, but, surprisingly, this weight does not necessarily increase the risk of a bank collapsing. Whether it does so depends on the weight of the vegetation, the height and slope of the bank, and the character of the bank material. In general, surcharge is an issue only when banks are vertical or nearly so. For sloping banks, vegetation will normally improve bank stability despite any additional weight imposed.

In general, the role of riparian vegetation root systems in strengthening the bank and in reducing flow speed are the most important factors by which vegetation can reduce streambank erosion and improve stability. This is illustrated in the table below.

Feature of vegetation	Impact on amount of bank collapse	Impact on amount of scour
Root systems	Large reduction	Large reduction
Water use	Small reduction	N/A
Buttressing	Significant reduction	N/A
Reduced flow speed	N/A	Large reduction
Surcharge	May be reduced or increased	N/A

Using vegetation to stabilise streambanks

Tackling the three main results of erosion

Landholders and managers normally face three general types of stream erosion:

- Incised streams — This occurs when the bed is deepening and the banks fail because they are over-steep and perhaps undercut. There is little point, in this situation, in stabilising streambanks until the streambed has been made stable. Vegetation on the channel or gully floor, while being very difficult to establish, is useful in stabilising the bed, although some initial grade control structures using rock or large woody debris may be needed. It is important that dense vegetation does not then fill the centre of the channel and divert flow onto the banks. In some cases, the best management is simply to fence the stream off from grazing, stabilise the bed with rock or woody debris, and allow the bed and banks to be colonised by grass. Another approach is to construct a stabilised rock riffle within the channel, positioned so as to retain an upstream pool that acts as a stilling pond during flow events, helping to protect the bed from further erosion.

Stream incision.
These photos Ian Rutherfurd.

Channel widening.

Erosion of the outer bank.

Recent research has demonstrated that in some parts of Australia large woody debris (branches and tree trunks from fallen riparian vegetation) were an important component of bed and grade (slope) control prior to European settlement. There are many instances where de-snagging led almost immediately to a period of significant stream incision.

- Channel widening — This may or may not be related to incision. If both banks of a stream are eroding, it may be that:
  - the stream cannot carry the increased flows which resulted from clearing of the catchment;
  - the channel has deepened;
  - unusual rainfall has caused a large flood or series of floods; or
  - the banks have been over-cleared and, as a result are vulnerable to erosion.

In large channels, the key is to establish vegetation as far down the face of the bank as possible, as well as on the bank top. Special attention needs to be given to stabilising the toe of eroding banks, and this may require rocks or other structures to help maintain the toe region while vigorous vegetation becomes established above it.

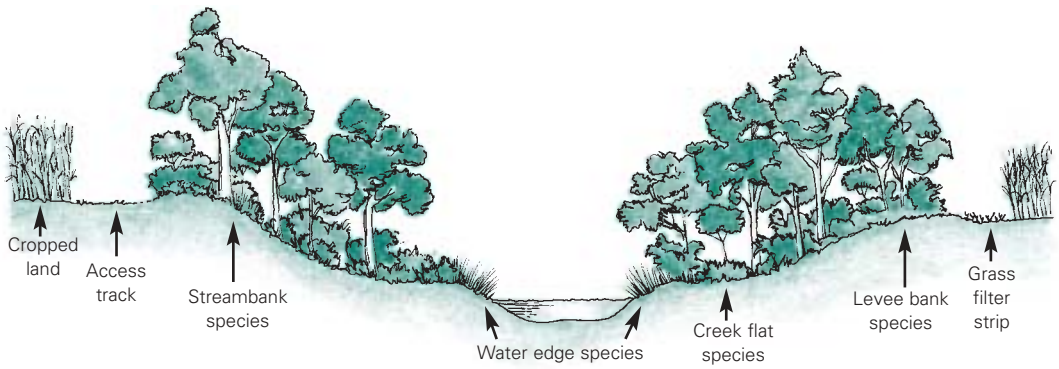
- Erosion of the outer bank — This usually occurs on steep banks located on the outside of a meander bend. This is the most common erosion problem faced on larger streams. The outside bank of a meander is often steep or even vertical, making it difficult to establish vegetation on the bank face. In general, the higher the bank, the less useful vegetation on the top of the bank is in reducing collapse. In other words, revegetation on its own is likely to be effective only when there is an approximate match between the height of the bank and the rooting depth of the vegetation.

In channels where the banks are under 3 metres high, establishing vegetation on the top of the banks will have some value if there is evidence that the streambank suffers rotational failure or toppling failure. In this case, vegetated blocks topple to the toe of the bank. If the vegetation is sufficiently vigorous, and there is sufficient moisture, it may continue to grow and thereby stabilise the toe of the bank.

Position of vegetation

In revegetating to reduce bank erosion, correct siting is most important. Poorly-sited plant growth can increase local flow speed and thereby increase erosion. Thought must be given to establishing vegetation all over the bank surface and not just on its top, particularly where sub-aerial and scour processes are dominant factors. Where banks are steep, it may be necessary to consider battering them back to an angle closer to 45° in order to give vegetation a chance to rapidly take hold and cover the surface. Planted vegetation will need adequate access to moisture and, if this is not available within the bank itself, supplementary watering may be required. The recently-developed technique of water-jetting into banks long-stemmed tubestock of native species has increased the range of situations where revegetation can be a successful approach to bank stabilisation.

The key to many bank erosion problems is to work at an actively-eroding toe at low water level. This is usually the most difficult part of the bank to revegetate with woody species, and it is usually best to start with water-edge grasses, sedges or similar plants. On the slope and top of the bank, match the rooting depth of the vegetation to be established with the height of the bank. If the roots of the species planted do not cross the potential slump zones of the bank, they will have limited ability to reduce this form of erosion. In particularly difficult situations, for example on outside meander bends, it may be necessary to use a combination of mechanical protection (e.g. rock placed along the toe) with vegetation used to help stabilise this and to protect the higher reaches of the bank.



It is important to select a range of plant species and to ensure your revegetation strategy mimics nature as closely as possible. Illustration The Idea to Here.

Selection of appropriate plant species

A range of vegetation types is usually necessary for successful streambank stabilisation. Under natural conditions, healthy riparian vegetation contains a range of species and you should aim to mimic this in restoration projects. Native grasses and reeds, and shrubs with flexible stems and branches, often occupy the lowest parts of the bank where they are subject to occasional inundation. Their ability to bind soil and resist flood flows are highly-prized characteristics. Further up the bank, shrubs and small trees may predominate, with either an understorey of grassy species or, if there is adequate shade and moisture, a strong mat of fibrous roots present on the outside of the bank. At the top, there may be large trees with a shrub understorey, or a combination of trees and grass. This type of generalised pattern, and the particular needs of individual species for water, light, initial frost protection and so on, must be considered when planning a revegetation project.

In general, vegetation planted along banks or within the mainstream channel (in order to reduce speed) needs to be securely-rooted, preferably with a spreading, fibrous root mat that will thoroughly penetrate bank soil, and with a flexible upper portion that can bend and move in peak flows. There are many native species that fit these requirements, and in most districts local advice is readily available.

Phragmites growing over the bank of the Murrumbidgee River helping stabilise it against scour. Note also the protection from tree roots and the contrast with the vertical bank on the outside of the bend.
Photo Ian Prosser.

Some golden rules in revegetating for bank stability

Understand why erosion has occurred

This may require a survey of the river reach or seeking professional advice. Once the major processes involved in streambank erosion, and their underlying causes have been determined, you can then design and carry out revegetation works with confidence — matching the type and position of vegetation to the nature of the problem and combining it, if necessary, with structural works.

Work with others

It is important to remember that the effects of over-clearing, and of revegetation, may have impacts downstream. There is much to be gained by joint planning and revegetation action by groups of landholders to deal with a whole section or reach of a river, rather than individual action by one or two landholders.

Carefully select species and methods for revegetation

The nature of many streams has changed substantially since European settlement. Revegetation on its own will rarely reverse this process and return the stream to its original condition. The type of vegetation needed must be determined once you are clear about why the area became degraded in the first place, and a goal and objectives have been set for the restoration project. For example, salinity is now a feature of many parts of southern Australia, and the riparian lands along valley bottoms are often highly saline. Careful selection of native species, and ripping and mounding of soil, may be necessary before revegetation can be attempted with confidence.

Establish vegetation as far down the base of the bank as possible

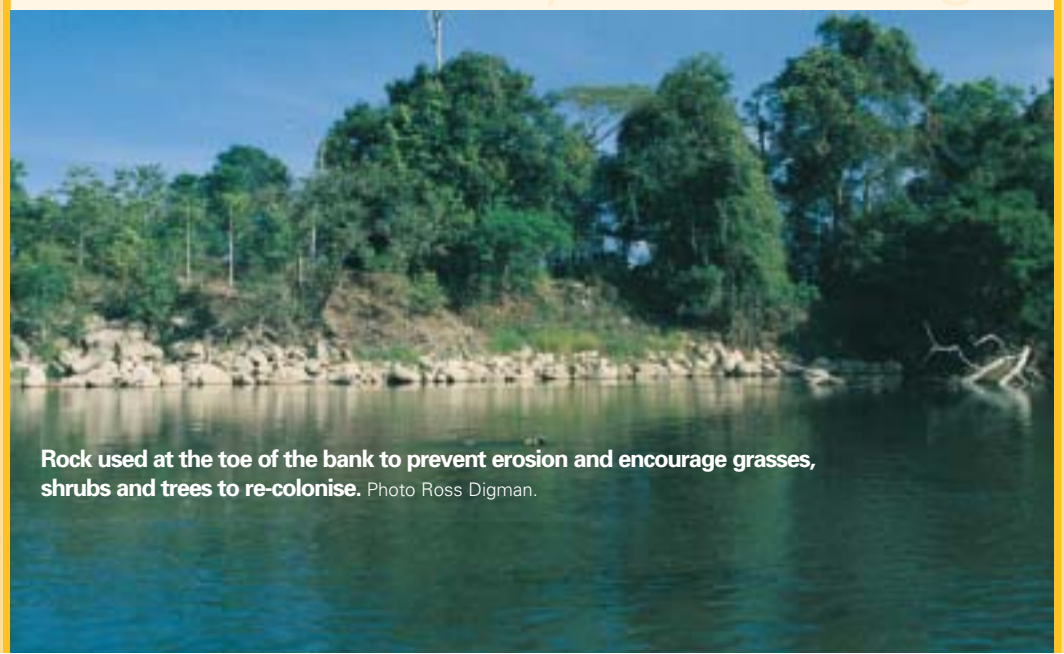
This may require special work to stabilise the toe of the bank, or to batter the bank to an angle where healthy riparian vegetation can become well-established and provide stability. Vegetation on a river floodplain and its banks has little impact on in-channel flow where the width of the channel is more than 30 times the depth. Even in smaller streams, it is important to protect as much of the bank face as possible if erosion is to be reduced to a minimum.

Use a range of vegetation species

The general approach would be to copy nature, with reference to local intact riparian areas. Natural, stable streambanks support a range of grasses and reeds, shrubs and trees. The fine roots of grasses and small shrubs are particularly effective in providing additional strength to streambank soils, and at binding soil together to reduce scour. In regions where moisture is not limiting, native riparian species often form a mat of dense, fibrous roots along the bank surface — a very effective protection to both sub-aerial processes and scour. In addition, by replicating the natural variety of vegetation, newly-planted areas can be self-perpetuating and require little maintenance. Weed control and removal of exotic species may be required until a natural canopy is re-established.

Choose suitable species

Dense undergrowth can provide more resistance to bank erosion than can widely-spaced tree trunks, particularly down towards the channel and at the toe of the bank. Species with a dense, fibrous root system and flexible stems and branches able to move with the flow are to be preferred. Higher up the bank, larger shrubs and trees can help to dry out the bank soil while their smaller roots add substantially to soil strength and reduce slumping failures.



Rock used at the toe of the bank to prevent erosion and encourage grasses, shrubs and trees to re-colonise. Photo Ross Digman.

Match vegetation to stream size

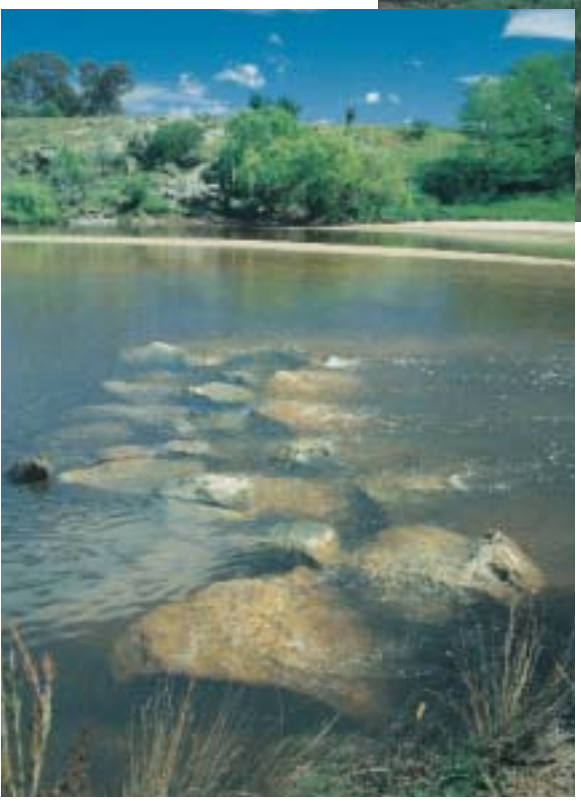
The effectiveness of revegetation depends in part on the size of the stream at the restoration site. Along small tributaries, whether in the upper part of the catchment or in the lowlands, where the channel depth is small relative to the height of vegetation, riparian plants can significantly improve bank stability. If vegetation is planted or allowed to recolonise the bank, the roots are able to penetrate to, or below, the bed of the channel, limiting bank collapse and increasing the bank's resistance to scour. Where the banks are undercut, the vegetated bank soil will collapse downward, enabling the vegetation to slow or protect the banks from further erosion. Further downstream, or as the channel gets wider, vegetation begins to play a different role. Very large channels, where slumping failures along streambanks are common, often have banks whose height is greater than the rooting zone of most trees.

Be careful with in-stream vegetation

If there is evidence that lack of channel capacity during flood flow is a cause of bank erosion, vegetation should not be planted within the channel or allowed to stabilise sediment bars. Although the impact of riparian vegetation decreases with channel size, willows and reeds choking a 15 metre-wide channel of about 4 metre depth will roughly halve channel capacity to convey major flows. Particular care should be taken to avoid planting species that are known to be invasive within stream channels. As a general rule, native species should be used wherever possible, particularly with the advent of new techniques for their use and rapid establishment.

Carefully consider the role of woody debris (snags)

Vegetation and large, woody debris would need to occupy at least 10% of the cross-section of the channel before having much effect on flow velocity and flooding. Large woody debris is now known to have an important effect in helping to control the grade of channel beds and to armour both bed and banks against erosion. Where the total amount of woody debris within a channel may be approaching the 10% zone, some may be dragged back against the banks at an angle of around 40°, where it is known to have very little effect in diverting water flow onto the banks.



Using rock deflectors to control bank erosion and create fish habitat.
Photos Louise Gallagher.

Can streambanks be stabilised by revegetation?

There are now many examples around Australia where careful revegetation, sometimes combined with structural works such as rock protection for an eroding toe, or groins and mesh to accumulate sediment, has been highly successful in stabilising previously-eroding streambanks. Replacement of large, woody debris, again in combination with well-planned revegetation, has also been shown to be very effective, even in high-energy streams. There is now an accumulating bank of technical knowledge and success that is enabling agencies, community groups and landholders to take positive action to improve streambank stability with confidence.

For further information

Abernethy, B. & Rutherfurd, I. 1999, *Guidelines for Stabilising Streambanks with Riparian Vegetation*, Cooperative Research Centre for Catchment Hydrology, Technical Report 99/10.

Rutherfurd, I., Abernethy, B. & Prosser, I. 1999, 'Stream erosion' in S. Lovett & P. Price (eds), *Riparian Land Management Technical Guidelines, Volume One: Principles of sound management*, Land & Water Australia, Canberra.

Abernethy, B. & Rutherfurd, I. 1999, 'Controlling stream erosion' in P. Price & S. Lovett (eds), *Riparian Land Management Technical Guidelines, Volume Two: On-ground management tools and techniques*, Land & Water Australia, Canberra.

FACT SHEET 2
BACK PAGE

These **Fact Sheets** are grouped according to whether they deal with riparian land, in-stream issues, river contaminants or other matters. They aim to set out the general principles and practices for sound management. Other information that focuses on local conditions and management issues is available from state government agencies, local governments, catchment management authorities, rural industry bodies and community organisations. Together, this information should assist users to understand the key issues in river and riparian management, and enable them to adapt general management principles to their particular situation, and to know where to go for advice specific to local conditions.

Other relevant Fact Sheets

1 Managing riparian land
3 Improving water quality
4 Maintaining in-stream life
5 Riparian habitat for wildlife
6 Managing stock
7 Managing woody debris in rivers
8 Inland rivers and floodplains
9 Planning for river restoration
10 River flows and blue-green algae
11 Managing phosphorus in catchments
12 Riparian ecosystem services
13 Managing riparian widths

Numbers 1–7 of these Fact Sheets are based on the previous *Riparian Management* series produced in the 1990s. The authors involved in the development of the earlier series were: Michael Askey-Doran, Stuart Bunn, Peter Hairsine, Ian Prosser, Ian Rutherfurd, Brian Finlayson, Ian O'Neill, Chris Gippel and Wendy Tubman.

Further information on river and riparian management can also be found at the Land & Water Australia 'River Landscapes' website.

www.rivers.gov.au

This website provides access to projects, fact sheets, guidelines and other information designed to assist people to better manage river and riparian areas across Australia.

River Landscapes

Edited by Phil Price and Siwan Lovett and produced by Land & Water Australia's National Riparian Lands Research and Development Program.

Australian Government
Land & Water Australia

Land & Water Australia
GPO Box 2182, Canberra ACT 2601
Tel: 02 6263 6000 Fax: 02 6263 6099
E-mail: public@lwa.gov.au
Website: www.lwa.gov.au

May 2002, reprinted June 2004

© Land & Water Australia
All rights reserved. No part of this publication may be reproduced, stored in any retrieval system or transmitted in any form or by any means electronic, mechanical, photocopying, recording or otherwise without the prior written permission of the publisher. The information in this publication has been published by Land & Water Australia to assist public knowledge and discussion and to help improve the sustainable management of land, water and vegetation. Where technical information has been provided by or contributed by authors external to the Corporation, readers should contact the author(s) and conduct their own enquiries before making use of that information.

Product number PF020254

Publication data
Price, P. and Lovett, S. 2002, 'Streambank stability', Fact Sheet 2, Land & Water Australia, Canberra

Cover illustration from River Landscapes, a painting by Annie Franklin

Design by Angel Ink, Canberra
Printed by Goanna Print, Canberra