4. Revegetation

Introduction

Riparian vegetation can contribute many benefits to a watercourse, including erosion control, bank stability, buffer zones, a food source, the control of light and heat, the provision of shade and shelter, the management of unwanted aquatic plants and the provision of essential habitat.

Riparian vegetation plays an important role in stabilising the stream banks and preventing bank erosion. Bank vegetation decreases water velocities near the bank and dampens turbulence by suppressing eddies. However, to be effective, the vegetation must extend to at least the low water level, otherwise flow will undercut the root zone.

Grasses and sedges are effective at both low and high velocities, being capable of withstanding much higher flow velocities than woody species such as trees. Plant roots also increase the shear strength of the bank soils.

Riparian and floodplain vegetation acts as an effective buffer between developed lands and their associated watercourses. Riparian vegetation functions as a source of leaves and small and large woody debris. However, in urbanised areas of Brisbane, street tree plantings include deciduous trees such as Jacaranda *(Jacaranda mimosaefolia)* and Golden rain tree *(Koelreuteria elegans)*. Widespread planting of deciduous species and the reticulated stormwater systems in urban areas consequentially result in a significant increase in the volume of leaf litter being transported into Brisbane's watercourses.

Shading produced by trees assists in the control of heat and light and can also be used as a management strategy to control the growth of aquatic plants. However, it is noted that it may take five to ten years for a canopy to be developed over a creek. Obviously this depends on the tree species and the width of the creek. During this canopy development time extra maintenance such as weed control may be required.

It is important that local politicians, interest groups and the local community are all aware that during this often long canopy development phase the revegetated channel may look messy and weed infested. Natural Channel Design should always be seen as a long-term management technique, not a short-term fix.

The provision of habitat by riparian vegetation is a key benefit for aquatic and terrestrial organisms. The vegetation may be of periodic importance as a refuge habitat during occasions of environmental adversity as well as function as corridors for wildlife movement between forest remnants (Arthington and Catterall 1990).

Interaction with Natural Channel Design

In Natural Channel Design, the long-term stability of the channel is primarily related to the suitability of the channel geometry to the given hydrological conditions. In major watercourses, such as river systems, the channel and overbank vegetation may only play a minor role in the long-term stability of the channel. However, in minor creeks and streams, vegetation can significantly influence both the short-term and long-term stability of a watercourse.

Natural Channel Design is primarily concerned with two aspects of vegetation; the revegetation phase immediately following the channel construction, and the long-term maintenance of channel and floodplain vegetation. The key to the appropriate integration of a natural channel into an existing developed or urbanised valley is the development of a watercourse that has long-term stability with minimal maintenance requirements, i.e. self maintaining.

Watercourse maintenance usually relates to the following factors:

(i) weed control
(ii) flood control
(iii) fire control
(iv) habitat management and conservation

Occasionally, vegetation maintenance is required for human safety and pest control reasons.

Relating vegetation density Manning's roughness

Many difficulties exist when trying to relate the desired planting densities to the hydraulic engineering roughness (termed Manning's n or Manning's roughness). To assist in this matter, reference may be made to Appendix C – 'Manning's Roughness', in particular, Table C.5

Significance of vegetation type

There are basically five types of vegetation that can be used in and along a watercourse. Each of these forms of vegetation have different characteristics that affect soil erosion and water flow in different ways. To design and maintain the vegetation along a watercourse it is important to understand the features of each form of vegetation.

The basic vegetation types are listed below in Table 4.1

Table 4.1 Vegetation types and characteristics

Vegetation type	Erosion control	Bank stability	Hydraulic effects
Aquatic plants	Provide good stability to the low flow channel	Can assist bank stability by protecting the toe of the bank These plants can become inflexible as plant density increases. This can cause channel flow to be deflected into the channel bank causing bank erosion.	Usually cause little flow resistance if the water depth is greater than the plant height, i.e. plant height is less than the bank height. Thick stands of reeds can effectively block a channel and aggravate upstream flood levels.

Table 4.1 Vegetation types and characteristics (cont)

Vegetation type	Erosion control	Bank stability	Hydraulic effects
Ground covers	The most effective form of soil erosion control. These plants control only soil scour (erosion of the surface layer), not the mass movement of soil resulting from bank failures. To be effective, ground cover plants should be flexible and continuous. Isolated, clumped plants can aggravate soil erosion. Plants with a matted or fibrous (hairy) root system are the best, especially in sandy soils.	Usually ineffective in the provision of bank stability These plants usually have a shallow root system and thus can only provide stability to the surface soil layer. They can help to stabilise the bank during the early stages of revegetation	Generally have little effect on flood levels. Some plants, such as Lomandra, can grow to a height of around 1 metre, and thus may choke small channels.
Shrubs and woody weeds	Can provide effective erosion control if the branches prevent high velocity water from contacting the soil. Soil erosion can occur around the edge of isolated plants caused by flood waters accelerating around the plant.	These plants can significantly increase bank strength depending on the height of the bank and the depth of the root system Unlikely to prevent undermining of the bank unless the shrubs are located close to the toe of the bank.	These plants have the greatest potential to affect the hydraulics of the watercourse and increase upstream flood levels. Avoid the planting of shrubs in areas where flood control is important.
Single trunk trees	Usually provide little protection against soil erosion. Some plants have root systems that survive when exposed to air. The root system of these plants can control toe erosion.	Trees provide the main form of bank reinforcement. They are needed to stabilise the bank, especially when toe erosion occurs and when the bank becomes saturated during a flood event.	Grouped trees can significantly affect flood levels if their spacing is less than 5 times their trunk diameter Generally well-spaced trees with branches above the flood level provide little hydraulic interference.
Multi-trunk trees	As for single trunk trees	As for single trunk trees	Grouped trees can significantly affect flood levels. Well-spaced trees with branches above the flood level can still provide significant hydraulic interference.

Channel vegetation

There are limits to the role that vegetation alone can play in controlling erosion. Although vegetated watercourses in the natural environment appear to be stable and experience extremely low erosion rates, it should be noted that these conditions of stability have evolved over many years.

The long-term objective of vegetation as an erosion control measure is the establishment of a ground cover that will be self-maintaining and thus be able to provide long-term (sustainable) erosion control. Ideally, plants should be native to the area, must be good soil binders, crowd out weeds, and form a good ground cover. Unfortunately, in urban areas, some of the most successful erosion control plants are weeds!

Channel vegetation can be divided into four categories (Figure 4.1):
(i) in-stream or aquatic vegetation
(ii) toe vegetation
(iii) middle bank vegetation
(iv) upper bank vegetation

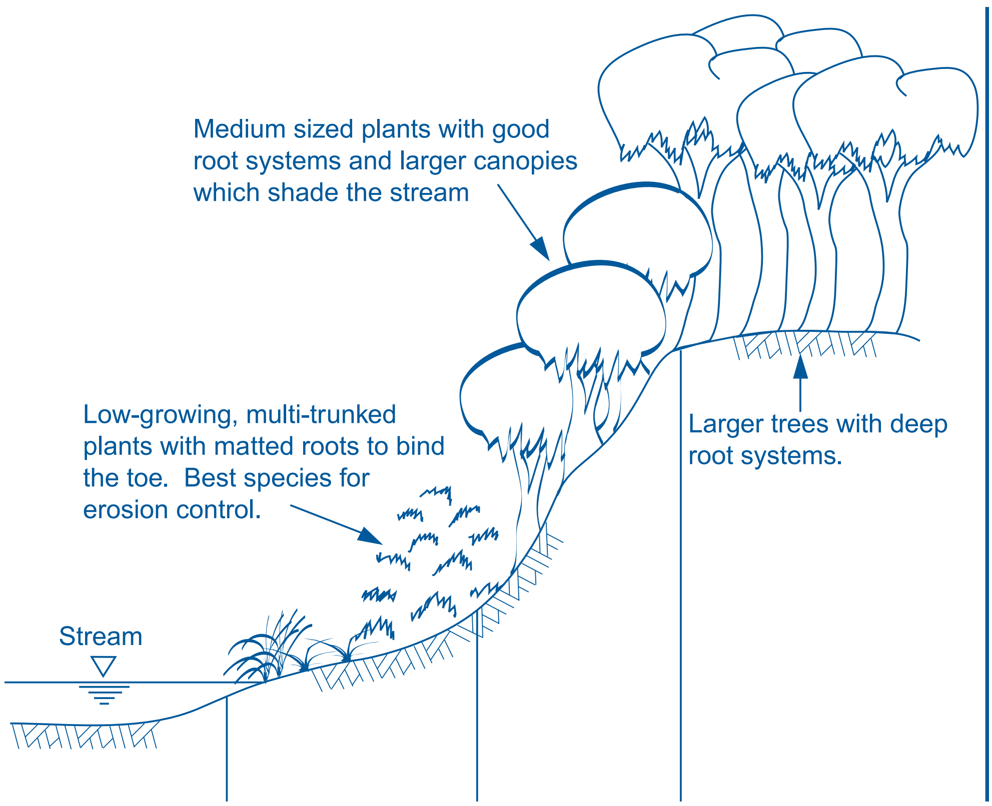

Figure 4.1 Categories of channel vegetation

Species such as reeds and sedges, with a dense network of fibrous or matted roots, are more efficient in the control of soil erosion than those with a sparse network of woody roots.

If trees are removed from a steep or high bank, then appropriate consideration needs be given to the long-term stability of the bank. It may take around five years before the old

tree root system within the bank begins to deteriorate. As the tree roots lose their strength, sheer stresses in the bank can fracture the roots resulting in sudden bank failures (land slips).

If, due to flood control reasons, the trees or shrub that were located on or near the watercourse bank cannot be replaced, then the bank may need to be benched or batter at a flatter grade to compensate for the long-term removal of the essential root reinforcement of the bank.

Floodplain vegetation

The impact of trees on the hydraulic roughness of a floodplain depends on the flow velocity; the shape and size of the trunk and canopy (if below flood level); and the number, arrangement, and spacing of trees. When the flow velocity is high, an obstruction such as a tree exerts a sphere of influence that is much larger than the width of the obstruction because the obstruction affects the flow pattern for considerable distance on each side.

The sphere of influence for flow velocities that generally occur in channels that have gentle to moderately steep slopes is about three to five times the width of the obstruction. Therefore, if the trees are spaced more than five times there truck diameter, then they gradually begin to act as independent obstructions. At a spacing of around ten times the trunk diameter the trees may be considered as totally independent obstructions.

The impact of trees on flood levels depends on the depth of water. Riparian trees located in relatively deep water along the edge of the channel can have a much greater impact on flooding than trees planted along the outer edges of the floodplain.

A summary of the hydraulic requirements for trees in floodplains is provided in Table 4.2.

Table 4.2 Vegetation in floodplains

Vegetation type	Floodplain planting requirements
Ground cover plants	Suitable in most areas of a floodplain.
Shrubs and woody weeds	Avoid in flood control areas. May be used in backwater areas and in areas of tree grouping where flood flows are mainly designed to flow around the vegetation not through it.
Trees	In flood control areas use smooth, single trunk trees with branches above the flood level. **Tree spacing less that 5 times the trunk diameter:** Considered as group plantings. Likely to have high restrictions to flood flow. Trees should be planted in rows parallel with the flow direction to minimise hydraulic affects. **Tree spacing between 5 and 10 time the trunk diameter:** Questionable benefit of planting trees in rows unless flood control is critical. Soil erosion may occur around individual trees if located in high velocity floodplains. Erosion may be controlled with selected planting of sedges around the base of the tree. **Tree spacing greater than 10 times the truck diameter:** No hydraulic benefit obtained by planting in rows. Soil erosion likely to occur around individual trees if located in high velocity floodplains. Erosion may be controlled with selected planting of sedges around the base of the tree.
Grouped trees	Tree spacing less than 5 times the truck diameter, or trees at wider spacing surrounded by shrubs. In flood control areas, grouped trees are only suitable in backwater areas, or adjacent to open, grassed floodplains where floodwaters can readily bypass the trees.

Planting patterns and hydraulic constraints

In urban areas of Brisbane there may be conflicts between ecologically preferred re-vegetation and flooding issues. This has lead to restrictions being placed on the revegetation of some floodplains.

It is generally shrub species and multi-branch trees that have the greatest influence on channel roughness and that may constrain the ecologically desirable planting pattern. The following discussion illustrates some general principles to address these issues.

When making estimations of hydraulic roughness, it is necessary to include consideration for regrowth of vegetation on cleared channel sides and overbank areas because this can significantly increase the resistance factor within one or two growing seasons. Understorey vegetation grows readily after removal of any shade-producing canopy.

A row of trees roughly aligned with the current can offer much less resistance to flow than perpendicular blocks of vegetation yet retained much of the shade and visual harmony of an uncleared bank. Further reduction in flow resistance may be obtained by pruning limbs that protrude below normal flood height.

The desired planting pattern would closely relate to the natural vegetation community structure for the area, with tall trees, an understorey of small trees and shrubs and a sparse herb layer. Where the canopy does not over-hang the stream bank, reeds, rushes and sedges could be planted.

In areas where hydrological constraints do not allow rehabilitation with dense vegetation, alternative planting patterns are planned.

Brisbane City Council (1995) details that the spatial patterns of species distribution follows two strategies. One strategy is planting parallel to the stream bank. This conforms with plant-water relations and produces least impact on water flow. The second strategy aims for planting in clumps with sparse connections between the clumps. Clumping vegetation has the effect of increasing the number of habitats for wildlife and allows migration between clumps. The location of these clumps will need to take account of the probable high flow paths to minimise their hydraulic impact.

Plans for rehabilitation, while using these two strategies as fundamental to the plan, also should consider the following points:

(i) Maximise the availability of habitat by considering the topography of the stream bank, floodplain and surrounding bushland, e.g. *Melaleuca* wetlands could be planted on lowlands as well as point bars or where the channel bank slopes gently into the channel bed and would be subject to frequent inundation.

(ii) The stream morphology may constrain planting, e.g. in a meander, it may be necessary to stabilise one bank with sedges and shade the opposite bank.

(iii) Problems due to ponding and appropriate selection of species for such areas.

(iv) Proximity to bridges. Trees with root systems which are susceptible to being undercut such as Eucalypts, should not be planted in such locations.

(v) Proximity to stormwater drains. Discharge of stormwater requires a consideration of water velocity and water quality. Use of a discharge structure and wetland filter may be required.

(vi) Access for maintenance equipment.

Group plantings

Group planting may be considered to be trees with a spacing less than 5 times the truck diameter or trees at a wider spacing but planted amongst shrubs and other understorey plants.

Grouped trees can provide significantly more ecological benefit than the equivalent number of widely spaced trees located across the floodplain. If the watercourse channel flows approximately parallel with the flood flow, then where hydraulically allowable, grouped trees should be located within the riparian zone as well as the high bank area as shown in Figure 4.2.

If the watercourse channel meanders across the floodplain, then care should be taken to avoid grouped plantings in areas were flood waters pass from one side of the channel to the other, as shown in Figures 4.3 and 4.4.

Floodplain vegetation should be selected and landscaped so as to require low maintenance. This would include group placement and sufficient density of shrubs and trees to avoid mowing. When grasslands are provided that require mowing, they should be placed in large enough areas and interconnected to permit easy mowing.

Planting around major hydraulic structures

In critical flood control areas, vegetation that may interfere with flood waters should not be located within the following areas:

(i) upstream of a bridge or culvert within a radius equal to the total bridge or culvert opening width;
(ii) downstream of a bridge or culvert within the zone defined by a 1 in 4 expansion of the outlet jet and for a distance equal to three times the flood water depth;
(iii) between the bridge or culvert opening and the bypass floodplain;
(iv) any areas judged necessary by hydraulic modelling.

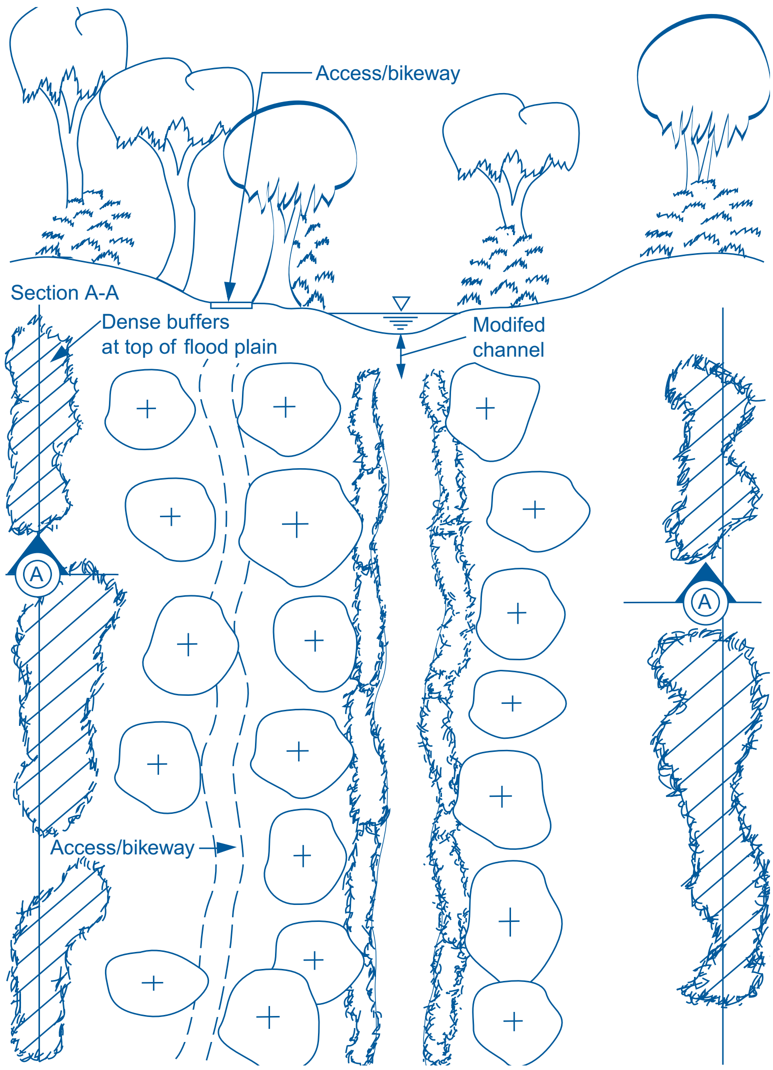

Figure 4.2 Floodplain vegetation along a straight channel

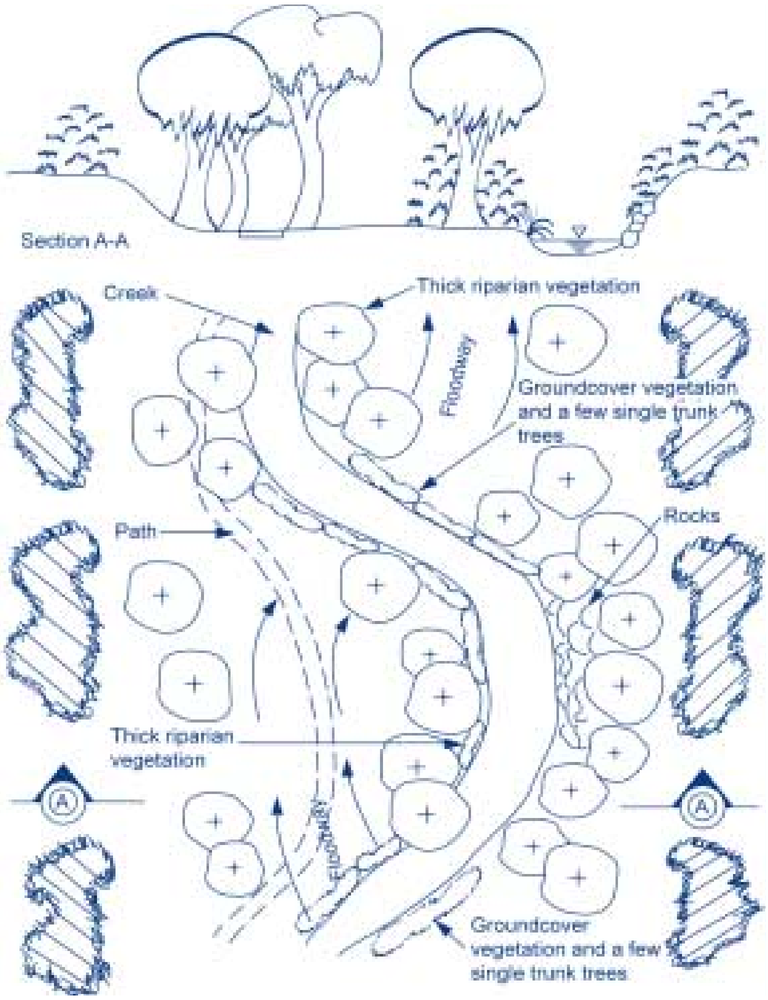

Figure 4.3 Floodplain vegetation along a channel meandering

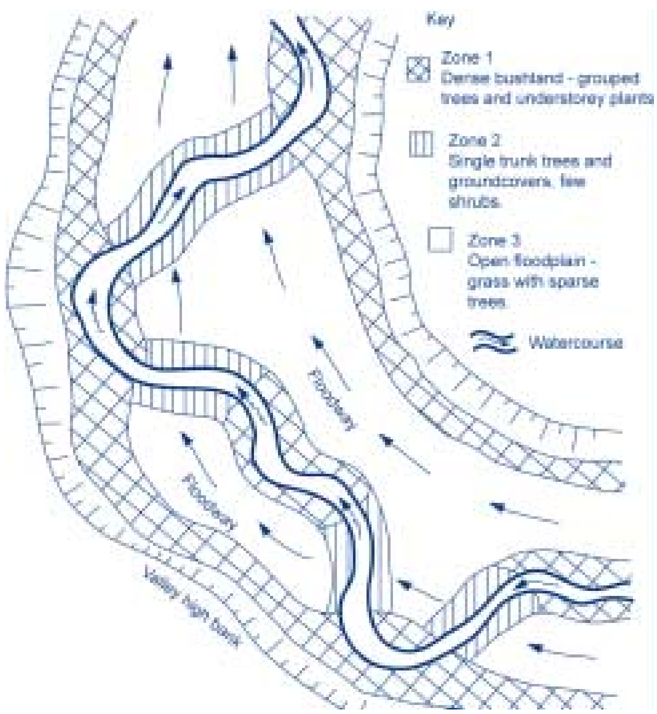

Figure 4.4 Floodplain vegetation densities along a meandering channel

Species for revegetation in Brisbane

Given the previously identified constraints associated with riparian vegetation and the effect on channel roughness and consequently flood frequency, the following section provides an analysis of those characteristics of vegetation that are required as to have a minimal impact on the effect of the roughness coefficient and subsequently the flooding frequency.

The species described in the following section were assessed as having the potential for use in waterway channel and floodplain rehabilitation projects in Brisbane. Assessment was based on:

(i) the influence of vegetation on channel roughness and hydrology;

(ii) ability to withstand and rapidly recover from inundation by floodwaters and battering by bed load and gravel;

(iii) ecological validity;

(iv) form of root system;

(v) ease of propagation by seed or division, and growth rates;

(vi) growth habit;

(vii) physiological adaption to flooding and to soil type;

(viii) appropriateness to various locations and problems within Brisbane; and

(ix) dominance of the species within the riparian zone.

Along undisturbed streams there is a diversity of riparian species present ranging from groundcovers and shrubs to trees, all of which have differing habits and root structures and contribute in various ways to stream stability. Riparian floristics also vary at catchment-wide and local scales.

Whilst the majority of the species detailed are both common and widespread in Brisbane, previous land use practices have severely restricted their current distribution. However, species distribution needs to be considered before undertaking any rehabilitation work so that those species best adapted to a particular site and indigenous to that part of the catchment are used. Locally collected seed should be used, where practicable, to maintain genetic integrity.

The following species are divided into principal locations within the riparian zone, obviously species occurrence and vegetation community composition is dependant on numerous more parameters than just proximity to mean water level within a given waterway. For example, a floodplain area may be predominately composed of Melaleuca woodland community with patches of standing water surrounded by Carex and Juncus species or alternatively a closed forest notophyll-type community.

Species of vegetation which have been determined as suitable for planting on the bank toe (Figure 4.1) within Brisbane's Waterways are detailed in Tables 4.3 & 4.4.

The species of vegetation which have been determined as suitable for planting on the middle bank area (Figure 4.1) are detailed in Tables 4.5 & 4.6.

The vegetation suitable for planting on level ground at the top of bank and the upper section of the bank (Figure 4.1) are detailed in Tables 4.7 & 4.8.

The vegetation suitable for planting on lowlands where flooding is expected and water may be retained are detailed in Tables 4.9 & 4.10.

Whilst the key objective of waterway rehabilitation projects is to establish a mixture of vegetation forms i.e. ground covers, climbers, shrubs and trees to give maximum structural diversity, this is not always achievable in flood sensitive locations. In general, planting schemes should be kept simple with a view to establishing ground cover/herb layer and a dense tree canopy.

Table 4.3 Emergent/Herb Layer plants suitable for planting on bank toe

Carex appressa	Philydrum lanuginosum
Crinum pedunculatum	Themeda triandra
Echinochloa telmatophila	Triglochin procera
Juncus usitatus	Triglochin striatum
Lomandra longifolia	

Table 4.4 Trees suitable for planting on bank toe

Acmena smithii	Leptospermum polygalifolium
Callistemon viminalis	Waterhousia floribunda

Table 4.5 Herb Layer plants suitable for planting on middle bank area

Crinum pedunculatum	Themeda triandra
Lomandra longifolia	

Table 4.6 Trees suitable for planting on the middle bank area

Acmena smithii	Ficus fraseri
Alphitonia excelsa	Ficus macrophylla
Aphananthe philippinensis	Flindersia australis
Araucaria cunninghamii	Flindersia bennettiana
Argyrodendron trifoliolatum	Flindersia schottiana
Castanospermum australe	Grevillea robusta
Casuarina cunninghamiana	Jagera pseudorhus
Cryptocarya glaucescens	Mallotus philippensis
Cryptocarya triplinervis	Melaleuca bracteata
Dissiliaria baloghioides	Melaleuca quinquenervia
Elaeocarpus obovatus	Melia azedarach
Eucaltptus microcorys	Polyscias elegans
Eucalyptus siderophloia	Toona australis
Eucalyptus tereticornis	Waterhousia floribunda

Table 4.7 Herb Layer plants suitable for planting on level ground at the top of bank and upper section of bank

Cymbopogan refractus	Lomandra longifolia
Dianella caerulea	Themeda triandra

Table 4.8 Trees suitable for planting on level ground at the top of bank and upper section of bank

Alphitonia excelsa	Eucalyptus tereticornis
Aphananthe philippinensis	Flindersia australis,
Araucaria cunninghamii	Flindersia bennettiana
Argyrodendron trifoliolatum	Flindersia schottiana
Castanospermum australe	Grevillea robusta

Table 4.8 Trees plants suitable for planting on level ground at the top of bank and upper section of bank (cont)

Casuarina cunninghamiana	Hymenosporum flavum
Corymbia citriodora	Jagera pseudorhus
Corymbia intermedia	Lophostemon confertus
Corymbia tessellaris	Lophostemon suaveolens
Cryptocarya glaucescens	Mallotus philippensis
Cryptocarya triplinervis	Melaleuca quinquenervia
Dissiliaria baloghioides	Melia azedarach
Elaeocarpus grandis	Polyscias elegans
Elaeocarpus obovatus	Toona australis
Eucalyptus microcorys	Waterhousia floribunda
Eucalyptus siderophloia	

Table 4.9 Herb Layer plants suitable for planting on lowlands, where water may be retained

Carex appressa	Themeda triandra
Crinum pedunculatum	Triglochin procera
Cyperus difformis	Triglochin striatum
Echinochloa telmatophila	Philydrum lanuginosum
Juncus usitatus	Scirpus mucronatus
Lomandra longifolia	

Table 4.10 Trees suitable for planting on lowlands, where water may be retained

Callistemon salignus	Lophostemon suaveolans
Eucalyptus propinqua	Melaleuca bracteata
Eucalyptus tereticornis	Melaleuca quinquenervia
Leptospermum polygalifolium	

Plants used for erosion control

Some herbaceous species within Brisbane can provide erosion protection by forming a mat-like root system that physically covers creek banks. Individual species are suitable for differing locations where the plants have access to groundwater. Table 4.11 details those herbaceous species that have been recorded in Brisbane waterways with these characteristics.

Table 4.11 Herbaceous species with attributes for bank protection

Carex appressa	Lomandra longifolia
Cyperus difformis	Phragmites australis
Juncus usitatus	

The matrush Lomandra *longifolia* is a very effective stabiliser. It grows in clumps and has a dense branching rhizome system which acts as a soil binder and promotes soil stability. The matrush is hardy, both in direct sunlight and shade and can be planted to prevent soil erosion at the mean water line on the steepest parts of banks and on mid slopes. It is generally planted at one metre centres, or at half metre centres in critical locations. It regenerates prolifically in moist sites. Rushes *(Juncus usitatus)* and sedges *(Carex appressa, Cyperus difformis)* are the most useful species in streams which change height quickly and which do not have a wide range of continuous flows, such that most of the marginal vegetation is not submerged for long.

Woody vegetation

A common misconception is that trees prevent creek erosion by binding the soil particles together, when it is well known that tree roots are easily exposed if subject to medium to high velocity flows.

Trees typically only stabilise a creek by providing structural strength to the banks. However, when masses of weather-resistant tree roots are exposed these roots can prevent high velocity flows from reaching the underlying earth bank. In these cases the trees and shrubs do provide significant erosion protection for the creek banks.

Successful bank stabilising tree species have root systems that can withstand exposure without drying out and capable of forming a dense mat over the creek bank as a physical erosion barrier. The roots must also be long enough to pass below the level of active bank erosion. Table 4.12 details tree species which have been recorded as exhibiting these characteristics which and which are endemic to the Brisbane local area.

Table 4.12 Tree species with attributes for bank protection

Acmena smithii	Elaeocarpus obovatus
Aphananthe philippinensis	Ficus fraseri
Callistemon viminalis	Ficus macrophylla
Castanospermum australe	Leptospermum polygalifolium
Casuarina cunninghamiana	Waterhousia floribunda
Cryptocarya triplinervis	

Trees greatly influence the stability of creeks not subject to meandering or changing catchment conditions, but they have only limited long-term influences on creeks responding to changing catchment conditions caused by urbanisation.

Shrubs and trees are valuable for erosion protection especially when they can be planted densely. When planted sparsely, they can result in enhanced erosion due to eddying effects. Thin trunked species such as River Lilly Pilly *(Acmena smithii)*, Weeping Bottlebrush *(Callistemon viminalis),* or similar species will reduce the eddying effect. A recommended density would be of the order of one tree/shrub every one to four square metres *(Raine and Gardiner, 1995).* Although trees and shrubs can sometimes be used for protection of actively eroding sites regularly exposed to flow (Table 4.12), they are generally more valuable for strengthening the bank and protecting it from collapse.

Some species such as River Oak *(Casuarina cunninghamiana)* have strong fibrous root systems and can provide excellent bank stabilisation. They produce a dense mulch from needle drop and are generally hardy but may be restricted by extremely wet conditions. The toxic effect of the needle mulch may however suppress ground cover.

Callistemons and *Melaleucas* can be used on the lower slopes of banks from just above mean water level. Hard Quandong (Elaeocarpus obovatus) and Tallowwood *(Eucalyptus microcorys)*, once established along a waterway regenerate rapidly and provide the foundation for highly stable tree cover higher up the bank. River Bottlebrush such as *Callistemon viminalis* and *C. salignus* can grow when flooded. *C. viminalis* is a riparian zone species, often found with the root zone partly submerged. *C. salignus* grows on higher ground and tolerates flooding. The bottlebrush root system is quite dense and is effective in protecting the bank. *Melaleuca quinquenervia* and *Eucalypt* species are not suitable for planting on actively eroding gully sites as their root systems may be undermined. Undercutting may be prevented if the bank is stabilised with herbaceous groundcover type vegetation such as *Lomandra longifolia*.