USING CONSERVATION TENDERS FOR WATER QUALITY IMPROVEMENTS IN THE BURDEKIN RESEARCH REPORTS

Overview of the Burdekin Case Study

RESEARCH REPORT No 2.

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These reports represent the provisional findings of a research project titled ***'Optimising the efficacy of conservation tenders under varying degrees of heterogeneity: Achieving water quality improvements in the Burdekin Dry Tropics across different management actions in different agricultural production systems and different parts of a river basin'.***

The project is being funded by the Australian Government through the National Market Based Instruments Program, with additional support provided by the Burdekin Dry Tropics Natural Resource Management Group. The project is being conducted as a partnership between Central Queensland University, River Consulting, the University of Western Australia and the Burdekin Dry Tropics Natural Resource Management Group.

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Introduction

In this report, an overview is presented of case study issues for a research project aimed at testing the efficacy of conservation tenders under varying degrees of heterogeneity, funded under Round Two of the National Market Based Instruments (MBI) Program. The MBI pilot program is a partnership between the Commonwealth and State Governments, and is aimed at investigating better ways of encouraging improved land and water management.

The intent of the MBI program is to prepare auction/tender design principles for use by natural resource management groups across Australia in achieving their regional-scale resource condition targets through the use of Market Based Instruments. The purpose of this project within the program is to analyse how auction and contract design issues vary in competitive tenders applied across different agricultural production systems and parts of river basins. The key issue to be addressed is whether competitive tenders are more efficient when they are tightly focused on specific areas, industry groups and the type of actions, or when they are broader in scope and allow greater participation.

The case study will be conducted in the Burdekin Dry Tropics region in north-east Queensland, which combines tropical savannah grazing lands with coastal floodplains. Within this region, the subcatchments of the Lower Burdekin River including Landers and Stones Creek, Haughton River and Barrata Creek Catchments will be the focus areas of the project as illustrated in Figure One. The prominent agricultural production systems applicable in these catchments include extensive beef cattle grazing and intensive farming enterprises, primarily sugarcane and horticultural production. The activities of these industries are argued to contribute non-point source pollution which is believed to result in water quality problems within the Great Barrier Reef lagoon. The region is subject to a natural resource management plan, which identifies the use of incentives to support landholders adopting management actions to achieve end-of-catchment water quality improvement.

This report will involve an overview of the specific characteristics of catchments within the Greater Barrier Reef system, relevant to the research project as well as associated issues of water quality. An outline of the specific industries within the research subcatchments will be presented and the relevant environmental issues identified. Recommended Best Management Practices to improve industry practice will be noted and discussed, particularly in regards to comparative environmental and economic value in addition to restrictions to adoption. It is intended that these key areas will support in identifying the most suitable practices to improve water quality for the purposes of the project.

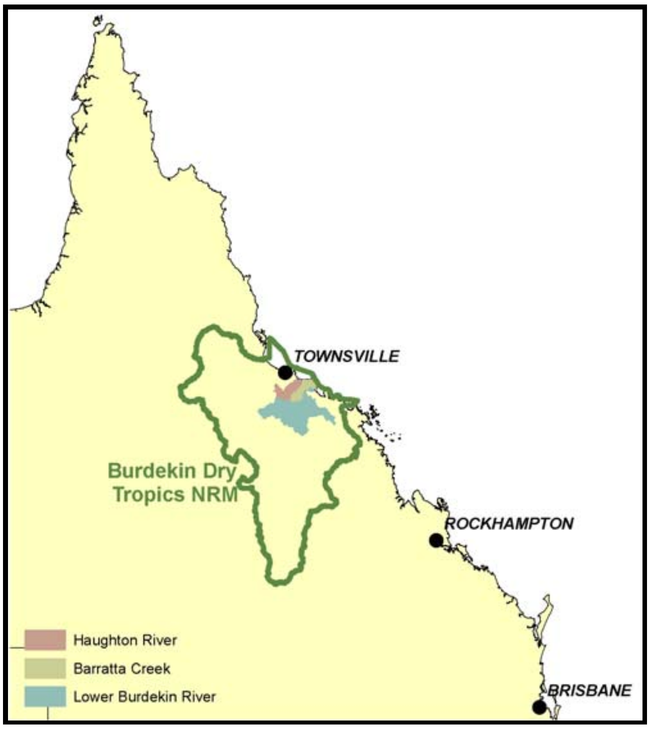

Figure 1: Research Focus Area
Source: Created from DNR&W Data, 2007

Characteristics of the region

The Great Barrier Reef and its Catchments

The Great Barrier Reef is the dominant marine geological feature and marine ecosystem of north-eastern Australia, consisting of over 2,900 individual reefs (Furnas 2003:21). Given its size, biological diversity and relatively undisturbed state, the Great Barrier Reef was given exclusive administration in 1975 when it was proclaimed under the *Great Barrier Reef Marine Park Act 1975*, with the Great Barrier Reef Marine Park Authority established, as a statutory authority charged with the management of the Park. Recognition for the reefs outstanding universal value was received in 1981 when it was inscribed onto the World Heritage Register. This listing places specific obligations on Australia to ensure the protection, conservation and presentation of this unique World Heritage Area (GBRMPA 2001:1).

The Great Barrier Reef Marine Park is managed as a multi-use reserve, with the reef itself contributing over $1 billion per annum alone to the Queensland economy through marine tourism, commercial fishing and recreational use. These industries, which represent a significant and growing proportion of Queensland's economy, are reliant on the continued health of the Reef system for their long term economic sustainability. The entire ecological functioning of the Reef and prosperity of these Park based industries is, however, argued to be threatened from declining water quality as a result of increased use in the coastal and catchment areas adjacent to the Reef (GBRMPA 2001:1).

The ecosystem of the Great Barrier Reef has a complex inter-dependent relationship with the adjacent river catchments. Many marine species rely on coastal freshwater wetlands and estuaries as breeding and nursery grounds. The Reef catchment area encompasses almost 25 per cent of the land mass of the State of Queensland for a combined area of some 423 070 km^2 (Furnas 2003:41). Whilst the Reef has been exposed to nutrients and sediment in natural runoff prior to Australian colonisation, extensive land modification in the Reefs catchment area have enhanced sediment and nutrient concentrations to the Reef. Most at risk from these elevated concentrations of sediment and nutrients in catchment run-off are the estimated 990 fringing and/or inshore reefs. (GBRMPA 2001:3).

The landscape of the Great Barrier Reef catchment area has been greatly modified to support land change and infrastructure for agricultural production, tourism and mining. More than 80% of the Great Barrier Reef Catchment supports some form of agricultural activity. These activities have impacted on the catchment area through increased erosion, clearing of vegetation, the destruction of wetlands and stream bank vegetation, with the run-off of sediment, fertiliser and chemical residues the primary anthropogenic impacts on water quality within the Reef (GBRMPA 2001:3). Whilst there are many measures of water quality, the most important for the health of coral reefs, and thus for assessing water quality in the Great Barrier Reef include those assessments of suspended sediment and nutrient concentrations, pesticides and herbicides, salinity and water temperature (Productivity Commission 2003:10).

Evidence suggests that land based activities within the catchment area over the last 150 years are impeding the water quality entering the reef, particularly during flood events (Furnas, 2003). It is argued that there has been a four to nine fold increase in the quantities of sediment entering the reef, in addition to a three to fifteen fold increase of phosphorus and two to four fold increase in total nitrogen inputs. Inorganic nitrogen contributions through fertiliser have also increased significantly with the expansion and intensification of agricultural farming systems. This form of nitrogen has the most direct effect on marine ecosystems given its complete bioavailability. Secondary industry, urban run-off, aquaculture and sewage have also contributed to pollution loadings to the Reef, but to a much lesser extent (DPI&F 2007:7).

Lower Burdekin

The Burdekin River catchment is the second largest river basin draining into the Great Barrier Reef (second to the Fitzroy catchment). The defined catchment area covers almost 136,000 square kilometres, or 8 per cent of the area of Queensland, when including the coastal plains between Giru and Bowen. The interior catchment extends in a north-south direction for over 700 kilometres, and based on hydrologic and landscape characteristics, is divided into four subcatchments: the Belyando Suttor system in the south, the Bowen-Broken system in the north east, the Upper Burdekin in the north west and the Lower Burdekin and coastal plains in the north (Beare et al, 2003:1). The latter areas are the focus of this project, including the catchments of Landers and Stones Creek.

Within the Lower Burdekin Catchment, grazing is by far the most dominant land use occupying over 98 per cent as illustrated in Figure 2. Other land uses include 193 km^2 of sugarcane and a small proportion of approximately 4 km^2 of horticulture. State forests, timber reserves occupy and protected areas cover only a small proportion of the catchment area at almost 0.5 per cent (GBRMPA, 2001). A map of the Lower Burdekin and associated land uses is depicted in Figure 3.

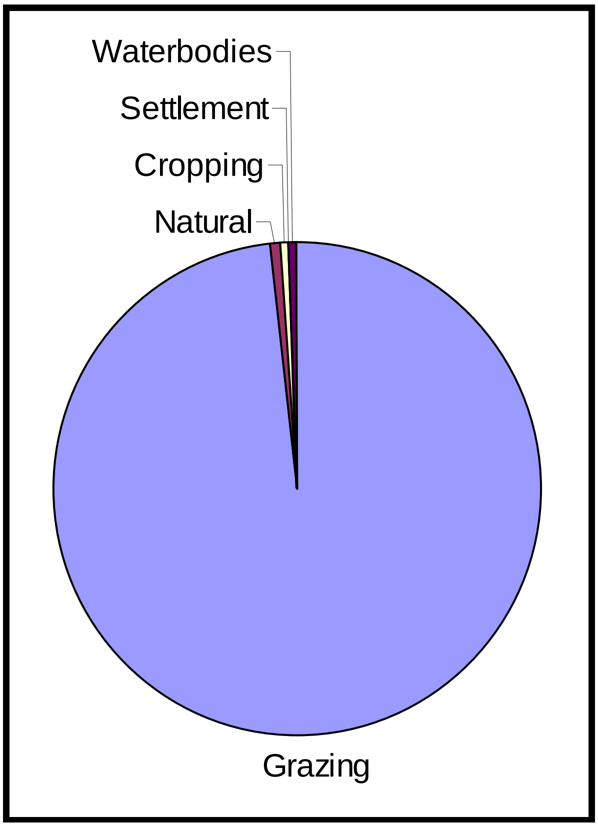

Figure 2: Landuse Allocation of the Lower Burdekin Catchment
Source: Mitchell et al., 2007

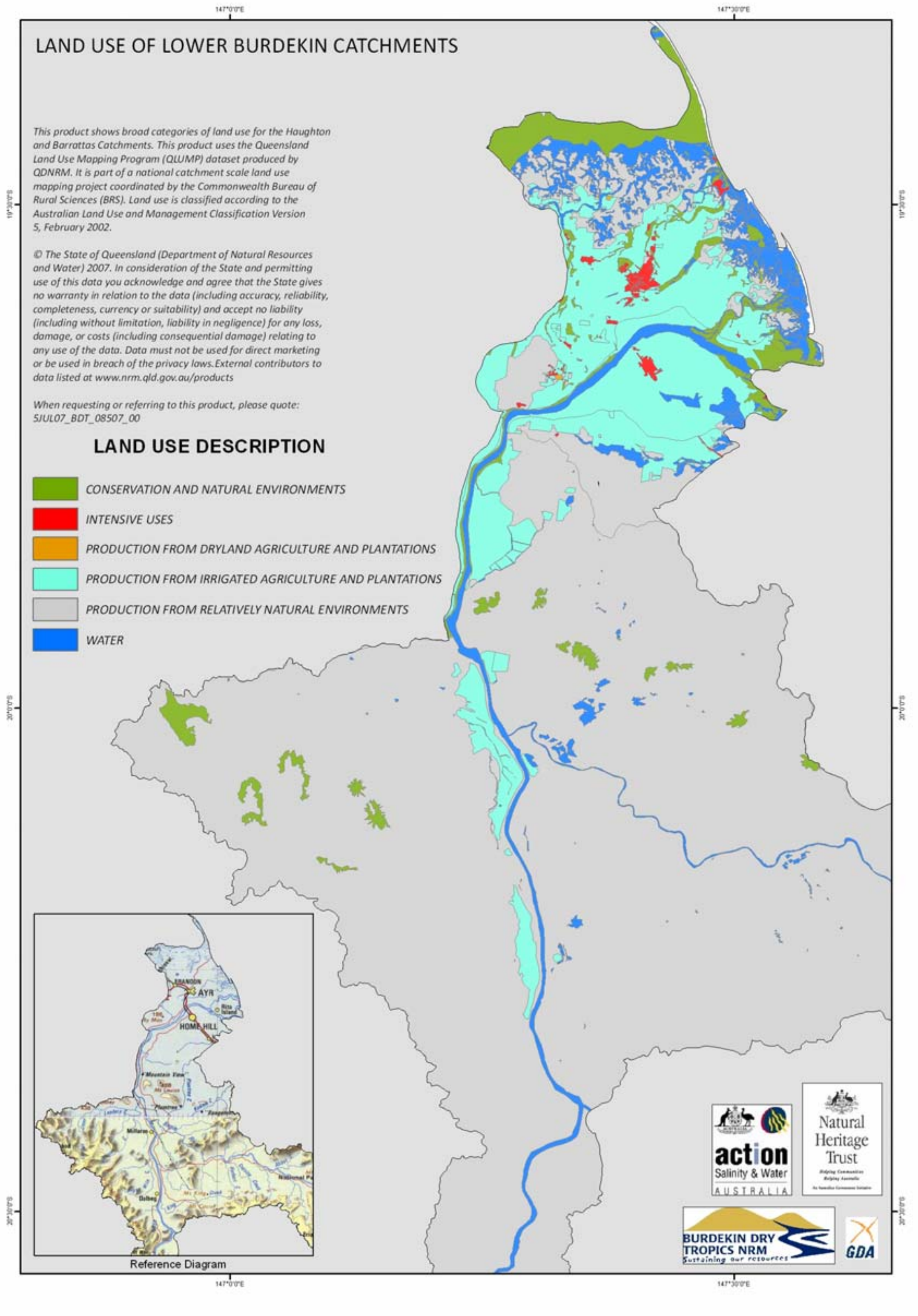

Figure 3: Land Use of Lower Burdekin Catchment
Source: Burdekin Dry Tropics, 2007

Haughton and Barrata Catchments

The Haughton River and Barrata Creek catchment areas cover a combined total area of 4,044 km^2. Data is limited for discussion of each catchment individually as the two are repeatedly discussed as the one system given the similarity of issues including location, climate, soils and landuse. This report will discuss the two catchments together.

As with the Burdekin catchment, grazing is the dominant land use in the Haughton and Barrata systems encompassing 3,441 km^2. Other land uses include sugarcane farming occupying 528 km^2 and horticulture production area with 21 km^2. State forests and timber reserves occupy 30 km^2 and protected areas cover 328 km^2 (GBRMPA, 2001). A comparative representation of the different landuses of the Haughton and Barrata catchments is represented in Figure 4 and a map of the different landuses in Figure 5.

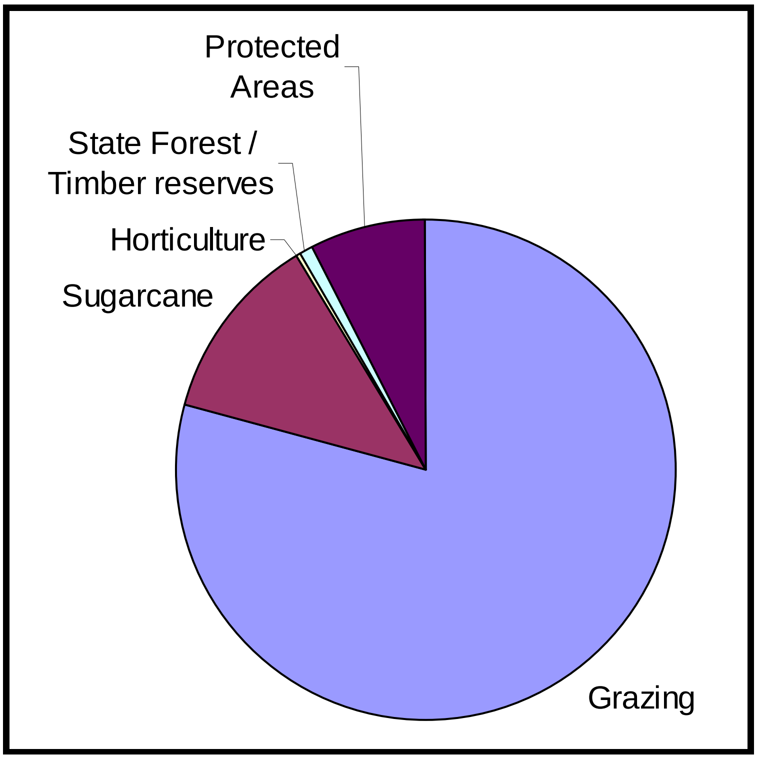

Figure 4: Landuse Allocation of the Haughton and Barrata Catchments
Source: GBRMPA 2001

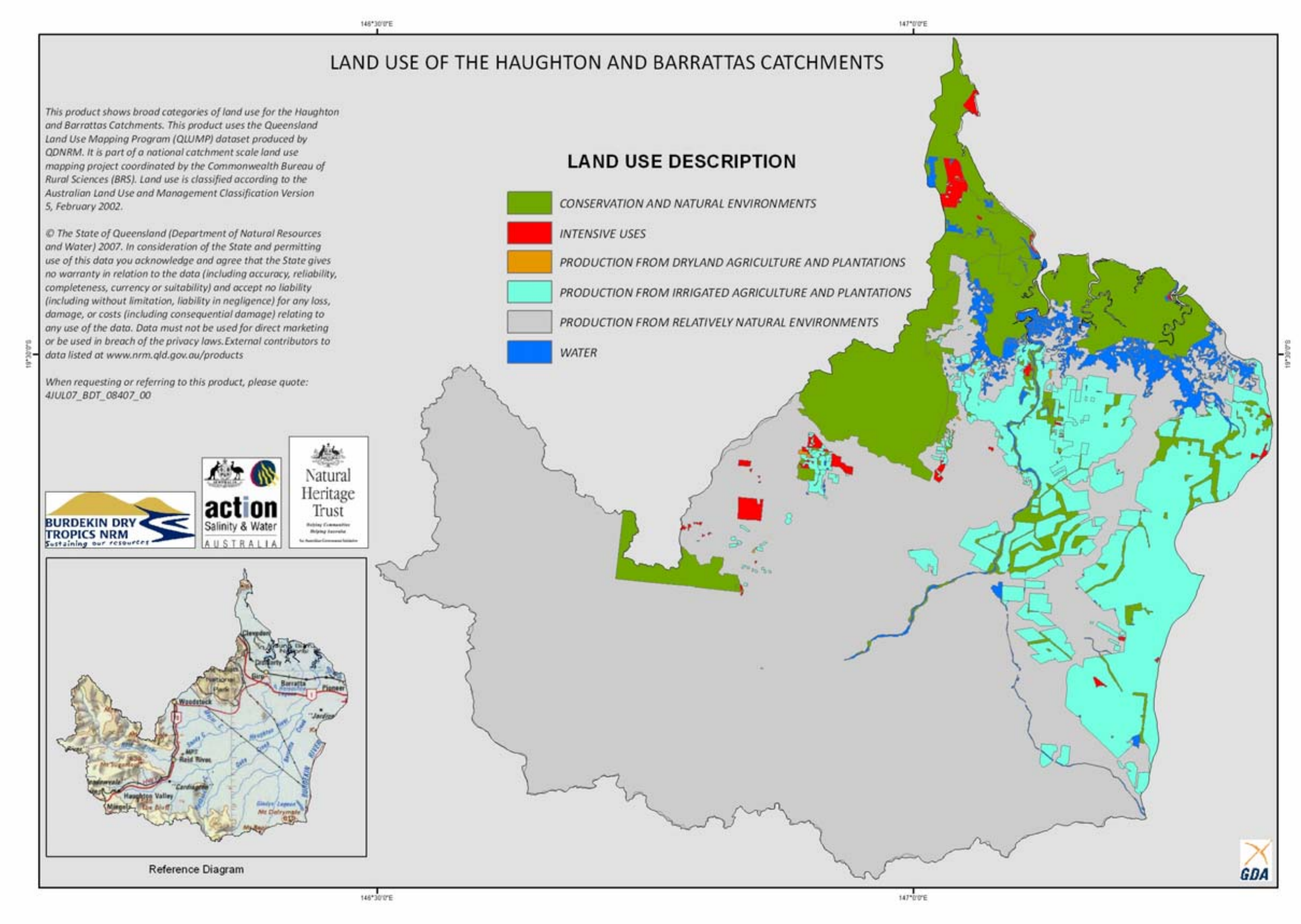

Figure 5: Land Use of Haughton and Barratta Catchments
Source: Burdekin Dry Tropics, 2007

Relevant industries within Catchment areas

Grazing

The beef cattle industry is the dominant agricultural industry by area in the Burdekin catchment. Whilst data is limited in regards to the economic value of the industry within the target research catchment areas, the Northern Statistical Division[1] data provides a valuable insight as it excludes much of the interior catchment area of the southern Belyando and Jericho shires which are included in the Mackay and Fitzroy Statistical Divisions respectively. In 2001-02, the gross value of beef production in the Northern Division was $131 million with a further $72 million added by marketing as illustrated in Table 1.

	Northern Statistical Division	Queensland	Percentage of Queensland
	$m	$m	%
Gross value at the farm level	130.5	2, 801.9	5
Value added by marketing	71.8	1, 541.1	5
	Number	Number	%
Employment	1, 230	16, 483	7

Table 1: Beef Industry in the Northern Statistical Division, 2000-01
Source: ABARE (2002)

Since the late 1970's, the average size of grazing properties in the catchment area has more than doubled to nearly 30, 000 hectares in 2001-02. Stocking rates have fluctuated based on seasonal conditions, cattle prices and market access, including live cattle exports. Average stocking rates are currently at 11 to 12 beef cattle per 100 hectares (Beare et al, 2003:18). Specifically in the upper and middle Haughton catchment areas, there is an estimated 15 to 20 active commercial graziers, with a number of recreational land users also in the area[2].

Beare et al (2003:37) identified a total of 868, 000 hectares of grazing land below the Burdekin Falls dam, including the Haughton catchment, to be contributing one tonne or more of sediment per hectare a year to the coast and referred to this area as 'hot spots'. Based on data from the Australian Bureau of Agricultural and Resource Economics agricultural and grazing industries survey in 2001-02, the value of grazing land within this hot spot area was $82.40 per hectare. Identified in Table 2 is a summary of the estimated economic value of the hot spot areas based on the varied rates of sediment contribution to the coast. The estimated $71.5 million value of the grazing industry within the 'hot spot' areas, begins to depict a better indication of the value of the grazing industry within the target catchment areas of the Lower Burdekin and Haughton systems.

Contribution of sediment to the coast	Estimated grazing area in 'hot spots'	Estimated economic value of grazing in 'hot spots'
t/ha/yr	'000 ha	$m
1 – 2	504	41.5
2 – 7	348	28.7
7 – 10	16	1.3
Total	868	71.5

Table 2: Economic value of grazing in hot spot areas within the Lower Burdekin and Haughton catchments
Source: ABARE, 2002

[1] The Northern Statistical Division includes the Local Government Shires of Burdekin, Dalrymple and Hinchinbrook shires and Charters Towers, Townsville and Thuringowa cities.
[2] Shepherd, R 2007, pers. comm.. 22 June 2007

Sugarcane

The Burdekin sugar industry, largely located on the delta and flood plains of the Burdekin and Haughton River systems, is Australia's largest sugar growing region, producing about 28% of Australia's total sugar production (Buono, 2005:4). This facet is largely attributed to the unique climate and geographical characteristics of the Burdekin which differentiates the region significantly from other sugar producing areas. High rates of solar radiation provide average sugar yields higher than those of other regions. However, as the area experiences relatively low rainfall (~1,000 millimetres per year), irrigation is a critical feature of the production system (Thorburn et al 2007:1). With the availability and affordability of water from the Burdekin Falls Dam through the Burdekin-Haughton Water Supply Scheme, 99.5 per cent of irrigation is applied by furrow irrigation systems, including the highly permeable soils in the river delta area. This widespread method of irrigation ensures the Burdekin accounts for the highest water use in Queensland for the production of sugarcane at 8 to 15 mega litres per hectare, which equates to approximately 300 millimetres of water to produce one tonne of cane per hectare (Qureshi et al, 2001:8). Four sugar mills operated by CSR Limited service the Burdekin River District including Invicta, Pioneer, Kalamia and Inkerman Mills (Morgan 2007:72). In 2006, the total net available cane production area in the Burdekin was 71, 541 hectares with 695 growers for an average farm size of approximately 105 hectares or 15, 000 tonnes of sugar (Morgan 2007:156). The average age of these growers is 53 (Buono, 2005:5).

While limited data is available in regards to the specific value of the sugarcane industry within the targeted study area, aggregate figures for Queensland's Northern Statistical Division provide a good indication of the gross value of sugar production in the catchment. As illustrated in Table 3, in 2000 – 01 the gross value of sugar production in the Northern Statistical Division was $177 million. This represented 28 per cent of Queensland's sugar production by value with a further $92 million in value added beyond the farm level and another $44 million through sugar processing. The sugar industry of the North is also a significant employer in both production and processing as also indicated in Table 3 (Beare et al 2003:16)

	Northern Statistical Division $m	Queensland $m	Percentage of Queensland %
Gross value at the farm level	176.9	621.8	28
Value added by marketing	92.0	328.5	28
Value added by sugar processing	43.7	273.2	16
	Number	Number	%
Employment in sugar growing	2 639	9183	29
Employment in sugar processing	1 511	5405	28

Table 3: Sugar Industry in the Northern Statistical Division, 2000-1
Source: ABARE (2002)

To substantiate the importance of the Burdekin production area to the national sugar industry, Table 4 outlines the harvesting details of the 2004 season and compares the production area, including tonnage of cane, the productivity of the crop represented in the tonnes of cane per hectares and the commercially available sugar through the average ccs (Comercial Sugar Content) between the four mills of the region and the rest of the Queensland industry.

Harvesting Details – 2004 Season - Totals and Weighted Averages				
Mill	Tonnes cane harvested from mill area	Total hectares harvested from mill area	Tonnes cane per hectare	Average ccs
Invicta	344,5979	29,220.6	117.9	14.95
Pioneer	208,5672	16,825.4	124.0	14.98
Kalamia	160,4629	12,858.6	124.8	14.91
Inkerman	180,1195	15,404.9	116.9	15.06
Burdekin	**893,7475**	**74,309.5**	**120.3**	**14.97**
Queensland	34,628,428	39,7555.0	87.1	14.20

Table 4: Harvesting Details comparison Burdekin Industry vs Queensland 2004
Source: Australian Sugar Year Book, 2007

Horticulture

Horticulture industries in the Reef catchment area are very diverse and valuable. The Burdekin catchment area has a relatively substantial area under horticultural production of approximately 3, 800 hectares. This area, which produces principally mangoes, pumpkins, rockmelons, watermelons, zucchini, cucumbers, marrows and squash, contributes an estimated $31.5 million dollars annually to the economy. Based on data from Growcom and Horticulture Australia Limited there are 57 vegetable and 69 fruit production enterprises in the study area with average farm sizes at 25 hectares for vegetable and 35 hectares for fruit (Queensland Department of Primary Industries and Fisheries, 2007:11).

Environmental issues

Water Quality

Water flows from the Lower Burdekin and Haughton-Barrata subcatchments vary between seasons and years, with fluctuations in flows highly prevalent given the variability of rainfall within the Dry Tropics. An indication of the rainfall patterns within the target catchments is provided in Table 5. The level of inter-seasonal variability means the Burdekin River only experiences a significant flood event every two to three years. This concentration of highly energetic events means there is little trapping of fine and suspended materials in the catchment. As such the Burdekin River is recognised as the main source of sediment discharge into the Great Barrier Reef catchment area (Science Panel, 2003).

	Burdekin	Haughton
Area (km^2)	130,126	4044
Mean Discharge Yr (km^3)	10.3	0.7
Rainfall (mm)	727	888
Runoff (mm/m^2)	79	183
Runoff/Rainfall Ratio	11	21

Table 5: Rainfall and runoff data by catchment
Source: GBRMPA, 2001

Whilst there is little debate that levels of sediments and nutrients entering the Reef lagoon have risen from pre-European catchment conditions, there is considerable argument about the extent these levels have risen by (Furnas, 2003). Models are the best established technique for predicting the catchment contributions to the Reef, however, there is a significant level of uncertainty associated with the use of models as tools. The debate in regards to the use of models centres largely on the use of low resolution digital elevation mapping, the uniform assumption of hillslope delivery ratios and limited understanding of the potential role of the Burdekin Falls Dam as a sediment trap (Fentie et al, 2006). While these limitations are acknowledged, modelling continues to be the best tool to use for cost effective, predictive management to allow for targeted management strategies (Coughlin, O'Reagain and Nelson, 2006:5).

Detailed in Table 6 is a comparison of export prediction from three different models developed by Furnas (2002), National Land and Water Resources Audit (2001) and the Great Barrier Reef Marine Park Authority (2001). These indicate end of catchment exports for sediment, nitrogen and phosphorus for the Haughton and Burdekin catchments. The results of these three models have been compared and averaged to provide an indicative allocation of the level of pollutants emitted from the two major study catchment areas of the project. To highlight the significance of these estimated exports from the study catchments, they have been also compared against the estimated total Great Barrier Reef exports as identified by Brodie et al (2001). A listing of the predicted chemical application rates in the various catchments by the Great Barrier Reef Marine Park Authority (2001) is depicted in Table 7.

Estimates of annual sediment and nutrient exports from the Burdekin & Haughton Catchments to the coast							
			Catchment				Total GBR exports (Brodie 2001)
			Haughton River	Mean average	Burdekin River	Mean average	
Sediment	Furnas (2002)	Million tonnes / year	0.27	0.22	3.77	2.88	12.00
	NLWRA (2001)		0.17		2.44		
	GBRMPA (2001)		0.17		2.44		
Nitrogen	Furnas (2002)	Tonnes / year	621	692	8 633	10, 027	39, 000
	NLWRA (2001)		653		10 314		
	GBRMPA (2001)		801		11 134		
Phosphorus	Furnas (2002)	Tonnes / year	122	145	1 695	2, 224	7, 000
	NLWRA (2001)		137		2 538		
	GBRMPA (2001)		175		2 438		

Table 6: Overview of three models for estimated annual sediment and nutrient exports from the Burdekin and Haughton Catchments against total GBR exports
Source: Furnas (2002), NLWRA (2001), GBRMPA (2001) & Bodie et al (2001)

	Burdekin	Haughton
Atrazine	19300	24299
Diuron	3272	4123
2-4D	5465	6887
Chlorpyrifos	207	285
MEMC	196	247

Table 7: Catchment Chemical application rates (Kg active ingredient / yr)
Source: GBRMPA, 2001

While several plans and projects are underway to establish targets in regards to end of catchment loadings in Reef catchments, based on both ecological and community values, exact values for these plans are yet to be determined. Currently, the best set of guidelines to identify are targets set by the Great Barrier Reef Marine Park Authority in 2001 in a report to the Ministerial Council on targets for pollutant loads. These targets that were set for 2011 are identified in Table 8 and based on the values sourced from the GBRMPA in Table 6.

	End of Catchment Targets 2011 (tonnes / year)	
	Burdekin	Haughton-Barrata
Sediment Export	1, 221, 616	115, 544
Total Nitrogen Export	7, 460	401
Total Phosphorous Export	1, 219	88

Table 8: Catchment Pollutant Export Targets for 2011
Source: GBRMPA, 2001

Ground Water

The Lower Burdekin river delta, with the Haughton River and Barrata Creek systems make up one of the largest alluvial aquifer systems in Australia covering an area of approximately 850 km^2 (Qureshi et al., 2002). The management of this large aquifer system is a critical and challenging, as it represents a major source of irrigation water that is heavily relied upon by the regional sugar industry, in addition to the systems proximity to environmentally sensitive wetlands, waterways, estuaries and the Great Barrier Reef lagoon (Bristow et al., 2000). In a response to the management of the aquifer systems, the Irrigation and Water Supply Commission established the North and South Burdekin Water Board Areas in 1965 and 1966 respectively as illustrated in Figure 6 with the Burdekin River Irrigation Area. The estimated percentage source of irrigation water in both the North and South Burdekin Water Board Areas is illustrated in Table 9. The difference between these two areas is attributed to the quality of the ground water, management with respect to recharge and differential pricing structure (Qureshi et al., 2002).

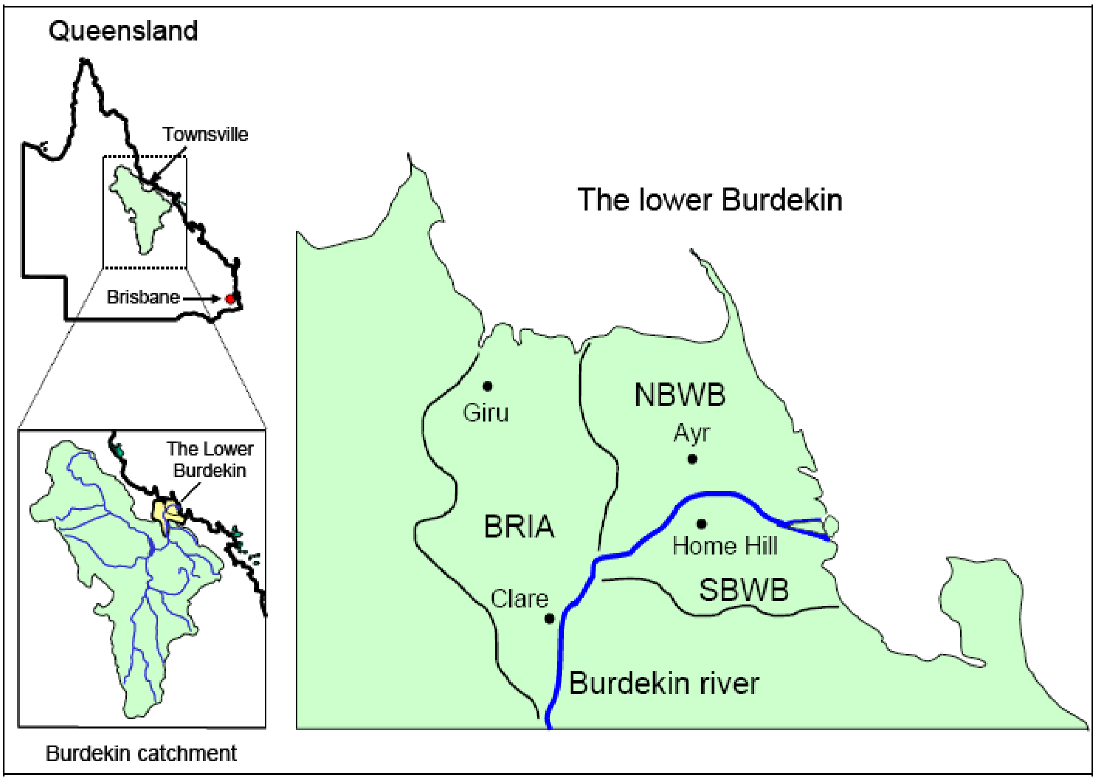

Figure 6: The Burdekin delta region the North & South Burdekin Water Boards (NBWB and SBWB) and Burdekin River Irrigation Area (BRIA)
Source: Charlesworth et al., 2002

	North Burdekin Water Board Area	South Burdekin Water Board Area
Ground Water	40%	70%
Surface Water	60%	30%

Table 9: Irrigation Water Source comparison between NBWB & SBWB
Source: Quershi et al., 2002

The issues associated with the ground water system include elevated levels of nutrients and pesticides as a result of intensive cropping and leaching of chemicals and fertilisers. The estimates from irrigation water to groundwater systems are limited. Based on single irrigation events, drainage below the crop root zone have been estimated at rates between 39 – 60% (Raine, 1995) to 43 – 60% (Holden et al., 1997). Whilst the eventual destination of contaminated groundwater is unknown, models suggest that upwards of 1,500 to 9,000 mg/L of groundwater is discharged to the Great Barrier Reef Lagoon every year (McMahon, Arunakumaren & Bajracharya, 2002).

Contributions from different land uses

There is a general agreement in scientific literature that the main source of sediment reaching the coast is from the grazing lands in the higher rainfall grazing areas within the Haughton catchment area and below the Burdekin Falls dam on the Burdekin river, while a primary source of nutrient runoff into the inshore lagoon of the Reef is from irrigated agriculture on the coast, namely the sugarcane and horticulture production area (Beare et al, 2003:36).

Through the use of modelling to stimulate patterns of erosion and sediment transport it is estimated that both gully and hillslope erosion are the most prevalent types by a factor of almost 40 per cent each followed by riverbanks at about 20 per cent (Fentie et al, 2006:9). Throughout the Burdekin catchment area, an estimated 18.4 million tonnes is delivered into the system. Of this however, only around 2.8 million tonnes or 15 per cent reaches the coastal estuaries as illustrated in Table 6. The balance of sediment is deposited in the Burdekin Falls dam and on floodplains or river beds downstream from the point of erosion (Beare et al, 2003:30).

To establish the areas most likely to be producing the sediment that reaches the coast, Prosser et al (2002) used a spatial model to trace sediment back to its source. The results from this study indicated that nearly all the sediment reaching the coast appeared to be coming from areas that had both high erosion potential (due to high rainfall), and limited opportunity for their streams to deposit sediment prior to reaching the coast. As a result, areas including the Lower Burdekin and Haughton catchment, given their proximity to the coast and higher rainfall, are attributed with an estimated 95 per cent of the sediment exported to the coast. In terms of land use, 85 per cent is estimated to be sourced from grazing lands and nine per cent derived from irrigated agriculture on the coast within the target catchments, with the remainder coming from other land uses (Beare et al 2003:30).

A National Land and Water Audit established that 75–100 per cent of stream lengths in the Burdekin catchment, including the Haughton and Barrata systems, showed increased phosphorus loads, and 50–75 per cent showed elevated nitrogen loads. Whilst these nutrients can naturally be present in the soil, the elevated levels are predicted to be sourced from agrochemical products and can be carried into waterways attached to sediments, or dissolved. During the dry season in the Burdekin when flows are limited, nutrients tend to remain in the river system, increasing in concentration. In the wet season, when high rainfall increases river flows, nutrients and sediments are flushed through the system to the coast (Beare et al 2003:30). As an indication of the potential sources of Nitrogen and Phosphorous in agricultural production, the Australian averages of Nitrogen and Phosphorous fertiliser application in the three focus crops in 2000 are reported in Table 10.

Crop	P (average kg/ha/year)	N (average kg/ha/year)
Sugarcane	29	230
Horticulture	98	188
Pasture	5	2.5

Table 10: Fertiliser applications for various Australian crop groups in 2000
Source: Fertiliser Industry Federation of Australia 2000

Grazing

Cattle and grazing practises have the potential to do considerable damage to land and associated waterway condition. Grazing can affect water quality in a number of ways through the removal and clearing of vegetation, particularly in riparian areas, overgrazing and soil disturbance, direct fouling of waterways, increased weed infestation, wildlife impacts and the application of fertilisers and herbicides to pastures (Coughlin, O'Reagin & Nelson, 2006:10). The main threat from grazing to water quality in the Lower Burdekin and Haughton catchment areas is increased sedimentation as a result of erosion in the catchment. This increase in erosion is largely attributed to the change in vegetation throughout these catchments as a result of extensive clearing and subsequent grazing pressure. Further concern for water quality within these catchments is that despite the minimal application of fertiliser in the grazing systems, the increases in erosion can still be associated with increases in nutrient runoff given the natural presence of nutrients in the soil that can be transported with particulate sediments (Beare et al, 2003:33, Brodie, 1997).

Sugarcane

Within the target catchments, the main continuous source of nutrient contamination in aquifers and river systems is a likely result of irrigation. Whilst water use efficient practices within the Burdekin industry have improved significantly in recent years, they remain comparatively low to the state level, with only 33 per cent adoption of the practice (Wrigely & Moore, 2006). This low water use efficiency adoption is attributed to the availability and affordability of water supply within the region and accounts for a 14 megalitre per hectare water use on sugar cane (Qureshi et al. 2001). The inefficient water use practices and high seepage rates are result from the use of mainly furrow irrigation on highly permeable soils. Approximately 99.5 per cent of the sugar cane in the Burdekin delta is furrow irrigated, even though the method is often less efficient than other methods such as overhead irrigation and has the potential for comparatively high rates of leaching of nutrients and pesticides into the aquifer and river network (Beare et al, 2003:34).

It is estimated that 40 to 60 per cent of irrigation extractions in the Burdekin River delta area are returned to the ground water systems This represents around three-quarters of the total annual recharge to the aquifer. Whilst it is suggested that nitrate exports from the ground water aquifer to the Great Barrier Reef through seawater interface are likely to be less than one per cent of total nitrate exports from the Burdekin catchment, a smaller, but potentially more concentrated impact may occur through the lateral discharge from the aquifer into catchment system (Beare et al, 2003:34).

Fertiliser application is a significant aspect of sugar cane production. Around 180 kilograms per hectare of nitrogen is applied annually to sugar crops in Queensland, but of this, the crop only takes up about 70 kilograms on average, with the remainder lost to the atmosphere, surface runoff, ground water or stored in soil or trash (Moody et al. 1996). A significant, although not well quantified fraction of the lost nutrients reaches adjacent rivers and the coast (Brodie and Furnas 2001).

A survey undertaken by ABARE (2003) reported that 88 per cent of sugar cane farmers in the Lower Burdekin applied fertilizer and 43 per cent sprayed weeds on fallow land prior to planting. These practices may contribute to nutrient and chemical loads in irrigation runoff reaching streams and rivers, with surveyed sugar properties having, on average, 1.6 kilometers of stream frontage that is used for cultivation. Furthermore, only 33 per cent of surveyed irrigators reuse drainage water on their properties, potentially intercepting nutrients and chemicals.

Other potential water quality impacts in the target catchment area as a result of sugar cane production include past clearing activities for production, including wetlands and riparian vegetation. Farming practices, including tillage and other soil disturbances can promote soil erosion and reduce soil health including nutrient holding capacity. Crop harvesting may also have water quality impacts through the release of cane juices and sugars into waterways and the removal of ground cover, particularly trash from the field (Productivity Commission, 2003).

Horticulture

Horticulture production in the Lower Burdekin, Haughton and Barrata catchments can have similar impacts on water quality as sugarcane production, particularly in regards to the offsite impacts of irrigation. This includes the possible off site movement of sediments, nutrients and pesticides from production areas. Additional possible water quality impacts within the catchment areas from the production of horticulture include past clearing activities for production, including the thinning of riparian vegetation. The cultivation of horticulture crops can also disturb soil structure promoting soil erosion and potential acid sulphate soils. The inappropriate storage and disposal of chemicals may also have an impact (Productivity Commission, 2003)

Other environmental issues

A number of other significant environmental issues are prevalent within the catchment areas. Extensive land clearing and modification has taken place to support highly valuable agricultural production within the catchment areas, namely beef cattle, sugarcane and horticulture. These activities have resulted in widespread erosion, increased the risk of dryland salinity outbreak and promoted the invasion of weeds and pests. The application of nutrients and chemicals in the flood plain areas has increased the risk of offsite contamination in surface and groundwater resources. Unmetered extraction of groundwater for agricultural production has degraded water quality within the aquifer through saltwater intrusion, in addition to the presence of elevated nutrient levels. Commercial and recreational fishing practices pressure the sensitive marine resources within the catchment, including significant seagrass beds. A small percentage of land within the catchments are protected, with one per cent of the entire Burdekin and eight per cent of the Haughton and Barrata systems (GBRMPA, 2001).

Key policy initiatives

A number of Government and community processes are currently under way to investigate and act on water quality issues and management within the Greater Barrier Reef Marine Park Area. At the Commonwealth Government level, the National Action Plan for Salinity and Water Quality is committed to improving land and water management in 21 priority regions across Australia including the combined Burdekin and Fitzroy rivers. At the State level, the

Queensland government has developed arrangements for water resource planning aimed at achieving water industry reformed as agreed to by the Council of Australian Governments (Beare et al, 2003:10). As a joint initiative, both the Australian and Queensland Governments have agreed on the *Reef Water Quality Protection Plan* to improve water quality entering the Great Barrier Reef. Largely, this plan recognises diffuse sources, particularly cattle grazing and crop production, as the most significant contributors to pollutant discharges to the Reef lagoon (Department of Primary Industries and Fisheries, 2007)

At a community level, the Burdekin Dry Tropics Natural Resource Management Group is aiming to ensure a high quality of life for current and future generations through the maintenance of viable natural ecosystems and the development of economically sustainable production and urban systems (Burdekin Dry Tropics, 2005).

Best management practices

The following section identifies a range of Best Management Practices for the various agricultural industries of relevance within the Lower Burdekin and Haughton Barrata catchment areas. It is important to note that the majority of these Best Management Practices were likely to have been developed with alternative aims to that of water quality, be this production, ecological or other, and as a consequence, lack indicators directly related to water quality condition.

Grazing

There are a couple of basic premises in regards to the management of grazing land for water quality outcomes. These are that land in good condition, with higher levels of ground cover and pasture composition, has lower levels of sediment and nutrient loss. A relatively open woodland structure maximises pasture production and ground cover – thereby minimising runoff and maintaining water quality (Coughlin, O'Reagin & Nelson, 2006). In addition to these basic principals, a number of specific Best Management Practices in regards to grazing have been identified.

Whilst water quality trends are determined by catchment wide uses, the specific conditions of the Lower Burdekin and Haughton catchments lead themselves to be considered as frontage country under the Burdekin Dry Tropics Coastal Catchment Initiative Best Management Practice guidelines. These non-prescriptive guidelines, developed to reduce the load of off site movement of sediment and nutrients, recommend the Best Management Practices as summarised in Table 11 for the target catchment areas.

Best Management Practice		**Management strategies**
Fence location	Large well defined rivers	Fence the ridge just above the floodplain and on the high bank levee.
	Braided rivers and tributary streams	Fence the ridge above the floodplain, excep if it is not practical to fence the immediate riparian area. Erodible, vulnerable and important channels/waterholes should be fenced and cattle excluded
	Smaller rivers and streams	Fence the ridge above the floodplain and at the start of the immediate riparian area.
Grazing and spelling		Grazing should be at light-moderate utilisation rages (15-20% of annual pasture growth)
		Riparian paddocks should be spelled from before the first summer rains until the middle to end of the wet season.

	Poor condition land will require an increased frequency and duration of spelling to assist in recovery
	Frequency and duration of wet season spelling will depend on land condition indicators including: • Ground cover kept at >60% at end of the dry • Drought cover to not fall below 40% • Pasture yield 1000kgDM/ha at end of dry season • Minimum standard to aim for is 'B' condition • River and waterhole banks should be stable and vegetated
Water lanes – should only be used as a temporary measure	Restrict stock to designated water points within the stream
	Selection of water point site that has low erosion hazard, is relatively flat and has easy access for stock
	Harden access point surface with gravel or alternative to minimise erosion and provide better footing for stock
	Do not select a shady site to minimise stock camping and loitering in the riparian area
	Allow stock to watering points only – exclude from rest of watercourse through fencing
	Locate site on the inside of a bend, and utilising slower watercourse movement to minimise erosion
	Angle access point in a downstream direction
Gully management	Actively regenerate and manage cattle and vehicular tracks to minimise gully formation and convergence of flow
	Stream side vegetation not to be distured
	Minimise further exposure of erodible subsoils
	In existing gullies, increase ground cover to minimise surface flow and starve existing water networks
	Riparian fencing should include existing gullies and exclude stock
	Fence existing gullies outside of fenced riparian zone and exclude stock
	Undertake mechanical repair with care – professional advice may need to be sought
Vegetation structure	Maintain native vegetation where practical and possible
	Manage frontage country to maximise ground cover with uniform cover at minimum heights of 10-15cm
	Dense, continuous grass filters are important and should be maintained to minimise erosion
	Maintain effective forested strips by managing tree shading or competition to enable an understorey of dense grass
	Promote deep rooted species to protect against streambank erosion

Table 11: Recognised Grazing Best Management Practices within the Burdekin
Source: Adapted from Coughlin, Nelson and O'Reagin, 2007

Further to the specific Best Management Practices developed for the Lower Burdekin and Haughton catchment areas, a number of generalized best management practices have been recognized through various studies including one undertaken by Roebling and Webster (2007) in the Tully-Murray catchment in Far North Queensland. A list of the best management practices identified through this project, and of similar importance to the Lower Burdekin and Haughton catchments, are recognized in the Appendices of this report.

Sugarcane

The scope of the Burdekin Sugar Industry enables for strong grower support by a number of prominent and recognised industry organisations for production support. Whilst a number of Best Management Practices have been developed to support the improvement of current management practices within the industry as indicated in the appendices of this report, some locally specific practices have been recognised under the Coastal Catchments Initiative to improve water quality leaving farm. Detailed following in Table 12 is a summary of these practices within a framework for management improvements in sugarcane production.

BMP Objectives	Management Practices	Infrastructure Options
Water Management *Minimise water excess*	• Time irrigation applications and control water application	• Improve irrigation system ie. furrow, overhead, trickle etc • Recycling pits
Nitrogen Management *Minimise Nitrogen Surplus*	• Soil test and leaf analysis to match crop Nitrogen requirements	• Improved and calibrated fertiliser box • Recycling pits
Herbicide Management *Minimise Herbicide losses*	• Reduce seed bank – effective fallow weed control • Apply at registered rates • Time applications to minimise runoff – irrigations and rain forecast	• Improved and calibrated spray rig • Recycling pits
Sediment Management *Minimise erosion*	• Crop in fallow • Maximise trash retention • Minimum till management	• Zero tillage machinery and operations • Recycling pits

Table 12: Recognised Sugarcane Best Management Practices within the Burdekin
Source: Adapted from Thorburn, Davis and Attard, 2007

Horticulture

At an industry level, a number of Codes of Practice have recently been developed including the Guidelines for Environmental Assurance (2006) for the horticulture industry. However, guidelines such as this remain commodity specific and difficult to translate into a prescribed list of recognised industry best management practices. A detailed list of some of the recognised best management practices within the horticulture industry is contained within the Appendices of this report.

Industry initiatives

Industry organisations play an essential role in supporting the adoption of best management practices in order to improve land use management for the benefit of off site water quality improvement. In recognition of the importance of sustainable land management activities, a number of industry based initiatives have been developed and implemented within Reef catchment areas. The following summary details a number of these programs that attempt to address the issues in regards to the quality of water moving off farm.

Grazing

The grazing industry in Queensland are in the process of developing a number of industry programs to address water quality leaving farm for improved catchment health outcomes with a number of these programs listed as following (AgForward, 2005):

- Sustainable Grazing for a Healthy Burdekin Catchment – the objectives of this project are to develop sustainable grazing management practices for the Burdekin catchment including tools to evaluate and document the effects of resource management practices, refine computer modeling for sediment and nutrient transport, and set realistic and measurable targets for reductions of diffuse pollutants. There is also a significant capacity building element through improving the understanding of beef producers in the Burdekin about implementing best-practice management guidelines and their impacts on forage production, water use efficiency, and runoff.
- Rangelands Australia – as an initiative within the research organisation, Rangelands Australia is a strategic response to education and training to support the sustainable management of Australia's pastoral industries. The program delivers courses based on stakeholder needs that encompass practical as well as theoretical aspects of management to equip land managers with skills to integrate production and environmental management.
- GLM development and workshops – the development of Grazing Land Management by the Department of Primary Industries and Fisheries for all reef catchments is near completion. GLM delivers a balanced holistic management guide to producers encompassing production and environmental management techniques.
- AgForward Roll out - AgForce is delivering the AgForward program. This program is focused on training and moving rural industry forward by assisting producers improve their skill base. The program, funded by the Queensland Government, is essentially equipping participants with the skills to develop a comprehensive Property Management Plan and adopting the relevant technologies and skills to manage resources sustainably.

Sugarcane

A number of sugar industry based initiatives have been established to improve natural resource management within the industry and minimise the impacts of sugarcane production on the environment (CANEGROWERS, 2005). The industry acknowledges that the alteration on Great Barrier Reef catchment landscapes for sugarcane production has impacted on catchment hydrology and water quality and that this can have detrimental impacts on the natural environment if adequate safeguards are not adopted (Wrigley and Moore, 2006). As a consequence of this, the industry supports the following initiatives to improve the management of water runoff and on-farm improvement of soils, pesticide, herbicides and nutrients to deliver better outcomes to the Great Barrier Reef lagoon:

- Accredited Nutrient Management Plans – Accreditation program for the development of individual property nutrient management plans
- Engagement with Natural Resource Management Regional Groups – the industry is working with Regional Groups throughout Queensland where sugar cane is produced, including setting targets for improved cane production
- Land and Water Management Plans – the development of Land and Water Management Plans for property water resource needs including water conservation, water recycling and best management farm practices
- Code of Practice for Sustainable Cane Growing – this code was developed in 1998 to assist growers in meeting their obligations of duty of care under the 1994 *Environmental Protection Act.*
- The Rural Water Use Efficiency Initiative - Stage 1 (1999 – 2003) – a partnership with the State Government to improve the use and management of available irrigation water.
- Combining Profitably and Sustainability in Sugar (COMPASS) - COMPASS (COMbining Profitability And Sustainability in Sugar) is a program designed by the industry to assist growers in identifying financial, social and environmental improvements to their farming practices.

- Eco-efficiency Agreement with the Australian Government – this agreement supports the delivery of COMPASS and the completion of the first Public Environmental Report for the Sugar Industry
- The Rural Water Use Efficiency Initiative - Stage 2 (2004 – 2006) – the initiative was broadened to also include a focus on the off-farm environmental impacts of irrigation. Some specific activities to have occurred in the Burdekin through the initiative include:
    - Control traffic to minimise run-off and better utilise farm inputs such as irrigation and crop nutrient requirements
    - Rotation cropping discussed at shed meetings
    - Recycle pits discussed at shed meetings
    - Irrigation scheduling at discussion groups
    - Link with region NRM and regional planning groups
    - Land & Water Management Plan workshop development
- SUGARCANE FMS – the SUGARCANE FMS or Farm Management System is a program to assist cane growers improve their farming operations on an ongoing basis.

The implementation of these practices is being underpinned by the collective agencies and groups involved in the sugar industry. These initiatives are aimed at supporting farmers in the improvement and documentation of their practices within Reef catchment production areas. This documentation will have future importance, as it will assist farmers in continuous improvement of on-farm performance in addition to benchmarking the industry against best management practice. These initiatives are complemented by the industries current ongoing development of improving farming practices based upon controlled traffic, legume fallow and minimum tillage systems.

Horticulture

The Queensland horticulture industry has undertaken a number of measures to demonstrate its environmental sustainability and supports a number of programs to address natural resource management issues, including water quality within the Great Barrier Reef catchment areas (Growcom, 2005). The industry has established partnerships with stakeholders to ensure balanced outcomes for its members and the broader community. Some of these supported initiatives include:

- Farmcare Code of Practice for Sustainable Fruit and Vegetable Production in Queensland – the code defines acceptable industry standards for on farm environmental management and to provide industry members with guidance on how to meet their general environmental duty.
- Growcom Land & Water Program – as the peak industry body for the Horticulture Industry, Growcom maintains an environmental program to deliver projects and services to assist growers achieve sustainable management of natural resources and environmental protection in addition to contributing to the development of workable policy and legislative frameworks to support improved natural resource and environmental management in horticulture
- Farm Management Systems in Horticulture – whilst still in development, the Growcom FMS program will encourage growers to implement a holistic and integrated management system, with the initial focus on supporting growers to address natural resource and environmental management priorities. In particular within Reef catchments, the key priority will be the implementation of management practices and processes that minimise sediment and nutrient movement off farm.
- Water for Profit – the Water for Profit program is part of the Rural Water Use efficiency Initiative. The program aims to achieve water savings and productivity gains, in addition to helping to deliver improved natural resource management on fruit and vegetable farms, in particular, water quality management.

- Regional Natural Resource Networks – the network aims to support the involvement of the fruit and vegetable industry in regional NRM processes and help identify priority NRM

Adoption issues

The adoption or non-adoption of best management practice by land managers, particularly for the improvement of water quality leaving farm, is a multi faceted issue that is influenced by a number of factors. Rolfe et al (2007) identified a number of key issues relating to adoption rates, this included the degree of private benefit to be obtained through adoption, as either an improvement in farm productivity or a reduction in farm costs. It was recognised that there was a tendency amongst land managers to adopt new practises if future benefits were likely and no financial losses experienced. Financial and profit constraints were recognised as key constraints to slow adoption, including implementation costs, production loss and time. It is suggested that there may be little motivation by land managers to adopt best management practices for the purposes of public or community benefit, when there is little private benefit perceived (Productivity Commission, 2003).

The scope of the management practice to be adopted appears to also influence a land managers decision making process. Rolfe et al (2007) suggest adoption rates of management practices that are small-scale, focused on a single item or issue, have been previously trialled, are low cost, are not highly technical and do not require large amounts of time are likely to be adopted over those which are large in scale, complex and require significant time and financial investment. Information and knowledge barriers are also recognised as impediments to adoption, whereby land managers have limited information and knowledge about the best management practices and the technical capacity to implement them. The visible outcomes of some best management practices are not always clear either, which may influence farmers attitudes to risk and uncertainty (Rolfe et al, 2007).

Factors influencing a land managers decision making process may also influence management practice behaviours including the reluctance to adopt certain practices. Individual farmer objectives, personal circumstances and management decisions are a key factor in determining the likelihood of adoption of new practices. Other factors may include time and non-financial contributions required, the skills of the landholder, attitude of peers and confidence and trust in the program and lead organisations. Impacts on property rights and transaction costs in negotiating new arrangements and changes in management practices are also likely to influence adoption (Rolfe et al, 2007).

In a study of landholders within the Burdekin catchment area regarding the adoption of best management practices, Greiner, Lankester and Patterson (2007) identified a number of key impediments as established by landholders in the Burdekin. Financial constraints were rated as highly constraining to adoption, and included the up front and ongoing costs associated with the uptake of management practices. The perception of regulation or 'red tape' was viewed as an interference to adoption given the connotation of interference in the farming system from governments and other institutions. Other barriers included climatic variability and the increased profitability of negative incomes; both of these are associated with uncertainty and risk. Time and labour constraints were also identified, particularly amongst graziers. Information constraints were also recognised as a challenge, with more information and relevant research required.

<u>Grazing</u>

A number of constraints to the implementation of best management practices within the grazing industry of the Burdekin were identified in a study undertaken by Greiner, Lankester and Patterson (2007). This study indicates that best management practices involving monitoring practices including pasture condition and stocking numbers are well implemented, compared to those practices which require capital investment and production losses such as fencing for conservation and those which require technical assistance and knowledge including fencing to land type, paddock rest, rotational grazing and fire management which experienced lower participation (Greiner, Lankester and Patterson, 2007:34). This study found that some of the key impediments to adoption of these practices included the high initial capital costs involved and low returns on investment, time constraints', labour requirements, climatic variability and government regulation as key inhibitors (Greiner, Lankester and Patterson, 2007:41).

Sugarcane

Whilst the sugar industry has a number of reputable nutrient management research and development, extension and support programs there are still a number of key impediments to the uptake of good nutrient management (Department of Primary Industries and Fisheries 2007:26). A number of these issues result from cultural practices, namely that of traditional fertiliser applications and a reluctance to change practice. There also tends to be a general lack of understanding or acceptance of best practice nutrient management, perhaps as a result of conflicting advice and recommendations not provided in grower friendly language or concern that changed practices may lead to crop loss. The ease of single application rates also suits the time constraints of many growers, as does the issues of appropriate mixtures and capital equipment constraints to apply variable rates.

Irrigation efficiency is another significant area in the sugar industry and despite substantial research into identifying more efficient and sustainable irrigation practices, growers in the Burdekin have been slow to adopt this new technology (Beare et al, 2003:34). Whilst available new irrigation technology is more efficient, it involves a high initial investment cost, including infrastructure and equipment, which is unattractive given the continuing low sugar prices. Growers also are provided with little incentive to reduce water use while ground water use is largely unmetered and water charges are related to production area rather than water use. The adoption of more efficient practices will continue to be avoided as long as water charges and delivery remain as affordable as they are in the Burdekin (Thorburn, Davis and Attard, 2007:17).

Discussion

While there are a number of recognised management practices that may be employed by those growers involved in the bid process to improve the quality of their water leaving farm, the individual values of their bid and cost to change their management practice will be specific to their individual property requirements. A number of opportunities exist under the best management practices identified previously for the adoption of actions to improve water quality and in regards to opportunity costs. Specifically, there are a number of general practices relevant to the Burdekin situation that may be adopted to have a positive impact on water quality. Within the grazing estate, stocking rates and spelling practices in addition to riparian and gully zone management through the use of buffers is considered to be an effective management practice. Similarly in the sugar cane industry, the management of the movement of water, including stormwater and irrigation, through buffer zones and tailwater recycling suggests that it will have a benefit as will nutrient management in regards to applying crop requirements for fertilisers. While not a focus of this specific study, the offsite impacts of horticulture production within the Burdekin could be treated along similar lines as that of irrigated sugarcane in regards to offsite water management and nutrient budgeting.

Conservative Stocking Rates

The Burdekin region is similar to other grazing regions is that there is a belief by landholders that stock turn over is more financially viable than kilograms of beef turned over. This attitude supports excessive stocking rates in excess of the recommended safe stocking rates for the area[3]. Whilst it is necessary to match stocking rates to the land type capability and condition, particularly in riparian areas, it is anticipated that the adoption of more sustainable stocking rates will be viewed with relative favourability by landholders in the Burdekin given the potential to increase the productivity of stock, whilst supporting good land management practices and reducing sediment runoff. A number of research projects have indicated that the level of sedimentation entering the reef can be reduced by managing grazing pressure to allow no more than 25 – 35 per cent utilisation of fodder and managing pasture to allow for no more than 50 per cent utilisation in combination with annual wet season spelling (Roth et al, 2003:112). An initial "spell" (period of time without stock) can help to rehabilitate degraded country.

Case study research previously undertaken in the catchment by Landsberg et al (1998) suggests that a more conservative stocking regime may assist perennial grasses to recover more rapidly, particularly after drought. On 'Trafalgar', the station where this research was undertaken, it was found that increased availability of feed per head translated into increased animal productivity per head and as a result, the gross margin per hectare under the new conservative management regime was only four per cent lower than the gross margin achieved under the previous high stocking rate regime (Beare et al, 2003:37).

Whilst the 'Trafalgar' case study was undertaken in the Upper Burdekin, many of the shared principles can be applied to the Lower area of the catchment. The main cost involved in moving to a more sustainable grazing regime is the cost of partially destocking a property for around four years. During this period, gross margins per hectare are expected to be reduced by an average of 50 per cent (Beare et al, 2003:39). Based on ABARE survey data (2002), the average annual return for grazing properties in the Lower Burdekin is estimated to be $4.20 per hectare. Applying this understanding to the 'hot spot' areas, the opportunity cost of the 'once off' partial destocking required during the transition to a more sustainable management regime was estimated to be in the order of $7.3 million (Beare et al, 2003:39) as indicated in Table 17. Based on these figures, however, there is a real opportunity to address those properties contributing the greatest sedimentation to the coast of seven to ten tonnes per hectare per year for approximately $130, 000 through reducing stocking rates in marginal areas.

Contribution of sediment to the coast	'Hot spot' area	Opportunity cost of destocking*	Total opportunity cost
t/ha/yr	'000 ha	$/ha	$m
1 – 2	504	8.40	4.23
2 – 7	348	8.40	2.93
7 – 10	16	8.40	0.13
Total	868	8.40	7.29

Table 17: Transition costs to a more conservative stocking regime
Source: Beare et al, 2003
*estimated by reducing the long term average gross margin of $4.20 per hectare by half for four years

[3] Laing, A 2007, pers. comm. 22 June

Riparian/Buffer setbacks on grazing land

Another identified practice likely to reduce sediment runoff from grazing lands within the Lower Burdekin system is the establishment of buffer zones along rivers and streams in the riparian zone. Based on work undertaken by Prosser (2002), the total length of rivers and streams in the areas of land estimated to be contributing one tonne of sediment per hectare a year or more to the coast is around 972 kilometres. The main costs involved in establishing buffer zones are the opportunity cost of excluding stock and the fencing of such areas. Further costs are dependent on the individual property requirements and may include the installation of new watering points and weed and pest management.

The recommended size of the zone is suggested to be 30 metres on either side of the stream, with the following calculations undertaken on this basis. However, a less conservative setback may be expected for the purposes of the tender and conditional on the extent of riparian vegetation. Data from Beare et al (2003:40) assumes the opportunity cost of the land included in the buffer setback to be $82.40 per hectare based on the value of the land[4]. Table 18 represents an estimation of the opportunity costs of the buffer setback, identifying the loss of the setback at almost $0.5 million and the cost of fencing the area to be around $9 million. In the instance of the tender process, the opportunity for the submission of bids to address the higher sedimentation contributions through the use of setbacks may be a cost effective approach to improving water quality condition.

Contribution of sediment to coast	Length of river network	Area of buffer setback*	Value of land in setback**	Area of fencing buffer setback***	Cost of fencing buffer setback****
t/ha/yr	km	ha	$m	ha	$m
1 – 2	527	3160	0.26	1054	4.9
2 – 7	423	2540	0.21	846	3.9
7 – 10	22	130	0.01	43	0.2
Total	972	5830	0.48	1944	9.0

Table 18: Opportunity costs of establishing a buffer setback
Source: Beare et al, 2003
*on the assumption that the buffer setback is 30 metres on either side of the stream (total width of 60 metres)
**land valued at $82.40 per hectare
***fenced both sides of the stream
****cost of fencing is based on $4645 per kilometre for materials and construction

Buffer strips within cane land

One suggested option for reducing nutrient runoff from cane farms is to establish grassed buffer strips of at least five metres wide around parts of the farm in natural water courses where nutrient runoff occurs. Trials to date indicate that the buffering effect for nutrients could be significant, with the main costs involved with this practise being the opportunity costs of taking cane land out of production, and ongoing maintenance for the buffer strips. Beare et al (2003:41) calculated the opportunity cost of the loss of cane land at approximately $7402 per farm, given that an average buffer area of 1.1 hectares would be recommended to be taken out of production based on a five metre buffer with land values at $6802 per hectare. Whilst the tender the use of buffer strips in cane land may provide an attractive bid for the purposes of the bid, caution will need to be established in regards to the longevity of the practice post contract.

[4] As soils in riparian areas tend to be more fertilise, this may be an underestimate

Irrigation efficiencies for cane

Water availability is not an issue to sugarcane growers in the Lower Burdekin and Haughton systems and they will continue to have little incentive to improve the efficiency of their irrigation application whilst water is readily available at low cost. The major components of the cost of water are electricity and levy charges, however, there is a belief that these pumping costs are offset by lower management costs and the perceived long-term benefit to aquifer recharge through deep drainage. This practice is of relative concern as with long furrows and no tailwater recycling, many growers continue to apply water after it has reached the end of the furrows to ensure that the soil in the root zone is completely recharged in the highly permeable soils of the delta. Over time, a significant component of the irrigation water applied, laced with nutrients, may be lost as excessive runoff (Qureshi et al, 2001:11).

Possible alternatives include the use of low pressure overhead systems such a centre pivot or a trickle irrigation system. Both these practices, while with some initial up front cost, have the potential to improve the efficiency of the application of irrigation water as identified in Table 19 on a number of soil types prevalent in the Lower Burdekin area and a further opportunity to incorporate fertigation practices. While a study undertaken by Qureshi et al (2001:17) established that a trickle irrigation system was not viable under the then (2001) conditions within the Burdekin, investment into overhead irrigation may be undertaken, given the right market conditions including sugar price and input costs. While the uptake of such irrigation practices may be beyond the scope of the tender process, bids which seek to improve the management the movement of excessive irrigation water may be encouraged as an alternative.

Soil type	Furrow (efficiency %)	Centre Pivot (efficiency %)	Trickle (efficiency %)
Low Permeable (Clay)	60	90	90
Medium Permeable (Silt)	50	80	85
High Permeable (Sand)	30	75	80

Table 19: Efficiency of irrigation systems in different soil types
Source: Qureshi et al, 2001:13

Conclusion

The focus of this report is a review of the agricultural industries and environmental issues relevant to the lower Burdekin catchment area in north Queensland. The purpose of the overview is to help in the design stages of a competitive tender to reduce the impacts of agriculture on water quality in the region. Several key conclusions can be highlighted.

First, the issues of poor water quality are multifaceted. Key pollutants of concern include sediments, nutrients and chemicals, but loads vary in significance over time and space, and may impact on environmental assets in different ways. Agriculture, principally the beef and sugar industries, is the dominant but not the only contributor to these problems.

Second, while there is general acceptance that emissions from agriculture impact on water quality and poor water quality impacts on the Great Barrier Reef, the scientific evidence and models to link specific activities with environmental outcomes is limited. The policy response has been to focus on implementation of a range of best management practices without necessarily identifying the environmental impacts at a farm level or the improvements generated by BMP adoption.

Third, there is a wide range of BMP action and other management changes across the relevant industries that can be used to implement water quality improvements. This range of action, together with variation in climate geography and land condition across the region, indicated that there will be substantial heterogeneity in the impacts of different management action that might be identified in a competition tender.

Fourth, there is also evidence of variation in the economic and social tradeoffs that might be associated, some management changes that improve water quality may have neutral or even positive impacts, while other actions may be costly or not embraced by farmers. These variation in the opportunity costs and willingness of farmers to engage in adoption of BMP action w\ill add to the heterogeneity of bids in the competitive tender process.

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Appendix 1 – BMPs for Grazing Production in the Tully-Murray catchment identified by Roebling and Webster (2007)

Table A1 1 Current BMPs in grazing production for the Tully-Murray catchment

BMPs for Grazing Production	Description
River and stream bank stability	Use a combination of rocks, groins, netting and vegetation to reduce the erosion of stream and river banks
River bank management	Exclusion of cattle from river and stream banks
Surfacing creek watering points	Controlled access to hard surfaced areas in creeks for watering of cattle
Off-stream watering points	Establishment of non-natural watering points away from the river or stream
Feral pig control	On-farm management of feral pigs
Species selection	Plant pasture species according to paddock situation
Nitrogen (N) management	Match N to pasture requirements, while taking into account all sources of N
Carrying capacity	Match stocking rate to pasture productivity
Cattle management	Timing of purchase and sale of cattle in accordance with pasture productivity
Pasture rotation/spelling	Application of flexible stocking rates around core areas
Chemical management	Use of chemicals as per label
Integrated weed control	Management of weeds through a combination of methods in conjunction with intensive follow-up campaigns.

Source: Roebling and Webster, 2007

Table A1 2 Future BMPs in grazing production for the Tully-Murray catchment

Future grazing BMPs	Description
Laser fencing	Fencing based on laser technology
New pasture species	Species that have better productivity and improved resource use efficiency
Slow release fertilisers	N fertilisers that are less prone to environmental losses

Source: Roebling and Webster, 2007

Appendix 2 – BMPs for Sugarcane Production

Table A2 1 – Best Management Practices in Sugarcane Production

BMPs for Sugarcane Production	Description
Farm Plan	Management tool to assist Farm operation – should contain property details, soil information, topography, block layout, natural watercourses etc. Requirement of applications for new Cane Production Area or expansion of existing cane area
Farm Layout Change	Modified farm layout to improve efficiency of operations including irrigation and harvesting
Variety selection	Plant early, mid or late maturing variety according to paddock situation, resource availability (water) and pest/disease pressures
Vegetation Management	Manage native vegetation for wildlife corridors. Stream bank vegetation enhances wildlife corridors, improves instream habitat and s
River and stream bank stability	Use a combination of rocks, groins, netting and vegetation to reduce the erosion of stream and river banks
Soil Management	Conservation and maintenance of soil structure, fertility and biological characteristics
Minimum/zero tillage	Apply no or minimum ploughing passes when preparing a block for planting to reduce potential of soil erosion
Wider Row Spacing	Similar to controlled traffic, but with modifications to row widths and farm machinery
Fertilisers and soil ameliorants	Use of essential cane nutrients to improve the condition and ground cover of crops
Fertiliser application methods	Calibrate fertiliser applicator and apply fertiliser below grounder, either stool split or directly beside the stool. For above ground application, delay application until cane height of 50cm and surface band applying close to the stool.
Fertiliser application rates / Soil testing	Elemental analysis of soils to assess crop nutrient status and requirements
Nitrogen (N) management	Match N to crop requirements, while taking into account all sources of N
Stool splitting nitrogen (N)	Underground application of N to ratoons using a stool splitter
Rotation Cropping & Legume Break cropping	Planting fallow land, about 15% of a farm area, on an annual rotational basis with nitrogen fixing legumes (for example soybeans, peanuts, chickpea)
Use of mill by-products	Recycling and reusing mill mud (filter press) from mills to provide plant nutrition and soil conditioning
Managing saline and sodic soils	Manage drainage systems, application of soil ameliorants including gypsum, retain harvesting residue, maintain adequate topsoil, adopt good irrigation management practices

Irrigation	Selection of the most suitable irrigation system is influenced by soil permeability, topography, water availability and cost.
Furrow irrigation	Furrow irrigation is less suitable than overhead low pressure or trickle systems on free-draining, highly permeable soils.
Furrow Design	Changed furrow shape to reduce deep drainage loss or to improve infiltration on poor soils and back end of furrow to reduce runoff
Overhead irrigation	Overhead irrigation systems need to be calibrated to soil type. Other factors to consider include green cane trash blanketing and climatic conditions including wind speed.
Tailwater recycling and water recycling systems	The installation of tailwater storage improves irrigation efficiencies, minimises run-off and traps sediments, nutrients and chemicals. The design of tailwater storages should ensure that off-farm run-off from irrigation does not exceed 10% of irrigation inflow rates.
Sediment traps	Establish hollows in drainage networks that are specifically designed to trap sediments in drainage water
Irrigation scheduling	Schedule irrigation with evaporation mini-pans and/or soil proves calibrated to stalk growth measurements and soil types
Water Use Efficiency	Match irrigation to daily crop requirements to ensure better targeted application of water use
Treated waste water	Effluent water should only be applied when it is of the appropriate quality, soils are appropriately permeable and ground water is of sufficient depth to minimise contamination.
Drainage	Drainage systems should be designed so that they do not significantly alter the nature of healthy streams, affect water quality or expose potential acid sulfate soils.
Drain design	Establish a shallow and grassed drains that are, preferably, spoon shaped
Block drainage	Facilitate block drainage by avoiding low spots and assuring that all headlands are lower than the block
Grassed headlands	Establish headlands of at least 4m wide and that are at least 80% grassed
Weed, pest & disease control	
Integrated pest management	Adoption of Integrated Pest Management strategies including biological and cultural controls.
Rat control	Application of Integrated Pest Management strategies for the control of rats through minimising weeds in cane and surrounding grass harbourage areas.
Feral animals	Abide by relevant legislation when pursuing feral animals and obtain Damage Mitigation Permits for the control of native animals.

Fire Management	Cane firing must be in accordance with the established local permit system. Every effort should be made to retain, incorporate or dispose of tops rather than burning. Green cane harvesting and trash blanketing should be adopted where compatible with profitable cane growing.
Green cane trash blanketing	Harvest without burning and leaving the cane residue on the block for the duration of ratoons
Timing of Operations and notifying neighbours	Time your farm management operations to minimise off farm impacts.
Fuel and dangerous goods – use and storage	Adhere to relevant codes and participate in approved training programs
Storage and bunding	Store chemicals in accordance with relevant Codes in a well ventilated, secure and child-proof area with impervious bunding.
Chemical Use	Maintain comprehensive records of any usage of agricultural chemicals.
Managing off-site risks of spray drift and chemicals	Ensure that people and the environment are protected from potential harm from the use of agricultural chemicals.
Waste management	Use approved facilities or contained sites for waste management.
Recycling	Where available, commercial recycling options should be utilised.
Chemical Containers	Chemical containers must be disposed of as specified in relevant codes.
On-farm monitoring	Maintain effective farm records to demonstrate sustainable cane growing practices including productivity records, soil tests, chemical usage, fertiliser use, tree plantings & survival rates.

Source: Adapted from CANEGROWERS 1998, Roebling and Webster 2007, Wrigley and Moore 2006

Table A2 2 Future Best Management Practices in Sugarcane Production

Future sugarcane BMPs	**Description**
Controlled traffic	Wider row spacing and controlled steering technology to prevent farm machinery from compacting stool area
Precision farming / Spatial crop imagery	Within block variable application of fertiliser and chemicals based on spatial within block data
Enzyme nitrogen (N) fixation	Enzymes that allow much of the crops N needs to be derived from the atmosphere
Denitrification inhibitors	Chemicals that prevent N fertilisers from denitrifying before crop uptake,
Double row harvesting	Harvesting two cane rows (as opposed to dual row) in one pass
GM varieties	Varieties that have better productivity and improved resource use efficiency
Soil health analysis	Using soil health indicators in farming
Fertigation	More frequent applications of fertilisers and chemicals as the crop needs them
Integrated pest management	Using chemical, cultural, biological and physical control measures

Slow release fertilisers	N fertilisers that are less prone to environmental losses
Safe chemicals	Chemicals that do not persist in the environment
Chemical resistant varieties	Varieties that can be sprayed with general knockdown herbicides and not suffer
Chemical ripeners	Application of chemicals to improve CCS
Climate forecasting	Using seasonal climate forecasts to time operations on farm

Source: Roebling and Webster, 2007

Appendix 3 – BMPs for Horticulture Production in the Tully-Murray catchment identified by Roebling and Webster (2007)

Table A3 1 Current BMPs in Horticulture Production for the Tully-Murray catchment

BMPs for Horticulture Production	Description
Drain design	Establish shallow and grassed drains that are, preferably, spoon shaped
Road design	Prevent water from running over road through establishment of culverts or spoon drains
Fallow management	Plant cover crop between cropping cycles
Trash management	All banana trash placed on plant row
Interrow management	Grassed interrows maintained through regular slashing or other means
Nutrient management	Match nutrient application to crop requirements based ons oil and leaf testing, while applying soluble nutrients through fertigation in small regular doses (or other means)
Soil moisture management	Soil moisture monitoring tools used to schedule irrigation and prevent deep drainage
Integrated pest management	Using chemical, cultural, biological and physical control measures for pests, diseases and weeds
Soil testing and ameliorate	Soil health analysis to identify lime and gypsum requirements
Chemical handling and application	Chemical handling and applications by Chemcert accredited operators and in accordance with Chemcert guidelines
Waste disposal	Dispose of non-vegetative waste through registered contractors or services
Waste water management	Packing shed waste water filtered through settling ponds or similar
Packing shed waste disposal	Fruit and stalk waste used as fodder or placed on fallow ground or plant rows

Source: Roebling and Webster, 2007

Table A3 2 Future BMPs in Horticulture Production for the Tully-Murray catchment

Future Horticulture BMPs	Description
Minimum tillage	Maintain permanent crop beds, spray out crop at end of crop cycle and minimise tillage prior to planting
Companion planting	Plant complementary crops for moisture retention, weed management and erosion mitigation
Sediment traps	Establish hollows in drainage networks that are specifically designed to trap sediments in drainage water
Alternative soil conditioners	Soil health analysis to identify conditioner requirements
Targeted pest management	Application of narrow spectrum, localised or systematic chemicals

Source: Roebling and Webster, 2007