ESTABLISHING THE POTENTIAL FOR OFFSET TRADING IN THE LOWER FITZROY RIVER

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THE IMPORTANCE OF RIPARIAN VEGETATION IN IMPROVING WATER QUALITY

RESEARCH REPORT NO. 2

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Abstract

This is the second of a report series about designing a market based instrument to address water quality issues in the Fitzroy Basin, Central Queensland. There are significant exports of sediment and nutrients from the Fitzroy River each year, with potential impacts on waterways, the estuary, and the Great Barrier Reef lagoon. The bulk of those exports come from non-point sources, principally agricultural land used for grazing, farming and irrigation purposes. Key mechanisms to reduce those exports are to protect riparian areas and to improve ground cover in grazing and farming areas.

The focus of this report is the protection of riparian areas and buffer zones as the key strategy to achieve improved water quality outcomes. The key ecological benefits of this strategy would come from three main sources: reduced nutrients directly associated with livestock in riparian areas, reduction in streambank and gully erosion, and increased trapping of sediments and nutrients from overland flows. The extent of ecological benefits from riparian vegetation will vary from site to site, and modelling tools such as *Sednet* may be useful to predict such outcomes.

The opportunity costs of establishing riparian strips fall into two main categories; capital costs (fencing and water) and recurrent costs (production loss and management effort). There are substantial variations according to industry, enterprise and location. When opportunity costs are assessed for different ecological outcomes, the variations will be cumulative, meaning that there will be large variations in opportunity costs to achieve water quality improvements, even between enterprises in the same industry and catchment.

Evidence about the benefits of improved water quality in the Fitzroy Basin has been assessed from a number of choice modelling studies that have been performed. The results of those studies show significant values for attributes such as waterway health and estuary health, where water quality is likely to be a key contributor to attribute levels. By association, there are high levels of community value for improving water quality in the Fitzroy Basin.

Regulation is one possible approach to improving water quality through better provision of riparian strips. The regulatory approach has been increasingly used since the 1990s to protect remnant vegetation in the catchment. However, it is much more difficult to use regulatory tools to set management actions. Devolved grants and market based instruments offer more flexible means of achieving these outcomes.

1. Introduction

Many streams in Queensland have poor or reduced levels of water quality. This is an issue of concern because of the impacts on environmental health of the associated ecosystems within streams, in estuaries and coastal zones, and for some streams, on the Great Barrier Reef lagoon. In recent years a focus on the health of the Great Barrier Reef and the potential impacts of terrestrial pollution has generated substantial interest in opportunities to improve water quality from inland streams (PC, 2003; SQCA, 2003). The largest systems draining into the Great Barrier Reef lagoon are the Fitzroy and Burdekin rivers.

Contributions to reduced water quality in the Fitzroy Basin have been reviewed by Rolfe *et al.,* (2004), where they report that agricultural land use is likely to be the major contributor to increased sediment and nutrient loads in the river system. Across the Burdekin and Fitzroy systems, agriculture (beef cattle and dryland cropping) account for about 80 percent of pollution loads to the Great Barrier Reef lagoon (PC, 2003). Cattle grazing can affect water quality in a number of ways, including:

- woodland removal and vegetation clearing, particularly in riparian areas,
- overgrazing, soil disturbance and stream bank erosion by cattle,
- cattle access to waterways/riparian strips, and
- applying fertilizers and herbicides to pastures.

(PC, 2003: 104)

Key mechanisms to reduce water quality impacts from grazing and dryland cropping areas include protection of riparian areas and improvements in ground cover. The protection of riparian areas would mean that these zones would tend not to be sources of sediments and nutrients, and may also act as filter and buffer strips where sediments and nutrients are entering streams from grazing and farming lands. Improvements in ground cover on grazing and farming lands are also important mechanisms for reducing sediment and nutrient losses to waterways and can be achieved through actions such as reduced stocking rates (on grazing lands), avoiding over-grazing, improved property management planning, and minimum tillage (on farming lands) (Carroll *et al.,* 2001).

In the project that this report forms an output, the focus is on exploring options for market based instruments to improve water quality in the Fitzroy river system. The high contribution of agriculture to water quality impacts, and the continued focus of regulatory effort on industrial and urban contributors means that most opportunities to improve water quality will be associated with agriculture. The purpose of a market-based instrument would be to relate incentives for improved water quality more directly to land managers and ensure that improvements in land management are achieved at lowest cost.

In this project, a choice existed between two broad mechanisms for minimising water quality impacts from agriculture: riparian protection and improved ground cover. Improved ground cover is a very important mechanism for improving water quality because it stops sediment and nutrient movement at the source. It may also be associated with relatively low opportunity costs in many cases. However, appropriate levels of

ground cover vary by land use, soil type, land condition, land slope, vegetation cover and rainfall patterns. There are also difficulties in developing an adequate monitoring system or predicting how sediment and nutrient movement vary according to ground cover. These factors may make it difficult to develop standard improvements or minimum conditions in ground cover that are easily definable to landholders.

Improvements in riparian protection are more easily defined as an action to landholders because the location (waterways) and area involved (width of riparian strip) can be easily described. The linkages between riparian buffer strips and water quality is expected to vary according to factors such as soil type and management actions (e.g. access by stock), but would not be expected to be as complex as the improved ground cover action. Consequently, 'improvements in riparian vegetation' has been selected as the key management action of interest for this research project.

In this report, the relationship between riparian vegetation and water quality impacts in the Fitzroy Basin are explored. The purpose of the report is to collate relevant information so that the key factors for landholders and policy makers in enhancing riparian vegetation in the basin can be identified. These factors will then be used in the subsequent design of a choice modelling experiment.

2. Definitional Issues

The riparian zone is any place/land along a riverbank, stream, creek or water body where land and water meet. Naturally it is a vegetated filter strip between terrestrial and aquatic systems. According to Narumalani *et al.* (1997:394), riparian buffer zones are "permanently vegetated areas located between pollutant sources and water bodies … which allow runoff and associated pollutants to be attenuated before reaching surface and underground water sources via infiltration, absorption, uptake, filtering, and deposition". However, it is important not to consider this as just a narrow strip of land covered with vegetation and trees. Besides providing material fluxes between terrestrial and riverine ecosystems, riparian zones are considered as wildlife corridors for maintaining biodiversity.

Depending on the nature of the land (e.g. floodplain and valley) and the adjacent land use (e.g farming, grazing, urban settlement and forestry), the width of riparian zone varies from a very narrow to a wide landscape with a varying degree of vegetation and tree covers. According to Apan *et al.* (2002:43), "riparian landscapes include land areas adjacent to a river or stream. They are unique environments because of their positions, structures and functions in the landscape. Riparian areas are important pathways for the flow of energy, matter and organisms through the landscape and act as ecotones between the terrestrial and aquatic zones and corridors across regions. They are valuable natural resources that could serve a wide variety of productive, protective, and aesthetic functions".

Due to its important role in providing many services, many riparian zones are fragile and vulnerable to both over-use and mis-use. Riparian zones have important roles to play in

reducing erosion, improving water quality, maintaining river course and stock management, controlling nutrients, decreasing algal growth, increasing fish stocks, providing landscape refuse and maintaining biodiversity.

The status of riparian vegetation within the Great Barrier Reef catchment is still only partly studied (Furnas, 2003). There have been detailed surveys of riparian vegetation in several catchments. According to Furnas (2003:124), "the results show that a significant proportion of the riparian vegetation along both large and small watercourses has been thinned or reduced in width. The degree of disturbance is often greater along smaller frontage in catchments. Most eroded soil initially enters river systems through these small, seasonally flowing streams. The enormous number of small streams in all catchments makes management practices such as fencing streams to exclude cattle, very difficult and expensive".

3. The Role of Riparian Vegetation in Maintaining Water Quality

Studies show that the riparian zone forms an important sediment sink, where fluvially transported sediment can temporarily be stored. Good riparian vegetation coverage is beneficial in reducing sediment, nutrient and pesticide runoff into creeks and streams (Askey-Doran *et al.,* 1996 reported in Jones *et al.,* 2000); that is why it is considered as most contributing factor in trapping runoff from the catchment to the GBRMP (Jones *et al.,* 2000). A study in Australia shows that approximately 90 percent of sediment transported overland to waterways may be trapped by a buffer strip of vegetation and grasses (Askey-Doran *et al.,* 1996 reported in Jones *et al.,* 2000). Another experimental trial in the wet tropics show that grass strips of sufficient width can trap up to 80 percent of eroded soil entering the riparian zone (Furnas, 2003). McKergrow et al. (2001) reported the results of a trial in Western Australia where a riparian area was fenced and managed separately. Suspended sediment concentrations fell dramatically, with average event mean concentration dropping by 94%.

Riparian vegetation has been shown to have a mitigating effect on pollution for receiving bodies of water. The effectiveness of narrow vegetated buffers in mitigating the effects of reduced water quality is well documented in the literature (Thibault, 1997). Cooper *et al.* (1986) found that a riparian forest buffer of only 16 m wide effectively removed most of the nitrate from ground water. Peterjohn and Correll (1984) found similar results. Gilliam *et al.* (1986) studied the sediment transport from soil erosion of agricultural fields and found that 88 percent of the sediment eroded from these fields over a 20-year period had been deposited in the riparian zone (reported in Thibault, 1997).

Eighty-nine percent of the nitrogen in runoff was removed by a riparian forest in Maryland (Peterjohm and Correll, 1984 quoted in Thibault, 1997). It was ascertained that the nutrient removal by reducing diffuse-source pollution in riparian forests is ecologically significant to receiving waters. Lowrance *et al.* (1984) considered the riparian zone to be important in maintaining stream water quality. A study shows that it can act as a filter for NO_3-N, Ca, Mg, K, and SO_4-S (Lowrance *et al.,* 1984).

The condition and extent of riparian vegetation along Australia's rivers and streams varies greatly. Qureshi (1999) summarizes a wide variety of literature on riparian zones width requirements, concluding that the minimum width recommended varies from 6 to 30 m (quoted in Qureshi and Harrison, 2001). The optimal or adequate width of riparian buffers remains an issue of controversy, and will vary with the circumstances. Castelle *et al.* (1994) found buffer widths of three to 200 m effective, depending on site-specific conditions (reported in Narumalani *et al.,* 1997). Karssies and Prosser (2001) report that under good management practices, relatively narrow filter strips of <10m of dense grass can protect streams effectively, and provide a table of reduced sediment loss according to width and slope of the buffer zone.

According to Qureshi and Harrison (2001:103), "the appropriate design and width of riparian vegetation buffers in north Queensland is a matter of considerable debate, in part due to the multi-purpose nature of these strips, e.g. dense grass can control runoff problems but only large trees will bind banks and reduce summer water temperatures. Conservation agencies would like the buffers to be wide and well wooded, but farmers are loath to take prime land out of cropping".

Deciding on the width of the stream corridor is perhaps the most important decision a land use planner or resource manager could face in designing the riparian zone management plans. Because external stresses on the corridor, such as the input of dissolved substances, are uneven along its length, good design and management practices often require uneven corridor widths. In most situations, the determination of the optimum width for particular management objective is not trivial – various factors such as land use, slope, rainfall, stream order, existing riparian vegetation, landform and geology, must be thoroughly considered.

4. Riparian Vegetation and Water Quality Impacts in the Fitzroy Basin

In terms of area, cattle grazing is the principal land use and comprises about 88 percent of the Fitzroy Basin area (Jones *et al.,* 2000) and 94 percent of the area used for agriculture (Furnas, 2003). Stock can have both direct and indirect effect on the riparian ecosystem, directly through impacting on the geomorphology of habitats as well as on vegetation and water quality and indirectly through altering habitat structure and patterns (Jansen and Robertson, 2001). Scrimgeour and Kendall (2003:348) comment, "livestock grazing can profoundly alter the abundance and composition of stream communities through interactive effects on nutrient loadings, bank stability, channel morphology, substratum size composition and riparian vegetation".

Because grazing is the dominant land use in the Fitzroy catchment, run-off from cattle grazing areas is the primary influence on water quality in the Reef. Davidson (2003:38) recognizes that "due to the vast areas involved in pastoralism, most of the collective sediments and nutrients reaching the coast come from cattle grazing lands in the drier catchments of the Burdekin and Fitzroy rivers". According to Science Panel estimates, agriculture including grazing contributes around 80 percent of the pollution loads to the GBR lagoon (PC: 2003). Modelling by Moss *et al*. (1993) suggest that around 73 percent

(51400 tonnes) of the nitrogen discharged annually from the GBR catchments is sourced from grazing lands and around 21 percent (14500 tonnes) from cropping lands (quoted in PC, 2003).

Maintaining riparian zone vegetation is crucial for the water quality of the catchment as well as the GBR lagoon. Riparian buffer zones can improve and maintain water quality by filtering sediment, nutrients, organic mater, and pesticides from surface and groundwater flow, through the processes of deposition, absorption, plant uptake, and denitrification. It can effectively reduce the amount of sediment reaching streams and rivers (Ducros and Joyce, 2003), although this will vary with the physical environment and vegetation cover in the riparian area.

Riparian vegetation plays a significant role in relation to soil erosion, channel stability, wildlife and fish habitat, and water quality. Vegetation in riparian areas also has important roles in regulating the upstream-downstream movement of matter and energy by filtering or stopping the movement of sediment, water and nutrients. Specifically, riparian vegetation has an important filtering role for dissolved nitrogen, phosphorus and toxins moving along the slope of discharge. For instance, Correll and Kingston (1992) found that riparian forest bordering agricultural fields removed over 80 percent of the nitrate and total phosphorus in overland flooding, and about 85 percent of nitrate in shallow groundwater drainage from the cropland (reported in Apan *et al.,* 2002).

There has been substantial clearing of riparian vegetation in the Fitzroy catchment. Removal of vegetation in general is considered as the primary cause of erosion and nutrient loss in the GBR catchment (Davidson, 2003), although Rolfe (2000) argues that it is the combination of clearing and subsequent grazing management that can cause erosion to occur. Many improved pastures for grazing have been established through extensive clearing of native vegetation throughout the region since European settlement[1]. In the peak clearing period, it has been estimated that the average clearing rate for the Queensland was 577,000 hectares (0.33 percent of Queensland's land area) per year between 1999-2000 and 2000-01, with approximately 94 percent of woody vegetation change attributed to clearing for pasture, and about 16 percent of the total clearing in Queensland occurred in the Fitzroy catchment (PC, 2003). The CRC (2003) stated that 63 percent of the original extent of native vegetation had been cleared by 1999 and the average rate of clearing is between 0.5 and 0.75 percent of the Fitzroy catchment annually.

Other problems relate to poor levels of ground cover in remnant vegetation (Taylor and Jones, 2000; CRC, 2003), as well as to poor riparian cover and access by stock. About 80 percent of the Dawson and 50 percent of the Comet/Nogoa/ Mackenzie have poor to very poor riparian coverage (Taylor and Jones, 2000). The presence of stock was found at 71 percent of sites in the Comet, Nogoa and Mackenzie and 87 percent of sites in the Dawson area of the Fitzroy catchment (Taylor and Jones, 2000). Studies show that stock

[1] EPA (1999) estimates that more than 50 percent of the Queensland's original 117 million hectares of woody vegetation have been cleared primarily for agricultural purposes since European settlement.

access to riparian zone and clearing of vegetation are the major contributors to poor riparian condition and bank stability (CRC, 2003).

4.1 Quantifying the impact of land use changes on the water quality

Studies about the quantification of the impact of establishment/protection of riparian vegetation on the improvements in water quality are not conclusive (Clausen *et al.,* 2000; Dosskey, 2001). In reviewing a large body of scientific literature on riparian buffers, Dosskey (2001:577) concludes "consensus of experimental research on functions of buffers clearly shows that they can substantially limit sediment runoff from fields, retain sediment and sediment-bound pollutants from surface runoff, and remove nitrate N from groundwater runoff. Less certain is the magnitude of these functions compared to the cultivated crop condition that buffer would replace within the context of buffer installation programs".

In many regions, sediment movement is closely linked to streambank and gully erosion. Because phosphorous movement is closely linked to sediment, reductions in sediment movement will help to reduce phosphorous movement. The protection of riparian areas, particularly by excluding cattle, can help to reduce streambank and gully erosion. However, in northern catchments such as the Fitzroy, lower levels of ground cover and occasional extreme weather events mean that high sediment loads can also come from cropping and grazing land. Taylor and Jones (2000) give the example of a single storm in 1994 that stripped 1.4 million tons of sediment and nutrients from cropping and grazing land in a small sub-catchment (lower Nogoa) of the Fitzroy. These episodic events and other characteristics of the Fitzroy Basin make it difficult to partition sediment and nutrient emissions between 'overland' erosion and 'streambank and gully' erosion.

However, recent advances in modeling the impact of land use and other changes on the water quality means that information is becoming more available about the degree to which establishment of riparian buffers can enhance water quality in waterways. Two such models, namely *Sednet* and *EMSS*, are currently being used in predicting pollution loads in different catchments in Queensland.

The CSIRO, together with the National Land and Water Resources Audit (NLWRA) has developed a model named *SedNet* (*Sediment Network)* (CSIRO, 2002). It was used to assess the movement of sediment and nutrient across Australia for the NLWRA. Using the GIS maps and other information, such as soil type, land use, geology and river and gully networks, the *Sednet* model can be used to assess the water quality for regional catchments and to identify the most cost-effective places (i.e. hotspots) to control the major sources of sediment and nutrients that cause the quality of water within a catchment (Olley and Deere 2003). The *SedNet* model has been used to identify sediment and nutrient hotspots in the Burdekin catchment and describe how best they can be managed (Prosser *et al.,* 2002).

An example of the *Sednet* model is provided by Olley and Deere (2003) in their description of the Wingecarribee catchment near Sydney. The model showed that 95% of

sediments were coming from channel bank erosion, particularly from mudstones in one area of the catchment, and that 90% of nutrients (nitrogen and phosphous) were coming from diffuse sources (mostly cattle grazing). Recommended remedial actions included improving and protecting riparian vegetation along channels to minimise erosion, and the establishment of stock-free buffer zones along waterways to filter out nutrients.

The *Environmental Management Support System* (*EMSS)* was developed by the CRC for Catchment Hydrology. The EMSS uses the lumped conceptual catchment scale model to estimate daily runoff and pollutant load of total suspended solids, total phosphorus and total nitrogen from 175 catchments within the 23,000 km^2 area in the south-east Queensland region (Chiew *et al.,* 2002). The model estimates are sensitive to changes in climate, storage operations, land use and land management practices, including point and non-point source loadings and treatments. The main use of the EMSS is to estimate present runoff and pollutant loads and to predict the impact of changes in land use (there are nine land use categories used in the EMSS) and land management practices on runoff and pollutant export loads to the receiving water.

These models are being applied to sub-catchments in the Fitzroy Basin to predict pollution exports. Preliminary models have been developed for a farming area in the Nogoa catchment (Gordonstone Creek catchment) and a grazing area in the Dawson catchment (Spottswood Creek catchment). Over time, these models should be useful in predicting reductions in pollution loads that result from establishing buffers along waterways.

5. Community Preferences and Values for Water Quality

A key stage in the economic analysis of appropriate environmental protection levels is to be able to assess what community preferences are for environmental protection. In an economic framework, this is done by assigning values for the benefits of environmental protection, so they can be subsequently compared to the costs. The valuation of environmental goods requires the application of non-market valuation techniques. In this section, details are provided about the values held, by a range of different population groups, for water quality benefits in the Fitzroy Basin.

These values, described in dollar terms, were determined through a series of valuation experiments relevant to the Fitzroy Basin. The Choice Modeling (CM) valuation technique was applied as it had two advantages. First, it is a “stated preference” technique and so is able to measure non-use values as well as use values. Second, it is able to measure multiple attributes of a good, unlike the other stated preference technique, the Contingent Valuation Method.

Values for improved water quality in the Fitzroy were assessed with the CM technique in a National Land and Water Audit project (van Bueren and Bennett, 2004). The water quality attribute was identified in terms of use values (kilometers of waterways suitable for fishing and swimming), but people may have also made assessments about beneficial impacts on environmental factors when making their choices. In this study, two

population groups were given tradeoffs involving water quality and other natural resource and social issues in the Fitzroy Basin. One group involved a sample of Rockhampton residents (within the catchment), while the other group involved a sample of Brisbane residents (outside the catchment). Another version of the survey involved a national sample (including Rockhampton and Brisbane residents) being asked about the same types of tradeoffs at a national level.

The water quality tradeoff was framed in terms of additional kilometers of waterways that could be maintained or improved to good health if remedial or protection actions could be taken. Respondents were asked if they would be prepared to pay (through an annual tax levy over twenty years) for the potential improvements. The results revealed that the Rockhampton residents were prepared to pay an average of $2.02 (each year for 20 years) for each 10 kilometers of Fitzroy waterways improved, compared to $0.07 per kilometer for each 10 kilometers of waterway improvements generally across Australia. Brisbane residents were prepared to pay $0.79 per 10 kilometers of Fitzroy waterways improved, reflecting their remoteness from the Fitzroy Basin. The results indicate that substantial values might exist for waterway protection in the Fitzroy, but it is unclear if the values reflect the full range of concerns that people might have for ecosystem values in the region.

Another series of CM valuation studies involving the Fitzroy Basin were conducted over a period of four years (e.g. Rolfe *et al.,* 2002). These were set in the context of new water reforms in Queensland and the introduction of the *Water Act 2000*, which provides for Water Resource Plans (WRP) and Resource Operations Plans (ROP). WRPs provide the strategic framework for water allocation and management in the major river systems. There are two aspects of water management that have had major environmental impacts – the amount of water being used and the use to which it is put. Under the reforms, the environmental flow or the quantity of water needed to remain in specific river systems to avoid major environmental damage is being assessed for all river systems in Queensland. Once the environmental flow requirements have been assessed and the quantity of water currently being used is determined, a Water Resource Plan can be developed to guide water use and further water allocations if appropriate.

In the Fitzroy Basin, 90% of current water allocation is used for irrigated agriculture, 9% for local industry and the remainder for urban, industrial and stock use (Loch and Rolfe 2000). While uncertainty remains about the exact nature and extent of environmental impacts of irrigated agriculture, it is well known that some impacts may be substantial. The potential use of any unallocated water involves tradeoffs between development benefits and protection losses. Water used for irrigation will have production benefits, but less water in the river system and more land development may involve losses in environmental resources. In addition, development may involve losses in social resources such as cultural heritage assets. The economic benefits of irrigated agriculture are relatively easy to assess through standard Cost Benefit Analysis. More challenging is the valuation of environmental losses.

A series of four CM valuation studies were conducted (Table 1). All studies were set in the same context of the tradeoffs between the benefits of water development and losses in environmental and social protection. In a CM study, respondents are asked for their views and opinions in a questionnaire format. An essential component of the survey is a section where respondents are presented with a number of choice sets. Each choice set describes a scenario in terms of different attributes, and the quantity of each attribute varies in each choice set. The results are analysed using multinomial logit models. The CM studies targeted different populations and the attributes being valued varied across some of the studies.

Table 1. Fitzroy Choice Modelling study details

	2000	**2001**	**2002**	**2003**
Populations sampled	*Brisbane* *Rockhampton* *Emerald*	*Brisbane* *Rockhampton* *Rockhampton-Aboriginal*	*Brisbane*	*Brisbane*
Catchment area	Fitzroy Basin, and CNM* and Dawson river sub-catchments	Fitzroy Basin	Fitzroy Basin	Fitzroy Basin
Environmental attributes	Vegetation Waterways Water reserve	Vegetation Waterways Water reserve	Vegetation Waterways Water reserve	Vegetation Waterways Estuary
Social attributes	People leaving country areas	Protection of Aboriginal heritage sites	People leaving country areas	Protection of Aboriginal heritage sites
Reference	Loch *et al.* (2002) Rolfe *et al.* (2002)	Windle and Rolfe (2003a) Rolfe and Windle (2003a)	Rolfe and Bennett (2003)	Windle and Rolfe (2004)

* Comet, Nogoa, and Upper Mackenzie rivers

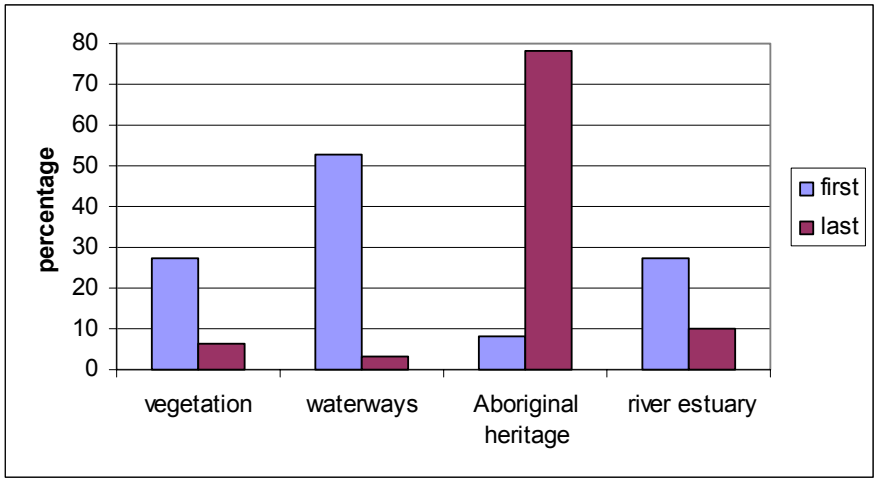
The environmental attributes are the most relevant to this research project, and these were:

- Kilometres of waterways in good health
- Amount of unallocated water in reserve
- Proportion of the river estuary in good health
- Amount of healthy vegetation left in the floodplain

The valuation results associated with waterway health are the most relevant to water quality and are discussed in detail below. The other valuation results, which are indirectly associated with water quality, are then briefly discussed. Evidence about how important the respondents viewed the different attributes can be gained from another

question presented in the 2003 survey. In that question, respondents were asked whether or not they had a consistent preference for the different attributes, and if so, what their rankings were. The results are presented in Figure 1. *Improving the health of the waterways* was the most important factor, with *vegetation* and *estuary health* taking equal second ranking.

Figure 1. Percentage of samples ranking attribute as most and least important



5.1 Values for water quality and healthy waterways

The attribute "*kilometres of waterways in good health*" is likely to be closely associated with concerns about water quality. This is because poor levels of water quality are likely to have an immediate impact on the health of waterways, as well as influencing vegetation areas and estuary health. The waterways attribute remained constant in all four surveys and therefore values can be compared across populations, sites and time (Table 1).

The scenarios presented to respondents were described in terms of the current trend in declining waterway health. Respondents were presented with several choices. They could choose to continue with the status quo situation, which would cost them nothing, and waterway health would continue to decline. The other choices would result in lower levels of decline in waterway health, ie, an improvement, but had an associated cost. Hence respondents were being asked to pay to reverse current trends. The results enabled marginal values for waterway health to be calculated. These values are the dollar amount each household was prepared to pay for a one kilometer improvement in water quality, on an annual basis over a 20 year period (Table 2).

Table 2. Mean marginal values ($) per kilometre improvement in waterway health

Year	Population	Fitzroy	CNM	Dawson
2000	Brisbane	**0.04**	**0.15**	**0.07**
	Rockhampton	**0.06**		
	Emerald	**0.07**		
2001	Brisbane	**0.05**		
	Rockhampton	**0.05**		
	Rockhampton Aboriginal	**0.06**		
2002	Brisbane	**0.06**		
2003	Brisbane	**0.08**		

The values for the Fitzroy Basin appear relatively similar across the different populations, which include Brisbane, (the remote urban capital), Rockhampton (the regional centre) and Emerald (a rural centre and an important irrigation area in the CNM sub catchment). The values of the Rockhampton Aboriginal community were also similar to those of the rest of the community. The values estimated by van Bueren and Bennett (2004) were lower (tradeoffs for Rockhampton residents were $0.02 per kilometer for the Fitzroy), but this may reflect their focus on recreational use values rather than biodiversity protection issues.

Statistical tests were conducted to see if there was a significant difference between these values (using a Poe *et al.* (2001) procedure). Applying a one tail test at the 95% confidence level, there was **no** significant difference between the values held for waterway health in the Fitzroy by:

- the Brisbane communities in any of the years, (apart from 2000 and 2003),
- the Rockhampton Aboriginal, Rockhampton general and Brisbane populations in 2001,
- the Rockhampton general communities in 2000 and 2001,
- the Brisbane and Rockhampton populations in 2000 and 2001 and
- the Rockhampton and Emerald populations in 2000.

The only significant difference that did occur was between the values of the Brisbane and Emerald communities in 2000 and between Brisbane community values in 2000 and 2003. Emerald is located in the Comet, Nogoa and Upper Mackenzie sub-catchment, and is the centre of an important irrigation area. The impacts on water quality of irrigated agriculture, especially cotton, are of local concern and probably why the Emerald community holds higher values for waterway health than the remote Brisbane community. The significant difference in Brisbane values from four cents a kilometer in

2000 to eight cents a kilometer in 2003 suggests that values for waterway health are increasing over time.

The values outlined above relate to samples of select populations. To extrapolate values to the wider population, it is important to identify the relevant population that might hold preservation values for the issue in question[2].

The results have indicated that people living within the Fitzroy Basin value waterway health, as do people living outside the area in the capital city. It is likely that people in the rest of the State also value waterway health in the Fitzroy, as might do some people outside the State. To take a conservative estimate, it would be realistic to assume that apart from Brisbane households (approximately 300,000), and households within the basin (approximately 30,000 or 5% of households in the State), another 15% of households in the State also hold similar values. At a value of six cents per kilometer, this totals to approximately $25,000 per kilometer. It is expected that much of this value can be attributed to concerns about water quality.

There are other values for environmental quality in the Fitzroy that can also be considered and these are outlined below.

5.2 Other environmental values relating to water quality in the Fitzroy

Three other environmental attributes have been measured in the Fitzroy CM studies that relate to water quality and are relevant to this research project. There is likely to be a close relationship between values for the *Proportion of the river estuary in good health* and values for water quality improvements because of the general understanding that water quality impacts on estuary health. Values for the health of the river estuary were assessed in the 2003 survey and estimated at $3.17 per household for a one percent improvement in the health of the river estuary (Table 3). This value extrapolates to approximately $1.33 million for each one percent of the river estuary maintained in good health. This would indicate that water quality may be valued because of the downstream benefits of improving the health of the river estuary, and by association, the Great Barrier Reef lagoon.

The other two attributes have weaker links to water quality, although there may be some association between them. The first of these, *Amount of healthy vegetation left in the floodplain*, was an attribute that was included in all the studies. It related to vegetation in the floodplain generally, and no distinction was made between different types of vegetation. Where water quality might be expected to impact on the health of vegetation, then values for protecting vegetation might reflect values for improving water quality. The values for vegetation protection from these case studies have been reported in more detail in Windle and Rolfe (2003b).

[2] It is also important that the socio-economic characteristics of the sample group match those of the population. Details of these tests are included in the references listed in Table 1.

The marginal values for a one percent improvement in native vegetation are presented in Table 3. This attribute was a significant variable for all the different populations, apart from the Rockhampton Aboriginal community. A one percent improvement in the health of the vegetation in the Fitzroy Basin had an average value of approximately $2.40. Although values appeared to increase over time, there was no statistical difference between the Brisbane values in 2000 and 2003. There was no significant different between the population groups, apart from the Rockhampton Aboriginal values, and also between Brisbane and Rockhampton communities in the 2000 study. If these values are extrapolated to all Brisbane households and 20% of state households, the total value of retaining 1% of native floodplain vegetation in the Fitzroy, is approximately $1 million.

Table 3. Mean marginal values ($ per 1%) for environmental improvements

Survey	Population	Vegetation	Water reserve	River estuary
2000	Brisbane	**2.46**	**1.52**	
	Rockhampton	**1.36**	Not significant	
	Emerald	**1.94**	**2.20**	
2001	Brisbane	**2.51**	**3.19**	
	Rockhampton	**2.22**	**2.95**	
	Rockhampton Aboriginal	Not significant	**3.86**	
2002	Brisbane	**2.87**	**5.77**	
2003	Brisbane	**3.36**		**3.17**

The other attribute where there may be some association to water quality was *Amount of unallocated water in reserve*. Some people may have preferred to keep water in reserve (rather than allocated for direct use) because of perceived water quality benefits. The Water Resource Plan in the Fitzroy identifies the amount of unallocated water in the system. All or part of this unallocated water could be used for development, or it could be kept in reserve, so the option to use it in the future remains open (including the option of using it for development). Keeping water in reserve means that it will not (currently) be used for development and so indirectly it is associated with improved water quality, or more precisely, it would avoid the water quality declines that might be associated with allocating the water for development.

In three of the Fitzroy studies values for the water reserve attribute were obtained (see Rolfe and Windle (2003b) for details). In all choice models the attribute was a significant variable, apart from the Rockhampton survey in 2000. There was no significant difference in values held by the different population groups in each study, but there was a significant difference between the values in the Brisbane community in 2000 and 2003, indicating that values for keeping water in reserve are increasing over time. At an approximate value of $3.20 per household, this extrapolates to a total value of $1.34 million for each one percent of water in the system kept in reserve (a total of 15% has been identified for the Fitzroy).

5.3 Summary of values for water quality improvements

Some indication of community values for improved water quality levels in the Fitzroy Basin can be gained by assessing values for environmental goods that are affected by water quality. Data from a series of Choice Modelling studies about environmental issues in the Fitzroy Basin suggests that each kilometre of healthy waterways is worth approximately $25,000 to the state population. There are also significant conservation values for preserving the river estuary in good health, maintaining floodplain vegetation and keeping the options open about what to do with current water reserves. Because water quality may impact on these environmental goods, the values reported here suggest that there are likely to be high community values for improving levels of water quality.

The values identified for waterway health and floodplain vegetation suggest that there are likely to be very significant values associated with the protection of riparian vegetation in the Fitzroy Basin. There will be direct costs and opportunity costs associated with such protection, and there may be some situations, i.e. in established farming or irrigation areas, where those costs are higher than the potential benefits of protection. In many areas though, it is likely that the benefits of protecting riparian areas outweigh any direct and opportunity costs involved.

6. Management and Restoration of Riparian Vegetation

There is an extensive body of literature on the need for the maintenance and establishment of riparian vegetation zone in catchments (e.g. Qureshi and Harrison, 2001; Olley and Deere, 2003), but little literature on how to make such actions happen. Buffer zones could be maintained and restored through a command-and-control approach, such as regulations. Regulations can be effective where goals and actions are clearly defined, infractions can be readily identified, and the monitoring and enforcement costs are relatively low.

There are two groups of actions involved in the maintenance of effective buffer strips along waterways. The first group relates to the retention of remnant vegetation along waterways, while the second group relates to the management of those areas. The retention issues have largely been addressed through a regulatory approach. As the Queensland Government introduced more controls over broadscale tree clearing from the early 1990s, a key component of those goals has been the retention of buffer strips along waterways. The introduction of legislation in 2004 to completely phase out broadscale tree clearing in Queensland means that there is unlikely to be any further losses to buffer strips along waterways in the Fitzroy Basin.

6.1 Limitations of the regulatory approach

In terms of water quality, the management of buffer strips and riparian vegetation is a much more significant factor than the avoidance of further clearing. This is because of the potentially major contribution that can come from streambank and gully erosion, particularly where there is stock access. If this can be avoided by stabalisation, adequate

levels of ground cover, removal of stock and other practices, significant improvements in water quality may be gained. Buffer strips also have the potential to trap substantial overland movement of sediments and nutrients. There may also be some direct gains in water quality from the removal of stock at watercourses.

Despite the potential gains in water quality from improved management of riparian areas, it would be difficult to develop a regulatory approach to these issues. There are a number of reasons why a regulatory approach may not be suitable. One problem is that the scale of the impact, and the potential gains to be made from better management, varies widely across the catchment. Impacts tend to be more pronounced in the larger streams, where there tend to be higher banks and more continual access by cattle (for watering purposes). In contrast, there may be little impact at the smaller, ephemeral stream (gully) level in many areas. Impacts would also be expected to vary according to soil types, slope, rainfall patterns, vegetation and ground cover.

Another group of difficulties relates to property rights issues. Many watercourses and potential buffer zones lie on private property, and so additional regulation to achieve water quality improvements may impact on those property rights. Other potential problems lie in monitoring and enforcement issues, and in defining the appropriate management actions.

The key issues are likely to revolve around the opportunity costs of better managing these riparian areas. There are three main groups of costs involved. The first group is where riparian areas would need to be fenced off to exclude cattle. The second group is where the exclusion of cattle means that artificial watering points need to be established away from the water course, and the third group relate to the opportunity costs involved in reducing production in those areas. The first two relate mostly to the grazing industry, while the third is relevant across grazing, farming and irrigation industries. There may be other costs as well for some landholders (eg weed and fire control) that are not discussed further here.

Fencing costs in the region are typically about $2,000 per kilometer. Major streams (eg rivers) tend to form a property boundary, so there may be little additional cost and trouble involved in fencing out a riparian strip. Where minor watercourses that traverse properties are involved, there may be substantial fencing required (both sides of a watercourse) as well as impacts on paddock layout and property functioning. Some properties may already have the riparian zones fenced off (to minimize stock losses in the flood season). In flood prone areas, it may be very difficult to fence a riparian zone without substantial repairs every wet season.

Artificial water needs and costs can vary widely. It may cost $20,000 or more to establish a replacement dam or bore, but it may be much cheaper for pumping and piping options. In some cases landholders may have little need for replacement watering points because they already have off-stream water. In these cases there would be little opportunity cost involved in reducing stock access to watercourses.

Potential production losses are also expected to vary widely between landholders. Where irrigators and farmers have to reduce production areas (e.g. to create buffer strips), then there may be large opportunity costs involved. Graziers may also incur production shortfalls if they have to reduce grazing areas. In some vegetation types less suitable for grazing the opportunity costs would be very low. In some cases the management change needed may simply be a reduction in grazing and stock pressure, or exclusion of stock at certain times of the year. In these cases there may be no production losses involved, although there would be some additional management effort required.

These factors show that large variations are expected in the opportunity costs of establishing riparian areas, both in terms of capital costs (fencing and water costs) and recurring costs (production losses and management effort). The positive contribution of riparian zones to water quality will also vary widely across the catchment for reasons outlined above. These variations are cumulative, so that the opportunity cost per water quality improvement will show more variation than both opportunity costs and water quality improvements per riparian zone. Because there is little scope in regulatory systems to tailor actions according to levels of opportunity cost and potential benefits, potential exists to use more flexible mechanisms for that purpose. Two main groups of these mechanisms are devolved grants and market-based instruments.

6.2 Use of Devolved Grants

There are some on-ground initiatives in the Fitzroy Basin to improve the riparian conditions and thus the water quality. Among them the significant one is the devolved grant scheme, titled *Fitzroy Basin Best Management Practices Devolved Grant*, run by the Fitzroy Basin Association (FBA) to establish and protect the riparian vegetation in the basin. The Devolved Grant provides funding support for on-ground projects aimed at improving riparian and groundcover condition across the whole Fitzroy Basin. The FBA also completed a devolved grant scheme for the Fitzroy region titled *Increasing Adoption of Best Management Practices in the Fitzroy Basin Region* in 2001-02. This scheme focused on protecting remnant riparian vegetation by providing incentives for the implementation of best management practices (BMPs) on private and public lands in the greater basin area with the exemption of the area covered by the Lower Fitzroy Devolved grant scheme (Greening Australia, 2003).

Currently the FBA is implementing its second phase of the devolved grant scheme, titled *Fitzroy Basin Best Management Practices Devolved Grant*[3]. To date a total of about 200 projects has been approved through the devolved grant involving a dollar value of about $1.5 million from the Natural Heritage Trust (NHT) fund and about $3 million from landholders' (normally in-kind) contribution[4]. Funding is normally provided for fencing off riparian areas and provision of off-stream watering, and management of strategic

[3] Another devolved grant scheme, titled *Lower Fitzroy River – Incentives for Strategic Community Action to Improve Catchment Health,* developed by a coalition of Livingstone and Fitzroy shire councils and Rockhampton city council with a similar focus to the FBA devolved grant was implemented in the Lower Fitzroy region during 2001-02 (LFRCAP, nd).

[4] Personal communication with the FBA official on April 2, 2004.

weed and erosion control based on the *Property Resource Management Plan* designed for each individual property.

While the devolved grant schemes are seen as a positive contribution on the part of the landholders towards the sustainable management of natural resources in the region, there may still be several limitations involved in their use. One issue is that some devolved grants tend to be focused on addressing capital cost components of opportunity costs (e.g. fencing and water improvements), and are not tailored to providing recurrent opportunity costs (production losses and management effort). It is very unclear what the incentives are for landholders to be involved with devolved grants when recurrent opportunity costs are involved. Another issue is that it is very difficult to judge the cost-effectiveness of many devolved grants. This is particularly the case when participation rates are low, standard rates are used for many capital items, and there is no set procedure to assess the biodiversity or other outcomes for each project.

6.3 Potential use of Market-Based Instruments

Market-based instruments offer a complementary approach that can address these limitations of command-and-control approach. They have the potential to create incentive mechanisms among landholders to protect and restore riparian vegetation zones along streams. There are three main types of market-based instruments that might be applicable to riparian vegetation issues.

The simplest market-based instrument to use would be a competitive tendering or biodiversity auction process. This would be very similar to a devolved grant in that the funding is likely to come from government, but that some transparent and competitive process would be used to allocate the funds. The processes for holding biodiversity auctions have been detailed by Latacz-Lohmann and Van der Hamsvoort (1997), and Strappazzon et al (2003). These suggest single-round competitive bidding processes where indexes are used to rank bids and identify the most cost-effective ones.

A slightly more complex option would be the use of offsets to provide landholders with incentives to manage riparian areas. Offsets could be required by industry and urban emitters, where the purchase of environmental services from landholders would be a more cost-effective option than additional on-site controls. The key benefits of offset mechanisms are that emission reduction costs tend to be minimized across industries, there is a reduced call on public funding, and that transaction costs remain low.

The most complex option is likely to be a cap-and-trade mechanism, where some cap is placed on emissions or an emission-related activity, property rights are established for emission creation up to the cap, and a trading market is established for those property rights. A potential example of a cap-and-trade arrangement in the Fitzroy Basin would be where minimum conditions were set for riparian vegetation standards for all landholders, and they were allowed to trade their compliance level between themselves and with other industries.

The application of market-based instruments to riparian vegetation issues will be complicated by several factors. One of these will be to define the 'duty of care' levels for landholders. These will be the minimum conditions or baseline conditions that they might be expected to provide before receiving incentives to make additional improvements. Another issue will be to identify whether the incentives are based on outputs (improvements in water quality) or inputs (establishing and maintaining riparian areas). Measurement issues imply that the incentives should be input-based, but this will require the definition of allowable actions that can form an allowable input.

A key issue in assessing the potential for market-based instruments to be introduced is to assess the supply curve from landholders for potential riparian options. Identification of the variation in supply costs, both within and between enterprises, will allow some assessment to be made of the potential efficiency gains available from the use of market based instruments. Supply information can also be used to make predictions about likely market behaviour in different scenarios. The information about potential supply is relevant to each of the different market based options (competitive tenders, offsets and cap-and-trade), and hence can be assessed independently of the choice about which market-based instrument to use. This will be the focus of the choice modeling experiments to be carried out in this research project.

7. Conclusion

There is potential for riparian areas to be used to achieve water quality improvements across the Fitzroy Basin, both to reduce emissions from those areas and to trap overland movement of sediments and nutrients. However, the impact of these buffer strips, in terms of improved water quality, will vary across the basin according to a number of factors.

The key actions from landholders will be to exclude (or partly exclude) livestock, and to allow buffer strips to regenerate. In some cases there will be capital costs involved, as well as ongoing production impacts and management actions. Differences in these costs between landholders mean that there will be large variability in the opportunity costs of reducing water quality impacts. This establishes a basic requirement of a market-based incentive program, where differences in opportunity costs drive offset and trading opportunities.

While regulation has been used to limit further clearing of remnant vegetation along waterways in the basin, a regulatory approach is not very suitable to improve management actions involving riparian areas. More flexible systems of incentives may be more appropriate. Devolved grants have advantages in terms of increasing landholder participation and sharing cost burdens, but may not be very efficient. Market-based instruments offer more alternatives to provide appropriate incentives to landholders.

Three types of market-based instruments may be used to enhance riparian vegetation as buffer strips: competitive tenders, offsets and cap-and-trade arrangements. Each have particular advantages, but competitive tenders are probably the easiest to apply, while

cap-and-trade systems are likely to be the most complex. The assessment of each of these potential mechanisms involves the estimation of a potential supply curve for the required input (riparian zones), as this allows predictions to be made about potential efficiency gains and market behaviour. This will be the focus of the choice modeling experiments to be carried out in this research project.

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