Riparian vegetation

What is riparian vegetation?

Riparian vegetation is similar to other types of forest in that such areas are generally composed of overstorey, understorey, groundcover and macrophyte species[1] each of which has a particular structural function and is found a predictable distance from the river channel.

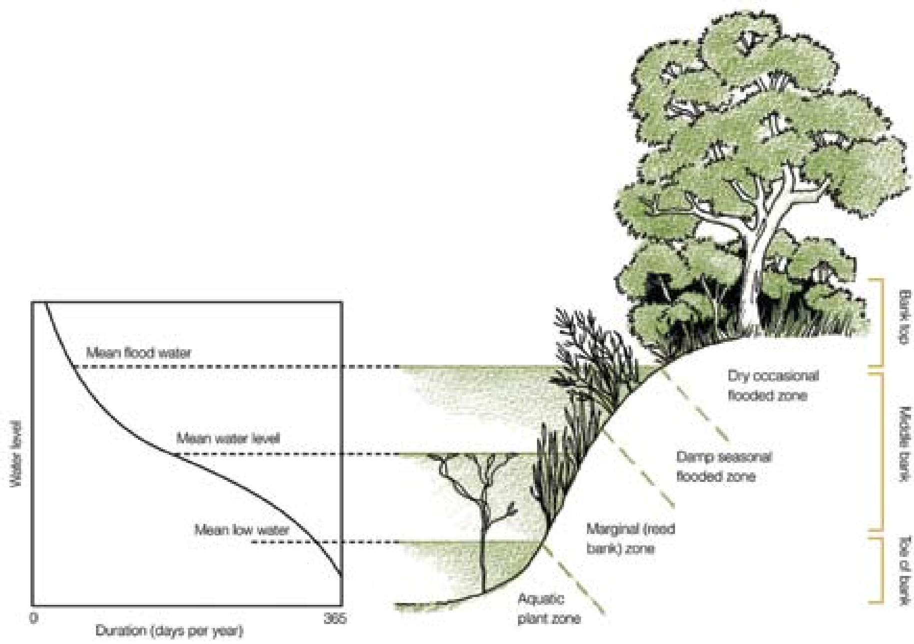


Figure 29
Diagram of channel, type of vegetation and associated mean water levels. Illustration Paul Lennon in Price, P, Lovett, S & Lovett, J (2005), *Wool Industry river management guide: Sheep/wheat zones*, Land & Water Australia, Canberra.

Overstorey vegetation can be found on the upper and middle, and to a lesser degree, lower banks and consists of trees that grow up to 20 metres tall. The geology and water table height of the site influence root depth, but generally overstorey vegetation has deep and complex root systems.

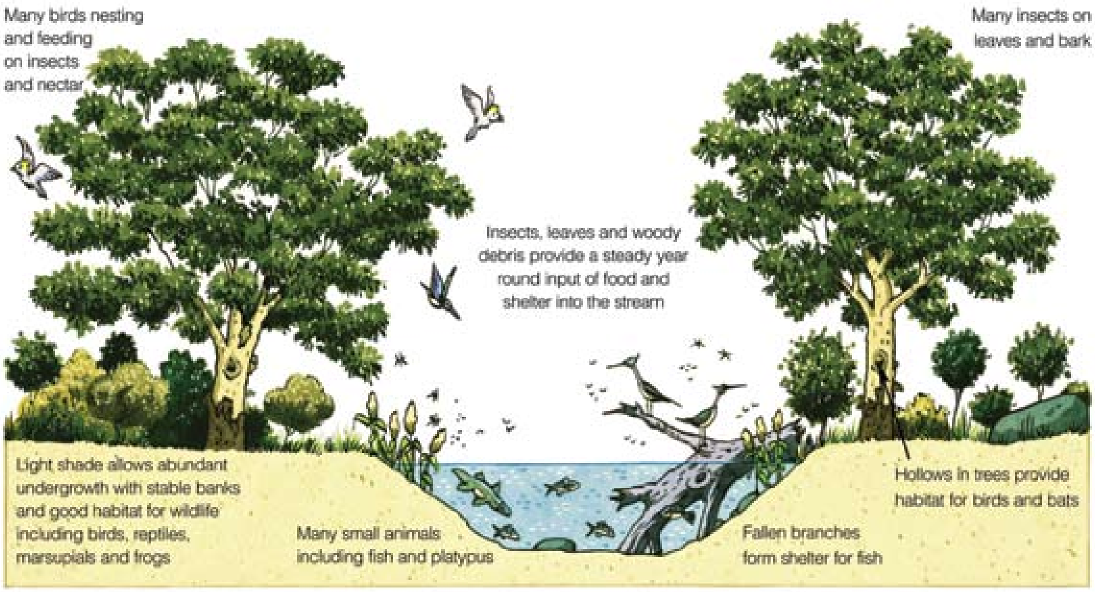
Understorey vegetation is also found on the upper and middle banks as well as the lower bank and consists of species growing from 1 to 5 metres. Rooting depth is shallower than overstorey species.

Ground cover shrubs, grasses, sedges and forbs less than 1 metre high are vital for stabilising the top 30 centimetres of soil. This type of vegetation is found with overstorey and understorey vegetation but cannot grow on the bank toe as it is not able to withstand inundation.

Macrophytes are found on the streambank toe and include sedges, rushes, and reeds which have shallow roots and grow at the water's edge.

Riparian forest differs from other types of forest in that they are usually linear, following the line of a river or creek. How wide they are is defined by landscape, geomorphology, contours of the waterway and drainage flow. In addition, the relationship between riparian forest and the river is important. It provides a number of benefits to aquatic and terrestrial habitat and the species that live there. The removal and modification of vegetation in sensitive riparian areas has been a common land management practice in the past, and has had a number of significant impacts on the health of both terrestrial and aquatic ecosystems. As knowledge improves and attitudes change the value of this essential habitat is being realised.

Figure 30
The benefits of native vegetation in riparian areas. Illustration Paul Lennon in Lovett, S & Price, P (eds) (2007), *Principles for riparian lands management*, Land & Water Australia, Canberra.



Values of riparian vegetation and effects from its removal.

1. Shade

Riparian vegetation controls in-stream temperatures by shading the water. Recommended stream temperature is 21°C in temperate systems and 29°C in northern systems[2,3,4].

In healthy streams light controls primary productivity. In nutrient rich streams shade can influence the impact of nutrient enrichment and prevent the development of algal blooms or excessive algal growth.

Effect of removing shade

Algal growth and algal blooms are synonymous with high light, high nutrient and low flow conditions. Reduction in algal biomass leads to a reduction in the abundance of invertebrate groups. For example, clearing previously forested areas alongside streams in New Zealand led to a decline in midge larvae populations [5].

Where streams are cleared, water temperatures can fluctuate widely and exceed tolerable ranges for aquatic flora and fauna: affecting life and growth stages and biodiversity. Temperature controls the life cycle of several in-stream fauna. For example, in a number of native fish species fluctuations in temperature are used to control metabolism, distribution patterns within a species, breeding cycles, embryo development, disease resistance and ultimately population size[3].

Removal of shade and the dappling effect trees can provide on the water also places in-stream fauna at risk from overhead predators.

2. Organic matter inputs

Most streams and rivers rely on the input of organic matter from terrestrial sources for carbon which provides the energy to drive the aquatic food web (i.e. they are heterotrophic)[2]. For example the Murray-Darling rainbowfish (*Melanotaenia fluviatilis*) and freshwater catfish (*Tandanus tandanus*) feed on terrestrial insects which fall from over-hanging vegetation[6].

Effect of removing organic input

Removing the source of leaves, twigs, fruit and insects that form the basis of in-stream food webs changes the quantity and quality of energy in food webs and the functioning of the ecosystem[2]. This effect will have consequential impacts on in-stream faunal and floral population abundance and biodiversity.

3. Channel geomorphology and stability

Riparian vegetation increases the geomorphological and hydrological complexity of a waterway and aids in river bed and bank stability[2].

Effects of removal

Removal of bank vegetation and woody debris affects flow rate so that water flows faster. This removal can potentially lead to flooding and downstream erosion[2], the destablisation of stream banks leading to an increase in stream widths, channel incision and gully erosion. Other effects may include increased channel instability or a reduction in nutrient processing and implications for sediment transport[7].

4. In-stream habitat

The input of woody debris from bank vegetation contributes to aquatic habitat directly via logs and branches and indirectly through the formation of features, such as scour pools, around anchored tree trunks[2]. Increased habitat complexity and diversity in turn leads to increased biodiversity. For example, the periphyton community (*algae, bacteria and fungi*) form the basis of the food chain in rivers and require hard surfaces such as fallen timber and rocks to develop[8].

In addition, some aquatic species are dependant on the provision of particular habitat for completion of key life stages. For example native fish such as the river blackfish (*Gadopsis marmoratus*) require hollow logs to spawn[6]. For further information on woody habitat see Section 7.

Effects of removing in stream habitat

Removing woody debris from the river will reduce stream habitat complexity in turn reducing the variety and type of habitat available to in-stream flora and fauna at all levels of the food chain[7].

5. River bank habitat

Riparian vegetation provides terrestrial and aquatic fauna habitat, food, access to water, refuge from predators and extreme weather and acts as a corridor for wildlife to pass from one area to another. The vegetated zone also provides a local microclimate with less extreme temperatures and more humid conditions than the local area[2]. For example, the vulnerable spotted–tailed quoll (*Dasyurus maculates*) is known to occur in riverine forests of Bogan-Macquarie, Hill-End, Orange and Upper Slopes[9].

Terrestrial vegetation will also provide habitat for in-stream life. For example, exposed roots on undercut banks can be used as a spawning site for fish[3].

Effects of removing riparian habitat
By fragmenting the links and corridors between habitat systems, or isolated remnants of native vegetation, removing riparian habitat will put fragmented populations at increased risk from random environmental events, hindering the ability of populations to remain viable and impoverishing the biodiversity of the riparian zone.

Direct impacts of the removal of riparian habitat include compromising the food web (reduced habitat for micro-organisms, with knock-on effects to bird populations), alteration of species lifecycles, and removal of habitat niches for species to occupy[2,3,4].

Retention of wildlife corridors is one of the conservation actions in the threatened species profile for the Central West region[9].

6. Riparian vegetation as buffer zones
Probably one of the most important roles of riparian vegetation is as a buffer between terrestrial activities and aquatic ecosystems. The buffering role of riparian vegetation includes filtering particles mobilised through anthropogenic activities and their subsequent delivery to the river. The mechanisms for transport of these particles include overland flow and aeolian (wind) transport[10, 11]. For example, vegetation barriers provide local protection to a river against airborne spray (e.g. from crop spraying) and dust. This filtering effect has site specific and regional scale benefits[11].

Aeolian transport *refers to the transport of particles by the wind. Here it refers to the transport of soil, pollutants or spray from crops on the breeze or and winds which then become deposited on the water surface.*

The presence of riparian vegetation also contributes to a landscape's resilience as cohesive ecological systems are seen as ways to mitigate against the effects of climate variability[12].

Removal of buffer zones
When riparian vegetation is removed larger volumes of particulate matter and sediment will be delivered to the river. This increase in sediment volumes can smother aquatic habitat while increased nutrient (bound to the surface of sediment particles) will stimulate weed and algal growth.

The use of riparian vegetation as buffers is discussed in detail later.

7. Water filter
As illustrated by the above example, riparian vegetation has an important role to play in improving the quality of water entering a waterway. This occurs on the surface, under the ground and in the water itself. Shallow rooted vegetation (grasses, herbs, sedges etc) can trap sediments and particulate matter, while deep rooted vegetation will absorb nutrients from subsurface flows [5,10]. Overhanging vegetation, exposed roots, snags and in-stream vegetation also act to slow water down, creating eddies that allow sediment to fall to the riverbed.

Effects of removing the water filter
Partially removing riparian vegetation diminishes this 'polishing' process while it can be appreciated that full clearance will eliminate this function entirely.

8. Riparian vegetation and salinity

Broadscale clearing of native vegetation and other significant changes in land use are the principal causes of secondary dryland salinity[14,15]. The removal of deep rooted vegetation allows the watertable to rise closer to or even up to the soil surface. Saline landscapes lead to saline water as salt-saturated water drains into rivers and streams[16,17].

9. Riparian vegetation and ecosystem services

All of the functions described above can be classed as 'ecosystem services', that is, the range of naturally occurring functions that provide a benefit to human society. Other services in addition to carbon storage, water filtration and salinity control discussed above include:

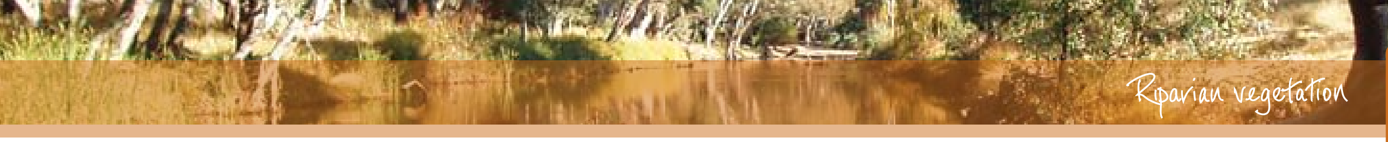
- wind breaks for livestock and crops,
- a habitat for pollinating insects,
- providing grazing and shelter for livestock, and
- provision of wood products (e.g. timber, poles, charcoal), seeds, essential oils, foliage, honey, bush foods and pharmaceuticals[4,18].

Figure 31
Vegetation encourages beneficial insects such as this bee on a red bloodwood flower *(Eucalyptus gummifera)* into riparian areas. NSW DPI.

A Key Threatening Process is a process that threatens, or that may threaten, the survival or evolutionary development of a species, population or ecological community of fish or marine vegetation[19].

Removing riparian vegetation removes the ability of the riparian zone to provide these services. The result of which is an increase of costs related to substitution of the service, loss in production or increased costs of resource refinement.

Due to the importance of riparian vegetation in the landscape, the ecosystem services it provides and in respect to the threats facing riparian vegetation, degradation of native riparian vegetation has been recognised as a Key Threatening Process under the *Fisheries Management Act 1994* and the revegetation of riparian lands is a major target in the Central West CMA CAP.



RAMAs or **Routine Agricultural Management Activities** are farming, safety and other activities where clearing of native vegetation does not require approval under t*he Native Vegetation Act 2003*. However, riparian land i.e. land within, or within 20 metres of, the bed or bank of a prescribed stream is classed as 'protected' and therefore clearing in these areas is limited. Clearing associated with RAMAs permitted in these protected areas includes;

- the removal of noxious weeds under the *Noxious Weeds Act 1993*,
- the eradication of pests under a pest control order or an eradication order, or
- the construction and maintenance of fencing to improve management of the protected land.

Rehabilitation of riparian vegetation

Revegetation projects should assess the need to plant for each riparian structural type (overstorey, understorey, ground cover and macrophytes) in order to maintain or restore ecosystem coherence and function. For example, shrubs and grasses on the bank face and macrophytes on the bank toe are very important for controlling sub-aerial and scour erosion[1].

While revegetation is a primary concern, readers are reminded that this alone is not a prescription for all that ails our riparian areas and may not be appropriate in the first or indeed all instances. A prerequisite for ALL riparian rehabilitation projects is the identification of the issues affecting the area and planning appropriate responses to them, considered both individually and cumulatively.

Note: wetland vegetation is a form of riparian vegetation and much of what is discussed here is applicable to it. For issues and rehabilitation considerations that are specific to wetlands, see Section 6.

Benefits of restoring riparian vegetation can be seen in:

The home:	Provides a welcoming environment for recreational activities.
The paddock:	Provides shade and a wind break for young livestock and crops.
The catchment:	Enhances water quality and aquatic habitat.
The community:	Supports healthy rural communities and contributes to increased land values.

Protecting existing remnant vegetation

The first recommended action in managing riparian vegetation is to protect existing (and coherent) remnant vegetation. This suggestion makes sense not only for cost and resource efficiency but also because remnant vegetation is very important as a naturally propagated seed source, for soil bank donations and as a benchmark for plant assemblages. With die-back on the increase (and affecting more than half of the Central West catchment[16]) and the continued presence of detrimental activities, rates of regeneration are falling[16] threatening the success of rehabilitation projects and the survival of remnant vegetation.

A primary example of how to protect remnant vegetation is fencing. Fencing effectively removes existing pressures such as grazing livestock and vehicular access. See Section 5 for information on livestock management. For wetland areas fencing smaller patches with wire netting may also be required if ducks are present.

Figure 32
As a Landcare demonstration project in the 1990s, this actively eroding gully west of Molong was fenced and replanted with native trees and shrubs. Since that time, the erosion on the site has been dramatically reduced, and habitat features are now starting to develop.

Why revegetate?

There may be many reasons to undertake revegetation:

- to supplement existing riparian vegetation,
- to reintroduce riparian vegetation,
- to combat erosion,
- to facilitate the removal of invasive species,
- to restore water quality values and support aquatic ecosystems,
- to restore and provide terrestrial and aquatic habitat, and
- to provide improved land values for stock and farm production.

Revegetation options

There are two options for revegetation: natural regeneration or supplementary planting. The choice depends on the aims and objectives of the project, the budget and length of time for the project. It is often easy to underestimate the time and resources needed to prepare a site, plant and provide ongoing maintenance, all of which need to be discussed and negotiated with the landholder[20]. Both options require knowledge of pre-clearance assemblages which can be determined by surveying the remaining habitat, comparing to similar areas and studying the seed bank.

Natural regeneration

Natural regeneration is only an option where there is a sufficient seed bank in the soil, usually provided by remnant native vegetation patches nearby or upstream of the site. This option is cost and labour efficient and achieved by fencing off an area of vegetation to exclude or remove a pressure. Fencing will eliminate the activity, restrict land use and protect regenerating vegetation. From here natural propagation of seeds will catalyse ecological succession and a return to vegetation cover. The growth rates of regenerating plants are often far greater than those of planted seedlings, and less attractive to pests and because of this can work well in combination with other replanting initiatives[20].
There are three ways to approach natural regeneration:

Option 1 – Fence and wait: Construct the fencing and wait to see how the area progresses. Light grazing or herbicides can be used to control weeds. Site monitoring is required.

Option 2 – Fence and scarify: Fence the area and use a germination trigger to progress natural regeneration. The use of fire as a germination trigger needs to be carefully considered and controlled; fire can damage sensitive riparian species. Otherwise physical disturbance by lightly turning the soil to aerate it can be trialed. Care is needed to avoid root damage to shrubs and trees. The timing and location of this technique is important as floods across ripped land will cause major soil loss and sedimentation. Weed control to reduce the competition for space, sunlight and nutrients may be needed and site monitoring is required.

Option 3 – Fence and weed control: Fencing with a weed control programme to reduce competition. Site monitoring is required.

Supplementary planting
Natural regeneration assumes that there is a fertile seed source on the site or in close proximity to it. However, if the system is too geomorphically modified or if the soil seed bank has been depleted or is sterile then natural regeneration may not work.

This was seen in the efforts of the Landcare group Macquarie 2100 to rehabilitate the Goan Waterhole. Initially fencing works were undertaken to exclude stock and the area recovered to a point. However, over time Landcare members noted a lack of plant substructure and native grasses and the presence of weeds in the waterway and on land. It was then recognized that further supplementary works were required[21].

Before planting can begin a number of factors need to be considered:

- What kind of riparian area is it?
- What problems is the site experiencing?
- Is revegetating the site the most appropriate response?
- Is the site ready for planting?
- If not, what site preparation works need to be implemented? (weed control, gully erosion stabilisation, fencing to control stock access etc.)
- What natural ecological zones are left and what species are found within each zone?
- What is the hydrological regime of the area? i.e. natural flows in a wetland or bank full heights on a river bank.
- What type of plant species are needed to return full ecosystem attributes?
- Is there a viable seed bank and enough local vegetation to allow the site to propagate naturally or will supplementary planting be required?
- Is the timing right for the species and are floods or fires likely at that time of the year?
- What infrastructure is present that will impede planting?
- What resources are available and how can they best be allocated?
- What maintenance will be required following planting?

What to plant

As outlined earlier a variety of species for all layers of the riparian zone will be needed to restore the natural attributes of the system and will be determined by the particular characteristics of the site (soils, climate and other factors including channel properties).

For example, the degree of shade created by riparian vegetation is influenced by canopy height, foliage density, channel width and orientation, valley topography, latitude and season. Riparian replanting for shade is best on the north bank of streams orientated east-west[2].

However a site may require specific types of vegetation to remediate a certain problem. Reed beds (for example *Phragmites* sp) are very good for bank stabilization as they can restrict flow velocity and will buffer the bank toe or wetland edge from boat wake energy. *Typha* sp, while contributing to bank stability, will not tolerate high flow velocities and will not therefore be as effective at protecting the bank from flow. *Typha* sp grow well in low-velocity streams with deep silt sediments.

A survey to determine the integrity and composition of each layer for your site will help determine what to plant.

Please refer to Appendix 2 for a comprehensive list of native riparian and wetland species of the Central West which can be used for revegetation.

Seed collection

Genetic integrity of the seed is very important and the best way to ensure this is by taking seed from the same area to be revegetated (or if necessary up to a few kilometres away)[23]. This is known as collecting within the 'province'.

Permits are required to collect seed from someone else's land, including, for example, from roadside reserves, council land, nature reserves, national parks and state forests. Section 132c permits may also be necessary from the NSW Department of Environment and Climate Change (National Parks and Wildlife Service) to collect seeds or fruits from plants listed on the *NSW Threatened Species Conservation Act 1995*[24]. Florabank has developed a guideline series with practical information on collection, storage and use of seed[23].

It is important to ensure the collected seed is not from an invasive species (natural or exotic) inadvertently introduced into another riparian area[20]. By germinating samples before the revegetation project begins the viability of the seed bank can be tested and species present identified. Doing so will provide an idea of which species need to be supplemented.

Note: many Australian wetland plants need to dry out before they germinate therefore the soil needs to be dried in the sun (this can take up to 20 days)[25].

It is important to also remember the donor soil will have different invertebrate life stages and fungal species so there may be a new faunal component introduced into the project site.

Soil preparation
The soil surface must be adequately prepared to provide a suitable surface for the seeds to grow. Bare ground may have become compacted so the soil will have to be loosened to aerate it and increase water and nutrient availability. If the site is small enough using a rake will do.

The decision to 'rip' the soil (running a line through soil to break up the clods) needs to be carefully considered for its suitability to the site. It can be fast and effective on highly compacted sites. Core considerations include:

- ripping requires that there is no native or remnant vegetation,
- the rip lines could become the source of new erosion problems (the rip lines can concentrate run-off), and the
- presence of heavy machinery on a badly eroded bank may further weaken the soil structure.

If ripping is necessary it should only be used on high-floodplain areas (minimum 40m from the waterway) that are out of reach of fast-flowing floodwaters.

Weed management
Invasive weed management is necessary prior to planting to reduce competition. Depending on the weed spectrum of the site, weed control may be needed up to 24 months before sowing to control spring and autumn weeds[22]. Spraying may need to be repeated over this time period and then just before planting. Spraying can be combined with light grazing as a means to control weeds however grazing should not lead to the compaction of the site once again. Weed control will be necessary for the first 6 months after planting[20].

Timing
Timing of supplementary planting is important and consideration needs to be given to the most appropriate time of year for the plants to germinate or grow, any periods of drought or lack of rain and the risk of flooding.

Planting techniques
The simplest rule when revegetating streambanks is to start as near as possible to the toe of the bank and to plant as much as possible.

Other things to consider include:

- Planting in rows may be easier for access and maintenance but random planting provides a more natural appearance[20]. It is advisable to mix the seeds to avoid clumps of similar species.
- Consideration needs to be given to species requiring shelter and to ensure a species is planted where it is suited (for example, Hakea wattle would not be suited to the water's edge but is suitable for middle and upper banks).

For wetlands it is recommended that planting be a mix of climax (80%- 90%) and pioneer species (10% - 20%) to give either maximum species diversity (wide variety of species representing different structures) or a framework (i.e. a few key species that are fast growing and resilient)[26]. Planting density will depend on riparian type and species and can be adapted to meet the aims of the revegetation.

Direct seeding

As its name implies direct seeding is the manual or mechanical application of seed directly onto the land to be revegetated. It is inexpensive, requires less labour than other methods, uses existing farm equipment and can be an efficient way of establishing large numbers of plants which when germinated can, because of their higher numbers, reduce weeds. Direct seeding creates more natural outcomes such as selection or better root development which in turn leads to a high degree of success (especially when a mix of species is used). Finally, less follow up care is required.

However, this method is best suited to plants which grow best from seed, and a large amount of seed is needed. Weed control is so important to the success of this method that it has been said that 'if you don't control your weeds, don't bother with direct seeding.'[22]

The site must be well prepared (see above), viable seed collected, and seeding must take place at the right time to reduce weed infestation. The planting area should be watered immediately after direct seeding[20]. Machines especially adapted for the purposes of direct seeding are available and are more suited to large areas. Small areas can be hand seeded.

Tubestock

Planting of tubestock is best undertaken after good rain when the soil is moist and easy to dig. The establishment of fast-growing shrubs (such as nitrogen-fixing wattles) before the planting of trees can make the environment more suitable to young trees. Shrubs also help to limit weeds and attract insect-controlling birds[20].

Figure 33
Planting tubestocks and seedlings is one option of regenerating riparian vegetation. NSW DPI.

Longstems

Longstems differ from tubestock as they are first grown for 18 months and then planted on the streambank. Compared to tubestock they have been shown to have a better survival rate, better erosion control ability and minimal follow-up care is required.

Longstem varieties of weeping bottlebrush, water gum, river oak, weeping myrtle, river red gum, blackwood, white cedar, snow in summer, prickly paperbark, creek lily pilly, creek tea tree, flooded gum, and swamp mahogany are available[27].

Jet lancing can be used as a means to prepare the ground for tubestock and longstems. This method provides deeper holes for the plant and roots than manual digging and creates a reservoir of water. These factors contribute to improved survival rates of the plantings[28].

Transplanting macrophytes

Sedges, reeds and rushes will spread naturally in undisturbed conditions by increasing their clump size or by dispersing their seeds into the river substrate. The same considerations for collecting seed bank material should be applied for transplanting, with autumn and spring recommended as the best seasons to undertake transplants[29]. Dig up the clump of vegetation for transplanting. Prevent the roots from drying out by placing them in plastic bags and then into an insulated container with cooler blocks. Clumps can be subdivided and the tops of leaves or stems cut off to reduce transplant shock[22]. The transplant can then be replanted in the desired spot. Take note where in the wetland or river bank they were collected from so they can be transplanted to a similar spot. On steep banks it may be easier and safer to access emergent vegetation in a boat.

Stakes and guards

Stakes and guards may be required to provide support and to protect the young plant from animals or herbicide spray. However, their use must be carefully considered as the root system of the plant might not develop, leaving the tree too weak to hold itself up as it continues to grow and prone to uprooting in strong winds and storms. In addition, plastic guards can be a potential source of pollution to the aquatic environment.

Geotextile use in riparian revegetation

Geotextiles can be applied to assist in the establishment of ground cover or other vegetation and to retard weed growth around saplings. Their use is dependant on site slope, soil characteristics, weathering, type of vegetation to be planted or already present, time of planting, and duration until root systems develop[20,30]. Geotextiles come in two forms: synthetic and natural.

Synthetic geotextiles are made from recycled materials or polypropelene. Natural geotextiles, including hessian fibre products such as coir blankets or jute netting, provide:

- 100% ground cover which is important at sites with bare ground to retain moisture
- suppress weed growth
- aid in soil stability, and
- are biodegradable

All ground covers and screening materials are porous to allow water filtration and air to pass through to the soil. In addition, hessian sheets can be filled and rolled to form a water filter around the mouth of drains, as water passes through it traps sediment before it passes into the main waterbody[20, 30].

Compost

Composted soil conditioners and mulches can play an important role in promoting the re-establishment of vegetation. Composted mulch blankets improve soil structure and can be used to increase organic carbon levels and improve soil health which encourages the growth and establishment of plants. However, care must be taken in their application as composted mulches and soil conditioners contain high levels of nutrients, organic matter and sediments. If used inappropriately in sensitive areas water quality will be at risk[31].

Site maintenance
Ongoing maintenance of the site is critical. Planting can be less than one-third of the work required, as watering, fencing and weed control are key post-planting tasks[20].

Watering
Watering is essential during planting as it minimises air pockets and improves contact between the soil and roots[20]. It is especially important for heat sensitive species or on freely draining soils. The ability to keep seedlings watered during periods of drought needs to be considered in the planning stages – it may not be realistic to install irrigation systems. The use of water crystals to prevent drying out after planting is highly effective.

Fencing
It is very likely that some form of fencing to control stock or other animals will be necessary. Once plants become established grazing regimes can be reintroduced, however on-going site assessments will be required to ensure stock do not have an adverse impact on the rehabilitated zone.

Property Vegetation Plans (PVPs)
It is important to remember that riparian vegetation, as with other types of native vegetation, is covered under the *Native Vegetation Act 2003* and as such, can be incorporated into a Property Vegetation Plan (PVP). PVPs are voluntary but legally binding plans developed between a landholder, or a group of landholders, and the relevant Catchment Management Authority.

A PVP describes the types of native vegetation on the land and outlines how it is to be managed for the life of the plan. PVPs are useful as they can be used for applications for incentive funding initiatives, or to meet obligations under the *Native Vegetation Act 2003* (such as to confirm the definition of regrowth or change the regrowth date)[32].

Riparian zones as buffers

As mentioned previously one of the most important attributes of the riparian zone is as a 'last line of defence' between the land and the riverine ecosystem. In the broadest sense, riparian buffer zones can be taken to mean areas of vegetation which act as 'buffers' between terrestrial activities and the river or wetland [5,10,33]. Riparian buffers filter sediment and attached nutrients from overland flow by slowing its flow velocity, spreading it to form rills and by the processes of infiltration and adhesion[5,10].

Buffer zone effectiveness
The relative effectiveness of riparian lands as buffer zones depends on a complex number of factors including the type of land use, topography, location of buffer, hydrology, soil type, the width of the buffer, the type of vegetation, how well the zone is maintained or even the age of the zone. Buffer zones are particularly effective because they can intercept pollution from point as well as diffuse sources[5,10,33].

How can they be applied?
The use of riparian buffer zones is becoming a key management option for improving aquatic ecosystem health and retaining vital soils on the land[33]. Further, buffers can be used to reduce edge effects around remnant vegetation or to link patches of remnant vegetation together in a corridor.

The following types of buffer zone can be used for riparian management[5]:

- grass filter strips: fenced strips of paddock grasses,
- headwater or riparian wetlands: fenced wetlands at river headwaters,
- rotational grazing: strips with varied stock grazing practices,
- forested or planted native trees,
- production trees or plants – e.g. flax for weaving, or fruit or nut trees, and
- multi-tier systems: a combination of buffer types.

Different types of buffer zones can be used where landholders do not want woody plants or shrubs in the riparian zone, or the area does not lend itself to being fully planted.

It is recommended that riparian buffer zones are used in conjunction with broader land management practices: such as limiting furrow length; incorporating drop boxes and settling ponds to tailwater systems. For example, contour banks or additional filter strips may be required where rainfall is more intense as the filter strip will not be able to prevent sediment and associated nutrients from entering the channel or alternate strips of trees interspersed with grass filters may be appropriate[34].

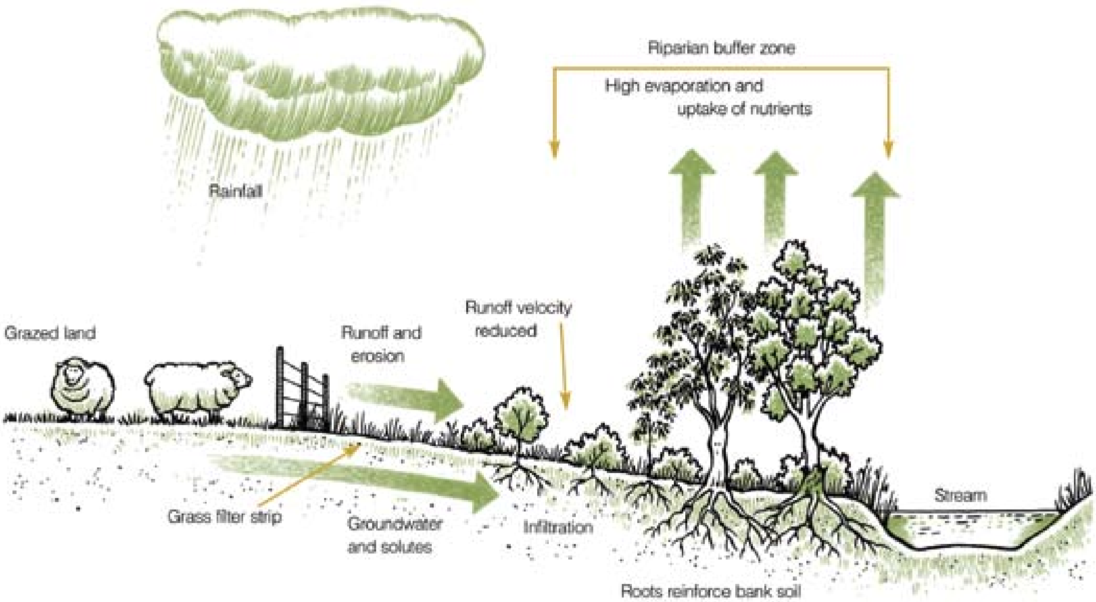


Figure 34
Processes that occur in the riparian area to assist streambank stabilisation. Illustration Paul Lennon, in Price, P, Lovett, S & Lovett, J (2005), *Wool industry river management guide: Sheep/ wheat zones*, Land & Water Australia.

Grass filter strips

Grass filter strips are particularly useful where landholders are not keen on woody plants and trees in the riparian zone. A grass strip provides dense ground cover on the flatter land approaching the river channel or wetland; it primarily acts as a sediment trap but also provides some stability.

Grass strips need to be applied to areas with effective surface drainage (for example, a levee break). Grass filter strips are very good at trapping sediment particles and are most effective where overland flow is shallow (less than 1 centimetre)[5]. However, grass strips can be ineffective on hillslopes[35] and difficult to establish in semi arid areas[10] or where trees are present and shade out groundcover. Grass filter strips may be more effective when combined with other buffer strips by using the replanting or regeneration techniques outlined previously and combining them with strips of trees and shrubs.

Creating a buffer zone can be as simple as maintaining vegetation along waterways (including drains and culverts etc.) by having set backs (i.e. areas where no grazing or other activity takes place), to maintain grass and shrub cover. Set back width is discussed in the next section.

Once established, the buffer zone, as with other areas of the property, requires maintenance. In this respect careful grazing may be required to keep them functioning[34] (see Section 5 for further information on grazing regimes suitable for riparian areas).

Riparian widths

There is no prescription for the ideal width of riparian vegetation. As indicated by earlier discussions, width is dependant on a multitude of site and project specific, logistical, legislative, environmental and financial factors. Table 6 provides details on objectives to consider when determining riparian widths.

Salinity

The Central West CMA has launched a series of initiatives to tackle salinity issues in line with the NSW Salinity Strategy, the focus of which is on reducing the level of salt entering water courses. Actions to address salinity issues include:

- increasing areas of well-managed perennials that minimise water table recharge,
- retaining and managing remnant vegetation in saline landscapes to control water table accessions and saline outbreaks,
- developing effective interception plantings to control recharge for salinity management, and
- increasing water use efficiency on cropped landscapes.

Rehabilitating riparian and wetland vegetation, in addition to tackling other NRM problems, will make a significant contribution to managing salinity problems throughout the Central West.

Table 6: Riparian widths and dependant factors

Objective	Where aim is to	Requirement	Considerations	Precautions
Land clearance (agriculture or urban development)	Minimise effects of clearance and soil disturbance	Generally prohibited within 20–200m		Need to obtain development/planning consent
Agroforestry production	Achieve long-term and sustainable profit	At least 30m recommended	Permanent riparian vegetation layer needed closest to bank to provide stability when timber felled	Need to obtain development/planning consent
Grazing livestock	Minimise disturbance and maintain productivity	At least 5m upslope from the top of the bank	Grazing regime and stocking rate	Stock should be managed to ensure sufficient ground cover is maintained
Maintenance or improvement of water quality	Filter out solids	Filter strips of at least 5–10m or 10m or more of native vegetation	Slope, sediment load and depth of overland flow	Stock should be excluded or managed with care to ensure full ground cover
Prevent streambank erosion	Cover, reinforce and dry soil	Complete vegetation cover of bank plus 5–15m upslope from the bank top	Allow for initial continued erosion	Exclude stock and vehicles and replant if necessary
Control light level and water temperature	Provide sufficient shade	Channels less than 10m wide 75% of natural shade level should be achieved. Requiring 1–3 tree widths and 5–20m of native vegetation	Shading effect will decrease with increases in channel width. Vegetating the northern bank of east-west aligned streams will provide more shade	
Maintain healthy aquatic ecosystems	Supply food and habitat	One to three widths and 5–20m+ of vegetation		Plant vegetation native to the locality
Maintain or enhance wildlife	Supply food, habitat, shelter	Width up to 100m. Benefits can be obtained from 20m corridors with 50–80m islands	Special requirements of any endangered or threatened species	Minimise edge effects and use native species
Multiple objectives	Combination of above	Place fencing 5m upslope from top of the bank – incorporate a 10m grass filter strip, include 20m or three widths of native trees/shrubs and fully vegetate bank	Weed and feral animal control	Plant vegetation native to the locality

(Adapted from Price, P *(2006) Riparian widths for different management objectives*[35]).

Alternatives to vegetation

So far discussion has focused on vegetation as the main catalyst for riparian rehabilitation. It is however worth noting that this assumes that the riparian area is stable enough for revegetation. In highly modified or eroded areas, or where extra support is required, the following could be considered:

- rock revetments,
- bank profile battering,
- groynes and retards, and
- a combination of measures with vegetation.

See Section 8 for information on engineered bank and bed stabilising structures.

Figure 35
Spike rush (*Juncus acutus*) is a good indicator plant of rising water tables and salinity.
NSW DPI.

Key things to remember:

- Riparian vegetation provides a multitude of 'ecosystem services' vital for healthy catchments.
- The first step in rehabilitating riparian vegetation is to protect remnant vegetation. After this degraded areas can be targeted and allowed to regenerate naturally or by using supplementary planting techniques. Both scenarios require planning, including steps to prepare the site, fencing, weed control and monitoring and evaluation.
- Establishing a vegetation buffer zone is an ideal way to protect riparian vegetation and improve environmental attributes on site and for the catchment.

Case study: Regenerating riparian vegetation

Trevor Toole – 'Killoola'

The site

'Killoola' is 629 hectare property located approximately 17 kilometres north of Bathurst adjacent to the township of Peel. The property is run by Trevor Toole as a family trust. Two creeks which are tributaries of the Macquarie River (upstream of Burrendong Dam); Clear Creek and Keg Hollow Creek run through the property dissecting it into three parts. The main enterprise across the property is wool, a self-replacing flock of 4,000 Merino ewes and wethers are run.

Soil types on the property range from alluvial loam on the flats adjacent to Clear Creek to Silurian and Devonian sediments on surrounding hills. Topography of the property is undulating rolling hills with scattered tree cover. Remnant vegetation on the property consists of yellow box (*Eucalyptus melliodora*), Blakelyi's red gum (*Eucalyptus Blakelyi*), apple box (*Eucalyptus bridgesiana*), red stringybark (*Eucalyptus macrorhyncha*) and river sheoak (*Casuarina cunninghamiana*) which are found predominately along Clear Creek. Native and semi-improved pastures occur across the property with approximately 120 to 140 hectares of winter wheat crops planted to help fill the winter feed gap and in favourable seasons harvest for grain.

The project

Both Clear Creek and Keg Hollow Creek suffered from major in-stream erosion issues. Previous structural works undertaken by the Clear Creek Rivercare group aimed to address these issues with the instalment of rock revetment, rock groynes and bed control structures. However, sediment and nutrient control (water quality) remained an issue in the creek systems. In addition Trevor hoped to improve native vegetation on his property and enhance biodiversity.

The Tooles were successfully funded by the Central West CMA in early 2005 to undertake a project to control stock and reintroduce/enhance existing native vegetation within the creek corridor, complementing previous structural works undertaken by the rivercare group.

Over the following year the Tooles:

- installed 7.8km of riparian fencing to manage grazing access to 6km of creek frontage to reduce sediment and nutrient input into the creek system,
- planted 8,000 native trees and shrubs endemic to the local area to revegetate the site and create a significant riparian corridor linking vegetation upstream and downstream of the site, and
- installed alternative water points in adjacent paddocks to the creek to provide suitable stock water.

However, the project was not without problems. Unfortunately as a result of severe drought conditions only 50–60% of the planted tube stocks survived. In contrast, the amount of natural river sheoak regeneration occurring within Clear Creek is very promising.

Trevor aims to replace some of the tubestock, especially the shrub component once seasonal conditions improve. One area targeted for future revegetation is around the benches created from previous rock revetment and rock groyne works within Clear Creek, also along the toe of some outside bends. This will ultimately reinforce these structures, decreasing erosion rates.

The control of invasive weeds at the site such as scotch thistle and Bathurst burr will be an on going management issue.

The benefits

In total, the project resulted in over 52 hectares of riparian corridor managed for erosion and sediment control as well as improved biodiversity outcomes. Furthermore, the project will decrease the amount of sediment and nutrients travelling downstream into Burrendong Dam.

Quote from Trevor:

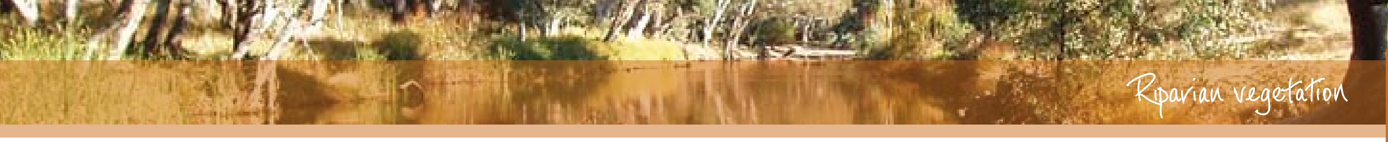
'Following fencing the area, planting trees and shrubs and removing stock I have noticed decreased rates of erosion resulting in cleaner water and improved aesthetics of the area in general. Stock movement has improved as they all cross at the one site now, also maintenance to flood gates following minor flood events is a thing of the past.'

Quote from Clayton Miller, Catchment Officer, Tablelands Central West CMA:

'I think what Trevor and his family achieved over one year is truly amazing. The revegetation survival rate following two years of drought is a bit disappointing; however Trevor's commitment to re-planting additional native shrubs along the toe of the bank and around existing rock structures will further reinforce these structures, decreasing erosion and improve the biodiversity of the area in general.

The natural regeneration of Casuarina's within the channel of Clear Creek is very encouraging. May be the next step once the vegetation is established and stream bank erosion is under control would be to re-introduce some large woody debris to improve the aquatic habitat values.'

Left: Trevor and Clayton inspect the success of the revegetation.
Right: The creeks on Killoola were suffering from severe erosion.



Case study: Improving riparian vegetation and biodiversity in a public space

Somerset Park, Orange, Orange City Council

The Site

Located to the north west of the city of Orange, Somerset Park is a linear parkland approximately 1.3 kilometres in length with a varying width of between 75 and 150 metres. The park provides a much needed passive open space for a range of recreational pursuits in an expanding urban landscape. The park also protects an un-named water course that collects urban stormwater runoff from the north western parts of the city and drains to Ploughman's Creek, a tributary of the Bell River.

The park was originally farmland, however as the City's urban residential needs increased the land was subdivided and developed. At that time, Orange City Council's Local Environment Plan and Development Control Plan set aside land along drainage lines to create public open space and recreational land – Somerset Park was one such area which resulted from this planning approach.

Previous agricultural activities such as grazing on the site resulted in poor water quality and destabilisation of the banks of the un-named watercourse. Following development in the area, an increase in urban storm water run-off further destabilised the bed and banks. These issues coupled with an infestation of crack willows which impeded flows and caused siltation of the creek and lack of vegetation cover resulted in a reduction in biodiversity at the site and further impacts downstream into the Bell River catchment.

The project

Recognising the poor health of Somerset Park and the impact willows were having in conjunction with the loss of valuable public land as a result of bank collapse, the Council initiated a riparian rehabilitation and revegetation project at the park which also complied with the Council's Greenways policy.

Over an 18 month period and with financial support from the Central West Catchment Management Authority, Council implemented a rehabilitation project in a 1.3 kilometre length of the watercourse which included:

- Removal of crack willows via best practice methods, Work for the Dole workers were engaged for willow poisoning and contractors for willow removal.
- Construction of in-stream structures; a rock chute and bank protection to create a chain of ponds system. Specialised contractors were engaged to undertake earthworks and rock placement.
- Revegetation of the site for biodiversity, bank stabilisation and aesthetic purposes. The Orange community were engaged to assist Council with planting native trees and shrubs throughout the park in biodiversity islands (small stands of trees and shrubs in mulched beds of up to 300 metres square).

The benefits

The project at Somerset Park which involved many members of the Orange community has vastly improved a public amenity and enhanced the local environment. The quality of run-off and stormwater leaving the park has improved and biodiversity has been enhanced.

Quote Nigel Hobden, Orange City Council:

'As a passive open space area Somerset Park provides an avenue for a range of recreational pursuits. The installation of children's playground and dual use pathways providing improved access to the park increased the park's passive use. The project has been important as it has resulted in the stabilisation of the waterway, created greater biodiversity through revegetation, retention of remnant trees and improved the water quality by reducing sedimentation and creating ponds of slow moving water.'




Above left: A 'chain of ponds' was created in the creek to slow water flow and aid sediment deposition.
Above right: A rock chute was also installed to prevent bed erosion.
Bottom left: Extensive replanting was carried out by Conservation Volunteers Australia.
Bottom right: 26 months on the revegetation and natural regeneration have been highly successful.
Images courtesy of Orange City Council.

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