RIPRAP
RIVER AND RIPARIAN LANDS MANAGEMENT NEWSLETTER

RIPARIAN RESEARCH

A second phase of the National Riparian Lands R&D program

Riparian lands play a vital role in a healthy, productive landscape. They offer a specialised habitat and corridors linking other parts of the landscape, as well as providing a refuge for plants and animals in times of environmental stress. They can exert a strong influence on in-stream health, and have the potential to affect water quality and quantity. They can influence the shape and stability of river channels and, as a result, break outs and flooding. Riparian lands also have special cultural, recreational and aesthetic significance, particularly when in proximity to urban areas. Over the past ten years we have increased our knowledge about how riparian areas function, however, research gaps still exist to frustrate attempts to better manage these special parts of our 'river landscapes'.

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RIPArian lands:

WHERE LAND AND WATER MEET

From the Editor

Welcome to another edition of *RipRap*. This edition is focusing on the research that is being funded in the second phase of Land & Water Australia's National Riparian Lands R&D Program. As you will see, we are continuing the good work started in phase one of the Program and investing in projects that explore ecological, physical and social aspects of riparian zone management. The strong practical focus for research remains a priority, with most of our projects developing products and guidelines designed to meet the needs of catchment management agencies, extension and field personnel, as well as those landholders that are keen to improve riparian zone management on-farm. We have also been very busy over the last few months producing information for you to use — this includes the proceedings of the highly successful Rivers Forum 2002; our new and updated Rivers and Riparian Management Fact Sheet series; a new Technical Update focusing on nutrient management in shallow lakes and wetlands; and, information about our revamped website. I hope you enjoy this edition of *RipRap* and that the material we are producing is assisting you in the work that you do!

RIPARIAN RESEARCH —

A second phase of the National Riparian Lands R&D Program

by Siwan Lovett
and Phil Price

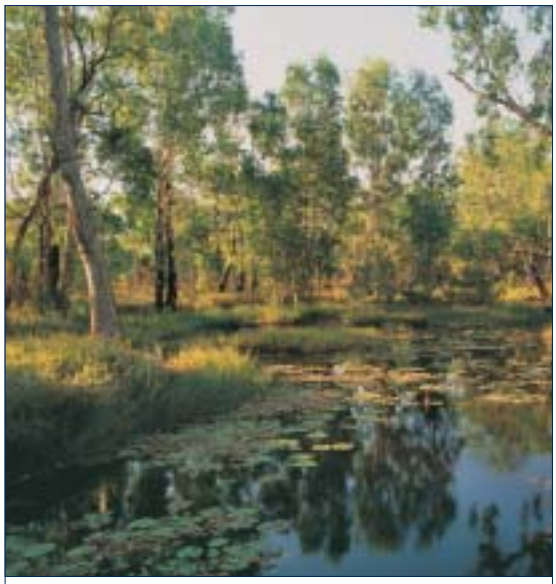
In Australia, poor management, or lack of management, has led to the substantial degradation of riparian lands. The removal, fragmentation and drastic alteration of vegetation cover, combined with changed flow regimes, has increased the incidence of bank erosion, resulting in a loss of agricultural land during floods, changes to the functioning of river systems and decreased water quality.

The economic costs of the poor management of riparian lands are significant. Ten per cent of the $450 million spent each year on water quality treatment for human use may be attributed to the degradation of riparian lands. Remedial works, such as protective infrastructure and flood mitigation measures designed to prevent or reverse riparian degradation, represent a substantial cost to landholders, communities and governments, and is estimated at costing $100 million per year. These estimates take no account of production losses, nor the environmental services provided by riparian lands and healthy riparian vegetation.

Simply put, riparian land is any land that adjoins or directly influences a body of water. It includes:

- *the land immediately alongside small creeks and rivers, including the river bank itself;*
- *gullies and dips which sometimes run with surface water;*
- *areas surrounding lakes; and*
- *wetlands and river floodplains which interact with the river in times of flood.*

The importance of riparian management has been borne out by the results from Phase One of the Riparian Lands R&D Program (1993–2000), which have identified the crucial processes and controlling influences undertaken by riparian vegetation. It is clear that although sound riparian management cannot, on its own, overcome the effects of poor management elsewhere in a catchment, it is an essential component of effective Integrated Catchment Management and without it, the health of our rivers will continue to decline. The key findings from Phase One of the Program were compiled into the two volume *Riparian Land Management Technical Guidelines* that provides both the science and the practical guidelines developed to assist landholders manage riparian areas. Some of the most important research findings from Phase One of the Program follow.



Riparian vegetation

- Vegetation roots are effective at reinforcing and stabilising streambanks to a distance of at least 1.5 metres height. This is especially important for incised streams where bed lowering leads to unstable banks, as well as in the middle sections of river systems where root depth and bank height are broadly equivalent.
- The weight of trees is a minor influence in bank mass failure, with trees being more important in reducing soil wetness and in resisting cracking and rotational failures. In other words, trees are a positive influence on bank stability and in general, do not increase levels of mass failure through surcharge weight.
- A 6-metre wide grass strip can trap up to 95% of sediment, nitrogen and phosphorus entering from upslope agriculture. Moreover, the trapped sediment is usually stabilised as the grass grows through it. The effectiveness of native riparian vegetation in trapping sediment and nutrients is very dependent on ground-level conditions — a grassy understorey can be very effective, while bare soil and litter is far less effective.

Note: the Guidelines referred to are the Riparian Land Management Technical Guidelines Volumes One and Two, available from CanPrint Communications Freecall 1800 776 616.

Erosion

~ River reaches and sub-catchments can be dominated by either hill slope erosion or channel erosion (gullying). Simple methods are now available to distinguish these two major sources of sediments, and to enable landholders to design appropriate management action.

~ Stock tracks are often a major source of sediment, and design guidelines can now be used to match the location or configuration of laneways and tracks with landscape characteristics.

In-stream health

~ Native riparian vegetation is the primary source of food and energy for the upper reaches of coastal streams in the form of leaves, flowers, fruit, bark, etc that fall into the adjacent stream. In-stream productivity is low under natural conditions due to low light, temperature and nutrient availability.

~ Native riparian vegetation is important in providing essential in-stream habitat, for example, in the form of large woody debris, root armouring of banks, etc. Declining habitat and declining food, both a consequence of over-clearing and poor management of riparian lands, are major causes of loss of native fish and other aquatic species.

~ In forested streams under natural conditions, nitrogen appears to be the limiting factor of in-stream growth rather than phosphorus, and this has significant implications for fertiliser, land and catchment management strategies.

~ The shade provided by riparian vegetation is the controlling influence preventing growth of nuisance aquatic plants, including blue-green algae, even in the presence of advanced nutrient levels.

~ Shade equivalent to around 70% of that of an intact canopy is required to prevent growth of nuisance aquatic plants. Depending on stream width and orientation, it may be necessary only to replant northern banks to provide the required shade to manage nuisance plants.

Stock management

~ Uncontrolled stock access to streams has negative impacts because they input massive nutrient into the stream through their urine and dung; they trample and pug streambanks which leads to increased scour and erosion; they overgraze riparian vegetation leading to weed invasion and loss of bank stability; and they allow the passage of disease organisms through to other stock.

~ It is possible, through strategic management of stock and grazing pressure, to both improve productivity and recoup fencing and watering costs while improving environmental management.

~ Improved stock management can lead to natural recruitment of native vegetation. Guidelines are now available that show replanting is possible using cost-effective approaches, that can be integrated into whole of farm planting.

RIPARIAN RESEARCH — a second phase

These findings have greatly contributed to our knowledge and understanding of riparian zone functioning, however, research gaps remain and Phase Two of the National Riparian Lands R&D program is now underway to address some of these issues.

The goal of Phase Two of the National Riparian Lands R&D Program is to:

Facilitate communities to implement, monitor and evaluate practices for ecologically sound, effective and economic management of riparian lands.

In order to realise this goal, the program is continuing to focus research and development activities on those management issues that people are dealing with on a day-to-day basis. Following an extensive consultation process with state and territory agencies, community and catchment management groups, and the research community, the program is conducting research into a set of issues that currently constrain our attempts to improve riparian management. These management issues have been grouped together according to the mix of scientific and communication skills required to investigate the research problem. These management issues are:

- development of conceptual model showing riparian zone interactions (page 9).
- influence of riparian management on flood hazard at a catchment scale (page 6).
- improving water quality and aquatic ecosystem health (page 10).
- reintroduction and maintenance of large woody debris (page 13).
- preventing or reducing pollution due to nitrogen and associated carbon sources (see 'River Contaminants' *RipRap* edition 20).
- management of domestic stock (page 18 and 22).
- development of simple but effective techniques for monitoring and evaluation of riparian management and vegetation condition (page 18 and 22).
- overcoming constraints to implementation of sound riparian management (pages 24, 25, 26 and 28).
- working with industry to improve riparian management (pages 31, 33 and 34).

This edition of *RipRap* covers each of these issues, with details provided about the objectives of the project, the approach that is going to be used, the researchers involved, and where you can go for more information. Each of the projects will be producing information in ways that make it readily accessible and applicable for people wishing to improve their management of riparian lands.

For further information about the National Riparian Lands R&D Program check out the www.rivers.gov.au website, or contact:

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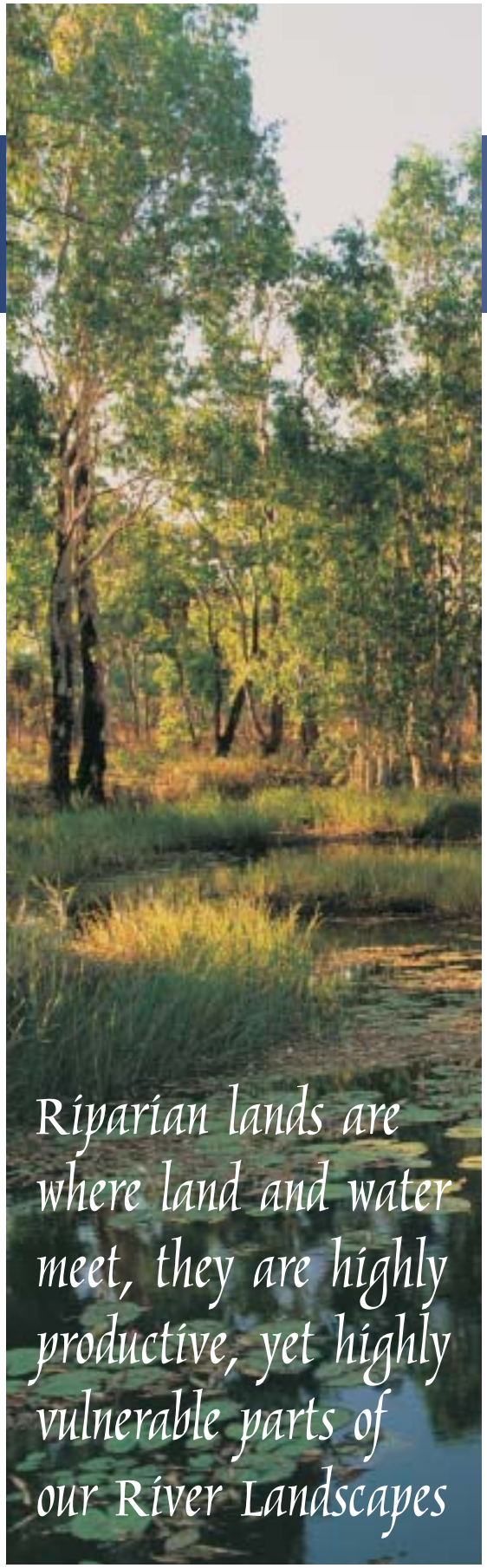

How does RIPARIAN VEGETATION affect floods?

by Ian Rutherfurd
and Brett Anderson

The fact that you are reading this article suggests that you are either revegetating riparian zones somewhere, or encouraging others to do so. Have you ever paused to consider what the effect of that revegetation will be on flooding? Toiling away on the stream banks, have you ever been taken aside by old-timers who tell you that your revegetation is just going to cause flood trouble? Is this true? You might answer that revegetating smaller headwater riparian zones will 'slow-down' flood waves so that flood heights will be reduced in the lower reaches — but is that true?

Land & Water Australia are supporting research that will identify how riparian revegetation in different parts of a catchment will affect floods. The word 'flood' means different things to different people. We are confident that really large floods will not be affected by riparian vegetation, but riparian vegetation could alter the duration (i.e. length) of 'nuisance' floods that may occur every year or two. The difference between two or four days under water can make all the difference to, say, sugar cane or pasture.

The problem with this project is that riparian vegetation affects all aspects of the progress of a drop of water after it has fallen from the sky, until it reaches the sea. It affects the amount of water reaching the stream (hydrology) via physical and physiological processes (Figure 2 and Table 1, opposite), as well as affecting the movement of water down the stream and across the floodplain once it is in the stream network (this is known as the roughness or hydraulic resistance).

Figure 1: Dandenong Creek approaching bankfull flow. How will the growing riparian trees affect the flood duration? *Photo Ian Rutherfurd.*

Some of the factors that influence the hydraulic resistance of vegetation include:

- the height of vegetation relative to the depth of flow.
- plant characteristics such as stem diameter, leaf size, surface texture and specific gravity which vary with the age of the plant and often the season.
- flexibility of the stems or the whole plant stand (e.g. in the case of a reed bank)
- orientation of stems within the plant and their areal density.
- degree of stem compaction with increasing flow velocity and the associated change in stand permeability.
- distribution of individual plants within a stand, their frequency and dispersion pattern.
- orientation of the plant with respect to the local flow direction.

All of these hydraulic effects are often described as 'roughness'. In a related project, we are investigating roughness as part of a National Rivers Consortium 'stream roughness' project, and will be developing a handbook of stream roughness for Australian conditions (see http://www.civag.unimelb.edu.au/~arlads/roughness.htm). We have already found that the hydrological effects of riparian vegetation on floods decrease downstream, whilst the roughness effects increase.

The work we are undertaking on 'roughness' and the effect of riparian vegetation on flooding will be brought together to produce a catchment scale hydrological model that identifies the effect of riparian vegetation on flood waves. This model will incorporate a rainfall-runoff component to account for getting water off the catchment and into the stream network, coupled with a

How does RIPARIAN VEGETATION affect floods?

***A**: Physical impacts*

***B**: Physiological processes*

Figure 2: Hydrological impacts of riparian vegetation. Source: Tabacchi et al. 2000.

Table 1: Hydrological impacts of vegetation (keyed to numbers in Figure 2)

Role of vegetation	Mechanism
Physical impacts (Figure 2a)	
1. Interaction with overbank flow by stems, branches and leaves generating turbulence limiting rilling and rain splash	*Quick flow**
2. Flow diversion by log jams	*Quick flow**
3. Change in the infiltration rate of flood waters and rainfall by litter	*Infiltration*
4. Increase in turbulence as a consequence of root exposure	*Quick flow**
5. Increase of substrate macroporosity by roots which prevents slaking	*Infiltration*
6. Increase of the capillary fringe by fine roots	*Infiltration*
7. Stemflow — the concentration of rainfall by leaves, branches and stems	*Interception*
8. Condensation of atmospheric water and interception of dew by leaves	*Interception*
Physiological processes (Figure 2b)	
1. Hydraulic lift, uptake of water from deep soil layers	*Soil moisture*
2. Hydraulic redistribution, lateral water flow to support root growth in dry soil zones which also limits soil moisture fluctuations, reducing desiccation	*Soil moisture and infiltration*
3. Water storage in large roots	*(Storage)*
4. Water storage in the stem	*(Storage)*
5. Water storage in branches and leaves	*(Storage)*
6. Evapotranspiration	*Soil moisture*

** These processes also have significant hydraulic implications*

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hydraulic model that routes water through the stream network and its floodplains.

At present we are working on the hydraulic routing component. Plants act to slow water down (and so back the flood up). The published literature contains many models that seek to predict how much a given plant, or community of plants will slow water down. For stiff vegetation, such as trees and large woody debris, the changes to the flow are relatively simple and can be predicted with reasonable confidence (Lopez and Garcia 2001; Shields and Gippel 1995). However, introduce either flexibility (saplings and pliant grasses) or architectural complexity (e.g. the porous branch-leaf complex of your typical blackberry bush) into the equation and prediction becomes more difficult.

Essentially, flow resistance due to vegetation is a three dimensional phenomenon, caused by changes to the turbulence structure of the flow. We are working with procedures initially developed to characterise atmospheric flows that reduce three dimensional behaviour into a one dimensional framework, by averaging flow quantities in time and space (Lopez and Garcia 2001). These will allow us to predict the form of hydrographs anywhere in the stream network, with and without riparian vegetation. From the hydrographs we can estimate the height (stage) and duration of floods. It is important to be aware that there is plenty of uncertainty in all aspects of hydrological and hydraulic modelling at this scale, but we should be able to estimate the general effects of vegetation on flooding with some confidence.

So far we have concentrated on what might be called a 'typical' or 'synthetic' catchment' before we embark on modelling a real one. The real ones we trial will see us working with industry partners to the program (see industry projects later on in this edition of *RipRap*).

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(more references available by contacting the authors)

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RIPARIAN VEGETATION and streams: how it all fits together!

by Ian Prosser,
Frances Marston
and Ian Rutherfurd

Ten years ago, people working in the first Land & Water Australia National Riparian Lands R&D Program had to explain to stream managers what the riparian zone was! Those days are gone. Almost all stream managers, and most landholders, now know what the riparian zone is and why it is important. But these same riparian managers can also be excused for being confused. The huge raft of basic and applied research into riparian zones (much of it funded by Land & Water Australia) has shown that riparian vegetation has a major influence on streams. They know that riparian vegetation provides shade, reduces aquatic weeds, prevents erosion, buffers streams from agricultural land, provides habitat, and so on. But these effects are not the same everywhere. The effect of riparian vegetation varies enormously depending where you are along a single stream, and where the stream is in Australia. In addition, many of the processes interact to give multiple benefits.

This project is designed to provide a tool that can help to cut through the confusion of riparian research, so that managers can identify the research that is likely to be relevant to them on their stream. We are producing a 'conceptual model' of riparian functions. Put simply, this model will attempt to illustrate the various 'functions' provided by riparian vegetation, in different parts of the landscape, as well as illustrating how these functions interact with each other.

Riparian management aims to achieve much broader goals than any individual function or process. This description will illustrate some of the interactions that have not been emphasised in the past. The exercise is aimed at communicating the many benefits of riparian management in an integrated way. A secondary consequence will be the identification of some knowledge gaps that still exist in riparian management.

The material will be structured around two themes for several different river settings:

1. enhancing the values of river landscapes and,
2. highlighting the most significant riparian functions for several different river settings.

This approach has been taken to demonstrate the interrelationship between values and functions of the riparian zone, and how our management actions impact upon these interrelationships.

We aim to produce several communication products. We will develop an interactive product that runs off the www.rivers.gov.au website and will allow users to explore the many benefits of riparian management. For those not wanting to connect to the web, the information will be placed on a CD as a navigable html product. We will also produce a Microsoft Powerpoint presentation for those wanting to use the information to illustrate to others how riparian management can benefit rivers. We hope to keep the material as graphical and illustrative as possible, with short sections of text. For detailed explanations of each of the processes we will refer readers to the *Riparian Land Management Technical Guidelines Volumes One and Two* published by Land & Water Australia, as well as to other freely available information.

We hope to have the final product up and running on the website by the end of September 2002.

For more information, or for suggestions on content or presentation

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SHADE, TEMPERATURE, large woody debris and river models

by Stuart Bunn
and Peter Davies

Riparian areas and their associated streams and rivers are the *ecological arteries* of the Australian landscape. It is now widely acknowledged that the health of our waterways is directly linked to the condition of their riparian zones. Although many of the important ecological roles of riparian zones are well recognised, there is a need for additional scientific information to underpin sound management. In this component of Phase Two of the National Riparian Lands R&D Program, we will address several important ecological knowledge gaps.

Riparian shade and stream temperature regimes

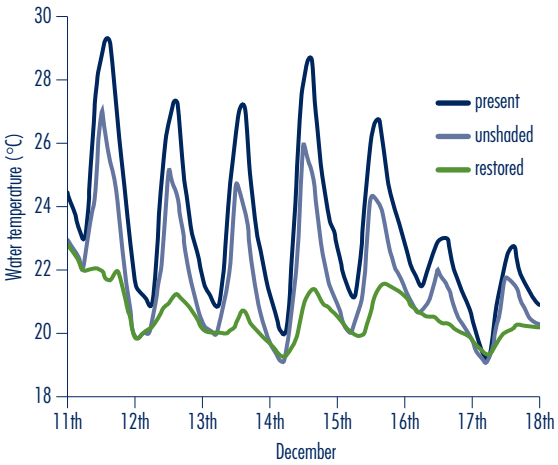
Collaborators: Kit Rutherford (NIWA), Nick Marsh (GU), Anna Price (UWA)

Riparian vegetation shades stream channels and can effectively buffer aquatic ecosystems from temperature extremes. If riparian shading is removed, daily variations in stream temperature often increase and, importantly, so do maximum temperatures. Unfortunately, many stream organisms (plants and animals) have little ability to cope with large fluctuations in temperature and, in particular, high temperature extremes. High water temperatures are associated with low oxygen levels that tend to increase microbial activity (e.g. bacteria), thereby further reducing the amount of oxygen dissolved in the water. Add to this the huge nighttime oxygen demands of aquatic plants that grow well in the absence of shade, and it is easy to see why ecosystem health declines.

A key question in riparian rehabilitation is how much shade (in terms of percentage cover), and how long a section of stream is needed to have a beneficial effect on the temperature regime? We aim to quantify this relationship between shading and temperature so that we can predict how the extent of cover and length of rehabilitation will reduce impacts to stream fish, other organisms, and ecosystem processes.

The first task has been to test a stream temperature model (STREAMLINE) developed by Dr Kit Rutherford at the National Institute for Water and Atmospheric Research for New Zealand forest streams (Rutherford et al. 1997). Field data have been collected from two rivers in Queensland, Echidna Creek in the Maroochy River catchment, and several sites in the upper Mary River catchment. In addition, detailed temperature recordings have been made in Echidna Creek before and after a major riparian restoration project, as well as from forest and open pasture reference streams. This work is being undertaken in collaboration with the CRC for Catchment Hydrology and the South-East Queensland Healthy Waterways Partnership.

Photo: In the absence of riparian shading, stream organisms are often faced with extremes of both (high) temperature and (low) dissolved oxygen. Photo Stuart Bunn.



Predicted temperatures in Echidna Creek assuming existing shade (present), the removal of all remaining riparian trees (unshaded), and the rehabilitation of riparian forest along the entire study reach (restored). Predictions assume average flow (Rutherford, unpublished data).

Some stream animals, like this predatory stonefly nymph, are highly sensitive to temperature extremes. Photo Jon Marshall.

Initial work suggests the model calibration is satisfactory and demonstrates that a significant decrease in water temperature can occur over a short distance if the channel is heavily shaded, and conversely, that a significant increase can occur over a short distance if the channel is unshaded.

The second aspect of this study requires data on the temperature tolerance of representative groups of aquatic invertebrates and fish. A review of the literature and unpublished data is currently underway and this, together with available data on stream ecosystem processes, will be used to predict the likely ecological consequences of changing temperature regimes, as well as enabling the setting of targets for the rehabilitation of disturbed streams.

Rehabilitation of in-stream woody habitat

Collaborators: Ben Cook (GU), Andrew Brooks (GU), Nick Marsh (GU), Peter Cottingham and others in the CRC for Freshwater Ecology and CRC for Catchment Hydrology

Many community groups and government agencies are actively involved in stream habitat rehabilitation projects using large woody debris (LWD), aimed at restoring local biodiversity and ecosystem health. However, much of the effort to date has been fragmented and many projects have failed as learning 'experiments' because of the lack of rigorous monitoring to assess whether the restoration has met predetermined environmental goals.

To meet the immediate needs of management, a working group has been formed, drawing on expertise in the CRC for Freshwater Ecology and CRC for Catchment Hydrology. The first goal of this group is to update sections of the *Riparian Land Management Technical Guidelines Volume Two* covering the management of woody material in streams and rivers (Price & Lovett 1999). A workshop was held in April 2002 and a draft report has been prepared. Some highlights of the update, include:

- discouraging the use of negative terms such as *woody debris* and favouring more ecologically based terms such as *woody habitat* or simply *wood*;
- strong arguments against removal or even realignment of woody habitat in rivers and a focus on putting it back;
- consideration of floodplains as well as the channel when planning woody habitat rehabilitation projects; and,
- planning of riparian rehabilitation to provide a sustainable source of woody habitat in the long-term.

Additional workshops are planned to provide recommendations on how to implement restoration of physical habitat, and to critically evaluate various design options for assessing the ecological success (or failure) of rehabilitation efforts.

There is little point in restoring woody habitat for aquatic organisms if other factors such as their ability to move within and between streams prevent successful recolonisation. To address this issue, Ben Cook has commenced a PhD project on the recovery and recruitment of aquatic organisms in rehabilitated streams. A primary goal of Ben's project is to determine how different aquatic organisms with various life history characteristics move within streams, and how far they extend. This will enable us to identify the factors that may potentially limit colonisation (settling) of new habitats. Using molecular techniques, Ben also hopes to determine the source of aquatic organisms to restored stream reaches and whether or not they

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An artificially placed log in the Broken River, NE Victoria. Photo Ian Rutherfurd.

represent the offspring of only one or a few matings (i.e. the chance arrival of a small number of colonists). With this information, we will have a better understanding of the factors that may constrain recolonisation of restored stream reaches by aquatic organisms and, if required, explore ways to enhance the rate of ecological recovery.

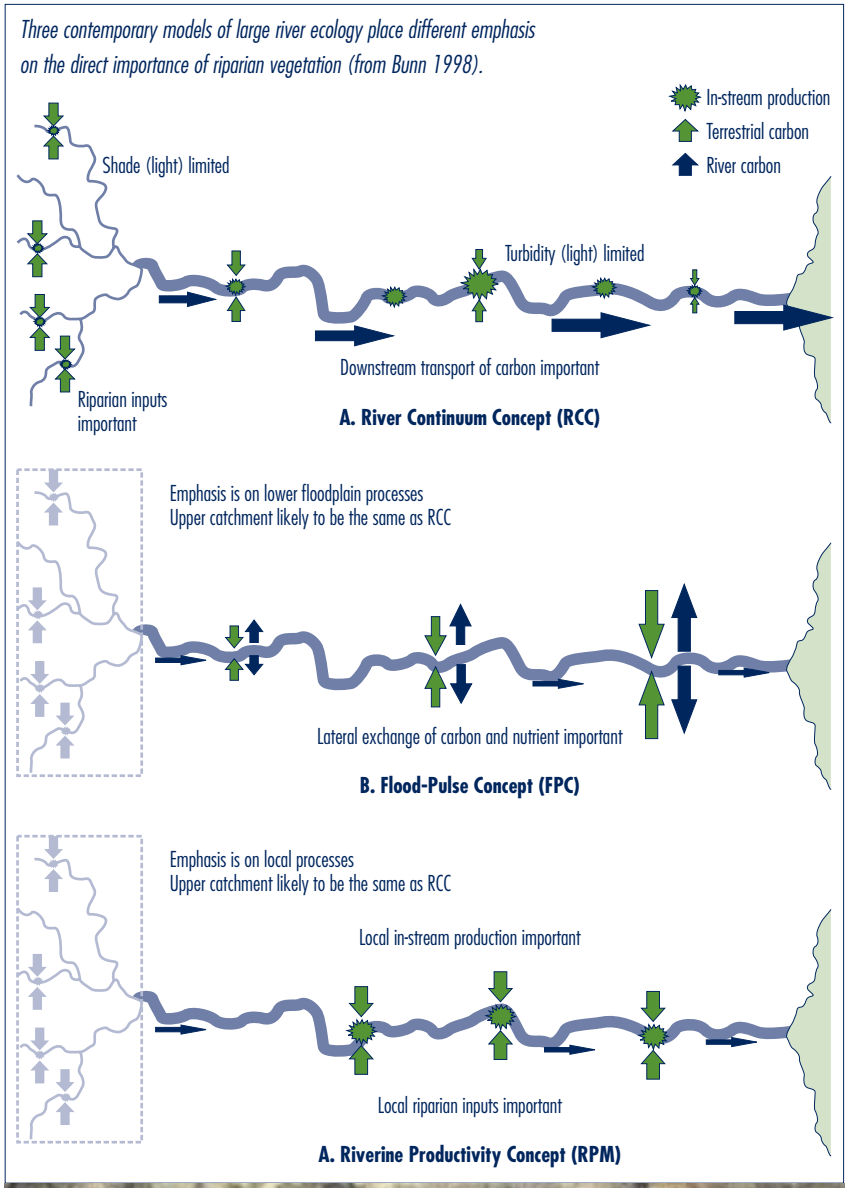
Testing ecological models of large rivers

Collaborators: Fran Sheldon (GU), Alistar Robertson (CSU)

Our current ability to manage large river systems is hampered by a limited understanding of basic ecological processes. Three contemporary models of large river ecology place different emphasis on the direct role of riparian vegetation. The River Continuum Concept emphasises the importance of terrestrial (derived from the land) carbon and nutrients 'leaked' from tributary streams to the structure and function of lowland river reaches. In contrast, the Flood-Pulse Concept emphasises the importance of lateral (sideways) river-floodplain exchanges and proposes that riverine food webs are more dependent on production derived from the floodplain, rather than from tributaries upstream. The Riverine Productivity Model provides an alternative view of ecosystem function in large rivers and highlights the importance of local in-stream production and, to a lesser extent, direct inputs of material from the adjacent riparian zone (from Bunn 1998).

The applicability of such models to large rivers in Australia is largely untested and has major implications for management (especially of riparian and floodplain regions). We aim to establish the degree to which riparian vegetation directly influences ecosystem processes and the overall 'health' of large rivers. In particular, we will examine the influence of riparian shade on littoral (edge of the river) algal production, the direct inputs of leaf litter and insects from riparian vegetation, and the importance of these sources to the aquatic food web. Replicate sites differing in channel orientation (north south *vs* east west) and riparian cover (shaded *vs* open) will be sampled in the Mary and Brisbane catchments in southeast Queensland during 2002–2003.

Three contemporary models of large river ecology place different emphasis on the direct importance of riparian vegetation (from Bunn 1998).



Can rehabilitation of riparian vegetation have a direct influence on ecosystem processes and the overall health of large open river channels?

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EXPERIMENTAL reintroduction of woody debris into rivers

by Andrew Brooks

Among scientists and rivers managers there is increasing acceptance of the need to reintroduce wood (logs, snags, large woody debris, etc) into rivers that previously had much higher wood loadings. Broad community acceptance of wood reintroduction into rivers as part of rehabilitation efforts is, however, still some way off. There is little doubt that in the longer term, natural recruitment of wood from healthy stands of native riparian trees is the only viable way of returning the vast lengths of river where it is required, to a more natural state. However, the timeframe for recreating natural wood recruitment processes is long in human terms (probably 50–100 years), and in the short term the physical and ecological degradation of rivers will continue until in-stream woody debris loadings can be brought up to acceptable levels. This means that a compelling case exists for kick starting the rehabilitation process by artificially reintroducing logs into rivers.

At present, the ecological argument for reintroducing logs into rivers is better understood than the geomorphic or engineering argument. Ask any fisherman where the best fishing spots are in a river and he/she will invariably take you to their favourite 'snag'. However, if this same fisherman happens to be a riparian landholder and you ask whether that same 'snag' serves any purpose in stabilising the river channel, he/she is more than likely to tell you that the snag causes bank erosion and flooding, and that it would be better if it was removed from the river.

At one level, this project was set up to address this apparent dilemma, and to demonstrate that rather than habitat and stability being mutually exclusive river management goals, they can in fact be complimentary. Indeed, from an historical perspective there is now a wealth of evidence demonstrating that the removal of logs from rivers is one of the principal causes of channel instability, and indirectly, of habitat loss and homogenisation (e.g. loss of pools).

Over and above the broad objective of improving the image of logs in rivers, the more specific goals of this project are to:

1. design and construct two demonstration sites highlighting the use of woody debris as a rehabilitation tool in conditions representative of coastal rivers in SE Australia (i.e. high energy sand- and gravel-bed streams).
2. design reach-based strategies at each demonstration site using woody debris to improve channel stability, and increase habitat diversity and productivity (i.e. indirect habitat associated with woody debris).
3. design stable log structures suitable for different channel conditions (unit stream powers for the design floods of up to 180 Newton m^{-2} for the sand-bed channel and 600 N m^{-2} for the gravel site).
4. undertake monitoring of:
   - ~ reach channel shape and function (morphology) to assess changes in habitat (i.e. increasing pool area, pool/riffle sequences, bed material distribution);
   - ~ sediment storage within the treatment reaches;
   - ~ reach hydraulics; and,
   - ~ appropriate ecological indicators that will demonstrate ecological benefits of the strategy.

Study sites

The project is now into its third year, and two sites have been established on tributaries of the Hunter River, NSW. The first site was constructed in September 2000 at Munni on the Williams River, a high-energy gravel-bed tributary in the north-east of the Hunter Valley. The reach rehabilitation strategy at Munni involved the construction of 19 'engineered log jams' incorporating 436 primarily eucalypt logs with root wads. This had the effect of increasing the wood loading within the reach from virtually zero to 0.014 m^3 m^{-2} (see Brooks et al. 2001 for more details of reach design). The structures were designed to withstand bankfull discharge during flooding, and involved no artificial anchoring or ballasting, relying solely on the interlocking of the logs and their root wads plus the ballasting effect of the on-site gravel.

EXPERIMENTAL reintroduction of woody debris

The second site was completed in April 2002 on Stockyard Creek, a tributary of Wollombi Brook in the south of the Hunter Valley. Stockyard Creek is an incised sand-bed stream that despite having a relatively small catchment area (~35 kilometres^2) is subject to highly variable and potentially extreme discharges for its catchment area. The rehabilitation strategy at this site involved the reintroduction of 550 logs in 22 structures, many of which were complete cross channel spanning structures, comprising up to 80 logs. Designing stable structures at this site was much more difficult than in the gravel-bed site at Munni, despite the high bankfull discharge and unit stream power at that site. Structure stability at Stockyard Creek relied largely on driven log piles. Binding logs together with high tensile fencing wire provided additional stability. Geotextile was incorporated into a number of the cross-spanning structures to help trap the highly mobile sand and to minimise undercutting. All channel spanning structures were excavated into the stream-bed to a depth > 1.5 metres.

Results so far

In the short period of time elapsed since the Stockyard Creek site was completed, there have been insufficient flows to generate any worthwhile results, so those presented here are from the Williams River site. In the 18 months since the Munni site was constructed it has experienced a fairly extraordinary run of floods, with all structures (some of which stand up to 2.5 metres above the low flow channel) being overtopped at least six times. This run of floods, three of which exceeded the mean annual flood, has provided a wealth of data with which to evaluate all aspects of the performance of the log structures and their effect on the test reach.

Structure stability

Of most interest to the collaborators on this project (LWA, DLWC and Hunter Catchment Management Trust), the local farmers, and an assorted array of local sceptics, was whether the structures would withstand the first major flow over them. I am happy to report that not only did the structures survive the first flow, but much to the amazement of the local sceptics, they survived all the flows since construction, one of which was large enough to warrant a 'natural disaster' declaration (see Figure 2c).

Reach morphology

Changes to the test reach following the first three bed-mobilising flows since construction can be summarised as an increase in the complexity of channel morphology and the number of riffle/pool sequences, and a reduction in the wavelength. These effects were most obvious in the upper half of the test reach, while the response in the lower half downstream of the large pool on the bend were still quite profound but less ordered.

Figure 2:
A. Upper section of Munni test reach at the commencement of construction of the upstream deflector jams. Note a 4 metre high actively eroding bank was located to the right of the tractor; B. The completion of construction; C. Same view in flood (270 m^3 sec^{-1}, 7/05/01) at about 1 metre below peak stage; D. Following the second major flood since construction — note the aggraded bar upstream of first structure and the increased scour around the two structures. The riffle crest in the foreground was raised as a result of backwater effects associated with the structures. Photos Andrew Brooks.

Sediment retention and bed texture changes

There has been a significant increase in the volume of sediment stored within the test reach that is not replicated in the control reach. Indeed, following the three bed mobilising flows the reach has experienced, there has been a net loss of sediment from the control reach and a net gain in the test reach. Over the whole reach, the net sediment gain following the second flood equated to 2100 metres^3 of gravel, or around 200 large truck loads of sediment. Not only was there an increase in the volume of sediment retained within the test reach, but it was significantly finer, suggesting that the rehabilitation works resulted in energy being dispersed and fine sediments being deposited throughout the test reach. The net effect of the three floods in association with the log structures would appear to be that variability in the distribution of bed material has increased markedly. This has contributed to increased habitat diversity for in-stream plants and animals.

Fish surveys results

The mean number of fish species in the test reach increased by 50.4% after rehabilitation, compared with an increase of 30.2% in the control reach. Mean fish abundance in the test reach increased by 53.4% compared to a slight decrease in the control reach. The mix of fish species in the test reach was more stable post-rehabilitation, suggesting that the increase in habitat complexity provided a refuge from high flow events. Numbers of Australian bass increased in both reaches post-rehabilitation, suggesting upstream migration during high flows may have facilitated an influx of fish to the study reaches (see also Gehrke & Brooks 2002).

Summary

The observed changes in the Munni test reach have greatly exceeded all preliminary expectations. Banks that were eroding have been stabilised, riffles have been raised by as much as 0.5 metres, and substantial volumes of gravel have been trapped within the test reach.

Excess transport and supply of sediment as a result of historical channel enlargement and reduced hydraulic roughness within channels is probably one of the greatest management problems in coastal rivers in south-eastern Australia. This experiment has shown that re-establishing structural woody habitat may be an effective technique to transform river channels that currently act as sources of sediment or transfer zones, into sediment sinks. The habitat and ecological benefits of the log based rehabilitation strategy appear to be highly encouraging, although ongoing monitoring is required to confirm the causes of the increased fish numbers and whether it is a lasting effect.

Perhaps one of the greatest successes of this project has been the dramatic change in the attitudes amongst the river managers in the Hunter Valley and the local farming community, regarding the benefits of not just retaining wood in rivers, but of reintroducing it. The attitudinal transformation is probably best summed up by the comments from Jim Stubbins, a third generation dairy and beef farmer on the Williams River.

> *"I thought the first flood would tear the whole thing out. My concern was that if the water undermined the logs and they were gouged out, they'd take half the bank with them and the situation would be ten times worse than it was before they started. But after six or seven 'pretty substantial floods', the logjams are still secure and there is clear evidence that they are helping stabilise the banks." As far as Stubbins is concerned , the jury is in: "I've lived here all my life and it's a real eye-opener. For anyone who has a similar problem, I'd strongly suggest they come and have a look. I know its an expensive operation but if it works as well elsewhere as it does here, I'd really recommend it."* (Excerpt from 'A river runs through it', *Sydney Morning Herald*, 27 September 2001).

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GOING WITH THE FLOW:

Studying how flooding and drying affect vegetation change on the Cooper Creek floodplain

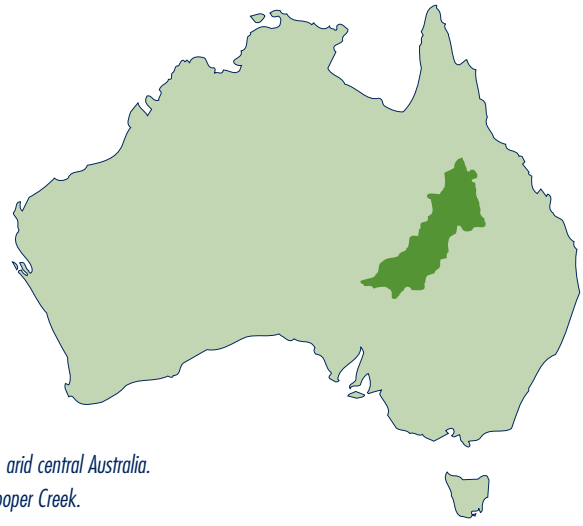
by Samantha Capon

After twelve hours crammed in a vehicle with various pieces of oddly shaped scientific equipment — not to mention odd scientists (!), it is a welcome relief to finally arrive at the main crossing of the Cooper Creek, just east of Windorah in south-west Queensland. The river is huge here — especially in comparison to the 'creeks' which you cross driving en route from Brisbane. The river red gums that line the banks really are majestic and, at most times, numerous waterbirds can be seen criss-crossing the channel — certainly not the picture of the desert river which I had in mind prior to my first visit! Continuing on towards the town, away from this lush river scenery, it becomes apparent that you are still driving across the river. Although mostly dry, the landscape is an intricate network of channels and floodplains, some of which may only receive water once in a decade, or longer. During these times of flood, this arid and sometimes harsh looking landscape is transformed into a vast wetland system, full of flourishing grasses and semi-aquatic plants. I have been studying these systems over the last few years, and it has been my privilege to visit this ever-changing area to investigate how these floodplain plant communities persist through such environmental extremes as flood and drought.

Hydrologically, the Cooper Creek is thought to be one of the world's most variable rivers (Puckridge et al. 1998) and from my observations, the vegetation appears to be no less variable. On every trip I find species that I haven't previously encountered, with dominant grass species often changing. Given this high level of variability, unravelling relationships between the flow regime and vegetation dynamics has been a difficult research question to study. However, it is one that water resource managers in such arid catchments urgently need addressed so they can better manage these areas.

The primary focus of my research has been to work out how flows structure plant community composition in time and space, and what the potential impacts of changes to flow, through water extraction or climate change, might be. In particular, I have been interested in identifying whether or not similar patterns exist in variable arid floodplains with those that are described for more regular catchments in temperate and tropical regions of the world.

My results to date indicate that vegetation structure and composition are strongly influenced by the flow regime, and that the time and space patterns that exist are also comparable with those in more predictable catchments. It has been possible, through a combination of field surveys and experiments, to identify a suite of plant community responses to both the wetting and the drying phases of the flow regime. For example, wetting appears to induce a significant



Map: The Cooper Creek catchment, arid central Australia.
Right: The vast floodplain of the Cooper Creek.

increase in total plant cover, an increase in the cover of annual grass species and hydrophytic species (i.e. plants that are adapted to wet conditions) such as nardoo and sedges. In addition, wetting phases homogenises plant community composition, with plant communities in frequently flooded areas reasonably similar throughout the catchment. Conversely, drying is associated with a decrease in total cover, fewer annual grasses and hydrophytes, and a shift in community composition. Floodplain areas that experience prolonged drying are more diverse from each other throughout the catchment.

Frequently flooded areas are structured predominantly by wetting processes and, as a result, have a higher total cover and a high abundance of annual grasses and hydrophytes. Drying processes structure the far edges of the floodplain that are rarely inundated. These areas tend to have lower plant cover and species diversity, as well as a higher abundance of perennial grasses and xeric species (i.e. plants which are adapted to dry conditions) which have invaded from neighbouring dune communities. Overall, the variability of the flow regime seems to maintain a dynamic and heterogeneous mosaic of plant communities across the floodplain.

Given these relationships between plant community composition and the flow regime, it seems likely that any changes to the flow regime will be reflected by changes in the vegetation. Water extraction, for example, would result in a decrease in wetting-related processes and an increase in drying-related processes. This could lead to the gradual replacement of hydrophytic species and annual grasses by more xeric species

in the middle and edges of the floodplain. Plant community zones may consequently narrow and move towards the channels where water is available. Eventually, vegetation patterns could become homogenised throughout the floodplain landscape with a possible loss of biodiversity. Clearly, this would also have a dramatic impact on the existing ecological and socio-economic values of the floodplain, for instance the provision of wildlife habitat or the highly productive cattle-fattening pastures.

Unfortunately, the field work phase of my studies is now complete and I am now spending most of my time in front of a computer screen as I try to finish my PhD thesis. However, I look forward to visiting the Cooper again as soon as possible and many times in the future to see how it changes, but hopefully not how we have changed it!

Reference

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Top and below: The mosaic of plant communities on the floodplain. All photos Sam Capon.

STOCK MANAGEMENT
in the riparian zone of the Burdekin River Catchment

by Neil Pettit and George Lukacs

A three year Land & Water Australia sponsored project is investigating the effects of livestock grazing and the management of livestock on riparian lands. This study is a collaborative project between researchers at James Cook University in Townsville and Charles Sturt University in Wagga Wagga. The main objective of this project is to determine the effects of livestock on the riparian zone of the Burdekin River in sub tropical Queensland and the Murrumbidgee River in temperate New South Wales. This will develop a better understanding of the ecological processes and animal and plant species that signal changes to ecosystems brought about by livestock grazing. By studying two contrasting river systems in different climatic zones, the influence of the physical environment and ecological factors on communities in the riparian zone can be distinguished from the effects of livestock. This article reports on work for the Burdekin River which is focusing on:

- providing a better understanding of the effects of livestock grazing on the riparian zone;
- developing indicators of riparian zone vulnerability; and,
- using modelling to integrate these results to the catchment scale.

Maintaining the riparian zone in good condition is particularly important in reducing sediment and nutrient run-off to streams. This means that managing livestock grazing in riparian areas is of high priority. However, on most rivers in the agricultural and pastoral zones of Australia, livestock have free access to the riparian zone for watering and grazing. In the Burdekin River catchment land tenure is predominately leasehold, with cattle grazing on undeveloped pasture the primary agricultural activity. Some regions have been degraded as a result of consistently high total grazing pressure. This has led to modification of riparian plants and surface soils in the riparian zone.

A survey of the literature indicates that there have been few studies specifically focusing on livestock grazing in the riparian zone in savanna landscapes like those of the Burdekin. There has been much important ecological research on grazing effects in northern Australian savannas; however, few studies have looked at the riparian zone as a specific land management unit. Too often, grazing systems developed for a particular land type and climate are used elsewhere without much consideration of the local conditions. We believe the aim should be for controlled grazing in the riparian zone so that the area is managed according to the unique combination of the many different factors (biological, geological, climatic) that shaped the system. This requires a good understanding of the ecological processes that drive that system.

Research objectives

The project aims to provide an understanding of the effects of livestock grazing on the riparian zone of the savanna lands in the Burdekin River catchment with specific objectives being to:

- provide an understanding of the changes in ecosystem function in the riparian zone under different livestock grazing management regimes.
- identify plant species that are vulnerable to high levels of livestock grazing.
- help in identifying thresholds of grazing tolerance for riparian plants and animals or physical conditions that can be used as indicators for monitoring guidelines.
- evaluate the different indicators of likely environmental change in the riparian zone brought about by livestock grazing that can be easily used and understood be livestock managers.

Site description

The Burdekin River is located in northeast Queensland and is the second largest catchment in the State. This project is mainly concerned with the upper Burdekin region of rangeland savanna, which is the area above Lake Dalrymple, an artificial lake formed in 1987 following the

completion of Burdekin Falls Dam (Figure 1). Approximately 94% of the area covered by the Burdekin River catchment is used for extensive cattle grazing. Property sizes range between 10,000 and 50,000 hectares and can run 2000 to 5000 head of cattle. In the upper Burdekin rangelands, paddocks generally have a low carrying capacity (4–20 hectares per animal), limited mainly by the high variability in seasonal production of low quality native pasture.

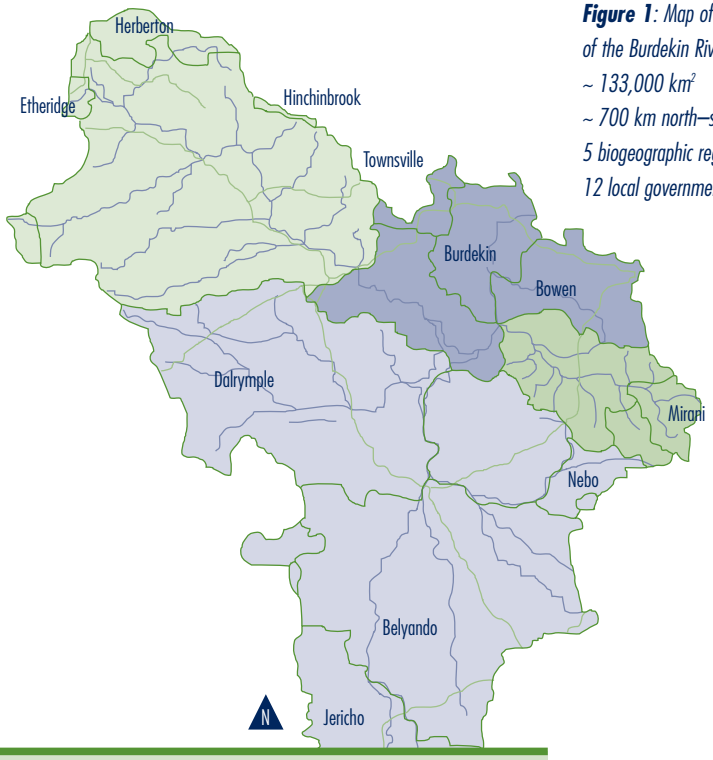

***Figure 1**: Map of the upper portion of the Burdekin River Catchment.*
~ 133,000 km²
~ 700 km north–south
5 biogeographic regions
12 local government areas

Research methodology

The approach taken for this project involves four areas of investigation:

1. *Historical change*
2. *Site impacts*
3. *Vulnerability assessment*
4. *Model development*

1. Historical change

As there is a lack of riparian areas in the Burdekin catchment that have never been subject to livestock grazing, there is no baseline on which to assess the impact of livestock grazing. One approach is to review historical records on the past condition of the riparian zone and develop a picture of the changes in the riparian environment with the advent of the pastoral industry. This will help develop an understanding of the historical changes in the vegetation and structure of the riparian zone that have taken place in the Burdekin catchment. This could include the use of diaries from explorers or early settler descriptions, or searching the photographic records from the district. There is also a wealth of knowledge from many long-term pastoral families in the area and information can be gained through oral histories about rivers and waterholes (Figure 2). Information on changes in water permanence, water quality and sedimentation, as well as changes to riparian and in-stream vegetation and fauna can also be useful in setting the background to more quantitative studies. In addition, this information can be used to increase awareness of issues in riparian management (e.g. weeds, erosion).

***Figure 2**: Historical changes to the Burdekin River as evidenced in this pair of photographs. The photo on the left taken in the 1960s while the photo on the right is from the same site taken recently showing changes to the vegetation and water quality. Photos Jim Tait.*

2. Site impacts

Ideally for this study, riparian sites affected by livestock grazing should be compared with sites not affected by livestock grazing or other disturbances. An undisturbed site would act as a control to which grazed sites can be compared. Unfortunately, in the Burdekin catchment there are few riparian sites that have not had some livestock grazing at present or in the past. This means that we do not know what the 'natural vegetation' conditions would be without the influence of livestock. This is a common problem throughout the pastoral lands of northern Australia, and it makes working out pre-European vegetation composition and structure very difficult. This means that the impacts of grazing can only be expressed in relative terms from the survey of a number of sites with different present and past grazing history.

An extensive survey of representative sites in the Burdekin catchment will provide a snapshot of the condition of the riparian zone and the effects of livestock grazing. This assessment will cover the various flow patterns, soils, geology and grazing history that occur in the catchment. Detailed studies on these sites will provide a general inventory of the vegetation in riparian areas and give an idea of the zonation of riparian vegetation.

In addition, at selected riparian sites in the Burdekin catchment long term grazing management experiments will be established. These experiments will assess changes over time in the ecology of the riparian zone as a result of different grazing management regimes. These trials by their nature, will take a long time for conclusive results to become apparent and require long-term commitment to monitoring and maintenance by researchers and landowners. The treatments at intensive study sites include two reach types (permanent/semipermanent pool and ephemeral reach), three levels of grazing intensity (heavy, moderate and light) and three levels of management (continuous grazing, no grazing and wet season spelling). This approach will also allow these areas to be used as demonstration sites for dealing with stock management in the riparian zone.

The most useful ecological and management results from this experiment will come after long-term monitoring (> 10 years) when some account of environmental variability can be made. However interim results will also identify useful information such as:

- the most resilient species and vegetation recovery after grazing is excluded
- the effect of grazing intensity on the rate of recovery and the particular species that return after grazing is excluded.
- the value of wet season spelling on the riparian vegetation and the rate of recovery.
- the difference in recovery of riparian vegetation between permanent pools and ephemeral reaches.
- the condition of stream banks and their potential for recovery with grazing relief.
- the effects of cattle watering points on stream bank condition and recovery rates.

3. Vulnerability assessment

Different riparian zones exhibit different vulnerability to the impacts from cattle. This may depend on many different aspects of riparian zone functioning and include soil type and underlying geology, geomorphology and flow regimes, which will in-turn affect such aspects as stream-bed type and bank formation. Biological components include vegetation types and structure, as well as the abundance and diversity of native and feral fauna. This project will also develop an index of vulnerability for riparian areas to livestock, based on physical and biological attributes. The index will be suitable for use by managers in setting grazing management regimes to minimise ecological damage to the riparian zone. We will also be evaluating the ecological effects of different livestock management strategies in the riparian zone, and will attempt to develop potential biological indicators that can be used to detect changes quickly. These will be simple to use and interpret. Potential indicators to be assessed will include some plant species, ants and other invertebrates and birds.

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4. Model development

This project is focused mainly on the paddock scale of ecological processes. To enable the broader applicability of the information gathered in this project, the work will be used as part of a larger CSIRO project developing a model of stock movement and utilisation on pastoral lands. This will provide a landscape perspective for impacts and management of livestock grazing in the riparian zone, and will also provide detailed information for the spatial model on an important savanna landscape unit.

The development of conceptual models is also an important outcome for this project so that the processes identified can be incorporated into a framework to describe the ecological change in the riparian zone under the effects of livestock grazing. These conceptual models can indicate research and management directions, and will be refined as results of this study are interpreted. Output from these models will also provide a landscape scale understanding of the effects of livestock in the riparian zone.

***Figure 3**: Cattle drinking from a waterhole on the Cape River in the Burdekin River catchment at the end of the dry season. Photo Neil Pettit.*

STOCK MANAGEMENT
in riparian zones of the Murray-Darling Basin

by Amy Jansen and Alistar Robertson

In this three-year project sponsored by Land & Water Australia, we are investigating management of domestic livestock in riparian zones. This is a collaborative project between Charles Sturt University in Wagga Wagga, and James Cook University in Townsville, a research partnership that will enable us to draw conclusions across very different systems. The previous article is about the north Queensland project, here we will discuss the work in south-eastern Australia.

Why manage livestock grazing in riparian zones?

Reviews of the literature generally conclude that grazing of domestic livestock in riparian zones is detrimental to the structure and functioning of both waterways and their associated riparian zones. This means that the best recommendation for grazing in riparian zones is exclusion, however, there are many reasons why grazing cannot or will not be excluded from riparian zones. These include:

- fencing is too expensive;
- small property sizes make it unviable to lock up portions of land to prevent stock accessing the riparian zone;
- frequent and/or severe flooding destroys fencing, which represents a significant cost for the landholder; and,
- weeds may infest areas excluded from grazing.

In these cases it is necessary to determine the best strategy for grazing in riparian zones.

Best management of grazing in riparian zones?

Very little work has been done comparing the effects of different grazing management practices in riparian zones, and nearly all of that work has been done in the western United States. In reviewing these studies, the main conclusions we could draw were that:

***Photo 1**: Cattle in the riparian zone of the Murrumbidgee River. Photo Amy Jansen.*

- rotational grazing *can* have lesser impacts than continuous grazing;
- the *timing* of grazing in a rotational system can be important;
- grazing affects some aspects of riparian and aquatic ecosystems more than others; and
- some level of grazing *may* have more positive outcomes than exclusion of grazing, under some circumstances.

With these studies as background, we have surveyed riparian zones in the Murray-Darling Basin (see Photo 1) and found that the following plant and animal communities all vary with different grazing regimes:

- understorey plants;
- wetland frogs;
- terrestrial invertebrates; and
- birds.

For example, Figure 1 shows how bird communities vary according to grazing intensity on the Murrumbidgee and Murray Rivers. Sites with similar bird communities are close together, while those with dissimilar bird communities are far apart. It is clear that ungrazed sites tend to have similar bird communities, as shown towards the left of the figure, while heavily grazed sites tend to be towards the right of the figure. These sites have many common farmland birds, such as magpies, willie wagtails and cockatoos, while the

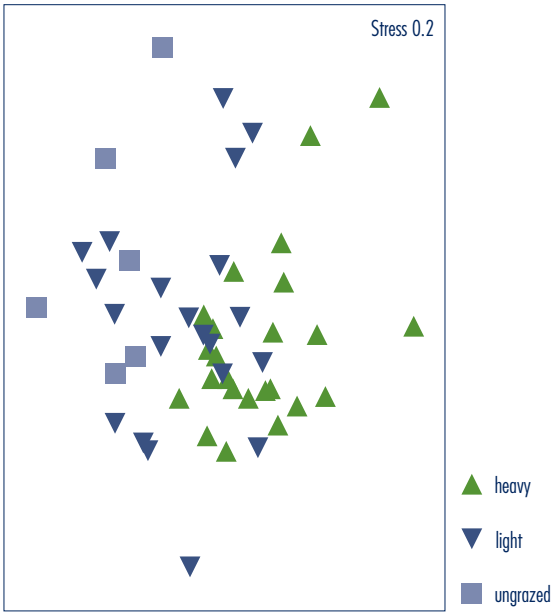

***Figure 1**: Non-metric multi-dimensional scaling plot of sites on the Murrumbidgee and Murray Rivers according to their bird communities. The key indicates levels of grazing intensity.*

ungrazed sites tend to have more small, specialist birds such as honeyeaters, treecreepers, wrens and robins.

The results of the survey work suggests that the impacts of grazing in riparian zones might be reduced by using a rotational grazing regime, where grazing occurs for only part of the year, with the remainder of the year having no grazing. Our collaborators, State Forests of New South Wales, have adopted rotational grazing in most of their floodplain forests to improve biodiversity values. In areas dominated by exotic annual plants, they have imposed winter grazing to control weed species and facilitate the recovery of native species, while in areas dominated by native perennials, they have imposed summer grazing to provide spaces for native herbs to grow between the dominant perennial grasses and sedges.

Given the different grazing regimes available on State Forest lands on the Murrumbidgee and Murray Rivers, we have designed an experiment to compare the effects of these different regimes on the structure and functioning of the riparian zone. State Forests is also contributing fencing costs to the project so that we can compare the different grazing regimes with exclusion plots where recovery from grazing will be occurring over the next three years. We are in the process of establishing sites in four different areas, with different grazing regimes and histories of flooding. In each area we have a number of fenced and unfenced plots. Monitoring of the experiment is focusing on understorey plant communities and terrestrial invertebrate communities, since these are likely to show the most rapid responses. We will also be looking at recruitment of native trees and shrubs.

Development of indicators

In addition to documenting the changes that occur in the plant and invertebrate communities, this experiment will enable us to determine what are the best *indicators* of changes in grazing management practices. We will then be able to develop a set of indicators that can be used by land managers to determine the status of riparian zones in terms of level of degradation and potential for recovery with changed management practices.

To expand the conclusions of the survey work completed earlier on the Murrumbidgee River, we are also conducting two other projects in south-eastern Australia to look at relationships between grazing management practices and condition of the riparian zone. In Gippsland, we have a project examining relationships between riparian condition and management practices in the dairy industry (see page 34). In the Goulburn Broken catchment in northern Victoria, we will be examining landholder knowledge of riparian issues and assessments of riparian health in relation to our condition assessments, as well as relationships with grazing management practices. This project is receiving additional funding from the Goulburn Broken Catchment Management Authority.

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A FAIR go for rivers:

The significance of environmental justice in river rehabilitation

by Mick Hillman

While there is still a lot of science to be understood about riverine ecosystems, many of the hurdles to effective stream rehabilitation lie in the social and institutional spheres. These include narrow, unclear or unrepresentative goals, and a poor recognition of the multi-disciplinary nature of the task (Rutherfurd et al. 1998). An overall long-term objective or vision is often neglected at the expense of piecemeal or reactive management (Brierley and Fryirs 2001), or implemented with minimal commitment to effective auditing (Australian National Audit Office 2001). These factors hinder the implementation of existing science 'on the ground' — that is, in community settings.

As with other areas of environmental management, rivers will continue to be the subject of limited resources requiring targeting of the where, when and how of rehabilitation. It is therefore imperative, that everything possible is done to ensure that both the perception and reality of priority setting is done on a just basis. Given this situation, the most successful river rehabilitation initiatives will be those that are just, participatory, and have a sense of community ownership. This is fundamental to the success of adaptive and ecosystem-based approaches to natural resource management, particularly in light of the uncertainty of scientific information and the outcomes of management intervention. The high variability and complexity of river systems in Australia mean that this uncertainty is an inherent feature of stream management, and must be incorporated in catchment specific visions that work with, rather than against riverine ecosystems.

This project will examine the science-community interaction in river rehabilitation using an environmental justice framework. Environmental justice is a term coined originally in North America as a response to the situating of toxic waste dumps and hazardous industries primarily in socially and economically disadvantaged communities. As a principle applying to the management of stream rehabilitation, environmental justice has three key components:

1. distributive justice: dealing with the *outcomes* of decision-making.
2. procedural justice: dealing with the *institutional processes* of decision-making.
3. relational justice: dealing with *relationships between stakeholders*.

The study will use case studies to look at how these components of a 'fair go' in environmental management can be integrated from a range of different perspectives. It will look at how scientific researchers, resource managers and local networks can contribute to putting rigorous science into practice with broad community support. The key stages of the research are:

~ a review of multi-stakeholder catchment-framed visions for stream rehabilitation;
~ a historical study of river rehabilitation practice and institutional processes; and
~ institutional analysis and community research.

The project will make recommendations in relation to:

~ information needs and methods of knowledge transfer to stakeholders in stream rehabilitation;
~ institutional arrangements which promote environmental justice in stream rehabilitation programs; and
~ integrating the biophysical and human dimensions in developing a vision for stream rehabilitation.

If you are interested in Mick's work, please contact him!

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THE MOST SUCCESSFUL RIVER REHABILITATION INITIATIVES WILL BE THOSE THAT ARE JUST, PARTICIPATORY, AND HAVE A SENSE OF COMMUNITY OWNERSHIP

Assessing COMMUNITY CAPACITY through riparian restoration

by Siwan Lovett

In Phase One of the National Riparian Lands R&D Program, a number of demonstration and evaluation projects (see www.rivers.gov.au for details), were used to examine different riparian rehabilitation methods across a range of different river types. We now want to find out if, two to three years after these projects were completed, these community based projects have built *capacity* within the communities that have undertaken them for long-term change in their approach to river and riparian management.

The term *capacity* is used to refer to an individual or groups' ability to learn, understand and act so that they can continue to build on the work that the original project funding was designed to achieve. We want to find out how we can measure the capacity within a community to implement best practice riparian management, and whether this capacity has changed as a result of investment in the area. We need to know whether these communities are now able to take the information and outcomes generated by the project (and from other sources) and use it in other parts of their catchment.

The Phase One riparian demonstration and evaluation projects have all tended to be site specific, but with some at a broader scale. The project will also seek to understand how far the outcomes of the demonstration and evaluation projects have extended to influence wider catchment management practices. This is an important issue, as it is now widely recognised that river and riparian functioning is directly related to the broader land and water use management practices that are operating at a catchment scale.

Don Thomson and Sharon Pepperdine will be working on this project over the next year, with their report due in June 2003. Outputs from the project will include a written report that will be published on the website and made freely available; another update article in *RipRap* to keep you posted on developments; and presentations at selected workshops and conferences. Land & Water Australia is also planning to run a workshop at the beginning of next year focusing on capacity building and what it means in the context of river and riparian management — stay tuned to future *RipRaps* and our website for details!

The specific objectives of the project are to:

1. Understand the opportunities and constraints to implementation of best practice riparian management practices, and identify and rank in importance key influencing factors, as well as providing advice on how to develop policies and programs that address these factors.
2. Assess the extent to which community-based projects have built capacity in the individuals and groups/organisations involved, and develop practical measures so that this capacity can be quantified.
3. Evaluate the extent to which the demonstration and evaluation projects have influenced management practices at a catchment scale, and develop ways in which Land & Water Australia and other organisations can improve program and project design to maximise community capacity building.

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DEMONSTRATION and evaluation of riparian restoration in the Goulburn Broken Catchment

by Wayne Tennant

This project is one of a suite of demonstration and evaluation projects that were invested in during Phase One of the National Riparian Lands R&D Program. It is these projects that are being examined in the project described on page 25. The Goulburn Broken Catchment Management Authority (GBCMA) has been working with Land & Water Australia to monitor and assess the impacts of grazing pressure on the status and management of riparian zones in the Goulburn Broken region. The objectives of the project were:

1. to monitor and assess the impacts of grazing pressure on the status and management of the riparian zone. In particular; vegetation communities; stream and soil erosion; and aquatic ecosystems.
2. to formulate management actions designed to enhance and maintain the condition of riparian land on a cost-effective basis with the support of landowners and managers; and,
3. to develop and publicise project results in the form of best management practices.

These objectives have now been met, and the project was successfully completed earlier this year. The Final Report for the project (known as GBC1) will be available on the www.rivers.gov.au website by the end of August. This report has three sections covering the following topics:

1. Literature Review — Impacts of grazing on riparian zones.
2. Evaluation of Grazing Trials in the Goulburn Broken Catchment.
3. Management of Riparian Areas — Understanding landowner perspectives — Social review.

A summary of the third topic that examined landowner willingness and capacity to improve the management of river frontages, is provided here. The full paper can be accessed in the proceedings from the RiverSymposium 2001, as well as being a stand-alone publication published by Charles Sturt University (see page 27). It will also be available on the www.rivers.gov.au website soon.

Understanding landholder willingness and capacity to improve the management of river frontages

by Wayne Tennant, Allan Curtis and Alistar Robertson

If we are to protect and rehabilitate riparian lands we need to understand landholder perceptions about riparian zone management and the factors that motivate or impede management actions. As part of a joint project between Land & Water Australia and the Goulburn Broken Catchment Management Authority, a mail survey was used to explore landholder adoption of practices expected to improve the management of riparian areas in the Goulburn Broken Catchment. As part of the research, participants in riparian projects managed by the GBCMA were compared with a random sample of river frontage owners.

The research findings highlighted the limited adoption of most current recommended practices, as well as the extent that GBCMA project participants represented a small, atypical set of river frontage owners. Higher adoption of current recommended practices (in particular fencing) was correlated with: greater knowledge of river frontage function and factors affecting river frontage condition; higher importance attached to environmental and social values; non-farming occupations; and, higher confidence in the efficacy of current recommended practices. The key results from the project were:

- the low levels of adoption of most current recommended practices (CRPs).
- that most landholders said their river frontage was very important to them for a range of economic, environmental and social attributes. This means that appeals to landholders must acknowledge and embrace the range of values landholders attach to their frontages.
- that most (67%) river frontage owners were not farmers and many of these landholders were motivated more by the environmental and social values they attached to river frontages than by the desire to maximise production and profits.
- that higher adoption of CRPs was correlated with greater knowledge of function and factors affecting condition and higher confidence in the efficacy of CRPs. This highlights the importance of community education programs in facilitating the adoption of CRPs.
- that concerns about the economic impacts of some CRPs was a factor constraining adoption of CRPs, particularly amongst farmers and most landholders who did not report an on-property profit. In cases where incentives and cost-sharing schemes were provided however, the same groups of people showed considerable interest in taking up grant schemes operated by the GBCMA.

Riparian zone in the Goulburn Broken Catchment — this project sought to understand landholder's perspectives on how these areas should be managed. Photo CSIRO Ecosystem Services Project.

~ that grant program participants were atypical of other river frontage owners in this case study and, as such, represented a small proportion of the community that needs to be engaged to protect and rehabilitate riparian zones.

These findings have important implications for managers and scientists, including the need to reassess the efficacy of current recommended practices and approaches to community education; as well as acknowledging that appeals to adopt current recommended practices need to embrace the full range of values landholders attach to their frontages. Only one third of respondents had any on-property profit, and survey data suggested that economic concerns were an important factor limiting the adoption of current recommended practices, particularly amongst farmers. Importantly, there was considerable interest in taking up grant schemes operated by the GBCMA that provided for higher levels of cost sharing by government, with incentives providing an opportunity to engage the large majority of river frontage owners that are not involved in GBCMA projects and activities. The GBCMA have learnt a great deal from this project and are using it to inform current strategies that seek to better manage riparian zones throughout the catchment.

Report available from the Johnstone Centre, Charles Sturt University

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MAPPING THE JOURNEY

an environmental travelogue focusing on the waterways resourcing the Bicentennial National Trail

by Saan Ecker

The Bicentennial National Trail (BNT) is Australia's longest recreation trail, following the Great Dividing Range from Healesville (Vic) to Cooktown (Qld), and linking 18 National Parks. Designed for self-reliant non-motorised trekking, the route follows the paths of pioneers along historic coach routes, packhorse trails, and fire and forestry trails. The aim of the *Mapping the Journey* project undertaken between December 2001 and April 2002, was to document stories of the rivers resourcing the trail and to increase the understanding of the relationship we have with our rivers.

The journey involved travelling around 2000 kilometres, through the Australian Alps to the Blue Mountains (Healesville, Victoria to Oberon, NSW) using only one riding horse and a packhorse. Three people, myself, Angie Grusuaskas and Pam Brookman, with two horses each, undertook the journey. Family and friends joined and supported us along the way. Travelling the remote reaches of the high country required us to carry all food and equipment on the horses.

Our relationship with the rivers was of course a very dependent one. The trekking lifestyle, including watering horse and human straight from creeks, gave a heightened awareness of our interdependent role and impact on the river ecosystem. We carried very little drinking water and were always grateful to come across a stream. Puddles on the track along ridgetops were a lifesaver for the horses. Having to cart water at camp each night certainly reduced our consumption rates! We found that we could manage with two large collapsible canvas buckets per evening for drinking, washing and cooking.

The trail visits some of Australia's great rivers, each of which had a story. The rivers we encountered had admirers and protectors, people who have grown up nearby, and people who have been drawn to the beauty of their grandeur. These people were farmers, cattlemen and women, landcare group members and coordinators, adventurers, tourist business managers and those who seek the serenity that this mountain country brings. The stories ranged from tales of childhood experiences, tales of profound life shifts as a result of spending time by a river, and tales of witnessing changes, some good but most talking about the negative impacts of water use on river health. These stories about the waterways were

We crossed the Howqua River 30 times in one day, Saan in centre. All photos Saan Ecker.

insightful and important in helping us understand what we need to do to look after these precious resources.

Observations of flora and fauna, river condition and river restoration efforts were recorded along the way. Macroinvertebrate sweeps were undertaken and, whilst they had little scientific value being one-off snapshots, they provided supporting evidence to local stories and were a great talking point. Waterways with willows occurring on the banks consistently had less sensitive species present. People encountered along the way freely gave anecdotal and historical information to account for their observations.

The impediments to sound river management were also recorded. Many of the river degradation issues are historical in origin, including impacts of gold mining, abandoned towns, farming, and even attempts by the old River Trusts to protect riverbanks by introducing willows. According to the local people I spoke with, poor communication is the major impediment to improving the management and conservation of these rivers. In particular, communication between government agencies and the community was highlighted as a problem in regional areas. For example, we observed the consequences of developing horse paddocks beside a high country hut, but no water access being provided. For our small party we could carry enough water for our horses, however, the larger trail riding company parties resorted (unwillingly) to putting horses in the creek paddock, an outcome that threatened the riparian zone and decreased river health.

In contrast to the bad, there were also many success stories, where communication had worked. For example, enthusiastic landcare officers with a drive to make a difference and a real commitment to improving river management and health. The issues are complex, with much of this country difficult to access and the cost of rehabilitation being high, but we certainly came across people with the desire to effect change and a connection with their river that they wished to maintain.

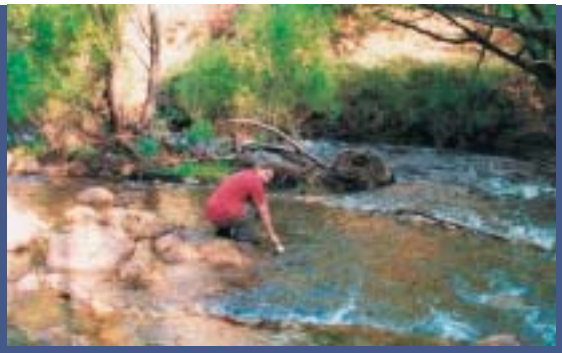
I cannot do justice to the rivers we encountered on our trip in this short article, but I can provide a few highlights.

The views were spectacular. Here at Mt Howitt, where a number of great rivers begin.

Leaving the *Yarra* catchment, our horses literally slid down the steep clay track leading down into the *Goulburn River* catchment. Heading up to the Victorian Alps, we met trout fishers who had travelled interstate to fish at the scenic *Big River*. We were shown the place made famous by a scene in the Man from Snowy River — where the 'baddie' falls off his horse into the beautiful *Howqua River*.

We were awestruck by the beauty of the *Wonangatta River* valley, site of the famous Wonangatta murders and an area still in transition between station and national park (according to community perception). Several devotees of the *Dargo River* shared their stories of annual pilgrimage for decades and the changes they had seen. My horses willingly carried me across a swing bridge to view the devastation caused by gold mining on the *Livingstone Creek*, still contributing significant heavy metal pollution, making it the scourge of the *Mitta Mitta River* catchment which contributes the lion's share of Victoria's water to the Murray.

We encountered all kinds of weather, snow at Lovicks Hut, Victorian Alps.



Macroinvertebrate testing was conducted whenever time allowed, here at the Mitta Mitta, Gippsland, Victoria.

I had the opportunity to wade in rolled up trousers in the crystal clear *Murray River* or *Indi*, as it is called at its beginning just over 10 kilometres from its headwaters. We also observed poplars growing not far from the bank of this otherwise wild waterway. We saw the confusion of the *Tooma* and *Tumut* Rivers as we rode into the Snowy scheme area. We spent hours looking for a safe place to ford the *Eucumbene River*, made mightier by its role in the Snowy Scheme. Whilst camped beside the *Murrumbidgee* we heard the stories of folk who argue for the rights of the Murrumbidgee, the headwaters of which end up in Lake Eucumbene in the Snowys. We followed humble but fast flowing high plains creeks such as the *Gudgenby* and *Naas Rivers*.

We were in drought conditions when we reached the *Wollondilly River* on its way to Sydney's water supply, and were grateful for the muddy remains. Finally, we met the *Abercrombie River* in the eastern Blue Mountains, a peaceful and relatively undisturbed river situated in a isolated community who rely on face-to-face communication and overcoming local conflicts to maintain the balance in their environment.

These rivers were the lifeline of our journey, and being at the source of some of these great waterways gave us a great appreciation of the importance of managing impacts from the headwaters down through the lands they traverse. Even in the headwater areas where these great rivers are at their best, we observed serious erosion, weed invasion, eutrophication, and a range of other degrading processes. For some rivers, such as those in the North-East Catchment Management Authority area (Vic), there are management plans and visible community groups working to resolve the issues. For other rivers, there didn't appear to be any coordinated effort occurring.

Mapping the Journey is a travelogue of my experience journeying along these great rivers and an attempt to piece together fragments of river related stories. I hope sharing this experience may provide some insight into managing our impact at the source of some of Australia's most important waterways.

The full *Mapping the Journey* travelogue is available on the website www.rivers.gov.au

My faithful companions never let me down, here near Mt Kosciuszko.

Making RIPARIAN RESEARCH relevant for industry

by Siwan Lovett

Industries that are leaders in the field of environmental management are seeking improved measures against which to base their performance, and to respond to community expectations. As the consumer push for clean, green environmental credentials grows, Land & Water Australia is being approached by different agricultural commodity groups to provide information, guidelines and demonstration sites to show how economic and environmental outcomes can be met on-farm. This work is providing the basis upon which Environmental Management Accreditation Systems can be developed to 'slot' into commodity specific Best Management Practice guidelines and manuals.

The National Riparian Lands R&D Program is working with several different industry groups to develop research projects and outputs that meet the demand for river and riparian information to be practical, relevant and tailored to meet a particular industry's needs. Current projects are:

- production of 'Managing Riparian Lands in the Sugar Industry' guideline (Sugar Research & Development Corporation and Land & Water Australia).
- Gippsland Dairy Riparian Project (Gipps Dairy, Dairy Research & Development Corporation, West Gippsland Catchment Management Authority).
- Land Water & Wool – Rivers (Australian Wool Innovation Pty Ltd and Land & Water Australia).
- production of 'Managing Riparian Lands in the Cotton Industry' guideline (Cotton Research & Development Corporation and Land & Water Australia).

Working with industry is an exciting way to ensure that the research undertaken by Land & Water Australia Rivers Arena is relevant and able to be practically applied. These four projects provide a snapshot of the sorts of activities, products and approaches we are using to make riparian research relevant across a range of different industries.

Production of 'Managing riparian lands in the sugar industry' guideline

The Sugar Research & Development Corporation and Land & Water Australia have co-funded the development of a guideline for the sugar industry that focuses specifically on riparian management on cane farms. Key sugar industry, research and government departments were involved in the project, as well as an important group of cane growers who worked with the research team to define the issues to be covered and ensured that the guideline met their industry's needs. The guideline is intended for use by extension officers and those working with cane growers to develop more sustainable management practices on-farm. The guideline is freely available from

- CANEGROWERS tel: 07 3864 6444,
- Sugar R&D Corporation tel: 07 3210 0495
- Land & Water Australia through CanPrint Communications on tel: 02 6295 4444 or Freecall: 1800 776 616.

The guideline is also available in pdf on the www.rivers.gov.au website.

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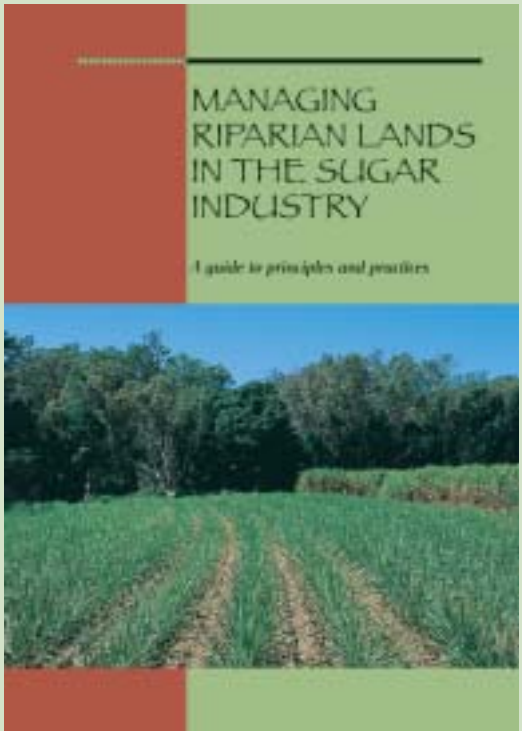

Gippsland Dairy Riparian Project

There is a high level of interest in river and riparian management in the Gippsland region, particularly following the major flood events of 1998. For a long time, there have been concerns over water quality, particularly enhanced nutrient concentrations, and the effects of these on the Gippsland lakes and estuaries. There are also widespread problems of bank instability, and channels that can no longer convey peak flood flows, with consequent stripping of flood plains, avulsion of channels and loss of valuable agricultural land.

Dairying is an important industry in the region, with an increasing number of high-input/high-production enterprises. The industry, through GippsDairy, has recognised the need to identify and demonstrate best practice methods for use by producers. The Gippsland Dairy Riparian Project is a joint undertaking between the Dairy Research & Development Corporation, GippsDairy, Land & Water Australia, and the West Gippsland Catchment Management Authority. The primary purpose is to establish at least two demonstration sites on commercial dairy properties, to further develop and communicate best management practice for riverine and riparian environments, to evaluate benefits to productivity and sustainability, and to record and analyse costs and benefits of changed management practice.

This project is working with dairy farmers to improve management of riparian zones on their farms and to demonstrate how problems such as the stock tracks and pugging shown in this photo, can be better managed. Photo Phil Price.

The initial phase of establishment and evaluation will run for five years (2002–2007), but the aim is to maintain these sites for a longer period, and for them to be used by GippsDairy, Catchment Management Authorities and others as long-term demonstration and evaluation sites for the dairy industry and other land managers in the region. Further details about this project are provided on page 22 of *RipRap*.

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See page 34 for more information.

Production of 'Managing riparian lands in the cotton industry' guideline

The Cotton Research and Development Corporation has highlighted riparian management and biodiversity on cotton farms as an area needing research. The cotton industry wishes to demonstrate that it is a responsible environmental manager. Some growers are aware that they have important areas for wildlife on their farms while others wish to improve their knowledge at the farm scale.

Cotton is an important industry to Australia that generates a large export income. Cotton growers often own properties that adjoin larger rivers, with the ownership and management of riparian lands being the responsibility of the landholder in most cases. Riparian land is important for the management and control of off-farm impacts, such as chemicals, sediment and fertilisers. Riparian lands and adjoining floodplains are also often important for biodiversity because they are fertile, provide access to water, support a greater variety of species and provide corridors for the movement of wildlife.

This project will prepare best practice management guidelines for riparian lands in the cotton industry, including case studies. It will also aim to have the cotton industry be seen to be proactive in addressing environmental issues and implementing sound riparian management practices as part of whole farm planning. The project will run from June 2002–June 2003.

For further information

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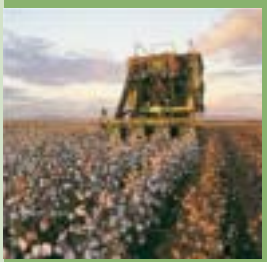

By working with the cotton industry we will try to achieve both economic and environmental gains on-farm.

Land, Water & Wool



Land, Water & Wool – Rivers

Land, Water & Wool – Rivers will work with wool producers to understand and manage their rivers and riparian areas to achieve both environmental and productivity goals. By working with the wool industry Land, Water and Wool – Rivers will research common riparian and river management issues for wool producers including gully and streambank erosion, water quality, contaminants, erosion control, weed management and riparian zone management within a total grazing system. This initiative will demonstrate a broad spectrum of management techniques to ameliorate these problems and establish environmental credentials of which the wool industry can be proud

Over the next five years Land, Water & Wool – Rivers will work with wool producers, leading riparian researchers, Landcare, local government and community groups to:

- gain an understanding of the issues facing wool producers when managing rivers and riparian lands.
- improve awareness, understanding and knowledge of practical methods for river management and water quality.
- develop practical and cost effective methods for river management that can be used by the wool industry, community groups, catchment management and Landcare groups.
- use demonstration sites to show best practice solutions for river and riparian management.
- establish producer groups in the demonstration site regions across Australia who are able to implement recommended guidelines for river management and stock management practices on-farm.
- create regional forums for information sharing and knowledge exchange.
- measure improvement in-stream condition and water quality in wool growing regions where demonstration sites have been established.
- enable the wool industry to be recognised as a sound environmental manager with best practice methods included in farm management systems.

Currently, there are two regions where research projects for Land, Water and Wool – Rivers are being established, these are in the Macquarie Catchment of Tasmania, and the Yass region of New South Wales. If you would like to learn more about these projects there is a Fact Sheet available on the www.rivers.gov.au website, or contact one of the people listed.

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Identifying BEST PRACTICES for riparian management in the Gippsland dairy region

by Leigh Thompson and Alistar Robertson

The Australian dairy industry is one of Australia's biggest agricultural success stories. At the centre of the industry's $3 billion market is the Victorian dairy industry. In 1998–99, over 60% of the industry's dairy farms were located in Victoria. Much of the state's primary dairy production is focused in the Gippsland region east of Melbourne, with approximately $1.2 billion worth of exports coming from this region annually.

In Australia's intensive dairying areas, the management and preservation of natural resources is increasingly becoming one of the industry's highest priorities. Reports such as 'Sustaining Our Natural Resources — Dairying for tomorrow' highlight the industry's desire to sustain natural resources while still remaining productive in a highly competitive market. The national strategy for the dairy industry has developed guidelines for best practice management in six major areas: Water, Land, Soil conservation, Nutrient run-off, Effluent, and Biodiversity. As well as developing a national strategy, this report also encompasses the eight regional action plans developed in Australia's recognised dairying areas.

The Gippsland Regional Action Plan recognises that the key resource management issues for the region's dairy farmers are:

'development of whole farm plans, managing land use change and local planning, achieving sustainable productivity gains, increasing water use efficiency, nutrient management, effluent management, increasing biodiversity and land protection' (GippsDairy 2001).

With total production in the Gippsland region expected to increase by 50% in the next 10 years, the implementation of environmentally sound management practices now, are vital to the future of the region's dairy industry. As production has increased, the quality of water leaving dairy areas and the fencing of waterways is becoming increasingly important. In the high rainfall area of West Gippsland, 60% of the region's waterways are estimated to be in poor to very poor environmental condition. The quality of these waterways is becoming increasingly important to dairy farmers with many now fencing their waterways to help better manage stock and improve the health of their riparian areas.

Land & Water Australia has funded a project to develop demonstration sites for best practice management of riparian habitats in the Gippsland dairy region. One of the major hurdles in doing this is the identification of best practice options that are specific to the Gippsland dairy region.

Riparian zone management — what advice is currently available to dairy farmers

The lack of specific information available to dairy farmers regarding best management practices for their riparian areas has been recognised by the dairy industry in recent environmental audits and reports on the state of the industry. A study of the information that is available reveals that a variety of generic material (based on research work in other regions) exists and that it covers topics such as:

- width and management of riparian vegetation and plantings;
- nutrient, riparian buffer strips and streams;
- soils and erosion;
- conservation of biodiversity;
- weed management;
- grazing management; and
- in-stream processes.

However, this information is not presented within the context of a functioning dairy enterprise and, as a result, is often difficult for a dairy farmer to apply on-farm. With productivity in the Gippsland dairy region expected to steadily

increase, the development of best practice management guidelines for riparian areas that specifically relate to dairy farms is imperative. For example, with the variation in slope and associated vegetation in Gippsland dairy farming areas, there is a strong need to investigate and develop best practice guidelines for riparian zones across these differing land types (e.g. flats, valleys, hill slopes, ridges/crests). Generic information cannot provide the level of detail required to assist farmers in these areas to manage their riparian zones so that both economic and environmental benefits can be maximised.

Land & Water Australia, GippsDairy and the Dairy Research and Development Corporation are addressing this problem by funding researchers from Charles Sturt University (with help from others in CSIRO and the University of Western Australia) to survey a large number of riparian sites throughout the Gippsland region. Individual dairy farmers are also being interviewed to investigate how different management practices effects the ecological condition of riparian habitats.

The researchers will be using a rapid appraisal survey approach (described in *RipRap* 15) to assess riparian condition. This allows the researchers to visit many sites and thus get a good overview of the region in a relatively short space of time. Because Charles Sturt University has been funded to develop assessment tools for riparian management, this is also an excellent chance to test their rapid appraisal approach in different terrain. Measures of in-stream health (metabolism, sediment type) will also be included in their appraisals, and this will allow exploration of whether their rapid appraisal technique is a good predictor of in-stream condition.

After a year of surveys, the researchers will be able to use their information to identify a range of best-practice actions that are specific to Gippsland, and that can be implemented by dairy farmers. A subsequent aim is to then illustrate the effects of good riparian management by implementing best practice management guidelines at established on-farm demonstration sites in the region. During 2002 some initial monitoring at these sites will establish baseline conditions before best management practices are implemented so that visitors to the demonstration sites will be able to appreciate the differences that management has made.

Further reading

Sustaining our natural resources – Dairying for Tomorrow (online). http://www.dairyingfortomorrow.com/reports/reportpluscover.pdf

GippsDairy, 2001, *Regional Natural Resource Action Plan for the Gippsland Dairy Industry*, Terry Makin & Associates, Viewbank, Victoria and NRM Consulting Balaclava, Victoria.

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