CSIRO SUSTAINABLE ECOSYSTEMS

Assessment of the Socio-Economic Impacts of Management Options for Improving Water Quality in Douglas Shire

DM Smith[1]
PC Roebeling[1]
AJ Webster[2]
M Kragt[1&3]
I Bohnet[2]
A Zull[1]

March 2005

[1] **CSIRO Sustainable Ecosystems, Davies Laboratory, PMB Aitkenvale, Queensland 4814**
[2] **CSIRO Sustainable Ecosystems, Tropical Forest Research Centre, PO Box 780, Atherton, Queensland 4883**
[3] **Wageningen University and Research Centre (WUR), Wageningen, The Netherlands**

ISBN
0 9751783 9 3

Important Disclaimer:
CSIRO Sustainable Ecosystems and the Douglas Shire Council advises that the information contained in this document comprises general statements based on scientific research. The reader is advised that such information may be incomplete or not appropriate for application to any specific situation. No reliance or actions must therefore be made on the basis of the information contained in this report without seeking prior expert advice. To the extent permitted by law, CSIRO Sustainable Ecosystems and the Douglas Shire Council (including its employees and consultants) excludes all liability to any person for any consequences, including but not limited to all losses, damages, costs, expenses and any other compensation, arising directly or indirectly from using this publication (in part or in whole) and any information or material contained in it.

Executive Summary

Introduction

Douglas Shire Council (DSC) has been contracted by the Department of Environment and Heritage (DEH) to develop a Water Quality Improvement Plan (WQIP) to address sediment and nutrient pollution in the waterways of the four main catchments of the Shire (the Daintree River, Saltwater Creek, Mossman River and Mowbray River). The process for developing the Plan is intended to align priorities for water quality protection held in the community with management actions in the WQIP. These priorities are set in consultation with the community using a categorisation of 'Environmental Values' (EVs), where EVs are features and uses for rivers and waters that are most important to stakeholders. Water quality objectives (WQOs) are set according to the water quality required to protect or re-establish desired EVs and management options for achieving these objectives are then selected. Selection of management options also depends on how acceptable any associated costs and benefits are to the community. CSIRO was contracted to undertake the assessment of the social and economic acceptability of alternate management options for improving water quality.

The assessment had four specific aims. These were:

1. assessment of attitudes in the Douglas Shire to Environmental Values for the Shire's waterways;
2. assessment of attitudes in the Douglas Shire to potential management options for water quality protection;
3. analysis of the financial costs of implementing options for management of water quality;
4. comparison of costs with the downstream benefits of improvements in water quality.

Results from the assessment were used to develop recommendations on which management options have the highest social and economic acceptability.

Methodology

Public attitudes to EVs and management options for improving water quality were assessed using a postal survey in July 2004. The survey was distributed to every postal address in the Shire. Respondents were asked to rate (1) the importance of a set of EVs in rainforest, freshwater and saltwater reaches of each of the Shire rivers; and (2) the expected effectiveness and their support for adoption of a range of management options.

The costs and benefits of options for management of sediment and nutrient runoff were estimated using economic modelling. Financial analysis of actual and alternative management practices was done at the plot level for sugarcane and beef production in Douglas Shire. Farm models were then constructed for the most important types of agricultural producers in the Shire, to enable estimation of the private economic effects of alternative management options on production, land use, income, leisure and water pollution indicators. Results from analysis at the farm level were aggregated for catchments to provide estimates of the aggregate agro-ecological and socio-economic effects of the adoption of alternative management practices by all agricultural producers in the Shire. Finally, these effects were utilised in a framework comparing the terrestrial and marine costs and benefits

of water pollution control, to enable estimation of the net welfare effects of management options at the Shire level.

Results

Community attitudes to EVs and management options

Aquatic ecosystems, aesthetics and drinking water quality were the EVs with the highest rating in all catchments and among all groups of land managers. Use of waters for agriculture, aquaculture and recreation were rated with lower importance by all groups. Farmers with >10 ha rated the importance of use of water for irrigation or stock more highly than others, though with less importance than aquatic ecosystems. Cultural and spiritual EVs were rated similarly to agricultural uses for water, while industrial uses for water were consistently rated with low importance.

Although results from the 2003 workshop on draft EVs (Bennet, 2003) and this public survey showed similar tendencies, respondents to the public survey placed a somewhat higher importance on aquatic ecosystems in developed river reaches, aquacultural uses for water, aesthetics and drinking water, while they placed a somewhat lower importance on cultural and spiritual uses for water.

Few differences were apparent among land-manager types for the expected effectiveness or support for adoption of management options. Respondents gave a high or medium-high rating to all management options. Non-land managers were more sceptical about fertiliser management than farmers with >10 ha, while farmers were more sceptical than others about exclusion of stock from riverbanks, riparian revegetation and wetland restoration.

Cost-benefit analysis

Minimum tillage, legume fallows and optimal management of N fertilisers were estimated to have positive income effects. When applied together, it was estimated that gross income[1] could potentially increase by up to 35% for both specialised sugarcane farmers and mixed (sugarcane and beef) farmers. The effects of these options on sediment runoff were small, though estimated use of nitrogen fertilisers was cut substantially. Improved management of drains in sugarcane farming was estimated to have a large effect on sediment runoff from farms, but at a cost to farmers, with the result that adoption of improved drains management is unlikely without the application of regulations or incentives. Adoption of riparian revegetation similarly creates a cost for farmers without any direct benefits.

Suggested changes to the management of grazing operations – specifically exclusion of stock from riverbanks and reduced stocking rates – were estimated to have negative income effects for graziers. Reducing stocking rates to recommended levels of less than 2 head/ha would cause gross income for specialised graziers to decline by more than 10%.

For the entire agricultural sector in the Shire it was estimated that the terrestrial producer surplus[2] could potentially increase by up to 30% because of adoption of minimum tillage, legume fallows and optimal N fertiliser management in sugarcane farming. Improved management of (constructed) cane drains and reduced stocking rates would cause terrestrial producer surplus to decline by almost 5%.

---

[1] Gross income is defined as the farm level gross value of agricultural production and employment net of corresponding production and labour costs.
[2] Terrestrial producer surplus is defined as the aggregate regional value of agricultural production and employment net of corresponding production and labour costs.

Analysis of the benefits of pollution control for reef tourism and fisheries showed that effects of reduced sediment runoff on these sectors were small, except for drains management, where it was estimated that the marine producer surplus[3] could potentially increase by up to 10%. These estimates excluded the effects of reduced nutrient pollution on marine systems and are therefore conservative. When the costs and benefits for terrestrial and marine industries were combined, all management practices caused positive net welfare[4] effects for the Douglas Shire, except grazing management practices, which would cause a small decline in net welfare.[5]

Conclusions

Results from the survey of community attitudes to control of water pollution showed that Environmental Values associated with aquatic ecosystems, aesthetics and drinking water quality were rated as highly important by both land managers and non-land managers. EVs related to, for example, agriculture, recreation and cultural values were rated with lower importance. These results indicate that setting water quality objectives and selecting management actions under the Plan with reference to aquatic ecosystems, drinking water quality and preservation of landscape character are likely to be widely accepted in the community. Setting objectives with reference, for example, solely to agriculture, recreation or cultural values is more likely to invoke a sceptical response in some parts of the community.

Table E.1: Summary of relative social and economic acceptability in the Douglas Shire of options for managing improvements in water quality. High indicates a positive effect, low a negative effect, and neutral indicates mixed and small effects.

Management option	*Property level acceptability*		*Shire level acceptability*	
	Economic	*Social*	*Economic*	*Social*
Minimum tillage	high	high	high	high
Fallow practice	high	high	high	high
Fertiliser management	high	high	high in growing sector low in regional industry	high in growing sector low in regional industry
All cropping system mgmt practices#	high	high	high in growing sector low in regional industry	high in growing sector low in regional industry
Drain management	low	(neutral)	low for sugar industry	low for sugar industry
Stocking rate	low	low	low for grazing industry	low for grazing industry
Stock exclusion	low	low	low for grazing industry	low for grazing industry
Riparian revegetation	low	low, unless individual preference	low for agriculture	low for agriculture
Infrastructure	-	-	high if cost effective	high if cost effective
Overall net effects on Shire	-	-	high	high

Note: # Combination of tillage, fallow and fertilizer management practices.

Management options for improving water quality listed in the public survey were, on average, rated by respondents with high or medium high expectation of effectiveness and support for adoption, although 20% or more of respondents were sceptical of many options. So, there is

[3] Marine producer surplus is defined as the aggregate regional value of marine-based production net of corresponding production and labour costs.
[4] Net welfare is defined as the sum of terrestrial and marine producer surpluses.
[5] Note that the cost-benefit analysis does not take non-use values of the GBR and re-suspension of water pollutants into account. Based on Roebeling (2004) we can therefore expect that the results presented in this report are based on, most likely, conservative estimates of the total costs associated with water pollution in the Douglas Shire region.

a sizeable minority who hold negative views and will likely greet management options within the WQIP with scepticism. Such scepticism is especially high among farmers (of >10 ha) for stock exclusion, riparian revegetation and wetland restoration, which is significant as it is largely the farming community who would be asked to implement these practices.

The relative social and economic acceptability of management options is summarised in Table E.1. These assessments are based on results of the property and Shire level analysis of costs and benefits and qualitative evaluation of impacts on socio-economic indicators for the Shire. In summary, options for management of water quality in the Douglas Shire appear generally to have high social and economic acceptability. However, there are specific risks associated with impacts on particular industries that indicate that the WQIP may have low acceptability among certain groups of stakeholders. Negative effects are likely to impact most heavily on the transport and milling sectors in the sugar industry and the grazing industry. Thus, in developing policy to support the implementation of the WQIP, the needs of these sectors should be treated as priorities.

Acknowledgements

This project has been developed at the request of the Douglas Shire Council (DSC), which is currently co-ordinating the development of a Water Quality Improvement Plan for the Douglas Shire. We acknowledge the price and production data as well as the expert knowledge provided by the Mossman Agricultural Services (MAS). Also, we would like to thank Katherina Fabricius of the Australian Institute of Marine Sciences (AIMS), who provided insight into the most important effects of water pollution types on GBR ecosystem health indicators. Were also greatly indebted to John Bennett and Sally Driml of the Environmental Protection Agency (EPA) as well as Brian Roberts and Scott Heckbert from CSIRO Sustainable Ecosystems, who provided valuable comments on earlier versions of this report. Finally, we would like to thank the colleagues at CSIRO Davies Laboratory in Townsville who helped with the preparation of the mail-out survey.

Table of Contents

1. Introduction

1.1 Background to the assessment

Douglas Shire Council (DSC) has been contracted by the Department of Environment and Heritage (DEH) to develop a Water Quality Improvement Plan (WQIP) to address sediment and nutrient pollution in the waterways of the four main catchments of the Shire (the Daintree River, Saltwater Creek, Mossman River and Mowbray River).

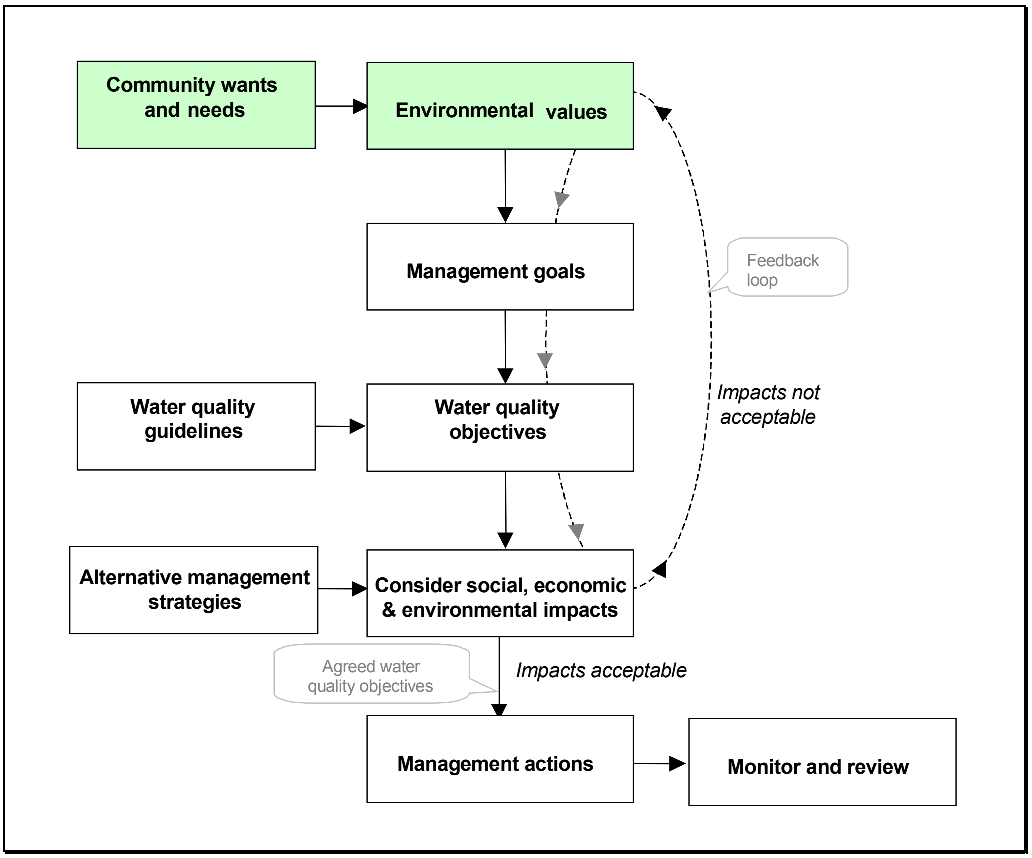

Figure 1.1: The Water Quality Management Framework underpinning the process for developing the Douglas Shire Water Quality Improvement Plan (Bennett, 2003).

The process for developing the Water Quality Improvement Plan has been designed on the basis of the Water Quality Management Framework shown in Figure 1.1 (Bennett, 2003). There are three key steps under this framework which align priorities for water quality protection held in the community with management actions in the WQIP. These are:

1. through consultation with the community, features and uses for rivers and waters that are most important to stakeholders are identified, using the categorisation of 'Environmental Values' (EVs) summarised in Table 1.1;
2. 'Water Quality Objectives' (WQOs) are set on the basis of the water quality required to protect or re-establish desired Environmental Values; and
3. management options for improving or strengthening protection of water quality are identified that will result in achievement of these objectives.

The framework in Figure 1.1 has been designed to facilitate public participation in development of the WQIP, as community views on environmental values form the basis for setting the objectives for water quality and selecting options for management. Selection of management options also depends on how acceptable any associated costs and benefits are to the community. It is thus critical that, under the framework in Figure 1.1, there is an assessment of (1) public attitudes to EVs and (2) the social and economic impacts of management options for water quality protection. CSIRO was contracted by Douglas Shire Council to undertake this assessment.

Table 1.1: Summary of Environmental Values included in the socio-economic assessment of the Douglas Shire WQIP.

Environmental Value	*Example features and uses for water*
Aquatic ecosystems	Water that supports aquatic vegetation and wildlife
Agricultural – irrigation	Irrigation of field crops and horticulture
Agricultural – stock	Water provided to livestock
Aquaculture	Water for aquaculture and fishing
Direct recreation	Recreation with direct contact with water (eg. swimming)
Indirect recreation	Recreation with indirect contact with water (eg. boating)
Aesthetics	Visual appreciation of the landscape
Drinking water	Supply of drinking water
Cultural & spiritual	Sacred, spiritual, traditional and cultural uses for water
Industrial	Water for industry (eg. manufacturing, power)

Source: Bennett (2003).

1.2 Environmental values and management options within WQIP

The term 'Environmental Values' is used within the process of planning for water quality improvement to describe a wide range of features and uses that people associate with waters and rivers (see Bennett, 2003). The EVs considered under the Douglas Shire WQIP are summarised in Table 1.1.

Table 1.2: Priorities identified by the Douglas Shire Council for improvements to control of sediment and nutrient pollution from point sources.

Site	*Issue*	*Priority action*
Mossman sewage treatment plant*	High nutrient load in effluent	Upgrade to tertiary treatment with effluent re-use
Seafarm Pty Ltd[#] (aquaculture)	Nutrients released with wastewater	Current discharge complies with licensed limits; further reductions to be sought, eg, through Seafarm's engagement in the WQIP and development of incentives.
Dredging*	Sediment discharge	Negotiation of improved license conditions to include turbidity
Quarrying*	sediment discharge	Improved monitoring of compliance with license
Stormwater	Increased volumes of urban stormwater as urban areas expand	Incorporation of water sensitive urban design principles into urban development plans; increased council budget for erosion minimisation from unsealed roads
Development sites	Sediment runoff during construction works	Training and education; higher level of compliance checks
Septic – residential	Nutrient pollution from septic systems in Cooya, Craiglie and Wonga	Upgrade to sewerage
Septic – rural residential	Nutrient leakage	Appropriate pump out practice and replacement when repairs required.

Source: DSC (2004).
Note: [#] Licensed point sources (DSC, EPA or NR&M).

A framework for rating EVs for the Douglas Shire waterways was developed during a workshop of key stakeholders in 2003 (Bennett, 2003). Each of the four main rivers was divided into groupings of river reaches: the relatively undisturbed, forested reaches typically at the heads of the catchments, the developed freshwater reaches and the developed saltwater (or tidal) reaches. 'Developed' reaches are those that have been impacted by clearing for agriculture and urban development. Participants in the 2003 workshop used this categorisation of reaches in developing draft EVs for the Plan, by rating the importance of each EV for each category of reaches in the four catchments of the Shire (Bennett, 2003).

Management options for improving water quality under the WQIP have been developed for both point sources and diffuse sources of sediment and nutrient pollution affecting the Shire waterways. The main point sources of pollution in the Shire are listed in Table 1.2 together with priorities for improvements in pollution control identified by Douglas Shire Council (DSC, 2004). Options for control of diffuse sources of pollution (resulting for example from land use for agriculture, horticulture and grazing) were identified from industry codes of practice and through consultation with experts, industry and the community (DSC, 2003). The main options are described in Table 1.3.

Table 1.3: Summary of management options for reducing the pollution of waterways by sediment and nutrient runoff from agriculture.

Management option	*Description*
Minimum tillage	Tillage systems that minimise cultivation and reduce the risk of sediment and nutrient runoff.
Contour planting	Preparation of land and orientation of rows across the slope leading to a reduction in soil erosion.
Fertiliser application	Application of fertiliser using the appropriate form and method, without exceeding recommended fertiliser rates.
Fallow practice	Non-managed or legume fallows between crop cycles leading to improved soil health and reduced sediment and nutrient runoff.
Ground cover	Maintenance of ground cover using crop residues within and between crop cycles and grassed inter-rows in tree crops.
Stocking rate	Appropriate stocking rates for livestock, to ensure adequate ground cover and reduced sediment and nutrient runoff.
Pasture management	Maintenance of a balanced mix between legumes and grasses, leading to improved ground cover and reduced sediment and nutrient runoff.
Exclusion of stock	Exclusion of livestock by fencing of riverbanks and provision of off-stream watering points, leading to reduced bank erosion
Drain management	Construction of flat, grass-covered (spoon-shaped) drains and maintenance of vegetation cover on banks of deep drains.
Riparian vegetation	Re-establishment of trees and shrubs along stream and river banks, leading to a reduction in sediments and nutrients entering waterways.
Wetland restoration	Restoration of natural wetlands, or construction of artificial wetlands, to facilitate filtering of sediments and nutrients in drainage systems.

Source: DSC (2003).

1.3 Objectives of the assessment

The social and economic assessment of the WQIP was designed to enable incorporation of information on community attitudes and the costs and benefits of pollution control into the planning process. Relevant community attitudes are those relating to EVs for rivers and waters, perceptions of the effectiveness of management options and support for adoption, as these may impact on the acceptability of the Plan to members of the community. Relevant costs and benefits are considered to be those associated with the implementation of management options and the direct-use values for water affected by downstream changes in water quality.

Summarizing, the assessment had the following four specific aims:

1. assessment of attitudes in the Douglas Shire to Environmental Values for the Shire's waterways;
2. assessment of attitudes in the community to potential management options for water quality protection;
3. analysis of the financial costs of implementing options for management of water quality;
4. comparison of costs with the downstream benefits of improvements in water quality.

Results from the assessment are intended to form the basis for recommendations of management options that demonstrate the highest social and economic acceptability.

2. Catchment profile: the Douglas Shire

2.1 The Douglas Shire catchments

The four main catchments of the Douglas Shire are the Daintree (1332 km^2), Saltwater (136 km^2), Mossman (208 km^2) and Mowbray (174 km^2) catchments (see Figure 2.1). Wet Tropics World Heritage Area covers some 80% of the Shire and forest is the dominant land cover in each catchment. Cleared areas of each catchment are mostly confined to the floodplain, where sugarcane production is the dominant land use in all catchments but the Daintree, where there is a substantial area of grazing. The Great Barrier Reef lies offshore from the Shire and thus protection of the Reef from terrestrial impacts is a principal driver for improved protection of water quality.

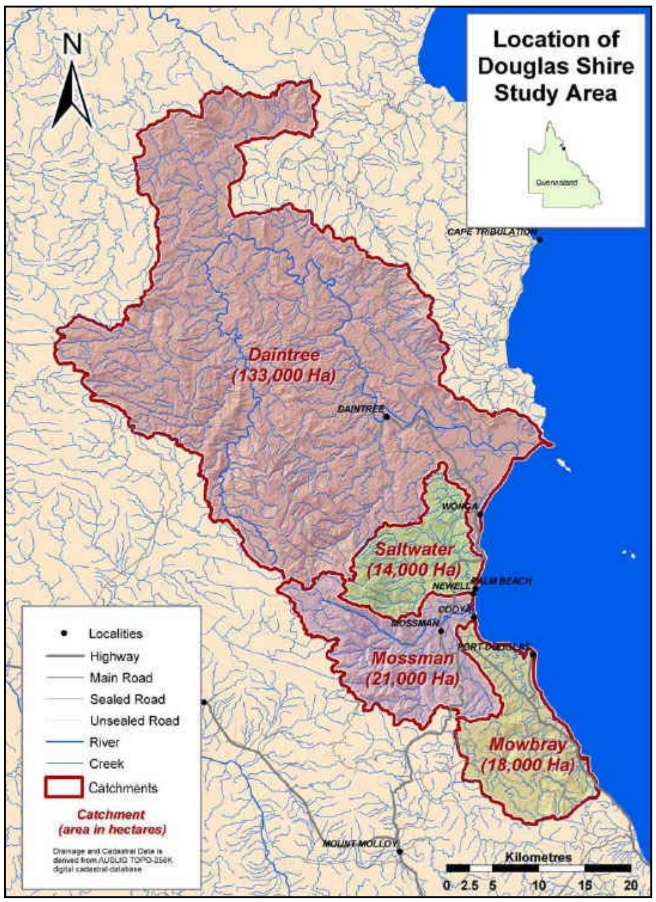

Figure 2.1: Location of Douglas Shire Catchments (Bartley et al., 2004).

2.2 The Douglas Shire economy

With two internationally-renowned tourism destinations in the Shire (Port Douglas and the Daintree National Park), and given its position between the Wet Tropics and Great Barrier Reef World Heritage Areas, tourism is the largest sector of the local economy. Total expenditure on tourist accommodation in the Shire in the year ending September 2003 was $81 million (OESR, 2004b) and additional tourism expenditure by visitors (but excluding spending on 'local tours') to the Daintree National Park was estimated as $93 million

(Kleinhardt, 2002). Even while excluding spending on tours, for example to the Reef off-shore from Port Douglas, the direct value of tourism to the local economy thus approaches $200 million annually.

Agriculture is another important sector of the local economy. The gross value of production in the Shire for the year ending June 2001 was $11.9 million for crops and $1.1 million for livestock (OESR, 2004b). Given a 0.40 ratio of value added to gross value of production for agriculture (Productivity Commission, 2003), this corresponds to an agricultural producer surplus of around $5.2 million.

2.3 Socio-economic indicators

A summary of socio-economic indicators for the Douglas Shire is given in Table 2.1. The estimated resident population for the Shire was 11,525 in June 2003 (OESR, 2004a) and grew at a rate of 2.6% in the preceding 12 months. The projected population of the Shire in 2026 (under a 'medium' growth scenario) is 17,059 (PIFU, 2004). In 2001, the median age was 35 years, while 20% of the population was under 15 and 8% were over 65. The projected median age for 2026 is 45 (PIFU, 2004).

Mean taxable income for Douglas Shire in 2000-01 was $29,810, compared to $34,980 for Queensland (OESR, 2004a). The percentage of the population over aged 15 with post high school educational qualifications in 2001 was 37.3% in the Douglas Shire and 32.3% in Queensland (OESR, 2004a).

Unemployment in Douglas at the time of the 2001 census was 4.8%, which was lower than the 8.2% recorded for Queensland (OESR, 2004a). Accommodation, cafes and restaurants was the largest employer in the region, accounting for 21.6% of the labour force. Employment in the agricultural, forestry and fisheries sector was 6.0% (OESR, 2004a). Of 414 jobs in this sector in the Shire, 168 were associated with sugarcane production, 53 with horticulture, 39 with beef production and 42 with fisheries (ABS, 2001).

Table 2.1: Summary of socio-economic indicators for the Douglas Shire.

Indicator		*Value*
Population, June 2003		11,525
Projected population, 2026		17,059
Annual population growth rate, 2002-2003		2.6%
	median age	35
	percentage <15	20%
Age structure, 2001	percentage >65	8%
Projected median age, 2026		45
	Douglas Shire	$ 29,810
Mean taxable income, 2000/01	Queensland	$ 34,980
Percentage of population >15 years with post high-school qualifications, 2001	Douglas Shire	37.3%
	Queensland	32.3%
	Douglas Shire	4.8%
Unemployment, 2001 census	Queensland	8.2%

3. Methodology

3.1 Assessment of stakeholder attitudes to environmental values and management options

A survey of public attitudes to environmental values for rivers and waters and management options for protection of water quality was done in July 2004. The survey was distributed to every postal address in the Shire (~3900). The survey form is reproduced in Appendix A.

The survey had three parts. In Part 1, the public was presented with a table of EVs and asked to identify how highly they rate the importance of each of the listed features and uses of rivers and waters for a rainforest river and developed freshwater and saltwater reaches. Respondents were asked to separately rate current and future uses for rivers and waters on a scale of 1 (low importance) to 5 (high importance). In Part 2, a table of options for management of sediment and nutrient runoff from agriculture was presented and respondents were asked to rate the expected effectiveness of each option and their support for adoption. Respondents rated their opinion on a scale of 1 (low) to 5 (high). A box was also provided in Part 2 for people to identify the location of their residence. This location was used to allocate data to catchments.

Part 3 of the survey comprised a series of questions used to characterise 'land managers' and was only filled in by those who manage more than 1 ha of land. Respondents were asked to provide data on occupation, land use, labour, income sources and their reasons for managing land. These questions were designed to enable categorisation of land managers using a typology of farmers in the Mossman region developed by Bohnet (2004), and therefore analysis of how stakeholder attitudes vary between land managers and non-land managers and among farm types.

The survey was returned to CSIRO using a reply-paid envelope and all data were recorded in an Excel spreadsheet. Ratings for EVs and management options from Parts 1 and 2 of the survey were compared using the non-parametric Kruskal-Wallis test for ranked data (SYSTAT version 8.0, 1998).

3.2 Analysis of the terrestrial costs and benefits of management options

Estimating the likely costs and benefits for different types of agricultural producers of options for management of sediment and nutrient runoff involved a number of steps:

1. a financial-economic analysis of actual and alternative management practices at the plot level was performed to identify and quantify the financial and environmental differences between management options;
2. a private-economic analysis at the farm level was used to predict the likelihood of adoption of alternative management practices by different types of agricultural producers; and finally
3. an aggregated private-economic analysis at the catchment and Shire level was performed to determine the likely agro-ecological and socio-economic effects of the adoption of alternative management practices by all agricultural producers.

Financial analysis of actual and alternative management practices was done at the plot level for sugarcane and (pasture-based) beef production in the Douglas Shire. Scenarios for

actual and alternative management practices were defined on the basis of expert knowledge, field observations and literature. Input-output data were generated for each scenario using the sugarcane crop growth model APSIM (see for example Keating *et al*., 1999, 2003) and the pasture-based beef production model PASTOR (see for example Bouman *et al*., 1998, 2000). In turn, the net contribution of these actual and alternative management practices (MPs) to total sediment supply at the river mouth was determined using the hydrological model SedNet (see Bartley *et al*., 2004). Finally, the financial implications of input use and output supply for each set of management practices was determined and compared using annuities of net present values (Zerbe and Dively, 1994). All input and output price data were based on the 2002 production year and obtained from the Mossman Agricultural Services (MAS, 2003).

The private economic analysis at the farm level provides insight into the likelihood of adoption of management options by different types of agricultural producers in the Douglas Shire, according to the objectives of each group and the constraints they face. Farm (household) models were developed for the most important types of agricultural producers in the Shire, the specialised cane farmers, mixed farmers (who combine sugarcane and grazing operations) and specialised graziers. Each group was characterised according to their specific objectives (gross income and leisure), agricultural production options (for sugarcane and grazing, as generated by the APSIM and PASTOR models) and agro-ecological as well as socio-economic constraints (see for example Singh *et al*., 1986; Hazell and Norton, 1986; Sadoulet and DeJanvry, 1995; Roebeling *et al*., 2000). Changes in decisions by agricultural producers resulting from the availability of alternative management options and constraints are then reflected in changes in land use, production, gross income, leisure and water pollution indicators (sediment loads and nitrogen leaching).

Under the farm model methodology, multiple-objective programming techniques were applied to determine the most efficient use of the limited resources available to agricultural producers (see Hazell and Norton, 1986; Romero and Rehman, 1989; Leonard and Long, 1992). For the analysis for Douglas Shire, a continuous, concave and (negative exponentially) increasing utility function was defined, in which two objectives, gross income and leisure time, were added through normalised weighted aggregation. Gross income was defined as the gross value from agricultural production, on- and off-farm employment, net of the costs related to the use of labour, agricultural inputs and the purchase of cattle. Leisure time was defined as the farm household labour time that is available for uses other than on- and off-farm employment.

Table 3.1: Farm type characteristics.

	Unit	*Cane farmers*	*Mixed farmers*	*Graziers*
Farm size	ha	90.0	163.0	212.0
Farm labour availability	fte/yr	1.4	1.8	1.0
Hired labour availability	fte/yr	0.2	0.0	0.0
Off-farm employment	fte/yr	0.4	0.3	0.5
Number of farms	#	75	10	20

Source: Bohnet (2004) and Bohnet and Webster (2004, personal communication).

The most important constraints faced by each agricultural producer or farm type were related to the use of production systems, land and labour, as well as the production of cane (see Table 3.1). Production systems available to agricultural producers were sugarcane (cane farmers and mixed farmers) and grazing (mixed farmers and graziers). Land use was constrained to the currently available agricultural area. Available farm household labour could be used for on- and off-farm employment, with the latter constrained to the current level of off-farm employment. Similarly, labour could be hired-in for on-farm agricultural

production up to the current level of engagement. Finally, sugarcane had to be supplied to the mill in equal portions over three harvesting rounds during the crushing season. Available production systems and current levels of available agricultural land, farm household labour, off-farm employment and hired-in labour were determined on the basis of Bohnet (2004).

Finally, aggregated private-economic analysis at the catchment level was used to estimate the likely aggregate agro-ecological and socio-economic effects of the adoption of alternative management practices by all agricultural producers in the Douglas Shire. Outputs from the farm models were aggregated on the basis of the number of farm types in each of the catchments (see for example Bade *et* al., 1997; Kruseman *et al*., 1997; Roebeling *et al*., 2000). In turn, the terrestrial producer surplus is calculated as the aggregate regional value of agricultural production and employment net of corresponding production and labour costs. Note that because the Douglas Shire is a relatively small area with good access to product and factor markets, it is not likely that aggregate product supply or factor demand influences product and factor prices, respectively.

3.3 Analysis of marine costs and benefits of management options

In considering the social and economic impacts of water quality improvement in Douglas Shire, it is important to recognise that in addition to costs and benefits for land managers, improved water quality may have impacts on other sectors of the Shire economy. Thus, while adoption of management for protection of water quality may have costs for land managers, these need to be examined in the context of the downstream benefits to the wider Shire economy of cleaner water. These wider benefits were estimated for marine tourism and the recreational and commercial fisheries. This required three steps:

1. estimation of the effects of agricultural production in the Douglas Shire on water pollution in the GBR lagoon, as outlined above;
2. estimation of the effects of water pollution on reef quality and fish stocks; and
3. quantification of the effects of changes in reef quality and fish stocks on marine-based economic activities.

Estimation of the downstream benefits of water pollution control has not been widely attempted for the GBR in the past, largely because of uncertainties in understanding of the ecological responses of ecosystems to changes in water quality. We have elected to include downstream effects in this assessment as a first step in building an analytical framework which accounts for the costs and benefits of pollution control in both the terrestrial and downstream environments. This initial implementation of the framework is inevitably highly simplified and based on sets of assumptions (as detailed below) that can be improved as further data and knowledge becomes available. Despite these simplifications, the estimation of downstream benefits provides a framework for estimating overall net effects on the Shire of improvements in water quality. Critically, it also provides a means of communicating a more complete picture to stakeholders than has been common in the past of how water quality impacts on upstream and downstream interests. Consequently, stakeholders will obtain a better appreciation of the shared interests they have in issues of water quality and pollution control.

The effects of water pollution in the GBR-lagoon on reef quality and fish stocks were estimated using results from research performed by AIMS, GBRMPA, the Reef-CRC and from evidence from studies in other parts of the world. Table 3.1 summarises the most important studies that analyzed the effects of water pollution on reef quality and fish stocks. It is clear that most of the information is rather qualitative and, also, that not all studies result in similar response reactions. The effects of water pollution on fish stocks, especially, are highly contentious.

In this assessment we considered the effects of sediment loads on reef-wide coral cover (*i.e.* soft and hard coral) and fish biomass, building on relationships estimated by Hodgson and Dixon (1988) (Table 3.2). At this stage, nitrogen (or phosphorus) is not taken into account as: i) the effects of nitrogen (or phosphorus) loads on reef quality and especially fish stocks are poorly understood; ii) the relationship between nitrogen (or phosphorus) and sediment loads has not been quantified; and iii) estimates of nitrogen loads derived from the hydrological model SedNet only account for surface runoff and exclude groundwater flows.

Table 3.2: Effects of water pollution on reef quality and fish stocks.

Study	*Change in runoff or ecosystem.*	*Effects on ecosystem*
Randall & Birkeland (1978)	Decrease in sediment loads from 162-216 $mg/cm^2/d$ to 5-32 $mg/cm^2/d$	Increase in coral species from <10 to over 100 species
Hodgson and Dixon (1988)	Additional 400 t/km^2 of annual sediment deposition	Decrease in coral cover (*i.e.* abundance) of 1 percent
	Additional 100 t/km^2 of annual sediment deposition	Decrease in coral richness of 1 specie
	Complete destruction of coral reef	Decrease in fish abundance of 90%
	Decrease in coral cover of 1%	Decrease in fish abundance of 2.4% per 1% annual loss in coral cover (*i.e.* abundance)
	Reduction in coral richness	Decrease in fish abundance of 0.8% per unit annual loss in coral richness
Koop *et al.* (2001)	Pulse level of 11.5 μM NH_4^+ and 2.3 μM PO_4^{-3}	Settlement of coral larvae is reduced, fewer successfully developed embryos are formed and fertilization rates decrease
	Pulse level of 36.2 μM NH_4^+ and 5.1 μM PO_4^{-3}	Increased coral mortality
	Pulse level of 36.2 μM NH_4^+ and 5.1 μM PO_4^{-3}	No effects on grazing rates and reproductive effort of various fish species
Fabricius and De'ath (2004)	Decrease in water quality[#]	Reduction in total abundance Reduction in coral cover (*i.e.* abundance) and richness
Brodie *et al.* (2004)	Doubling the level of chlorophyll (0.2 to 0.4 mg/m^3)	Survival of COTS larvae is enhanced by 8.6 times
Rogers (1990)	Reduction in coral cover	Decrease in the number of hiding places, which can lead to a reduction in fish abundance and richness

Note: [#] Quantification of the relationship between sediment/nutrient loads and abundance and diversity of coral and fish was not possible on the basis of this article, because a water quality index is used for which base parameter values and calculations are not mentioned in the article (nor were they, so far, available from the author).

The effects of a change in reef quality and fish stocks on marine-based economic activities (*i.e.* marine tourism and the recreational and commercial fisheries) were determined using an analytical framework developed by the World Bank (see for example Ruitenbeek *et al.*, 1999; Cesar et al., 2002). This framework basically assumes a linear relationship between reef quality and fish stocks and the respective local use values (Gustavson and Huber, 2000). Consequently, marine-based producer surpluses, generated by marine tourism and the recreational and commercial fisheries industries, are proportional to reef-wide coral cover and fish biomass, respectively.

Estimates of the gross production value for the marine tourism industry in the Douglas Shire are based on Baker (2000), Tourism Queensland (2004) and GBRMPA (2004), while estimates of the gross production value for the recreational and commercial fisheries industry are based on Fenton and Marshall (2001). Respective marine-based producer surpluses are calculated using value added ratios for each industry (Productivity Commission, 2003). In turn, the total marine producer surplus is calculated as the aggregate regional value of marine-based production net of corresponding production and labour costs.

3.4 Assessment of net welfare effects of management options

The net welfare effects of management options for protection of water quality were assessed by combining the estimates of their costs and benefits for terrestrial and marine economic activities.[6] This allows determination of whether the adoption of management options leads to more (Pareto) efficient levels of resource use and water pollution (Varian, 1992). Put differently, it allows us to determine whether all economic agents in the Douglas Shire together would be better of when agricultural producers in the Douglas Shire adopt specific alternative management options.

There are two assumptions that are worth mentioning with respect to the developed approach. Neither re-suspension of water pollutants nor non-use values of the GBR were taken into account in the developed approach. Roebeling (2004) shows that the costs from water pollution are significantly larger when re-suspension of water pollutants and non-use values of the GBR are taken into account. Consequently, the results presented in this report are based on, most likely, conservative estimates of the total costs associated with water pollution in the Douglas Shire region.

[6] Net welfare is calculated as the sum of terrestrial and marine producer surpluses.

4. Analytical results

4.1 Community attitudes to environmental values for Douglas Shire waterways

A total of 242 responses to the postal survey of community attitudes to EVs and management options were received, comprising 172 from non-land managers, 39 from managers of 1-10 ha and 31 from farmers with >10 ha. This represents a response rate of 6.2%, though given that duplicate forms would have been received in some households because business addresses were included, the true response rate was likely closer to 8-10%. Such a response rate is typical for a mail-out survey.

Ratings of EVs by respondents, under Questions 1 and 2 of the survey, are shown in Figure 4.1 for each river system and grouping of reaches. Mean ratings of importance in the range of 4-5 were regarded as 'high'; ratings of 3-4 as 'medium-high'; ratings of 2-3 as 'medium-low'; and 1-2 as 'low'. Uses of water that are not compatible with saline water – namely irrigation, stock watering and drinking water – were excluded from the data for saltwater reaches.

Key findings were:

- ***Aquatic ecosystems*** and ***aesthetics*** were rated with *high* importance in all reaches of all rivers.
- ***Drinking water*** was given a rating of *high* in all rivers, except for the freshwater reaches of Saltwater Creek, where it was rated as *medium-high*, reflecting people's concerns over the safety of residential water supplies taken from the Shire's rivers. Differences between ratings for aquatic ecosystems, aesthetics and drinking water were not significant ($P<0.05$) for most reaches.
- ***Direct recreation*** was rated as *medium-high* importance in all reaches of all rivers.
- ***Indirect recreation*** was rated as *medium-high* in all saltwater reaches, but *low-medium* in rainforest and freshwater reaches.
- Direct economic uses for water (***agriculture*** and ***aquaculture***) were consistently rated as having *medium-low* or *medium-high* importance. Ratings for aquaculture were highest for saltwater reaches. Ratings were significantly lower ($P<0.05$) for agriculture than aquatic ecosystems in all reaches.
- ***Cultural and spiritual*** features and uses for water were given *low* or *medium-low* importance in Saltwater Creek, *medium-low* importance in Daintree and reached *medium-high* importance in Mossman and Mowbray. Differences between ratings for agricultural and cultural EVs were significant ($P<0.05$) only in Daintree reaches.
- ***Industrial*** uses for water were rated as having *low* or *medium-low* importance.

Ratings of EVs for the future were generally similar to ratings for the current time, though mean ratings of importance tended to be slightly higher for the future (Figure 4.1), perhaps reflecting public aspirations for future improvements in water quality.

Figure 4.2 shows ratings of EVs by different groups of respondents. Data are means for groupings of reaches in all catchments. In general, there was good agreement between groups on ratings of EVs. The high importance attached to aquatic ecosystems and aesthetics was shared by all groups in all river reaches. Non-land managers rated the importance of drinking water in freshwater reaches significantly ($P<0.05$) more highly than land managers.

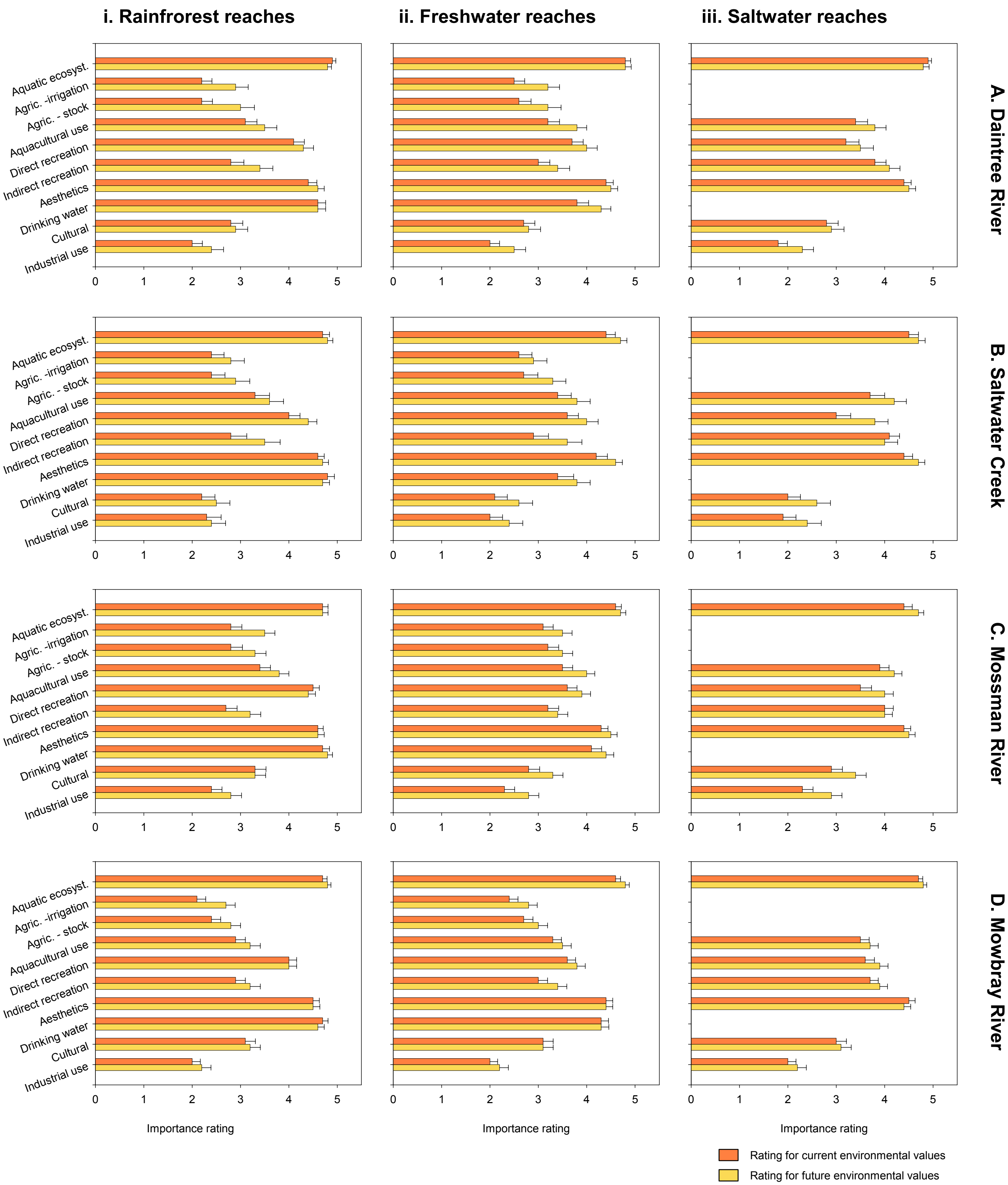

Figure 4.1: Mean rating of importance for current and future Environmental Values for (i) rainforest, (ii) freshwater and (iii) saltwater reaches of the (A.) Daintree River, (B.) Saltwater Creek, (C.) Mossman River and (D.) Mowbray River, on a scale of 1 (low importance) to 5 (high importance). Error bars show +1 standard error.

The most substantial differences between groups related to the direct economic uses for water. Farmers with >10 ha tended to rate use of water for irrigation, stock watering and aquaculture more highly than others, though their ratings for these EVs were still below ratings for aquatic ecosystems and aesthetics. Ratings for agriculture and aquaculture were significantly ($P<0.05$) higher for farmers with >10 ha than others in rainforest reaches. In freshwater reaches, differences between groups were similar, but significant ($P<0.05$) only for stock watering. The high importance attached to aquatic ecosystems and drinking water by all groups of land managers in all catchments indicates that the more stringent objectives for water quality needed to protect these EVs are likely to be supported by the Douglas Shire community.

Results from this assessment of public attitudes to EVs can be compared to ratings determined by participants in the 2003 workshop on draft EVs (see Bennett, 2003). Although results from the workshop and the public survey showed similar tendencies, respondents to the public survey placed a somewhat higher importance on aquatic ecosystems in developed river reaches, aquacultural uses for water, aesthetics and drinking water, while they placed a somewhat lower importance on cultural and spiritual uses for water.

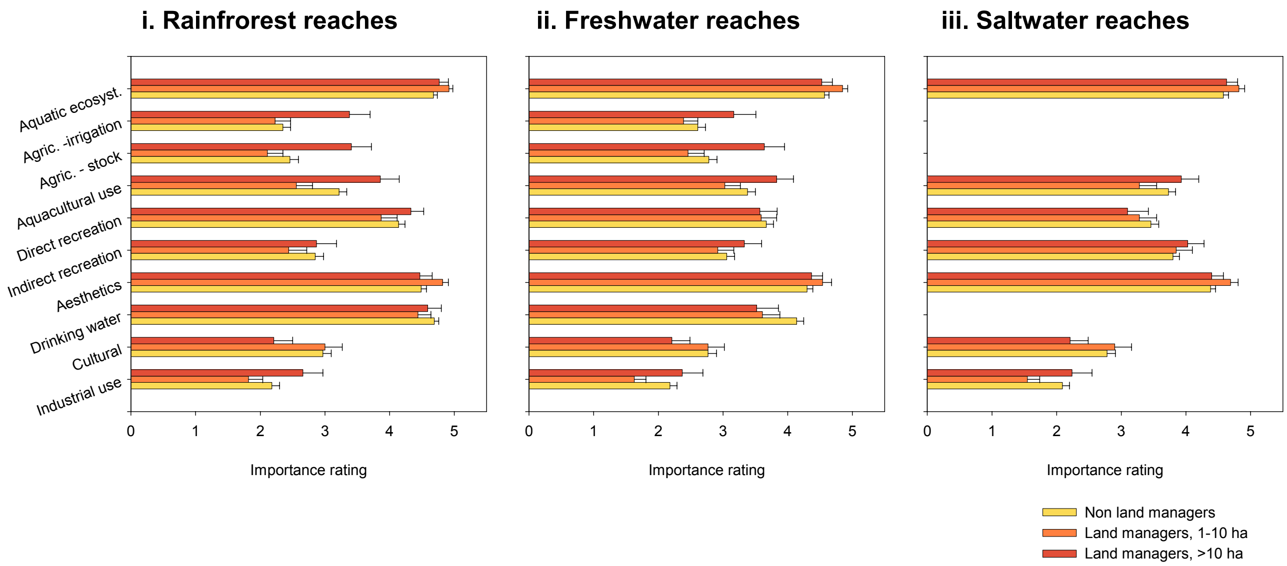

Figure 4.2: Mean rating of current Environmental Values by non-land managers, land managers of 1-10 ha, and land managers of >10 ha, for rainforest, freshwater and saltwater reaches of Douglas Shire waterways, on a scale of 1 (low importance) to 5 (high importance). Error bars show +1 standard error.

4.2 Community attitudes to options for management to improve water quality

Mean ratings of the expected effectiveness and support for adoption of options for management (see Table 1.3) of diffuse sources of sediment and nutrient pollution in Shire waterways are listed in Table 4.1 and 4.2. The data shown are means for the freshwater reaches of all catchments, grouped by type of land-manager. Data for saltwater reaches were very similar.

Mean values indicate that respondents gave a high or medium-high rating to the expected effectiveness and support for adoption of management options. Few differences were

apparent among land-manager types. Examination of data with low ratings, however, provides some clarification. Figure 4.3 shows the percentage of respondents in each group of land managers who scored their support for adoption as 1-3, as opposed to 4 or 5. Several contrasts in ratings of support are then apparent:

- Support for adoption of ***better fertiliser management*** was significantly ($P<0.05$) higher among farmers with >10 ha than non-land managers, as this practice was given a low rating by more non-land managers than farmers with >10 ha. The importance for pollution control of reducing fertiliser inputs may be less well recognised among non-farmers than farmers (or conversely non-land managers may see the suggested controls as inadequate).
- More than 30% of farmers with >10 ha gave a low rating to support for ***exclusion of stock*** from riverbanks, indicating weakness in the support for stock exclusion among farmers, although differences among groups were not significant ($P<0.05$).
- Over 20% of farmers with >10 ha gave a low rating to support for ***riparian vegetation*** and ***wetland restoration*** as a means of pollution control, compared to 12% or less for other groups. Support for adoption was consequently significantly ($P<0.05$) lower among farmers with >10 ha than others. A substantial minority of farmers are thus distrustful of calls for restoration of riparian vegetation and wetlands that are strongly supported in the rest of the community.

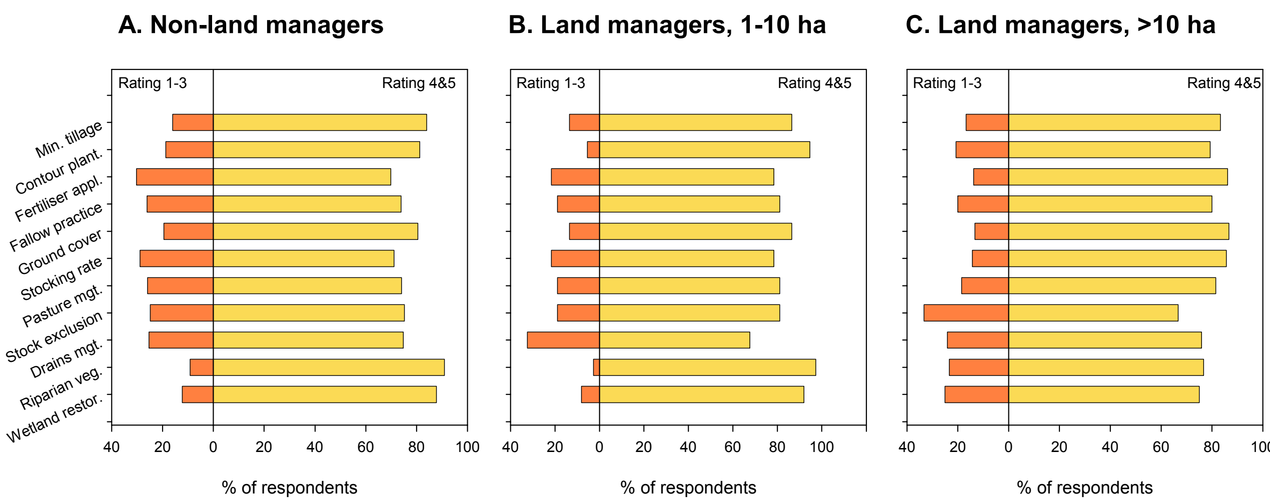

Figure 4.3: Percentage of respondents who scored support for adoption of management options for improving water quality as 1-3 or 4 and 5, among A. non-land managers, B. land managers of 1-10 ha, and C. land managers of >10 ha.

Low ratings of support were given by 20% or more of respondents in the land manager (1-10 ha) and farmers with >10 ha groups for contour planting, fallow practice, stocking rate, stock exclusion, drains management, riparian vegetation and wetlands restoration. Among non-land managers, low support exceeded 20% for fertiliser management, fallow practice, stocking rate, pasture management, stock exclusion and drains management. There are thus sizeable pockets of scepticism about most of the management options for improving water quality in all of the groups surveyed. The differences identified between groups suggest, however, that inclusion of some management options in the Water Quality Improvement Plan may cause division between farmers and other groups, particularly riparian vegetation, wetland restoration and stock exclusion.

Table 4.1: Mean rating of expected effectiveness of options for management of water quality by non-land managers, land managers of 1-10 ha, and land managers of >10 ha in the freshwater reaches of Douglas Shire, on a scale of 1 (low) to 5 (high).

Management Option		*Land managers*	
	Non	*1-10 ha*	*>10 ha*
Minimum tillage	4.3	4.3	4.4
Contour planting	4.2	4.4	3.8
Fertiliser application	3.7	3.9	4.4
Fallow practice	4.1	4.2	4.1
Ground cover	4.2	4.4	4.4
Stocking rate	4.0	4.3	4.4
Pasture management	3.9	4.2	4.3
Exclusion of stock	4.2	4.5	3.8
Drain management	4.1	4.2	4.1
Riparian vegetation	4.6	4.9	4.0
Wetland restoration	4.5	4.8	4.1
	n=162	*n=37*	*n=30*

Table 4.2: Mean rating by non-land managers, land managers of 1-10 ha, and land managers of >10 ha of support for adoption of options for management of water quality in freshwater reaches of Douglas Shire, on a scale of 1 (low) to 5 (high).

Management Option		*Land managers*	
	Non	*1-10 ha*	*>10 ha*
Minimum tillage	4.4	4.5	4.4
Contour planting	4.5	4.5	4.1
Fertiliser application	4.0	4.3	4.5
Fallow practice	4.2	4.3	4.3
Ground cover	4.4	4.6	4.6
Stocking rate	4.1	4.4	4.6
Pasture management	4.2	4.4	4.3
Exclusion of stock	4.2	4.5	3.8
Drain management	4.2	4.1	4.2
Riparian vegetation	4.7	4.9	4.2
Wetland restoration	4.6	4.8	4.1
	n=164	*n=37*	*n=30*

4.3 Terrestrial costs and benefits of management options at the property level

Land managers occupying the largest areas of agricultural land in the Douglas Shire are cane farmers who specialise in sugarcane production, mixed farmers who combine cane and beef production, and graziers who specialise in cattle fattening for beef production. In the Shire there are about 75 cane farmers holding an average of 90 ha of land each, 10 mixed farmers holding 163 ha of land each, and 20 graziers holding 212 ha of land each. These farm types thus cover 105 farm enterprises and 12,620 ha of land in the Shire. Note that farm type numbers are determined on the basis of expert knowledge (personal communication Bohnet and Webster, 2004).

In Table 4.3 the baseline results for each of these farm types are presented. Specialised cane farmers produce almost 9000 t of cane per year, with an average cane yield of 99

t/ha/yr. Off-farm employment utilises just over 25% of total labour availability, and forms an important source of income. Water pollution from sediment run-off amounts to 850 t/yr or 9.4 t/ha/yr, and includes hillslope erosion from sugarcane fields as well as cane drain erosion. Finally, nitrogen use is about 15 t/yr or 170 kg/ha/yr.

Mixed farmers produce just over 14,000 t of cane per year, at cane yields similar to the specialised cane farmers, and, in addition, 8 tonnes of beef per year. Off-farm employment is not an important source of income. Sediment loads per hectare are lower than those for the specialised cane farmers (8.4 t/ha/yr), as part of the land is used for grazing which does not suffer from cane drain erosion.[7] Similarly, the partial focus on livestock production leads to lower levels of nitrogen use compared to the specialised cane farmers (160 kg/ha/yr).

Table 4.3: Baseline results for agricultural producers in the Douglas Shire (annual data per farm of the specified type)

	Unit	*Cane farmers*	*Mixed farmers*	*Graziers*
Objective:				
Gross income[#]	AU$	84,333	148,467	108,340
Leisure	hrs	1,036	1,352	400
Land use:				
Sugarcane	ha	90	143	0
Grazing	ha	0	20	212
Labour use:				
On-farm - hired	hrs	325	0	0
On-farm - own	hrs	643	1,572	504
Off-farm - own	hrs	595	0	721
Production:				
Sugarcane	t	8,924	14,098	0
Beef	t	0	8	85
Water pollution:				
Sediment loads	t	842.5	1,369.1	211.3
Nitrogen use	t	15.3	26.0	20.7

Note: [#] Gross income is defined as the gross margin from agricultural production plus on- and off-farm labour income, *and does not include taxes, fixed asset depreciation and maintenance costs, and capital costs*.

Specialised graziers produce almost 90 tonnes of beef per year, at an average yield of about 175 kg/head/yr and stocking rates ranging from 1.75 head/ha on poorly drained soils to 2.50 head/ha on well drained soils. With almost 45% of the total labour availability used off-farm, off-farm employment is an important source of income. Sediment loads per hectare for grazing are well below those for sugarcane production (1.0 t/ha/yr), due to the absence of cane drain erosion. Nitrogen use per hectare is, also, well below that for sugarcane production (less than 100 kg/ha/yr).

To reduce water pollution in streams and rivers and, eventually, in the GBR-lagoon, a variety of management options have been identified. These management options include reduced tillage systems, fallow practices, more efficient N-application, reduced stocking rates, exclusion of cattle from riverbanks, drain management and restoration of riparian vegetation (Table 1.3). The likelihood of adoption of management practices by farmers was assessed using the methodology outlined in the previous section.

[7] Cane drain erosion is considered the major (human-made) source of sediments in the Douglas Shire (see Bartley *et al*., 2004).

4.3.1 Management practices in sugarcane production

The most important changes to crop management proposed in sugarcane production are reduced tillage systems, fallow practices, and more efficient N-application.[8] Table 4.4 shows the estimated impacts on specialised cane and mixed farmers when reduced tillage systems, fallow practices and/or alternative N-application levels are available for adoption.

Minimum tillage is likely to be adopted by specialised cane and mixed farmers, as it leads to a reduction in production costs as well as labour costs. Minimum tillage is estimated to be beneficial on all soil types, except heavy water logged soils. Compared to the baseline situation presented in Table 4.3, total cane production marginally increases for the specialised cane farmers, while total cane production increases by almost 6% for the mixed farmers as they convert part of their grazing land to sugarcane production. In turn, gross income levels increase by just over 4% and almost 2% for the specialised cane and mixed farmers, respectively. The effects of minimum tillage on water pollution are mixed. While sediment loads from existing cane fields reduce by almost 2% (see specialised cane farmers), the partial shift from beef cattle to sugarcane production[9] leads to a 5% increase in sediment loads and nitrogen use (see mixed farmers).

Table 4.4: Management practice results for sugarcane producers in the DS (annual data per farm of the specified type)

	Unit	*Tillage systems*		*Fallow practices*		*N-application*		*All crop mgmt practices*	
		Cane farmers	*Mixed farmers*	*Cane farmers*	*Mixed farmers*	*Cane farmers*	*Mixed farmers*	*Cane farmers*	*Mixed farmers*
Objective:									
Gross income	AU$	88,003	151,049	100,757	186,064	99,994	176,098	113,862	204,586
Leisure	hrs	1,106	1,493	1,381	1,409	1,376	1,312	1,667	1,636
Land use:									
Sugarcane	ha	90	155	90	155	90	155	90	155
Grazing	ha	0	8	0	8	0	8	0	8
Labour use:									
On-farm - hired	hrs	325	0	325	0	325	0	325	0
On-farm - own	hrs	518	1,431	549	1,515	599	1,611	416	1,288
Off-farm - own	hrs	650	0	345	0	299	0	192	0
Production:									
Sugarcane	t	8,935	14,917	8,628	14,998	7,815	13,761	7,990	14,042
Beef	t	0	3	0	3	0	4	0	3
Water pollution:									
Sediment loads	t	827.1	1,444.0	832.8	1,455.0	842.6	1,472.7	818.2	1,429.7
Nitrogen use	t	15.3	27.0	10.0	17.9	9.9	19.6	7.5	14.2

Managed (legume) fallow practices are also likely to be adopted by specialised cane and mixed farmers, as a legume fallow provides a considerable reduction in production costs and labour costs albeit at a slight reduction in sugarcane yields. Compared to the baseline situation, total cane production by mixed farmers increases by over 6% as they convert part of their grazing land to sugarcane production, while total cane production by specialised cane farmers decreases by just over 3%. Gross income levels, however, increase relative to

[8] See Appendix A in Roebeling *et al.* (2004) for a detailed description of the mentioned management practices in sugarcane production.
[9] The partial shift from beef cattle to sugarcane production is triggered by the larger gross margins that can be obtained from sugarcane production when cultivated using minimum tillage.

the baseline case for both the specialised cane farmers as well as mixed farmers by about 20% and 25%, respectively. Effects on water pollution are, again mixed. Sediment loads from existing cane fields reduce by about 1% (see specialised cane farmers), while the partial shift from grazing to sugarcane production leads to a 6% increase in sediment loads (see mixed farmers). Nitrogen use, on the other hand, decreases by more than 30% due to the reduced fertiliser requirements when a legume fallow is used, especially for plant cane.

More efficient N-application leads to a considerable reduction in fertiliser costs, as compared to the baseline situation, though at a decrease in yield. N-application levels are likely to decrease from 165 kg/ha/yr to 95 kg/ha/yr for well drained soils and to 130 kg/ha/yr for heavy water logged soils. Total cane production by mixed farmers decreases by almost 2.5% as they convert part of their grazing land to sugarcane production, while total cane production by specialised cane farmers decreases by almost 12.5%. Gross income levels, on the other hand, increase by almost 20% for both the specialised cane and mixed farmers relative to the baseline case. Effects on water quality are mixed. Changes in sediment loads from existing cane fields are negligible (see specialised cane farmers), while the partial shift from grazing to sugarcane production[10] leads to a 7.5% increase in sediment loads (see mixed farmers). Nitrogen use, however, decreases by between 25% and 35% for the mixed and specialised cane farmers, respectively.

All management practices together have mixed water quality and positive income effects, albeit at a reduction in sugarcane yields. Compared to the baseline situation, total cane production by mixed farmers decreases marginally as they convert part of their grazing land to sugarcane production, while total cane production by specialised cane farmers decreases by about 10%. Gross income levels increase by over 35% for both types of farmers. Sediment loads decrease by about 3% for the specialised cane farmers, but increase with by about 4% for the mixed farmers. Nitrogen use, on the other hand, is about halved for both types of farmers.

4.3.2 Management practices in cattle production

The most important changes to management proposed in beef cattle production are reduced stocking rates and exclusion of cattle from riverbanks (Table 1.3).[11] Table 4.5 shows the estimated impacts on mixed farmers and specialised graziers of reducing their stocking rates to recommended levels of below 2.0 head/ha.

Compared to the baseline situation, reduced stocking rates lead to relatively small losses in gross income for the mixed farmers (less than 1% decrease), as they convert part of their grazing land to sugarcane production. Gross income losses are, however, much larger for the specialised graziers (over 10% decrease), as they do not have the option to shift to sugarcane production. Effects of the decrease in stocking rates on water quality are, again, mixed. Sediment loads and nitrogen use increase by, respectively, 8% and 4% for the mixed farmers (as they, partly, switch from livestock to sugarcane production), while sediment loads and nitrogen use decrease by, respectively, 8% and 11% for the specialised graziers.

[10] The partial shift from beef cattle to sugarcane production is triggered by the larger gross margins that can be obtained from sugarcane production when cultivated using efficient levels of N application.
[11] See Appendix B in Roebeling *et al*. (2004) for a detailed description of the mentioned management practices in beef cattle production.

Table 4.5: Management practice results for livestock producers in the DS (annual data per farm of the specified type)

	Unit	*Stocking rate*	
		Mixed farmers	*Graziers*
Objective:			
Gross income	AU$	147,991	94,503
Leisure	hrs	1,255	362
Land use:		.	.
Sugarcane	ha	155	0
Grazing	ha	8	212
Labour use:		.	.
On-farm - hired	hrs	0	0
On-farm - own	hrs	1,669	450
Off-farm - own	hrs	0	812
Production:		.	.
Sugarcane	t	15,246	0
Beef	t	3	74
Water pollution:		.	.
Sediment loads	t	1,471.5	194.8
Nitrogen use	t	27.0	18.4

Exclusion of livestock from riverbanks involves fencing of riverbanks and provision of alternative watering points, which leads to a reduction in bank erosion. Like the general management practices discussed below, exclusion of livestock from riverbanks involves a cost without a direct financial return to the farmer. The establishment cost of alternative watering points varies between AU$6,000 (diesel pump) and AU$9,000 (solar pump) for 200 head of cattle, while fencing of the riverbank costs about AU$100 per 100 metres. Note that operation of the diesel pump requires additional fuel and labour costs.

4.3.3 General management practices

General or non production system specific management options include riparian vegetation and cane drain management. These management options involve investment and maintenance costs to the farmer, while they do not provide a direct financial return. Consequently, in the absence of proper incentives or regulations it is not likely that these management options will be adopted by farmers in Douglas Shire.

Riparian vegetation involves the restoration of trees and shrubs along streams and river banks, which may lead to a reduction in sediment and nutrients entering streams and rivers. The benefits of riparian vegetation for control of sediment and nutrient runoff are, however highly contentious and not well quantified (see for example McKergow *et al*., 2004a, 2004b). The establishment costs of a 10 metre wide riparian zone is approximately AU$1,600 per 100 metres of riparian zone.

Cane drains are identified as one of the most important contributors to water pollution in the Shire (see Bartley *et al*., 2004). Cane drain management involves the establishment of spoon-shaped and grass-covered drain banks which reduce sediment and nutrient run-off, while the grass-cover does not impede water flow. Table 4.6 shows the estimated impacts of the (imposed) adoption of spoon shaped cane drains on cane and mixed farmers.

Table 4.6: Cane drain management results for sugarcane producers in the Douglas Shire (annual data per farm of the specified type)

	Unit	*Drain management*	
		Cane farmers	*Mixed farmers*
Objective:			
Gross income	AU$	83,628	145,883
Leisure	hrs	1,019	1,379
Land use:			
Sugarcane	ha	89	140
Grazing	ha	0	22
Labour use:			
On-farm - hired	hrs	325	0
On-farm - own	hrs	637	1,545
Off-farm - own	hrs	618	0
Production:			
Sugarcane	t	8,855	13,783
Beef	t	0	9
Water pollution:			
Sediment loads	t	252.5	417.9
Nitrogen use	t	15.2	25.7

Cane drain management is not likely to be adopted by sugarcane growers, as establishment and maintenance of spoon shaped cane drains requires the input of farm land, capital and labour. Compared to the baseline situation, cane production and gross income levels reduce by about 1% to 2% for the specialised cane and mixed farmers, respectively. Mixed farmers convert part of their sugarcane land to beef cattle production to reduce cane drain erosion and subsequent income effects resulting from cane drain management. Effects on water pollution are, however, spectacular. Sediment runoff from farms is estimated to decline by 70% while nitrogen use decreases marginally.

4.4 Terrestrial costs and benefits of management options at the catchment level

The likely aggregate socio-economic effects of the adoption of alternative management practices by all agricultural producers in the Douglas Shire is obtained through weighted aggregation of the outcomes of the farm models on the basis of the number of farm types in each of the catchments. Table 4.7 shows the estimated total terrestrial producer surplus for all agricultural producers in the Douglas Shire for each of the management practice scenarios.[12]

It is clear from Table 4.7 that the adoption of reduced tillage levels, fallow strategies and/or more efficient N application all lead to an increase in terrestrial producer surplus (up to almost 30%). Cane drain management and the reduction in stocking rate, however, lead to a slight decrease in terrestrial producer surplus (up to 3%).

[12] The baseline terrestrial producer surplus is larger than the 2001 agricultural producer surplus presented in Section 2.2, as the baseline terrestrial producer surplus: i) includes returns from off-farm employment that comprise up to 15% of famers' gross income, ii) is based on 2002 instead of 2001 prices, iii) is based on potential yields that exclude the effect of weeds, pests and diseases, and iv) is based on an optimization approach where resource are used in the most efficient way in a simplified version of the region.

Table 4.7: Terrestrial producer surpluses for management practices (annual data per catchment in million AU$)

Catchment	*Baseline*	*Tillage systems*	*Fallow practices*	*N-application*	*All crop mgmt practices*	*Stocking rate*	*Drain management*
Mowbray	1.65	1.71	1.98	1.95	2.23	1.65	1.63
Mossman	2.49	2.59	2.99	2.95	3.37	2.49	2.47
Daintree	3.28	3.33	3.54	3.51	3.72	3.03	3.27
Saltwater	2.56	2.65	3.07	3.01	3.43	2.55	2.53
Terrestrial producer surplus	9.98	10.28	11.58	11.43	12.75	9.72	9.90

4.5 Marine costs and benefits of management options

As in the previous section, the estimated aggregate water pollution effects resulting from the adoption of alternative management practices by all agricultural producers in the Douglas Shire are obtained through weighted aggregation of the outcomes of the farm models on the basis of the number of farms of each type in each of the catchments. Table 4.8 shows the estimated total sediment loads produced by all agricultural producers in the Douglas Shire for each of the management practice scenarios.

Table 4.8: Sediment loads for management practices (annual data per catchment in tonnes)

Catchment	*Baseline*	*Tillage systems*	*Fallow practices*	*N-application*	*All crop mgmt practices*	*Stocking rate*	*Drains management*
Mowbray	37,000	36,867	36,994	37,213	36,672	37,209	25,850
Mossman	46,000	45,805	45,956	46,217	45,571	46,213	29,353
Daintree	198,000	197,971	198,062	198,219	197,833	197,906	189,073
Saltwater	41,000	40,956	41,119	41,397	40,712	41,365	23,963
Total	322,000	321,599	322,132	323,045	320,787	322,693	268,239

Table 4.8 indicates that the identified management practices in sugarcane production (*i.e.* reduced tillage, fallow strategies and efficiency in N application) have a mixed and relatively small net effect on sediment loads. If all of these management practices would be adopted, which is likely given their positive income effects, total sediment supply would decrease by less than 0.5%. The proposed reduction in stocking rates has a small though negative impact on water quality, as the associated reduced profitability in beef cattle production provides an incentive to mixed farmers to reduce their grazing land in favour of sugarcane production. Finally, cane drain management leads to a significant decrease in total sediment supply (over 15% decrease in sediment loads), though this comes at a cost to the agricultural sector (see Table 4.7).

Subsequent effects of changes in sediment loads on the quality of the reef (in terms of soft and hard coral cover) and fish stocks (in terms of fish biomass) are determined on the basis of Hodgson and Dixon (1988). They show that coral cover decreases by 0.25% per additional kilotonne of sediment per km^2, while fish biomass decreases by 2.4% per 1% loss in coral cover (see Table 3.2).

Given these relationships between sediment loads, reef quality and fish stocks, we see from Table 4.9 that the effects of changes in sediment loads on coral cover and fish biomass are small for the different management practice scenarios. While the adoption of all sugarcane management practices together would lead to a marginal increase in coral cover and fish

biomass (less than 0.25% increase), model estimations suggest that the adoption of spoon shaped cane drains would lead to an important increase in coral cover and fish biomass (10% and 6% increase, respectively).

Table 4.9: Reef status and fish biomass for management practices (annual data)

Indicator	*Baseline*	*Tillage systems*	*Fallow practices*	*N-application*	*All crop mgmt practices*	*Stocking rate*	*Drains management*
Coral cover (%)	26.5	26.5	26.5	26.4	26.6	26.5	29.2
Fish biomass (t)	1,024.8	1,025.3	1,024.6	1,023.5	1,026.3	1,023.9	1,090.9

Finally, the effect of a change in reef quality and fish stocks on marine-based economic activities is determined by: i) assuming the tourism industry producer surplus is proportional to coral cover and fish biomass, and ii) assuming the recreational and commercial fisheries industries producer surpluses are proportional to fish biomass.

Table 4.10: Marine-based producer surpluses for management practices (annual data per industry in million AU$)

Industry	*Baseline*	*Tillage systems*	*Fallow practices*	*N-application*	*All crop mgmt practices*	*Stocking rate*	*Drains management*
Marine tourism	9.27	9.28	9.27	9.24	9.30	9.25	10.81
Commercial fishery	3.31	3.31	3.31	3.31	3.32	3.31	3.52
Recreational fishery	5.67	5.68	5.67	5.67	5.68	5.67	6.04
Marine producer surplus	18.25	18.27	18.25	18.21	18.30	18.23	20.37

Table 4.10 summarises the economic impact of management practice scenarios for the marine tourism and the recreational and commercial fisheries industries. The marine tourism sector is clearly the biggest of the marine-based economic sectors, with a producer surplus of almost 10 million AU$ per year or 50% of the total marine producer surplus. Also, the marine tourism industry benefits most from improved water quality, as reef quality as well as fish abundance are important sales arguments for this industry.

As the effects of most of the proposed management practices on sediment loads and, in turn, reef quality and fish stocks are relatively small, the gains from these management practices for the marine-based economic sectors are limited. The adoption of all sugarcane management practices together would lead to a marginal increase in total marine producer surplus (less than 0.5% increase), while the adoption of spoon shaped cane drains would lead to a more substantial increase in marine producer surplus (over 10% increase).[13]

---

[13] Results may be quite different when we also take the effect of N-loads on reef quality and fish stocks into account. Table F1 presents a comparison between preliminary calculations on nitrogen loads (based on SedNet; see Bartley *et al*., 2004) and the earlier presented sediment loads. Note that the presented changes in N loads are a result from changes in N surface run-off only.

Table F1: Sediment and nitrogen loads for management actions (annual data in tonnes)

Indicator	Baseline	Tillage systems	Fallow practices	N-application	*All crop mgmt practices*	Stocking rate	Drain management
Sediment loads	322,000	321,599	322,132	323,045	320,787	322,693	268,239
Nitrogen loads	1,566	1,569	1,427	1,431	1,363	1,538	1,562

With the exception of drain management, we see that the evaluated management actions are, generally, more effective in reducing N-loads than in reducing sediment loads. Also note that for all (individually analyzed) management actions a reduction in sediment loads is accompanied by an

The benefits of control of sediment and nutrient runoff from the Douglas Shire catchments for the marine-based industries is likely to be higher than estimated using the current analytical framework. First, no accounting of multiplier effects for the local economy has been made and thus, for example, effects of higher earnings from reef tourism on spending by visitors on accommodation has not been assessed. Second, the current analytical framework does not include the effects of nutrient pollution, especially by N and P, on marine systems. As development of the analytical framework continues and estimates of these effects are incorporated, the estimated size of downstream benefits from pollution control will grow. Thus, the current estimates of benefits are based on a simplistic analytical framework, but they are conservative and likely to be underestimates of the true value of the benefits of pollution control for marine-based industries.

4.6 Net welfare effects of management options

Comparison of Table 4.7 and Table 4.10 allows us to assess the net welfare effects resulting from the adoption of alternative management practices. Results of this comparison are summarised in Table 4.11, which shows the terrestrial and marine producer surpluses as well as net welfare for the different management practices.

Table 4.11: Producer surpluses and net welfare for management practices (annual data per industry in million AU$)

Economic sector	*Baseline*	*Tillage systems*	*Fallow practices*	*N-application*	*All crop mgmt practices*	*Stocking rate*	*Drains management*
Terrestrial producer surplus	9.98	10.28	11.58	11.43	12.75	9.72	9.90
Marine producer surplus	18.25	18.27	18.25	18.21	18.30	18.23	20.37
Net welfare	28.23	28.55	29.83	29.64	31.05	27.95	30.27

Apart from the reduction in stocking rates, all proposed management practices lead to an increase in net welfare. While a reduction in stocking rates would lead to a less than 1% decrease in net welfare, the adoption of all sugarcane management practices together would lead to a 10% increase in net welfare. Adoption of spoon shaped cane drains would lead to a more than 7% increase in net welfare, indicating that it is economically feasible to compensate farmers for the construction and maintenance of spoon shaped cane drains.

increase in N-load, and vice versa. Finally, we see that all sugarcane management actions together and drain management lead to a reduction in sediment loads as well as a reduction in N-loads.

5. Relative Acceptability of Practices to Improve Water Quality

5.1 Social and economic impacts at the property level

At the property level, the social and economic impacts of options for control of water pollution on individuals and households are of primary concern. Outputs from the economic modelling described in Section 4 provide estimates of costs and benefits at the farm scale. These are summarised qualitatively in Table 5.1.

Gauging social impacts at the property level is more difficult. However, the economic modelling provides a useful proxy indicator for social and economic effects on individuals and households. Computed changes in leisure time resulting from implementation of management options reflect time available to address social needs and obligations, whether within the household or the community. Effects of management options on leisure time are summarised in Table 5.1.

Table 5.1: Summary of estimated effects of options for control of diffuse sources of water pollution on gross income, on-farm labour and leisure time for sugarcane, mixed and beef farms. Symbols: +/ –, <10% change; ++/—, >10% change; ., no estimate available; (–) qualitative estimate based on costs given in Section 4.

Practice	*Farm type*	*Gross income*	*On-farm labour*[1]	*Leisure time*
Minimum tillage	cane	+	++	+
	mixed	+	+	+
Fallow practice	cane	++	++	++
	mixed	++	+	+
Fertiliser mgmt	cane	++	+	++
	mixed	++	+	–
Combined[2]	cane	++	++	++
	mixed	++	++	++
Drains mgt.	cane	–	+	–
	mixed	–	+	+
Stocking rate	mixed	–	–	–
	graziers	––	+	–
Stock exclusion	mixed	(––)	(–)	(–)
	graziers	(––)	(–)	.
Riparian revegetation	all	(––)	.	.

[1] Reduction in labour use assumed beneficial (+).
[2] System combining minimum tillage, legume fallows and optimal fertiliser management.

Table 5.1 shows that within the dominant agricultural industries in the Shire, minimum tillage, fallow practice and optimal fertiliser management are likely to have the highest economic and social acceptability at the property level. Cost implications will result in lower acceptability for improved drains management, reduced cattle stocking rate, stock exclusion and riparian revegetation. Lower leisure time also suggests lower social acceptability for these options. Additionally, however, the almost total lack of benefits to the grazing industry in the Shire from options for control of water pollution means that these options are likely to cause division between the grazing and wider community, at least unless some form of compensation is available.

Results from the postal survey of attitudes in the community to action on water quality improvement indicate that broad support exists for implementation of these types of

measures on farms. Both non-land managers and managers of smaller landholdings rated protection of aquatic ecosystems and landscape aesthetics highly and expressed generally strong support for adoption of pollution control options on farms. Thus, outside of the grazing and cane farming communities, the acceptability of on-farm options for water quality improvement is likely to be high. However, higher levels of distrust of some options among farmers and concerns over costs at the property level show that there is the potential for division between farmers and others in the community over the acceptability of some options, particularly riparian vegetation, wetland restoration and stock exclusion.

5.2 Social and economic impacts at the Shire level

The implications at the Shire level of proposed management options for improving water quality are summarised in Table 5.2. These effects were derived by considering how the analytical results in Section 4 can be expected to affect the set of socio-economic indicators for Douglas Shire provided in Table 5.2. The principal impacts identified are that:

- Action taken to improve water quality in the Shire catchments will contribute to the maintenance of environmental quality and therefore the maintenance of the attractiveness of Douglas Shire as a place to live. Improving water quality is thus likely to sustain projections of future population growth and, without inward migration of young people, the projected ageing of the Shire population (Table 2.1).
- Modelling results show that adoption of best-practice in sugarcane cropping (eg. minimum tillage, legume fallows and optimal N fertiliser management) is likely to improve profitability in the growing sector of the sugar industry. Improved management of cane drains and riparian revegetation, however, will reduce gross income for growers. Management practices in cane farming are likely to put downward pressure (by up to an estimated 9%) on cane supply to the Mossman sugar mill and therefore aggravate financial pressures in the cane transport and milling sectors, raising the risk of reduced employment in these activities. Thus, while action to improve water quality offers environmental ‘win-wins’ for the growing sector, the mill and therefore the regional industry may be destabilised by changes in cane supply without appropriate policies to mitigate these effects.
- Reducing the impact of the grazing industry on water quality the Shire is focused on reducing stocking rates and exclusion of stock from riparian zones. Both practices impose costs on the industry without direct revenue benefits. Thus, options for managing water quality in the local beef industry will likely destabilise the grazing community and cause reduced levels of gross incomes and employment in the sector, at least without appropriate policies to mitigate these impacts.
- Higher water quality will help to sustain the attractiveness of the Shire as a tourism destination. Results from economic modelling indicate that higher water quality will contribute to growth in the tourism sector, directly in reef tourism and recreational fishery and indirectly through spin-off benefits to the sector as a whole. Possible growth in tourism-related jobs could attract young people to employment in the Shire, slowing the projected ageing of the population (Table 2.1).
- Modelling results indicate that gross income levels in the cane production and tourism sectors are likely to move upwards under management to improve water quality. As the two principal economic sectors in the Shire, improving water quality is likely to contribute to growth in average incomes in the Shire.
- Improvements to infrastructure aimed at reducing point source pollution (Table 1.2) of Shire waterways will, in the main, require public-spending on upgrading sewage treatment, roads and stormwater management. Funding for these upgrades could put upward pressure on local rates.

Table 5.2: Implications of management options for water quality improvement on socio-economic indicators for the Douglas Shire. Entries in the table were derived from interpretation of the analytical results presented in Section 4.

Sector	*Action*	*Population & growth rate*	*Median age*	*Income*	*Employment*
Sugar industry	• Cropping system best mgmt practices • Drains management • Riparian vegetation & wetlands	• Maintains attractiveness of Shire as a place to live; therefore sustains projected population growth.	• Projected changes in population sustained.	• Cropping system best mgmt practices improve profitability of cane growing and increase terrestrial producer surplus in the Shire. • Drains management and riparian revegetation detract from income. • Benefits depend on stability of the sugar mill.	• Reduced on farm labour requirements, but most labour from farm household and therefore effects on employment small. • Reduced cane supply would exacerbate instability in the milling and transport sector, raising the risk of reduced employment in milling and transport.
Grazing	• Stocking rates • Stock exclusion	• Maintains attractiveness of Shire as a place to live; therefore sustains projected population growth.	• Projected changes in population sustained.	• Income from grazing reduced.	• Fewer jobs in grazing sector.
Horticulture & aquaculture	• Cropping system best mgmt practices • Enhanced control of point source pollution from aquaculture	• Maintains attractiveness of Shire as a place to live; therefore sustains projected population growth.	• Projected changes in population sustained.	• Effects small at the Shire level as these industries currently small.	• Uncertain, as effects of best mgmt practices in horticulture not assessed and changes in aquaculture not specified.
Infrastructure	• Sewage treatment & sewerage • Road sealing • Erosion control from development sites • Stormwater control	• Improvements to infrastructure will reduce the water quality impacts and sustain population growth.	-	• Upgrades in public infrastructure require funding from tax revenues.	• Employment created in the near term in implementation of upgrades to infrastructure.
Tourism	• Cumulative effects of action to improve water quality. • (Direct costs to tourism sector)	• Improved water quality will sustain the attractiveness of the Shire as a tourism destination.	• New jobs in tourism may attract young people to the Shire, thus slowing the projected ageing of the population	• Improvements in water quality may sustain higher income from tourism.	• Potential for new jobs in tourism because of income growth.

6. Conclusions

The social and economic assessment of the WQIP was designed to enable incorporation of information on community attitudes and the costs and benefits of pollution control into the planning process. Community attitudes to Environmental Values for rivers and waters, perceptions of the effectiveness of management options and support for adoption were surveyed, as these may affect the acceptability of the Plan to members of the community. An economic modelling approach was developed to enable comparison of the costs and benefits of alternate management strategies for improving water quality at both the property and catchment or Shire scales.

Results from the survey of community attitudes to control of water pollution showed that Environmental Values associated with aquatic ecosystems, aesthetics and drinking water quality are rated as highly important by both land managers and non-land managers. Environmental Values related to, for example, agriculture, recreation and cultural values were rated with lower importance. These results indicate that setting water quality objectives and selecting management actions under the Plan with reference to aquatic ecosystems, drinking water quality and preservation of landscape character are likely to be widely accepted in the community. Setting objectives with reference, for example, solely to agriculture, recreation or cultural values is more likely to invoke a sceptical response in some parts of the community.

Conclusion 1: Water quality objectives set under the WQIP should be justified with reference to aquatic ecosystems, aesthetics or drinking water quality. Other Environmental Values should be used in setting and communicating water quality objectives only alongside these priority values.

Management options for improving water quality listed in the public survey were, on average, rated by respondents with high or medium high expectation of effectiveness and support for adoption. However, 20% or more of respondents were sceptical of many options and, despite a generally favourable view of management options by the majority, there is a sizeable minority who hold negative views and will likely greet management options within the WQIP with scepticism. Moreover, there was an indication that scepticism of stock exclusion, riparian revegetation and wetland restoration is higher among farmers (of >10 ha) than other groups. These practices are thus likely to create division between farmers and others, which is especially significant as it is largely farmers who would be asked to implement these practices.

Conclusion 2: Support for most options for managing diffuse sources of water pollution in the Douglas Shire community is generally high. However, the acceptability of stock exclusion, riparian revegetation and wetland restoration is lower among farmers with larger landholdings.

Analysis of the costs and benefits of on-farm management options at the property level showed that the adoption of the nominated changes in the sugarcane cropping system (minimum tillage, legume fallows and optimal management of N fertiliser) would create positive economic and social benefits for farmers. Impacts on sediment runoff were estimated to be small, but the estimated reduction in N fertiliser use was substantial.

Conclusion 3: Best-practice management of tillage, fallows and fertilisers on sugarcane farms is likely to have high economic and social acceptability. Adoption of these practices is therefore likely to occur provided, for example, that there is adequate technical guidance, extension support and on-farm demonstrations.

Improved management of drains in the sugarcane production areas of the Douglas catchments has been estimated to have a large effect on sediment runoff from farms. However, this benefit comes at a net cost to farmers and is therefore unlikely to be adopted by farmers without regulation or incentives.

Conclusion 4: Best-practice drains management on sugarcane farms is likely to have low economic acceptability. Incentives which support adoption would thus likely increase acceptability.

Both reduced stocking rates and exclusion of stock from riparian areas impose costs on graziers without direct revenue benefits and reduce leisure time. At the property level, therefore, there is likely to be considerable resistance to adoption of these measures.

Conclusion 5: Best-practice management of grazing land entailing reductions in stocking rates (maximum 2 head/ha) and exclusion of stock from riverbanks will have low economic and social acceptability. Incentives for graziers could increase acceptability.

Riparian revegetation similarly imposes a cost on landholders without revenue benefits. In the absence of a personal commitment by landholders (ie. individual preference) to riparian restoration or support by the community, riparian restoration is unlikely to be implemented. A similar conclusion can be drawn for wetland restoration.

Conclusion 6: Riparian revegetation and wetland restoration are likely to have low economic acceptability at the property level. Incentives for implementation or community-based action (eg. under Landcare-type arrangements) would increase acceptability.

At the Shire level, the benefits of pollution control for marine-based industries (reef tourism and fisheries in this analysis) are estimated to exceed the costs (or amplify the benefits) for agricultural producers of sugarcane production best management practices and drains management. Only costs to graziers resulting from reduced stocking rates are higher than the benefits for marine industries estimated using the current analytical framework. Net welfare effects from stock exclusion, riparian revegetation and wetland restoration will depend on the size of costs relative to the benefits for marine-based industries. Benefits for marine industries will be higher if assessed using a more comprehensive analytical framework which includes, especially, the benefits for marine environments of reduced N and P runoff from catchments. At the Shire level, the net welfare effects from terrestrial pollution control measures are therefore positive, and likely to grow in size as the sophistication of the methods applied to this assessment improves.

Conclusion 7: Action to improve water quality in the Douglas Shire catchments is likely to have high social and economic acceptability at the whole Shire level because of net positive income and employment effects. These effects result from the combined positive outcomes for agriculture from some practices and the benefits of reduced pollution of the marine environment for the tourism and fisheries industries.

Net benefits at the whole Shire level, however, need to be weighed against impacts on industries at the Shire level. In the case of the sugar industry, practices taken to reduce water pollution caused by sugarcane cropping will create income benefits among growers, although these would be offset in part by the costs of improving drains management. These effects would be accompanied by negative impacts on the Mossman sugar mill for fertiliser management, combined cropping best management practices, and to a lesser degree drains

management, caused by a reduction in cane supply. Thus, there is a danger that adoption of fertiliser best management practices in sugarcane production creates income benefits for growers but causes financial instability at the mill. Such an effect would threaten jobs in the milling and cane transport sectors of the Mossman sugar industry, and if serious enough, threaten the stability of the industry in general.

Conclusion 8: Action to control water pollution through improved fertiliser management may reduce cane supply to the mill and increase instability in the Shire sugar industry. Improved drains management may have a similar though smaller effect on cane supply. Thus, at the Shire level, action to control water pollution by sugarcane growers may have low economic and social acceptability among stakeholders in the sugar industry, unless negative impacts on the sugar mill can be offset.

Similarly, the cumulative effects of action on water quality for the grazing industry will be negative at the Shire level. Changes in grazing management are likely to reduce incomes and employment in the industry.

Conclusion 9: Action by graziers to improve water quality is likely to reduce the size and value of the Shire grazing industry. Such action will thus have low social and economic acceptability among stakeholders in the grazing industry.

Net welfare benefits for the Shire may also be offset by the costs of infrastructure improvements needed to reduce point source pollution of waterways. The acceptability of these actions depends principally on support for public-spending on water pollution control. Such spending is shared across the community and can be linked to high ratings given by the community to, for example, protection of aquatic ecosystems. Thus, such spending may have high social and economic acceptability.

Conclusion 10: Public-spending on improving infrastructure to reduce point source pollution of waterways may have high acceptability where costs are seen by the community as good value relative to the environmental protection achieved.

In summary, options for management of water quality in the Douglas Shire appear generally to have high social and economic acceptability for the Shire as a whole. However, there are specific risks associated with impacts on particular industries that indicate that the WQIP may have low acceptability among certain groups of stakeholders. Negative effects are likely to impact most heavily on the transport and milling sectors in the sugar industry and the grazing industry. Thus, in developing policy to support the implementation of the WQIP, the needs of these sectors should be treated as priorities.

7. References

Australian Bureau of Statistics (ABS), 2001. Integrated regional database: Geographical statistics platform. ABS, Canberra, Australia.

Bade, J., H. Hengsdijk, G. Kruseman, R. Ruben and P.C. Roebeling, 1997. Farm household modelling in a regional setting: the case of Cercle Koutiala, Mali. DLV-report No.6. AB-DLO/WAU, Wageningen, The Netherlands. 39 pp.

Baker, B., 2000. Douglas Shire Tourism 1999-2000 Visitor Survey Statistics. Report prepared for Paul Walker's Douglas Shire Tourism Project. CSIRO, unpublished data.

Bartley, R., A. Henderson, G. Baker, M. Bormans and S. Wilkinson, 2004. Patterns of erosion and sediment nutrient transport in the Douglas Shire catchments (Daintree, Saltwater, Mossman and Mowbray), Queensland. CSIRO Land and Water Client Report, Atherton, Australia. 61pp.

Bennett, J., 2003. Towards establishment of Environmental Values and Water Quality Objectives for Douglas Shire waterways. Draft Report. Queensland Environmental Protection Agency, July 30, 2003.

Bohnet, I., 2004. Agricultural landscapes in the wet tropics. Future visions balancing environmental, social and economic needs. CSIRO-Sustainable Ecosystems, Atherton, Australia. 16 pp.

Bouman, B.A.M., A. Nieuwenhuyse and H. Hengsdijk, 1998. PASTOR: a technical coefficient generator for pasture and livestock systems in the humid tropics, version 2.0. Quantitative Approaches in Systems Analysis No.18. AB-DLO/C.T. de Wit Graduate school for Production Ecology. Wageningen, The Netherlands. 59 pp., plus appendices.

Bouman, B.A.M., H.G.P. Jansen, R.A. Schipper, H. Hengsdijk and A. Nieuwenhuyse (Eds), 2000. Tools for land use analysis on different scales: With case studies for Costa Rica. Kluwer Academic Publishers, Dordrecht, The Netherlands. 274 pp.

Brodie, J., K. Fabricius, G. De'ath and K. Okaji, 2004 (in press). Are increased nutrient inputs responsible for more outbreaks of Crown-of-Thorns Starfish? An appraisal of the evidence. Australian Centre for Tropical Freshwater Research, James Cook University, Townsville.

Cesar, H., P. van Breukingen, S. Pintz and J. Dierking, 2002. Economic valuation of the coral reefs of Hawaii. Hawaii Coral Reef Initiative Research Program, Hawaii, U.S.A.. 123 pp.

Douglas Shire Council (DSC), 2004. Determination and demonstration of agricultural best management practices in the Saltwater Creek catchment of Douglas Shire. DS-WQIP Milestone Report for P2A7, Douglas Shire, Queensland, Australia. 3 pp.

Douglas Shire Council (DSC), 2003. Determine best management practices for all agricultural practices in the Douglas Shire. Milestone report for P1A2, Douglas Shire, Queensland, Australia. 16 pp.

Fabricius, K.E. and G. De'ath, 2004. Identifying ecological change and its causes: A case study on coral reefs. Ecological Applications 14(5): 1448-1465.

Fenton, D.M. and N.A. Marshall, 2001. A guide to the fishers of Queensland, part A: TRC analysis and social profiles of Queensland's commercial fishing industry. CRC Reef Research Centre Technical Report No. 36, Townsville.

Great Barrier Reef Marine Park Authority (GBRMPA), 2004. Data from Environmental Management Charge, http://www.gbrmpa.gov.au/corp_site/key_issues/tourism/gbr_visitation/page_02.html, viewed on 31-06-2004, Townsville, Australia.

Gustavson, K. and R.M. Huber, 2000. Ecological Economic Decision support modelling for the integrated coastal zone management of coral reefs'. In: H.S.J. Cesar (ed.) Collected Essays on the Economics of Coral Reefs. CORDIO, Department for Biology and Environmental Science, Kalmar University, Kalmar, pp. 183-202.

Hazell, P.B. and R.D. Norton. 1986. Mathematical programming for economic analysis in agriculture. Collier MacMillan Publishers., London, UK. 400 pp.

Hodgson, G. and J.A. Dixon, 1988. Logging versus fisheries and tourism in Palawan. Occasional Paper, Vol. 7, East-West Environment and Policy Institute, Hawai.

Keating, B.A., M.J. Robertson, R.C. Muchow and N.I. Huth, 1999. Modelling sugarcane production systems I. Development and performance of the sugarcane module. Field Crops Research 61: 253-271.

Keating, B.A., P.S. Carberry, G.L. Hammer, M.E. Probert, M.J. Robertson, D. Holzworth, N.I. Huth, J.N.G. Hargreaves, H. Meinke, Z. Hochman, G. McLean, K. Verburg, V. Snow, J.P. Dimes, M. Silburn, E. Wang, S. Brown, K.L. Bristow, S. Asseng, S. Chapman, R.L. McCown, D.M. Freebairn and C.J. Smith, 2003. An overview of APSIM, a model for farming systems simulation. European Journal of Agronomy 18: 267-288.

Kleinhardt, 2002. Tourism and recreation values of the Daintree and Fraser Island. Consulting report prepared for the Australian Tropical Research Foundation (AUSTROP). March 2002. 58 pp.

Koop, K., D. Booth, A. Broadbent, J. Brodie, D. Bucher, D. Capone, J. Coll, W. Dennison, M. Erdmann, P. Harrison, O. Hoegh-Guldberg, P. Hutchings, G.B. Jones, A.W.D. Larkum, J. O'Neill, A. Steven, E. Tentori, S. Ward, J. Williamson and D. Yellowlees, 2001. ENCORE: The effect of nutrient enrichment on coral reefs - synthesis of results and conclusions.' Marine Pollution Bulletin, vol. 42(2): 91-120.

Kruseman, G., H. Hengsdijk, R. Ruben, P. Roebeling and J. Bade, 1997. Farm household modelling system for the analysis of sustainable land use and food security: theoretical and mathematical description. DLV Report No.7. AB-DLO/WAU, Wageningen, The Netherlands. 56 pp.

Leonard, D. and N. van Long, 1992. Optimal control theory and static optimization in economics. Cambridge University Press, Cambridge, UK. 353 pp.

McKergow, I.P. Prosser, R.B. Grayson and D. Heiner, 2004a. Performance of grass and rainforest riparian buffers in the wet tropics, Far North Queensland. 1. Riparian hydrology. Australian Journal of Soil Research 42: 473-484.

McKergow, I.P. Prosser, R.B. Grayson and D. Heiner, 2004b. Performance of grass and rainforest riparian buffers in the wet tropics, Far North Queensland. 2. Water quality. Australian Journal of Soil Research 42: 485-498.

Office of Economic and Statistical Research (OESR), 2004a. Local government area profile: The Douglas (S) region. Queensland Government, Brisbane, Australia. 11 pp.

Office of Economic and Statistical Research (OESR), 2004b. Queensland regional profiles 2003: Far North statistical division. Queensland Government, Brisbane, Australia. 17 pp.

Planning Information and Forecasting Unit (PIFU), 2004. Population and housing fact sheet: Douglas Shire. Queensland Government – Department of Local Government, Planning, Sport and Recreation, Brisbane, Australia. 2 pp.

Productivity Commission, 2003. Industries, land use and water quality in the Great Barrier Reef catchment, Research Report, Canberra, Australia. 415 pp.

Randall, R. H. and C. Birkeland, 1978. Guam's reefs and beaches - Part II: Sedimentation studies at Fouha Bay and Ylig Bay. University of Guam Marine Laboratory, Report No 47, University of Guam, Mangilao, Guam.

Roebeling, P.C., 2004. Efficiency in GBR water pollution control: A case study for the Douglas Shire. Paper presented at the Natural Resource Modelling World Conference, 12-15 December 2004, Melbourne, Australia. 14 pp.

Roebeling, P.C., D.M. Smith, J. Biggs, A.J. Webster, and P. Thorburn, 2004. Private-economic analysis of drivers promoting the adoption of best management practices for water quality improvement in the Douglas Shire: Report on the cost-effectiveness of BMP implementation for water quality improvement. Report prepared for the Douglas Shire Water Quality Improvement Program, CSIRO-Sustainable Ecosystems, Townsville, Australia. 95 pp.

Roebeling, P.C., H.G.P. Jansen, R.A. Schipper, F. Sáenz, E. Castro, R. Ruben, H. Hengsdijk and B.A.M. Bouman, 2000. Farm modelling for policy analysis on the farm and regional level. Pages 171-198 in: Bouman, B.A.M., H.G.P. Jansen, R.A. Schipper, H. Hengsdijk and A. Nieuwenhuyse (Eds) Tools for land use analysis on differrent scales: With case studies for Costa Rica. Kluwer Academic Publishers, Dordrecht, The Netherlands. 274 pp.

Rogers, C.S., 1990. Responses of coral reefs and reef organisms to sedimentation. Marine Ecology Progress Series, Vol. 62: 185-202.

Romero, C. and T. Rehman, 1989. Multiple criteria analysis for agricultural decisions. Elsevier, Amsterdam, The Netherlands. 260 pp.

Ruitenbeek, J., M. Ridgley, S. Dollar and R. Huber, 1999. Optimization of economic policies and investment projects using a fuzzy logic based cost-effectiveness model of coral reef quality: Empirical results for Montego Bay, Jamaica', Coral Reefs, vol. 18: 381-392.

Sadoulet, S., and A. De Janvry, 1995. Quantitative development policy analysis. The Johns Hopkins University Press, Baltimore, USA. 397 pp.

Singh, I., L. Squire and J. Strauss, 1986. Agricultural household models: extensions, applications and policy. Johns Hopkins Press for the World Bank, Baltimore, USA.

Tourism Queensland, 2004. Tropical North Queensland regional update: Abstract. Tourism Queensland Research Department, Australia. 19 pp.

Varian, H.R., 1992. Microeconomic analysis. W.W. Norton & Company Inc., New York, USA, 506 pp., plus appendices.

Zerbe, R.O. and D.D. Dively, 1994. Benefit-cost analysis in theory and practice. Harper Collins College Publishers, New York, USA. 557 pp.

Appendix A: Postal Survey of Community Attitudes to Environmental Values and Management Options for Improving Water Quality

Assessment of Socio-Economic Impacts of the Douglas Shire Water Quality Improvement Plan

Dear Sir or Madam,

The Douglas Shire Council is currently developing a Water Quality Improvement Plan (WQIP) for the Daintree River, Saltwater Creek, Mossman River and Mowbray River catchments. This Plan is intended to reduce the amount of sediment and nutrients entering the Shire's waterways and the offshore marine environment. As part of the WQIP, objectives for water quality are to be set, based on the uses people have for rivers and water and the values people wish to see maintained or improved in the Douglas waterways. Management options designed to achieve these objectives will be included in the Plan.

In preparing the Plan, an assessment of the social and economic impacts of alternative management options must be done. Douglas Shire Council has asked our research team from CSIRO Sustainable Ecosystems to undertake this assessment. Our team will be using a combination of economic analysis and public consultation to complete the analysis.

We wish to ask for your participation in the assessment of the potential socio-economic impacts of the Water Quality Improvement Plan, by requesting that you complete the enclosed survey and return it before August 1 in the postage-paid envelope provided.

This survey forms part of the public consultation process and has been designed to provide some of the data needed by the research team to analyse the social and economic impacts of the WQIP. Consequently, your participation is important. Without it, your priorities and concerns may not be properly reflected in the Plan.

Our survey has three parts:

- In Part 1, we would like you to identify which features and uses for rivers and water you value most highly in three examples of river settings.
- In Part 2, we would like to know which options for improving water quality you think will be most effective and to what extent you support their adoption.
- In Part 3, we ask those who manage more than 1 hectare of land to provide some basic social and economic information about themselves.

If you have any questions or require further information about this survey and its use within the Douglas Shire WQIP, please feel free to contact us.

Thank you for your time and co-operation.

Tony Webster
CSIRO Sustainable Ecosystems
PO Box 191 Mossman Queensland 4873
PH: 07 4030 4148, FX: 07 4098 2156
e-mail: tony.webster@csiro.au

Dr Peter Roebeling
CSIRO Sustainable Ecosystems
PMB Aitkenvale Queensland 4814
PH: 07 4753 8586, FX: 07 4753 8600
e-mail: peter.roebeling@csiro.au

Note: This survey is anonymous and all information provided by individuals will be kept strictly confidential.

Part 1 Importance of Water Quality

Question 1: At the current time, how important to you are the following features and uses of rivers and water?

Please rate the importance of each attribute to you for the three different river settings.

Features and uses for rivers and water	Importance in each river setting (tick box)		
	Rainforest river 	Fresh water zones 	Salt water zones 
Aquatic ecosystems: water that supports aquatic vegetation and wildlife	low medium high ☐ ☐ ☐ ☐ ☐	low medium high ☐ ☐ ☐ ☐ ☐	low medium high ☐ ☐ ☐ ☐ ☐
Agricultural/farm use: - water for irrigation - livestock watering	low medium high ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐	low medium high ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐	low medium high ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
Aquacultural use: water for fishing and aquaculture	low medium high ☐ ☐ ☐ ☐ ☐	low medium high ☐ ☐ ☐ ☐ ☐	low medium high ☐ ☐ ☐ ☐ ☐
Direct recreation: recreation with direct water contact (swimming, etc.)	low medium high ☐ ☐ ☐ ☐ ☐	low medium high ☐ ☐ ☐ ☐ ☐	low medium high ☐ ☐ ☐ ☐ ☐
Indirect recreation: recreation with indirect water contact (boating, etc.)	low medium high ☐ ☐ ☐ ☐ ☐	low medium high ☐ ☐ ☐ ☐ ☐	low medium high ☐ ☐ ☐ ☐ ☐
Aesthetics: visual appreciation (views, etc.)	low medium high ☐ ☐ ☐ ☐ ☐	low medium high ☐ ☐ ☐ ☐ ☐	low medium high ☐ ☐ ☐ ☐ ☐
Drinking water: drinking water supply	low medium high ☐ ☐ ☐ ☐ ☐	low medium high ☐ ☐ ☐ ☐ ☐	low medium high ☐ ☐ ☐ ☐ ☐
Cultural & spiritual: sacred, spiritual, traditional and cultural uses	low medium high ☐ ☐ ☐ ☐ ☐	low medium high ☐ ☐ ☐ ☐ ☐	low medium high ☐ ☐ ☐ ☐ ☐
Industrial uses: water for industrial uses (manufacturing, power, etc.)	low medium high ☐ ☐ ☐ ☐ ☐	low medium high ☐ ☐ ☐ ☐ ☐	low medium high ☐ ☐ ☐ ☐ ☐
Other (please specify): ……………………………	low medium high ☐ ☐ ☐ ☐ ☐	low medium high ☐ ☐ ☐ ☐ ☐	low medium high ☐ ☐ ☐ ☐ ☐

Question 2: **How important is it to you that these features and uses for rivers and water are maintained or improved in the future?**

Please rate each attribute for the three different river settings.

Features and uses for rivers and water	Importance of protection or improvement in each river setting (tick box)		
	Rainforest river 	Fresh water zones 	Salt water zones 
Aquatic ecosystems: water that supports aquatic vegetation and wildlife	low medium high ☐ ☐ ☐ ☐ ☐	low medium high ☐ ☐ ☐ ☐ ☐	low medium high ☐ ☐ ☐ ☐ ☐
Agricultural/farm use: - water for irrigation	low medium high ☐ ☐ ☐ ☐ ☐	low medium high ☐ ☐ ☐ ☐ ☐	low medium high ☐ ☐ ☐ ☐ ☐
- livestock watering	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐	☐ ☐ ☐ ☐ ☐
Aquacultural use: water for fishing and aquaculture	low medium high ☐ ☐ ☐ ☐ ☐	low medium high ☐ ☐ ☐ ☐ ☐	low medium high ☐ ☐ ☐ ☐ ☐
Direct recreation: recreation with direct water contact (swimming, etc.)	low medium high ☐ ☐ ☐ ☐ ☐	low medium high ☐ ☐ ☐ ☐ ☐	low medium high ☐ ☐ ☐ ☐ ☐
Indirect recreation: recreation with indirect water contact (boating, etc.)	low medium high ☐ ☐ ☐ ☐ ☐	low medium high ☐ ☐ ☐ ☐ ☐	low medium high ☐ ☐ ☐ ☐ ☐
Aesthetics: visual appreciation (views, etc.)	low medium high ☐ ☐ ☐ ☐ ☐	low medium high ☐ ☐ ☐ ☐ ☐	low medium high ☐ ☐ ☐ ☐ ☐
Drinking water: drinking water supply	low medium high ☐ ☐ ☐ ☐ ☐	low medium high ☐ ☐ ☐ ☐ ☐	low medium high ☐ ☐ ☐ ☐ ☐
Cultural & spiritual: sacred, spiritual, traditional and cultural uses	low medium high ☐ ☐ ☐ ☐ ☐	low medium high ☐ ☐ ☐ ☐ ☐	low medium high ☐ ☐ ☐ ☐ ☐
Industrial uses: water for industrial uses (manufacturing, power, etc.)	low medium high ☐ ☐ ☐ ☐ ☐	low medium high ☐ ☐ ☐ ☐ ☐	low medium high ☐ ☐ ☐ ☐ ☐
Other (please specify): ……..……………..………	low medium high ☐ ☐ ☐ ☐ ☐	low medium high ☐ ☐ ☐ ☐ ☐	low medium high ☐ ☐ ☐ ☐ ☐

Part 2 Opinion regarding management options

The next table lists a set of management options for maintaining or improving water quality in rivers. For the river settings shaped by human activity, please answer the following:

<u>**Question 3:**</u> **(a) How <u>effective</u> do you think each proposed management action would be in maintaining or improving water quality?**
(b) To what extent do you <u>support the adoption</u> of the proposed management actions?

Management options for maintaining or improving water quality in rivers	Effectiveness and support for adoption of management options (tick box)		
		Fresh water zones 	Salt water zones 
Minimum tillage system: adoption of a tillage system that minimizes cultivation leads to reduced soil compaction, larger soil organic matter availability and reduced levels of sediment and nutrient run-off	Effectiveness: Support for adoption:	low medium high ☐ ☐ ☐ ☐ ☐ low medium high ☐ ☐ ☐ ☐ ☐	low medium high ☐ ☐ ☐ ☐ ☐ low medium high ☐ ☐ ☐ ☐ ☐
Contour planting: land preparation and rows running across the slope lead to a reduction in soil erosion and, therefore, reduced levels of sediment and nutrient run-off	Effectiveness: Support for adoption:	low medium high ☐ ☐ ☐ ☐ ☐ low medium high ☐ ☐ ☐ ☐ ☐	low medium high ☐ ☐ ☐ ☐ ☐ low medium high ☐ ☐ ☐ ☐ ☐
Fertilizer application: nutrient run-off is reduced by applying fertilizer of appropriate form and in the appropriate way, without exceeding recommended fertilizer rates	Effectiveness: Support for adoption:	low medium high ☐ ☐ ☐ ☐ ☐ low medium high ☐ ☐ ☐ ☐ ☐	low medium high ☐ ☐ ☐ ☐ ☐ low medium high ☐ ☐ ☐ ☐ ☐
Fallow practice: adoption of a bare or legume fallow between crop cycles leads to improved soil health and reduced levels of sediment and nutrient run-off	Effectiveness: Support for adoption:	low medium high ☐ ☐ ☐ ☐ ☐ low medium high ☐ ☐ ☐ ☐ ☐	low medium high ☐ ☐ ☐ ☐ ☐ low medium high ☐ ☐ ☐ ☐ ☐
Ground cover: sediment and nutrient run-off are reduced by maintaining ground cover with crop residues (eg. trash blankets) or live vegetation (eg. grassed inter-rows) within or between crop cycles	Effectiveness: Support for adoption:	low medium high ☐ ☐ ☐ ☐ ☐ low medium high ☐ ☐ ☐ ☐ ☐	low medium high ☐ ☐ ☐ ☐ ☐ low medium high ☐ ☐ ☐ ☐ ☐
Stocking rate: appropriate livestock stocking rates ensure adequate ground cover, leading to reduced levels of sediment and nutrient run-off	Effectiveness: Support for adoption:	low medium high ☐ ☐ ☐ ☐ ☐ low medium high ☐ ☐ ☐ ☐ ☐	low medium high ☐ ☐ ☐ ☐ ☐ low medium high ☐ ☐ ☐ ☐ ☐

Management options for maintaining or improving water quality in rivers	Effectiveness and support for adoption of management options (tick box)		
		Fresh water zones 	Salt water zones 
Pasture management: maintenance of a balanced mix between legumes and grasses leads to improved ground cover, more continuous fodder supply and reduced levels of sediment and nutrient run-off	Effectiveness:	low ☐ ☐ medium ☐ ☐ high ☐	low ☐ ☐ medium ☐ ☐ high ☐
	Support for adoption:	low ☐ ☐ medium ☐ ☐ high ☐	low ☐ ☐ medium ☐ ☐ high ☐
Exclusion of stock: exclusion of livestock by fencing of riverbanks and provision of alternative water points leads to a reduction in bank erosion	Effectiveness:	low ☐ ☐ medium ☐ ☐ high ☐	low ☐ ☐ medium ☐ ☐ high ☐
	Support for adoption:	low ☐ ☐ medium ☐ ☐ high ☐	low ☐ ☐ medium ☐ ☐ high ☐
Drain management: flat, grass-covered (spoon-shaped) drains reduce sediment and nutrient run-off, while the grass-cover does not impede water flow	Effectiveness:	low ☐ ☐ medium ☐ ☐ high ☐	low ☐ ☐ medium ☐ ☐ high ☐
	Support for adoption:	low ☐ ☐ medium ☐ ☐ high ☐	low ☐ ☐ medium ☐ ☐ high ☐
Riparian vegetation: restoration of trees and shrubs along stream and river banks leads to a reduction in sediment and nutrients entering streams and rivers	Effectiveness:	low ☐ ☐ medium ☐ ☐ high ☐	low ☐ ☐ medium ☐ ☐ high ☐
	Support for adoption:	low ☐ ☐ medium ☐ ☐ high ☐	low ☐ ☐ medium ☐ ☐ high ☐
Wetland restoration: filtering of sediments and nutrients in drainage systems is improved by restoring natural or constructing artificial wetlands	Effectiveness:	low ☐ ☐ medium ☐ ☐ high ☐	low ☐ ☐ medium ☐ ☐ high ☐
	Support for adoption:	low ☐ ☐ medium ☐ ☐ high ☐	low ☐ ☐ medium ☐ ☐ high ☐

<u>Question 4:</u> Where do you live in the Douglas Shire?

Location (town/district)	

Part 3 Characterization of land managers

The remaining questions need only be answered if you manage more than 1 hectare of land.

Information provided in this part of the survey will allow us to assess the social and economic consequences for land managers of adopting specific management options. In turn, this will help the planners to adjust and adapt proposed management actions in response to the needs of land managers.

Question 5: What are your reasons for having or managing acreage?

Reason(s) for acreage	Importance of having or managing acreage (tick box)
Income generation	low medium high ☐ ☐ ☐ ☐ ☐
Life-style	low medium high ☐ ☐ ☐ ☐ ☐
Environment / landscape	low medium high ☐ ☐ ☐ ☐ ☐
Other (please specify): ………………………..	low medium high ☐ ☐ ☐ ☐ ☐

Question 6: What are the main occupations of you and members of your household over 18 years of age?

We would like you to indicate the percentage of time spent, on average, by you and members of your household working in each of the business sectors mentioned.

Occupation of household members		Sex (circle)	Main occupation(s)			
			Agriculture	Tourism	Other	Total
Household member (18 yrs +)	1.	M / F	… %	… %	… %, namely ……………………	100%
	2.	M / F	… %	… %	… %, namely ……………………	100%
	3.	M / F	… %	… %	… %, namely ……………………	100%
	4.	M / F	… %	… %	… %, namely ……………………	100%
	5.	M / F	… %	… %	… %, namely ……………………	100%
	6.	M / F	… %	… %	… %, namely ……………………	100%
	7.	M / F	… %	… %	… %, namely ……………………	100%

Question 7: **Approximately how much land do you have under each of the land uses listed below?**

Please fill in the total area for each land use in the column marked 'Total Area'. Indicate how much of this land is leased in the column marked 'Area Leased'.

Land use	Unit	Land use area	
		Total Area	Area Leased
Sugarcane	ha		
Pasture	ha		
Horticulture crops	ha		
Tree plantings	ha		
Remnant rainforest	ha		
Wetlands & streambank vegetation	ha		
Fallow	ha		
House & garden	ha		
Land leased out	ha		
Other (please specify): ………………………….	ha		
Total	ha		

Question 8: **Approximately how many days per week do you and members of your household (over 18 years of age) spend in working on-farm (agricultural and non-agricultural) and off-farm?**

Labour use of household members		Unit	Household member labour use		
			On-farm		Off-farm
			Agricultural	Non-agricultural	
Household member (18 yrs +)	1.	days/week			
	2.	days/week			
	3.	days/week			
	4.	days/week			
	5.	days/week			
	6.	days/week			
	7.	days/week			

Question 9: **If you hire in labour on your farm, on average how many days per week do you employ labour?**

Use of fixed and casual labour		Unit	On farm labour use	
			Agricultural	Non-agricultural
Hired-in labourer	1.	days/week		
	2.	days/week		
	3.	days/week		
	4.	days/week		
	5.	days/week		
	6.	days/week		
	7.	days/week		

Question 10: **In approximate terms, what percentage of your income comes from on-farm (agricultural and non-agricultural) and off-farm sources?**

Income sources	Importance of different income sources
On-farm agricultural	… %
On-farm non-agricultural	… %
Off-farm employment	… %
Off-farm investments	… %
Total	100%

Thank you for filling out this form and the time you have contributed to the assessment of the potential social and economic impact of the Water Quality Improvement Plan.

Please return this form before August 1 in the enclosed postage paid envelope.

Comments: