The Importance of Riparian Vegetation To The Health & Stability of Aquatic Systems.

1.1 Introduction.

The riparian zone is the place where aquatic systems merge with the terrestrial environment. Virtually all rainwater runoff must pass through the zone before moving into adjacent aquatic/estuarine systems. It has been termed the terrestrial/aquatic interface. Only in the last fifteen years have studies really begun to reveal the intimate relationship between aquatic systems and the riparian zone (Bunn 1993). The legal definitions of the riparian zone do not reflect what is presently understood and are based on land form definitions rather than ecological.

This review is a brief synthesis of what is presently known about the riparian zone and its importance to aquatic systems in Australia. Given the present disturbed status of Australia's water resources, it is vital that we begin to better understand their processes and to implement appropriate management practices to restore the integrity of the resource.

1.2 Definitions of the Riparian Zone

The legal definition of the riparian zone (see Figure 1.) comes under two acts, the Soil Conservation Act and the Rivers and Foreshores act (Water Resources Council 1992). The Soil Conservation act (1938) defines the zone as " a twenty meter strip adjoining prescribed streams". The Rivers and Foreshores act describes it as a forty-meter strip. These definitions are quite arbitrary and could not always encompass the ecological systems which are evident adjacent to rivers and streams.

Figure 1 (Adapted From Water Resources Council 1992)

The landform definition of the riparian zone is based upon a cross section of the channel. The riparian zone includes all the area from the low flow level up to the highest point on the bank, which marks the transition between channel and flood plain (Water Resources Council 1992).

Vegetation definitions are an attempt to typify the zone via localised vegetation types and associations that characterise an area where the hydrology is the key determinant (Water Resources Council 1992).

The riparian zone, defined as an ecological complex, is all land directly adjacent to a watercourse including flood plains and wetlands (Parsons 1991, Walker 1993). Riparian lands can also include intermitent streams gullies and dips which sometimes run with water (Askey-Doran et al 1996). The vegetation ranges from emergent aquatic and semi-aquatic plants through to terrestrial understorey and canopy species (Parsons 1991). Further, the zone can be seen as an interface between terrestrial and aquatic systems and is described as a series of ecotones between these systems (Risser 1990, Walker 1993). The high level of interaction between the riparian zone and its respective watercourse (particularly in the case of rivers and streams) makes defining an ecosystem boundary difficult. The riparian zone can be seen as an extension of the river continuum, with an "energy driver association" acting upon the in-stream biology (Cummins 1993).

1.2.1 Principal Legislation Concerning Riparian Areas in NSW.

In NSW there are Twelve acts pertaining to the riparian zone (Richard Hagley Pers. Com. 1998, Roberts et al. 1993) (see Table 1). Roberts et al (1993) states that even with so many acts governing the activities and resource use that occurs within riparian areas, sustainable management of these areas has not been acheived. Further, Roberts et al (1993) states that sustainable management was not an objective of such legislation which was oriented towards limited and specific activities with no clear policy framework in which to apply the legislation. This legislation is also limited to development control which is essentially ineffectual when active rehabilitation is required.

These policy short-comings were addressed by the introduction of the Catchment Management Act 1989 which sets a framework for legislation regarding total catchment management (Roberts et al. 1993). The act was defined as:

"the coordinated and sustainable use and management of land, water, vegetation & other natural resources on a catchment basis so as to balance resource utilisation & conservation."

This act stresses the need for all land users/owners to participate in natural resource management.

Further the State Rivers & Estuaries Policy which was developed according to the principles of total catchment management provides the key to the management of the riparian zone (Roberts et al. 1993). The objective of the State Rivers & Estuaries Policy is as follows:

"to manage river and estuary systems to achieve the beneficial use of these resources and progressively reduce the overall rate of degradation in our river and estuary systems in order to ensure long term sustainability of their essential bio-physical functions." (WRC 1993)

In 1993 a proposed riparian zone policy which specifically addressed the key issues of riparian zone restoration and public education was rejected because of opposition from primary producers (Gary Varger Pers Com. 1998).

Table 1.Priciple Legislation in NSW Pertaining to the Riparian Zone. (Adapted from Roberts et al. 1993)

Legislation	Principal Agencies	Purpose	Application
Soil Conservation Act 1938	CaLM Deparment of Land & Water Conservation (non-tidal).	Protect sensitive areas from tree removal.	Permit required to remove trees within 20m of the banks of a prescribed stream and other

	Public Works (tidal).		designated areas. Provisions for penalties.
Rivers & Foreshores Improvement Act (1948)	Department of Land & Water Conservation(non-tidal) Public Works (tidal)	Protect stability of river channels.	Controls over excavation and fill within 40m of a watercourse or activities that detrimentally affect the stability of a water course.
Environmental Planning & Assessment Act (1979)	Department of Planning Local Government.	Assessment of development for environmental impact.	Environmental planning instruments. Environmental assessment procedures.
Clean Waters Act (1970)	Environmental Protection Authority.	Prevention of pollution of waters.	Licensing of activities that may cause pollution. Classification of protected waters. Enforcement through fines.
Water Administration Act (1986) **Water Act (1912)**	Department of Land & Water Conservation.	Management of water resources. Control over use and flow of surface and groundwater.	Licensing of activities. Provision of conditions to protect riparian corridor from water development activities.
Local Government Act (1919)	Local government authorities.	Allow local government to undertake a range of functions & responsibilities.	Allow opportunities for works such as drainage, removal of obstructions, erosion control, protection of roads.
Crown Lands Act (1989)	Department of Land & Water Conservation.	Ownership & management of crown lands.	Reservation of riparian crown lands. Conditions for lease of crown land eg grazing, extraction.
Western Lands Act (1901)	Department of Land & Water Conservation.	Management of the NSW Western division.	Licensing vegetation clearance including limitations on clearing within 300m of a watercourse. Conditions on leases.
National Parks & Wildlife Services Act.	NPWS	Management of National Parks. Protection of flora & fauna. Protection of Aboriginal sites.	Permits required for damage to Aboriginal sites. Interim protection orders for significant natural areas. Management plans for National Parks & reserves.
Forestry Act (1916)	Forestry Commission	Management of State Forests.	Implementation of buffer strips to streams during logging operations.
Fisheries & Oyster Farms Act (1935)	NSW Fisheries	Management of the States fisheries resources.	Permits for dredging/ fish habitat destruction under certain circumstance.
Native Vegetation Act (1997)	Department of Land & Water Conservation.	To control the removal of native vegetation.	Requires that a permit is aquired for the removal of more than 2 hectares of native vegetation.

1.3 Bank Stability & Water Quality

1.3.1 Hydrology & Geomorphology.

The present synthesis on stream ecosystem theory generally supports the River Continuum Concept (RCC), (Vanote et al. 1980). This theory emphasises the unifying aspects of flowing water (particularly geomorphology and fluid hydraulics) in structuring stream communities and providing a template for stream ecosystem function (Minshall et al. 1985).

Riparian vegetation plays an important role in the maintenance of stream and foreshore stability. Streams and rivers are essentially dynamic systems, their path and flow constantly changing with time (Warner 1982). The presence of vegetation in riparian areas acts to reduce the rate of change and therefore maintain a level of stability. Removal of naturally occurring riparian vegetation leads to accelerated change (Water Resources Council 1992).

Buttressing is the term applied to the function performed by vegetation of supporting (buttressing) the streambank soils above it, preventing or inhibiting collapse (Askey-Doran et al 1996). Binding root systems of riparian vegetation act to prevent soil erosion from stream banks by increasing bank strength. The vegetation also reduces the hydraulic load of the banks by depleting soil water, which is used by the plants in transpiration (Water Resources Council 1992). The penetration of soil by root systems also leads to improved soil permeability and drainage reducing the risk of bank failure (Askey-Doran et al 1996).

Bank erosion is also inhibited because of a reduction in stream velocity that can be attributed to drag on large woody debris and in stream vegetation (Cummins 1993). Surface runoff is intercepted and slowed by vegetation and its associated debris. This acts both to dissipate the energy of the flow and to increase catchment storage capacity. The increased catchment storage leads to a reduction in peak flows of the watercourse (Water Resources Council 1992).
In some circumstances invasive vegetation colonises in the river channel causing deflection of flow to outer banks which in turn leads to increased bank scour (Askey-Doran et al 1996). However this channel floor colonisation can be advantageous by facilitating deposition and bed stability (Askey-Doran et al 1996).

Surcharge is the weight of vegetation that is imposed on a bank (Askey-Doran et al 1996). The weight of individual trees can reach several tonnes however this weight is distributed by the tree's root system and thus will only lead to bank collapse if the bank is vertical (Askey-Doran et al 1996).

Smith (1976 as cited in Barling & Moore 1992) found that vegetated flood-plain channel banks in Alberta were 20 000 times more resistant to erosion than comparable unvegetated banks. The stability of the channels over the last 500 years was attributed to the resistance of vegetation to erosion.

Newbury (1993) states that engineering has provided us with an extremely efficient means for the removal of water from a catchment via "hard engineered" "uniform" drainage channels. For many drainage ditches and channels, this hard engineering involves the use of an equation that gives depth and design cross section by minimising the hydraulic radius of the flow. The bed material size and the river's gradient are then adjusted to produce a stable channel with riprap lining and drop structure controls. This produces a typical trapezoidal open channel which has been used in most river engineering projects. This hard engineering approach does not provide for the natural processes that occur in rivers and streams. This has unfortunately led to many problems. In a natural channel there is a typically large width to depth ratio. Natural channels also have meanders and reaches of shallow riffles and deep pools. These pool and riffle areas provide a variety of substrates and flow conditions that aerate the water and also allow for zones of varying water pressure and back eddies of reverse velocities. Newbury (1993) proposes soft engineering can implement "naturalised" design by mimicing the natural variations in stream bed morphology and meander patterns. This would also allow for the incorporation of vegetation into the design because it removes the need for "hardened" streambanks.

1.3.2 Buffer/Filter Effect.

"The intimate association between streams and the adjacent land in their riparian areas makes these areas the obvious focus for buffering (mitigating) the effects of agriculture, whilst minimising the disruption to farming practices." (Quinn et al 1993)

Soil erosion due to water occurs as a result of rain impact and overland flow (Hairsine & Grayson 1992; Allen 1978). Particulate matter is mobilised by the rain impact or by water flowing over the surface of the soil and then, if left unobstructed, it is carried away in the main body of the flow (Hairsine & Grayson 1992; Allen 1978). Riparian vegetation sufficiently slows surface runoff to deposit the main portion of its sediment load before reaching a watercourse. Vegetation also acts to reduce the initial impact of rainwater on the soil (Hairsine & Grayson 1992; Allen 1978).

Pollutant removal in riparian lands is attributed to processes of infiltration, deposition, filtration, adsorption and absorption. These processes operate synergistically ie infiltration of overland flow reduces velocities which leads to increased deposition rates also increasing soil water contact time thus opportunity for adsorption (Quinn et al 1993). Through reduction of surface flows and rainwater impact, vegetation dramatically slows the process of erosion and effectively filters out suspended particles (Hairsine & Grayson 1992; Allen 1978). The action of slowing runoff also allows nutrients to be taken up by bacteria attached to buffer material this is particularly so with wetland vegetation (Hairsine & Grayson 1992; Allen 1978). Vegetation-trapped sediments, in conjunction with microbial and chemical processes can bind and biodegrade a variety of chemicals and nutrients thus providing a broad spectrum filtering effect against non-point source pollution events (Odum 1990).

Riparian vegetation uses significant quantities of sub-surface water and can thus influence the levels of sub-surface waterflows and associated contaminants entering a watercourse (Askey-Doran et al 1996).

Moore et al. (1988) as cited by Walker et al. (1990) suggests that vegetative filter strips are only successful in removing bacteria from runoff at levels greater than 100,000 organisms per 100ml of water. It is difficult to assess bacterial counts lower than this due to background levels of soil bacteria (Walker 1990).

Doyle etal. (1977 as cited in Barling & Moore 1992) investigated the uptake of nutrients from manure polluted runoff in forest and grass buffer strips. Samples from rainfall runoff were collected at varying distances from the pollution source. Results indicated significant reductions in the nutrient content of the water within the first few meters of the buffer strips. Phosphorous, soluble nitrogen and potassium levels were reduced by 99.7%, 94.7% and 95.0% respectively within 3.8m of the forest buffer strip. In the grass buffer strip soluble phosphorous was reduced by 62% after 4m while the other nutrients all approached levels from the positive control plots.

The effectiveness of a riparian forest as a nutrient sink is heavily dependent apon the retention time of the water within the forest. Many riparian forests do not have a lot of ground cover which can act to effectively slow and spread overland flows (Prosser 1998). This can lead to the flows becoming concentrated into gullies and depressions which move the water quickly through the forest reducing retention times. This is particularly so in areas of steep topography (Prosser 1998).

Organic pollutants can occur from a variety of sources, industrial, agricultural and urban (Kookana 1992). These pollutants include petrochemicals, polyaromatic hydrocarbons, detergents, pesticides, chlorinated hydrocarbons and various other synthetic organic compounds (Kookana 1992). Very little is known about the runoff rates of these compounds in Australian conditions (Bunn 1986). Reduction of the loss of such chemicals into aquatic systems can be achieved through infiltration, interception sorption, transformation / degradation and reducing sediment loading (Kookana 1992). A permanent vegetative buffer zone adjacent to waterways will offer some measure of protection to the waterway by facilitating the above-mentioned processes (Kookana 1992).

Organic material in the soil plays an important role in adsorption of organic pesticides such as dieldrin (Gould 1972). The adsorption process helps reduce the impact of the chemicals on aquatic systems by slowing their release into the adjacent watercourses (Gould 1972). Dieldrin and its oxidised form Aldrin are adsorbed from aquatic systems by aquatic surface vegetation (Gould 1972).

Table 2. Adapted from Quinn et al 1993 shows pollution processes and the potential instream effects of a riparian buffer zone.

Processes Potentially Maintained	Potential Instream Effects
♦ Stream sediment & nutrient inputs: ⇒ Buffer from increases associated with agriculture & forestry by filtering sediment & associated contaminants in overland flow. ⇒ Denitrification of groundwater prior to entry.	♦ maintains water clarity ♦ prevent nuisance algal growths ♦ prevents sedimentation & degredation of quality of invertebrate food. ♦ reduces toxicant loads (for example, pesticides)
♦ preventing of trampling of streambanks & direct input of excreta to streams by excluding grazing stock	♦ controls streambank erosion and subsequent sedimentation and degradation of water clarity and quality ♦ controls pathogens & eutrophication
♦ buffering effects on streambank erosion & channel morphology of changes in hydrology associated with landclearance (eg via reduced interception of rainfall & infiltration rates & increasing channel roughness during floods	♦ controls on streambank erosion & subsequent sedimentation & degradation of water clarity
♦ buffering natural energy inputs (solar energy & hence temperatures, photosynthetically active radiation, detritus, large wood), from influences of wider changes in catchment vegetation	♦ maintains natural thermal regimes ♦ retains key habitat features & organic matter retention associated with woody debris ♦ prevents nuisance algal growths ♦ maintains food webs
♦ maintain microclimate and near stream habitat for native birds, amphibians & terrestrial phases of aquatic insects also provides habitat for native fish	♦ maintains habitat required for life cycle completion for riparian species & many instream species
♦ maintains refuges & dispersal corridors for plants & animals through catchment	♦ maintains biodiversity ♦ provides drought refuge

Although riparian vegetation offers a buffering effect to aquatic systems from pollutants it is important to note that the effects of pollutants such as pesticides, herbicides, nutrients and industrial waste may be a significant factor in the decline of riparian vegetation (Parson 1991).

Walker (1993) informs us that the riparian zone should not be thought of as just a 'buffer strip'. A buffer is what Walker (1993) terms a "dump box" or as defined by Barling & Moore (1992), "something that lessens shock or protects from damaging impact or circumstance". The riparian zone can perform this function; however the long-term sustainability of this at present levels of pollution is questionable (Walker 1993). A riparian buffer zone is only a part of the solution to reducing pollutants in waterways. Walker (1993) points out that it is total catchment management that is the key to sustainable aquatic systems.

1.3.3 Designing & Implementing Buffer Strips

(Summarised from Askey-Doran et al 1996).

Buffer zones need to be implemented where surface waters enter a watercourse. This does not mean a zone of a set width along the length of the water course. The buffer zone needs to follow the contours of the landscape. It should extend in width where channels occur that enter the watercourse and can in turn contract where little or no overland flow enters the watercourse. Attention needs to be focussed on landscape depressions where flow concentrates, here broad well-grassed areas that cover the entirity of the flow concentration need to be implemented. These grassed areas in combination with a native vegetation strip along the foreshore slow the overland flow allowing sediments to be deposited, nutrient uptake and bank stabilisation. Buffer zone widths for filter strips depend on the volumes of water and sediment being transported and the nature of the landscape adjacent to the stream channel. In general as the volume of flow or the amount of sediment increases, the wider the riparian strip needs to be. A general recomendation of ten metres of grassed area and ten metres of native vegetation adjacent to the stream should be effective in most situations.

Stock with direct access to water courses cause significant damage to the surrounding environment (Bourchier 1996). Damage is caused by the trampling of the stream bank, destruction of vegetation and contamination of the water with manure and urine. The results of bank erosion, stream sedimentation and eutrophication are widely evident. Aside from the environmental damage, stock are also detrimentally affected, by allowing them direct access to natural water courses (Bourchier 1996). Studies in Canada have shown that stock drinking from waterholes with unrestricted access gained 20% less weight than those drinking piped water. The cause of the difference in productivity is attributed to organisms present in the polluted water. Also stock tend to drink less water if it is polluted leading to reduced productivity (Bourchier 1996). The loss of animals in steeply sided channels is a significant cost to the farmer in both economic and environmental terms. The contamination of a dead animal in the water supply can cause disease and represents a large nutrient input into the stream (Askey-Doran et al 1996).

1.4 ECOLOGY

1.4.1 The Terrestrial/Aquatic Interface.

The structure and function of stream ecosystems is largely determined by adjacent riparian vegetation. Ross (1963, cited in Minshall 1985) noted the strong association between stream macroinvertebrates and terrestrial biomes (what Ross termed as the landscape aspect). Ross (1963) postulated that the combination of climatic conditions necessary for the existence of stream side vegetation zones and the factors that the physical nature of these vegetation zones impose upon the streams is of great importance to the streams' ecology. The importance of the land-stream interaction is well understood. Hynes (1963 cited in Minshall 1985) first drew attention to the importance of terrestrially derived detritus (allocthonous material) to lotic systems. The overall implications of Hynes (1963) study made it quite plain that the terrestrial environment (be it forested, desert or grasslands) is crucial to the operation of stream ecosystem processes.

Interaction between the aquatic environment of streams and their terrestrial riparian zone is continuous and interlinked (Walker 1993). The riparian zone plays an integral role as food source and habitat area for both aquatic and terrestrial fauna (Parson 1991; Campbell and Doeg 1989; S.P.C.C. 1983). The export of energy across the terrestrial / aquatic interface is through riparian flora and fauna, which intercept materials and nutrients and export them back to the terrestrial environment (Catterall 1993). While much work has been done to determine the energy flux from the riparian zones into the stream, not much is known about the transfer of energy and nutrients in the other direction (Bunn 1993). Bunn 1993 asks how much of the secondary production from streams actually finds its way back into terrestrial food webs and does this represent a major or minor contribution with respect to the energy and nutrients available from terrestrial sources?

Riparian vegetation provides aquatic communities with allocthonous input for the food chain (Cummins 1993, Walker 1993, Williams 1980). The debris also provides building material for macroinvertebrates such as Trichopterans. to produce their protective cases (Williams 1980).

Large woody debris also provides some measure of refuge to other larger aquatic inhabitants such as fish, molluscs and crustaceans (Cummins 1993, Walker 1993, Williams 1980). Vegetation also attracts terrestrial insects, which can fall into the stream contributing to the allocthonous inputs (Parson 1991). A significant proportion of the organic allocthonous material that enters the stream may be due to insect plant predation on riparian vegetation (Parson 1991, Helman and Estella 1983).

Fish diet contains a large proportion of terrestrial insects in river sections that are well-vegetated (Department of Agriculture and Fisheries 1986). These well-vegetated river sections provide a high diversity of food sources for fish. This is facilitated by the large allocthonous input into the food chain and the attraction of high numbers of terrestrial insects (Department of Agriculture and Fisheries 1986; Koehn and O'Connor 1983).

Terrestrial wildlife has a role in structuring aquatic communities via predator / prey relationships (Catterall 1993). Well vegetated shaded streams and watercourses provide excellent refuge for the nests and burrows of terrestrial animals (Catterall 1993). Birds and other vertebrates use riparian vegetation as an important source of food and act to transport materials and nutrients back to the terrestrial biome (Catterall 1993, Parson 1991). In Australia 80% of all birds are dependent on riparian areas for at least part of their life history (Catterall 1993). Forty-three species of birds of the eastern Australian highlands have been identified as having an intimate relationship with water courses (Gregory & Pressey 1982).

There are many vertebrate groups other than birds, which have close associations or even dependencies upon riparian areas. Reptiles such as the water dragon live and hunt within the zone. Up to nineteen species of bat frequent or inhabit riparian habitat (Gregory & Pressey 1982). Many other non-flying mammals also frequent the zone. Obvious inhabitants of the riparian zone are frogs whose life cycles are inextricably linked with riparian habitat. Clyne (1969) states that most species of frog live close to water, aquatic frogs in particular. Clyne (1969) expands on this stating that nearly all frogs migrate, during appropriate seasons, to ponds and streams.

The platypus (Ornithorhynchus anatinus. Occurs in Tweed Shire) is Australia's most aquatically adapted mammal. The platypus can only exist in areas where the riparian zone is intact (Gregory & Pressey 1982). This also applies to the Water Rat (Hydromys chrysogaster.Occurs in Tweed Shire) and False Water Rat (Xeromys myoides.Tweed Shire is just outside the southern range of this animal), (Gregory & Pressey 1982, Cayley & Strahan 1987).

Nix (cited in Catterall 1993) proposes that Australian fauna have adapted to be dependent on specific places for drought refuge. He proposes that riparian areas are critical survival zones for the 1:100 and 1:1000 year droughts.

1.4.2 Aquatic Systems

Large items of organic debris such as trees and branches fall into the stream from adjacent vegetation contributing to the stream structure (Campbell and Doeg 1989). The irregularities of roots and large fallen material increase the roughness factor of the channel and provide a diverse range of shelter for fauna (Campbell and Doeg 1989, Parson 1991, Koehn and O'Connor 1990). Fish use the woody debris and other associated habitat to shelter from water velocity, predators, competitors and sunlight (Parson 1991). The debris is also used by the fish as territorial markers and places to spawn (Parson 1991). For invertebrates these varied substrata are particularly important throughout their different life stages (Koehn & O'Connor 1990, Williams 1983).

The Flood Pulse Concept (Junk et al. 1989 as cited in Walker 1993) discusses the lateral exchanges between riparian zones and their respective rivers. Large amounts of debris are taken up by rivers during flood events, which can occur both regularly and irregularly. Sediment is deposited along the path of the floodwaters during these flood events. The Murray River is the prime example of this concept in Australia. The river now has to be artificially flooded at three year intervals because of riparian dieback due to the weirs that are now in place along the Murray River which halt the natural flood events. These flood events along large river systems, such as the Murray River appear to extend the riparian zone well beyond the banks of the river; in the Murray River basin the riparian zone is considered to extend from two to five kilometres into the flood plain (Walker 1993).

Riparian trees are important for shading the instream habitat, helping to maintain lower water temperatures (Koehn & O'Connor). Temperature is one of the greatest influences on the lifecycles of stream biota (Quinn 1993). Different species of fish have specific temperature tolerances, and the vegetation helps to maintain temperature within these regimes (Koehn & O'Connor 1990). Water temperature is also important in controlling the lifecycles of aquatic and terrestrial invertebrates, which use the stream for part of their lifecycles (Lake et al. 1985). The camouflaging effect of dappled shade on water also helps to reduce fish predation (Koehn & O'Connor 1990; Dept. of Agriculture and Fisheries 1991). Stream shading affects primary in-stream production through a reduction in the levels of light which reach the stream thus reducing photosynthesis (Arthington et al. 1992, Lake et al. 1985).

1.5 Effects of Disturbance.

Campbell (1993) states that removal of normal riparian vegetation can have immediate effects on channel morphology. The removal of shrubs and trees has a tendency to lead to a contraction in channel width. Campbell found that the channel can be reduced in width by up to 50% as it becomes choked with grasses. Grasses bind the banks more tightly leading to a deeper narrower stream (Campbell 1993).

Land development for grazing changes hydrology and riparian vegetation (Quinn et al 1993). Water runoff increases after the clearing of native vegetation for pasture lands which leads to higher rates of flow. This is attributed to the ability of riparian vegetation to retain water and also to deplete soil water through evapotranspiration (Quinn et al 1993).

Forestry operations near watercourses lead to siltation and turbid run-off after rainfall (Borg etal. 1988). Where clear felling of stream buffers has occurred and where logging roads cross watercourses there is a high risk of erosion and deterioration in water quality (Borg et al. 1988). Removal of shade trees can lead to a marked increase in water temperature (Koehn & O'Connor 1990). Campbell and Doeg (1989) and Clinnick (1985) provide an excellent summary of the impact of forestry operations on water resources, including the riparian zone. The removal and disturbance of protective vegetation and compaction of the soil surface following forestry operations, reduces soil permeability to water and increases erosive surface runoff. Duplex soils, widespread in southeastern Australia are particularly prone to "sealing" when exposed to rainfall (Walker 1986 cited by Campbell and Doeg 1989). This, combined with the high clay levels in Australian soils, leads to the risk of elevated stream turbidity.

Suspended sediment and stream turbidity are the most common types of pollution in Australian forest streams (Cornish 1983). A major effect of sedimentation, which may result after the removal of riparian vegetation, is the blanketing of the stream substrate and the filling in of small pools and scour holes. This represents a significant decrease in substrate variety and hence useable habitats (Koehn & O'Connor 1990). Sediment-laden turbid water will also kill some of the more sensitive aquatic filter feeders, eg. Blephariceridae a type of aquatic invertebrate (Lemly 1982); this would further disrupt the food chain. Cornish (1983) recommends that the integrity of streamside buffer strips needs to be maintained and further that any disturbed areas be revegetated in order to control erosion and minimise the degradation of water quality.

Rural areas can have high levels of organic pollutants and nutrients as well as higher levels of turbidity. Non-point source pollution events contribute a large part of these pollutants in rural areas (Department of Agriculture & Fisheries 1986). Watercourses that do not have buffer strips are far more susceptible to eutrophication and even poisoning from organic pesticides and other residues (Lockington 1992, Kookana 1992). Lemly (1982) found that the combined effects of nutrient enrichment and turbidity lead to reduced biomass, diversity and species richness in aquatic invertebrate communities. Bank vegetation disturbances such as unrestricted stock access may lead to bank destabilisation and soil compaction and higher overbank flow velocities (Parson 1991, Fitzpatrick 1986). Flood events are then more likely to erode banks and adjacent land, which may require extensive work to stabilise (Department of Agriculture and Fisheries 1986).

The eutrophication of Australia's waterways has lead to toxic blue-green algal blooms; most notably in the Murray-Darling basin (Alexandria & Eyre 1993). In 1991 the world's largest recorded blue-green algal bloom occurred in the Darling River along one thousand kilometres of its length (Alexandria & Eyre 1993). This should give some indication of the present state of Australia's water resources. The degradation of riparian vegetation can only contribute to the nutrient influx from the terrestrial environment by degrading the main terrestrial means of nutrient infiltration and fixation along watercourses (Hairsine & Grayson 1993).

The present day landscape of much of eastern Australia consists of cleared lowlands with intermittent small patches of forest and forested highlands (Catterall 1993). This fragmented environment which is a direct result of European farming methods, means that much of the land is unsuitable for the passage of many native plants and animals. Consequently these plants and animals will not be able to change their ranges in response to climatic change or catastrophic events (Catterall 1993, Main 1983 as cited in Parson 1991). Benson (1989 cited in Parson 1991) describes plant associations of inland watercourses, floodplains and discharge areas as having the poorest conservation status in NSW. Fragmentation of riparian zones is a direct threat to habitat complexity and diversity (Walker 1993). Remnant strips of vegetation such as riparian areas provide linkages with other geographically separate areas and act as corridors for flora and fauna (Catterall 1993, Parson 1991, Gregory & Pressey 1982, Hobbs & Saunders 1989).

Where native vegetation has been degraded by exotic species some quite significant changes to the ecology and actual physical nature of the watercourse can take place. Native leaves are processed quite slowly by in stream fauna due to the sclerophyllous nature of the leaves (excluding rainforest species), (Campbell 1993). Australian leaves have a higher nitrogen content than exotic species. Australian forests produce more bark than European or American forests (Campbell 1993). Large amounts of green non-abscised leaves which are rich in nutrients fall in winter in Australian forests due to wind or animal activity, many northern hemisphere exotics do not have this capacity (Campbell 1993). Many Australian invertebrate shredders appear to be green leaf preferential (Campbell 1993). These green leaves fall virtually all year round leading to less synchronous life histories (ie. broad range of ages and sizes) of Australian aquatic invertebrates compared with those of the northern hemisphere (Campbell 1993).

The willow (Salix spp..) is a major weed problem for the Murray River region (Walker 1993). Willows smother native regrowth and standing vegetation producing a sterile habitat (Walker 1993). The willow is soft tissued and rapidly rotting and has a seasonal fall in autumn (Campbell 1993, Dept. of Agriculture & Fisheries 1986). This contrasts starkly with the native vegetation in that area. Eucalypts have harder tissues and do not decompose as quickly (Dept. of Agriculture & Fisheries 1986). Eucalypts are not seasonal and have year round litter fall (Dept. of Agriculture & Fisheries 1986). Our summer pulse is the time of maximum leaf fall, but 15-29% still falls in winter (compared with North American 5%), (Campbell 1993). The large woody debris from eucalypts can form hollows that appear to be essential for the aquatic organisms of the Murray River region. Willows do not form hollows (Dept. of Agriculture & Fisheries 1986). Native forests have a more open canopy than the dense closed canopy of willow stands; this means that willows affect the ratio of allocthonous to autochthonous food production by reducing in-stream photosynthesis (Campbell 1993).

Other exotic weeds that threaten Australian riparian areas include Rubber vine (Cryptocaria grandiflora.) which covers an estimated three million hectares of Queensland spreading outwards from riparian zones (Sattler 1993). Rivers in the Gulf of Carpentaria have been reported to be choked with rubber vine from source to the Gulf itself (Sattler 1993). Pond apple (Cerimoya.) is a top priority weed species (as ranked by QLD Department of Environment & Heritage, Sattler 1993). In the wet tropics Melaleuca. forests have been virtually eliminated in vital wetland communities by Pond apple infestations (Sattler 1993)#2. Athel pine (Tamarix aphylla.) is another weed, which infests northern Queensland rivers (Sattler 1993). The Athel pine alters river flow regimes by lowering the water table more than native vegetation (Sattler 1993). Local exotic weeds include Coral Tree, Para Grass, Barner Grass, Camphor laural, Small Leaved Privet and Large Leaved Privet (personal observation).

Status of Tweed Shire's Riparian Zones

The following information includes extracts from the Tweed River Management Plan, Lower Tweed Estuary Technical Summary (September 1991) and my own observations.

Native vegetation in Tweed Riparian areas has been heavily degraded and largely replaced with exotic species. This is mainly due to clearing, increased nutrient levels and modification of flow regimes in the waterways.

Remnant flora along the lower Tweed includes; fringing open swamp-forest, rainforest, open forest and shrub/heath lands. Many rare, threatened or locally significant species occur in the region, mostly in association with rainforest, although a few belong to the shrub heathland vegetation communities.

Fringing open swamp forests occur on seasonally inundated land, often adjacent to the landward edges of saltmarshes. These are characterised by *Melaleauca quinquinervia* (Paperbark) and *Casurina glauca* (Swanp Oak). Areas of fringing forest occur adjacent to Wommin Lake, Cobaki Broadwater and within Ukerebagh Nature Reserve. Two large areas, one adjacent to the southern end of Terranora Broadwater and one in the western portion of Cobaki Broadwater were cleared in the late 1970's.

The largest area of subtropical rainforest along the Tweed occurs on Stotts Island. Littoral rainforest occurs along the lower Tweed & is extremely fragmented, occuring in fragments of one to two hectares along the Fingal Peninsula, at Banora Point and Cobaki Broadwater.

Open forest occurs on land above tidal and most freshwater inundation. Several associations of local forest occur along the lower Tweed River, their component canopy species varying with change in topographic position, aspect and soil type. Only small areas of this forest remain - the red gum forest on Portion 224 and swamp messmate/paperbark tea tree forest fringing parts of Terranora and Cobaki Broadwater.

Shrublands and heathlands are characterised by dense stands of woody and herbaceous (sedges & rushes) plants of low stature. Included in this category is the coast banksia vegetation which varies in stature between shrubland and low forest. The most extensive and well preserved area of shrub and heathland occurs west of Coolangatta Airport on the margins of the Cobaki Broadwater.

Wetland vegetation occupies tidal inundated land and includes saltmarsh, mangroves and seagrass communities. These communities provide habitat for a wide variety of animals. They function as important nursery and feeding grounds for fish and crusteaceans, most of which are of direct fisheries value.

Saltmarsh vegetation comprises shrubs, sedges and grasses growing on land at the upper limits of tidal innundation. Saltmarsh is most extensive on Ukerebagh Island, adjacent to Cobaki Creek and on Letitia Spit. Approximately 21ha of saltmarsh occurs on the lower Tweed estuary.

Five species of mangrove occur in the Tweed Estuary. Mangrove forests cover approximately 309ha. Mangrove vegetation ranges from tall forests to low shrublands. In terms of mangrove area, the Tweed River estuary is the eleventh largest mangrove estuary in N.S.W. Two species (*Rhizophora stylosa, Bruguiera gymnorhiza*) are at their southern most limits. Most mangrove vegetation along the lower Tweed River occurs on islands and around the shores of the broadwaters. Fringing mangroves on most riverbanks are sparse to absent.

Seagrass beds in the lower estuary cover aproximately 67.4ha (1991 survey). One species (*Zostera capricorni*) is dominant with some small areas of *Halophila ovalis*. Major seagrass communities include; Kerosene Bay, Wommin Lake, Ukerebagh Passage, Chindera Bay, Jack Evans Boat Harbour, Terranora Inlet & Terranora

Broadwater. The seagrass community in Ukerebagh passage is currently in decline which has been attributed to a decrease in water quality within the passage. Other seagrass communities within the estuary appear to be increasing in size (in 1976 only 40ha of seagrass was recorded within the Tweed Estuary).

Exotics on the Tweed

Some exotic plants that exert a strong influence over Lower Tweed River Riparian communities include; Camphor Laural, Coral Tree, Para Grass, Madiera Vine, Coastal Morning Glory (Mile a Minute), Barner Grass & Sirretro. For the upper Tweed River and its tributaries, exotics that exert a strong influence on riverine ecology include; Small Leaved Privet, Large Leaved Privet, Camphor Laural, Cats Claw Vine, Madiera Vine, Barner Grass, Sirretro, Morning Glory, Para Grass.

The above mentioned exotic species are but a few of the many invasive "weed" species that infest the waterways of the Tweed

1.6 Conclusion.

Riparian vegetation is an essential, integral part of our water resources. Its decline is to the detriment of our waterways. There is still much to be learned about its many wildlife refugia and and buffer zone functions. Considering that much of our watersheds have been denuded of their native vegetation it is not surprising that we are experiencing a rapid decline in water quality. For example and most notably, the vast toxic blue-green algal blooms that have occurred in the Murray-Darling basin. Remnant, disjunct and mostly depauperate thin strips of native riparian vegetation are all that now buffer Australia's ailing waterways (Golding 1993 pers com).

In the process of stabilising the quality of water resources in this country, the vital nature of the riparian zone cannot be overlooked. The importance of the riparian zone to aquatic systems is unquestionable, all that remains to be done is to implement sustainable management practices. The NSW Government already has begun to incorporate public education with schemes such as TCM (Total Catchment Management Committee) which encourage landholders to maintain their water resources. More scientific research needs to be done in order to better understand the different functions of riparian zones and to determine the sustainability of using riparian vegetation as a buffer/filter zone.

From Dr Ian Prosser CSIRO:

Grant,

Natural vegetation works well as a riparian buffer against sediment and nutrients as long as there is a dense ground cover that slows and spreads overland flow. Many riparian forests do not have dense ground cover and concentrate flow into narrow streams of high velocity. If this is the case in your area then you need to supplement the natural vegetation with a managed grass filter strip on the outside edge. You probably only need 2-10 m width of dense spreading grass.

If you are to protect a weir you need to protect the tributary streams that come into a weir as they carry far more pollutants than runoff around the weir itself. Erosion of bare weir banks at times of low water level can be a problem, however. The focus points for protection should be streams with intensive land use upslope and steep slopes that drop straight into the stream. Flat areas such as floodplains and terraces act as natural buffer zones so they are a lower priority for managed filter strips. Use trees on the stream banks to protect from bank erosion and to provide ecological benefits to the stream. Small valleys and hollows need extra protection with grassed waterways that extend up the hollow.

We would be interested in monitoring particulalry if you have data from before restoration began.

14 August, 1998
Riparian Plant Species recommended for planting adjacent to Tyalgum water intake:

Recorded adjacent to site;
Apananthe philippinensis – Rough-leaved elm
Cryptocarya obovata – Pepperberry ash
Grevillea robusta – Silky oak
Brachychiton discolor - Lacebark
Alchornea ilicifolia – Native Holly (understorey shrub)

Casuarina cunninghamiana – River she-oak

Acacia melanoxylon – Blackwood wattle

Diospyros mabaceae – Red fruited ebony

Other suggested species;

Melaleuca bracteata – Black tea tree

Castanospermum australe – Black bean

Elaeocarpus angustifolius – Blue quandong

Macaranga tanarius – Macaranga

Ficus virens - White or Strangler fig

Commersonia bartramia – Brown Kurrajong

Angophora subvelutina – Broadleaf apple

Lophostemon suaveolens – Swamp Turpentine

Sloanea australis – Maiden’s blush

Tristaniopsis laurina – Water gum

Syzygium francisii – Giant water gum

Guioa semiglauca - Guioa

Alphitonia excelsa – Red ash

Glochidion ferdiandii – Cheese tree

Acmena ingens – Red lilly pilly

Syzygium moorei – Durroby

Baloghia inophylla – Brush bloodwood

Archontophoenix cunninghamiana

Polyscias murrayi – Pencil cedar

Flindersia schottiana - Cudgerie

Dysoxylum muelleri – Red bean

Alectryon subcinereus – Wild quince

Diploglottis australis – Native tamarind

Toona australis – Red cedar

Macadamia tetraphylla – Rough-shelled macadamia

Diospyros pentamera – Myrtle ebony

Endiandra globosa – Black walnut

Waterhousea floribunda – Weeping lilly pilly

Jagera pseudorhus – Foambark

Elaeocarpus obovatus – Hard quandong

Podocarpus elatus – Brown Plum pine

Shrubs/Small trees;

Trema aspera – Native peach

Eupomatia laurina – Bolwarra

Desmodium acanthocladum – Thorny pea

Cordyline spp. – Palm lillies

Bosistoa transversa – Three-leaved bosistoa

Daphnandra micrantha – Socketwood

Mallotus philippensis – Red kamala

Cyathea cooperi – Straw treefern

Callistemon viminalis sp. wollumbin -

Syzygium australe – Scrub cherry

Acmena smithii – Lilly pilly

Lepiderema pulchella – Fine leaf tuckeroo

Pipturus argenteus – White nettle

Ficus coronata - Sandpaper fig

Austromyrtus spp.

Groundcover/Low binding species;

Lomandra longifolia – Long-leaved mat rush

Lomandra hystrix – Mat rush

Alpinia caerulea – Native ginger

Dianella coerulea – Paroo lilly

Kreysegia cunninghamii – Kreysegia

Adiantum spp.

Rubus spp.

Smilax australis – Austral sarsparilla

Rare/Uncommon/Threatened etc. species

Diospyros mabaceae – Red fruited ebony

Desmodium acanthocladum – Thorny pea

Lepiderema pulchella – Fine leaf tuckeroo

Macadamia tetraphylla – Rough-shelled macadamia

Syzygium moorei – Durroby

Bosistoa transversa – Three-leaved bosistoa

Macadamia tetraphylla – Rough-shelled macadamia

Reference List

Alexandria J. Eyre D. (1993)

'Restoring Our Rivers.'

Habitat Australia February 1993 pp24-31.

Allen, H.H. (1978)

'Erosion Control of Riparian Shorelines. Wetland Functions & Values:\The state of our understanding.' In Greeson, P.E., Clarke, J.R.,Clarke, J.E. (eds) Proceedings of the National Symposium on Wetlands. American Water Resources Association.

Arthrington, A., Bunn, S., Catterall, C. (1992)

‘The Ecological Roles of Riparian Vegetation.’ In Woodfull, J., Finlayson, B., McMahon, T. Workshop proceedings ‘The Role of Buffer Strips In the Management of Waterway Pollution from Diffuse Urban & Rural Sources’ University of Melbourne Occasional Paper Series LWRRDC.

Arthrington, A.H., Conrick, D.L., Connel, D.W, Outridge,P. (1982)
‘The Ecology of a Polluted Urban Creek’
Aust. Govt. Publishing, Canberra.

Askey-Doran M., Bunn S., Hairsine P., Price P., Prosser I., Rutherford I.
Riparian Management Fact Sheet 1. “Managing Riparian Lands.”
Land & Water Resources Research & Development Corporation 1996.

Barling, R., Moore, I. (1992)
‘The Role of Buffer Strips In the Management of Waterway Pollution’ in Woodfull, J., Finlayson, B., McMahon, T. Workshop Proceedings ‘The Role of Buffer Strips In the Management of Waterway Pollution From Diffuse Urban & Rural Sources.’ Universtiy of Melbourne Occasional Paper Series LWRRDC.

Beadle, N.C.W., Evans O.D., Carolin, R.C., Tindale, M.D. (1986)
‘Flora of the Sydney Region.’
Reed Books Pty Ltd Sydney.

Borg, H., Hordacre, A. & Batini, F. (1988)
‘Effects of Logging in Stream & River Buffers on Water Courses & Water Quality in the Southern Forests of Western Australia.’
Australian Forests 51.

Bourchier J. (June 1996)
A.Kondinin Group, Journal: Farming Ahead Edition No. 54 pp 38 - 52.

Bunn, S. (1993)
‘Riparian Stream Linkages: Research Needs For The Protection of Instream Values.’
Australian Biologist Vol.6(No.1) Printed March 1993 QLD.

Bunn, S.E. (1986)
‘Fate of Organic Matter in Australian Upland Streams’ in Dekker, D.E. & Williams, W.D. (eds). CSIRO/ Dr W. Junk Publishers, Dordrecht.

Campbell, I. (1993)
Riparian Stream Linkages: An Australian Perspective on Instream Issues’ in Proceedings of the 1993 workshop, Bunn, S., Pusey, B., Arthington, (eds) ‘Ecology & Management of Riparian Zones’ Marcoola QLD in print Occasional Paper Series LWRRDC.

Campbell, I.C., Doeg, T.J. (1989)
Impact of Timber Harvesting & Production on Streams: A Review’
Australian Journal of Marine & Freshwater Resources 1989, 40, 519-39.

Catterall. C. (1993)
‘The Importance of Riparian Zones to Terrestrial Wildlife’ in Proceedings of the 1993 workshop,
‘Ecology & Management of Riparian Zones’ Marcoola QLD Bunn, S., Pusey, J., Price, P, (eds) LWRRDC.

Cayley, N.W., Strahan, R. (1987)
‘What Mammal Is That?’
Angus & Robertson Publishers Sydney.

Clyne, Densey (1969)
‘Australian Frogs’
Landsdowne Press, Melbourne.

Cummins, K.W. (1993)
‘Riparian Stream Linkages: Instream Issues’ in Proceedings of the 1993 workshop, ‘Ecology & Management of Riparian Zones’ Marcoola QLD. Bunn, S., Pusey, J., Price, P, (eds) LWRRDC.

Deparment of Agriculture & Fisheries (1986)
Trees & Streams - Preserving a Fish Habitat.
Munroe, A.T. (ed) Agfact 5.
Agdex 486/042

Fitzpatrick, C. (1986)
‘The Use of Buffer Strips In Controlling Agricultural Run-off.’ In Cambell, I.C. (ed) ‘Stream Protection. The Management of Rivers For Instream Uses.’
Water Studies Centre, Chisholm Institute of Technology Australia.

Golding J., Rayne, A. (1993)
‘The Survey of Native Riparian Vegetation of the Tweed River.’ NSW Department of Water Resources, Grafton.
Gould, R. F. (1972)
‘The Fate of Organic Pesticides in the Aquatic Environment’
Printed in USA - American Chemical Society Publishing.

Gregory, B., Pressey, B. (1982)
River Improvement.
Wildlife In Australia. 19(2)

Hairsine, P., Grayson, R. (1992)
Surface Transport & Decomposition Processes’ in Woodfull, J., Finlayson, B., McMahon, T. Workshop Proceedings ‘The Role of Buffer Strips In The Management of Waterway Pollution From Diffuse Urban & Rural Sources’ University of melbourne Occasional Paper Series LWRRDC.

Helman, P., Estella, P. (1983)
The Conservation Status of Riverine Ecosystems in Western NSW.
NSW S.P.C.C.

Higgs, J. (1990)
'Factors controling weed invasion and soil nutrient levels in the Upper Hacking Catchment'
University of Technology, Sydney unpublished report.

Hussey, B.M.J., Hobbs, R.J., Saunders, D.A. (1989)
Guidlines For Bush Corridors.
Surrey Beaty & Sons Pty. Ltd.

Koehn, J.D., O'Connor, W.D. (1990)
Threats to Victorian Native Freshwater Fish.
Vic. Nat. V.107 (1) 1990.

Kookana, R. (1992)
The Role of Buffer Strips in Reducing Waterway Pollution by Organic Chemicals Especially Pesticides.' in Woodfull, J., Finlayson, B., McMahon, T. Workshop Proceedings 'The Role of Buffer Strips In The Management of Waterway Pollution From Diffuse Urban & Rural Sources' University of melbourne Occasional Paper Series LWRRDC.-

Lake, P.S., Barmuta, L.A., Boulton, A.J., Campbel, I.C., St Clair, R.M. (1985)
Australian Streams and Northern Hemisphere Stream Ecology: Comparisons & Problems.
Proc. Ecol. Soc. Aust. 14.

Lemley, D.A. (1982)
'Modification of Benthic Insect Communities in Polluted Streams:
Combined Effects of Sedimentation & Nutrien Enrichment.'

Hydrobiologia 87, 229-244 printed in Netherlands, Junk Publishers.

Lewis, B. (1990)
‘Land Use & Benthic Macroinvertebrate Community Structure of the Upper Hacking River.’
University of Technology, Sydney Unpublished Report.

Lockington, D. (1992)
‘Groundwater Flow & Contaminent Transport’ in Woodfull, J., Finlayson, B., McMahon, T. Workshop Proceedings ‘The Role of Buffer Strips In The Management of Waterway Pollution From Diffuse Urban & Rural Sources’ University of melbourne Occasional Paper Series LWRRDC.

Minshall, W.G., Cummins, K.W., Petersen, R.C., Cushing, C.E., Bruns, D.A., Sedell, J.R., Vannote, R.L. (1985)
‘Developments in Stream Ecosystem Theory.’
Can. J. Fish. Aquat. Sci. Vol 42 (1985).

Newbury R. (1993)
The Ecology & management of the riparian zone occasional paper series LWRRDC (p 89).

Odum, W.E. (1990)
Internal Processes Influencing The Maintenance of Ecotones. Do They Exist?’ in Naiman, R.J & Decamps, H. (eds) ‘The ecology & Management of Aquatic - Terrestrial Ecotones’ UNESCO, Paris;
Parthenon Publishing Group. Man & The Biosphere Series.

Parson, A. (1991)
‘The Conservation & Ecology of Riparian Tree Communities In the Murray Darling Basin, NSW A Review’
NSW NPWS Hurstville.

Quinn, J. A.B. Cooper & R.B. Williamson (1993)

‘Riparian Zones as Buffer Strips- A New Zealand Perspective.’ In Proceedings of the 1993 workshop, ‘Ecology & Management of Riparian Zones’ (p53) Marcoola QLD. Bunn, S., Pusey, J., Price, P, (eds) Occasional Paper Series LWRRDC.

Risser P.G. (1990)
‘The Ecological Importance of land water ecotones’ in Naiman, R.J. & Decamps H. (eds) “The Ecology & Management of Aquatic - Terrestrial Ecotones’ UNESCO, Paris; Parthenon Publishing Group. Man & the Biosphere Series.

Roberts K., Wettin P. &.Gunthorpe J
Riparian Zone Management in NSW & ACT policy and perspective. 1993 from the Ecology & management of the riparian zone occasional paper series LWRRDC.(p131)

Sattler P. (1993)
‘Management of Riparian Zones Policy & Practice - Queensland & Northern Territory’ in proceedings of the 1993 workshop, Bunn, S., Pusey, B., Arthington, (eds) ‘Ecology & Management of Riparian Zones’ Marcoola QLD Occasional Paper Series LWRRDC

Vannote, R.L., Minshall, G.W., Cummins, K.W., Sedell, J.R., Cushing, C.E. (1980)
“The River Continuum Concept’
J. Fish. Aquat. Sci 37: 130-137

Walker, K. (1993)
Issues in the Riparian Ecology of Large Rivers.’ in Proceedings of the 1993 workshop, ‘Ecology & Management of Riparian Zones’ Marcoola QLD. Bunn, S., Pusey, J., Price, P, (eds) LWRRDC.

Warner, R.F. (1983)

Channel Changes in Sandstone & Shale Reaches of the Nepean River, NSW' in Nanson, G.C. & Young, R.W. (eds) 'Ecology & Management of Riparian Zones' Marcoola QLD in print Occasional Paper Series LWRRDC.

Water Resources Council (1992)
'Riparian Zone Policy - Discussion Paper'
NSW Water Resources Council Parramatta.

Williams, J.B., Harden, G.J, McDonould, W.J.F. (1984)
Trees & Shrubs of Rainforests of NSW & Southern QLD.
Botany Department, University of New England Armidale NSW.
Williams, W.D. (1983)
'Life in Inland Waters'
Blackwell Scientific Publications 1983 Vic.

<u>To Add To Refferences</u>

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