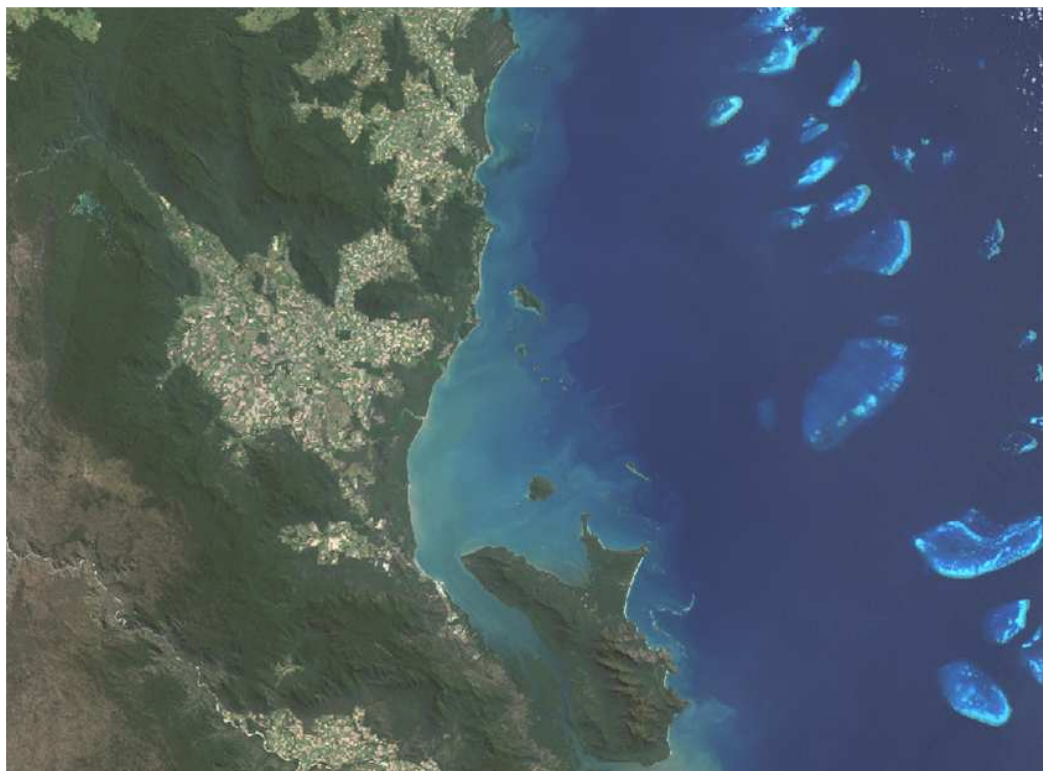


Draft Tully Water Quality Improvement Plan

Frederieke J Kroon
July 2008

Report to Terrain Natural Resource Management



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Tully Murray Floodplain Program



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EXECUTIVE SUMMARY

The development of a Tully Water Quality Improvement Plan (Tully WQIP) has been identified as a high priority under the Reef Water Quality Protection Plan (the 'Reef Plan'). The development and delivery of the Tully WQIP has been managed by the regional NRM board (Terrain NRM), with support from the Cardwell Shire Floodplain Program (CSFP) and Cardwell Shire Council. The CSFP forms a partnership between major local, regional, state and federal stakeholders, and is incorporated under the Cardwell Shire Catchment Management Association.

The Tully WQIP covers the combined geographical area of the Tully and Murray rivers and the Cardwell Shire Local Government Area. The area contains parts of the Wet Tropics World Heritage Area and discharges into the Great Barrier Reef World Heritage Area. During flood events, approximately 2,000 km² of marine receiving waters are influenced by discharge from the Tully WQIP area.

The Tully WQIP includes the following components:

- it identifies the environmental values (EVs) of water bodies and the water quality objectives (WQOs) that will protect the EVs (Section 2),
- it estimates the sustainable target loads based on the WQOs, and compares these with the estimated current status of pollutant loads (Section 3),
- it assesses management measures and control actions to reduce pollutant loads to receiving waters in order to protect water quality (Section 4),
- it identifies management action targets, and associated management actions, that will result in the progressive (quantified) reductions in pollutant loads from both diffuse and point sources required to achieve sustainable loads (Section 5), and
- it identifies processes and management arrangements to ensure effective implementation (Section 6).

Draft Environmental Values and Water Quality Objectives

The Tully WQIP has established draft environmental values (EVs) and draft water quality objectives (WQOs) for freshwaters, estuarine and marine reaches. Preferred uses of local water bodies (including surface and groundwater) were determined by identifying the current and future values or uses of the environment that contribute to public or private benefits (i.e. EVs). Based on the community's choices for draft EVs, and the existing water quality guidelines and standards intended to protect them, draft WQOs were established.

Draft EVs were identified through interviews and workshops with community members in the Tully WQIP area, as well as discussions with the CSFP Steering Committee. The results demonstrate that all groups use and value the aquatic ecosystems, drinking water and aquatic food that local waterways provide. Moreover, all surface waters are used and valued for their aquatic ecosystems, for their indigenous and non-indigenous cultural heritage, and for their amenity. Differences and potential conflict between the various values is often between 'consumptive' (e.g. irrigation) and 'non-consumptive' (e.g. recreational and cultural) uses. The final EVs will incorporate comments on the draft EVs received during further meetings with, and input from, key stakeholders and the community during the public consultation phase.

Draft WQOs were established to serve as water quality targets to protect the EV identified by the community. These draft WQOs should be considered trigger values that would indicate a potential problem if exceeded, and 'trigger' a management response. A comparison of draft WQOs in inshore marine waters against available data on current water quality in these waters shows that draft WQOs are met, except for chlorophyll-a (Table 1).

Table 1. Comparison of draft water quality objectives (WQOs) for nutrients, sediment, and pesticides of two inshore marine water types in the Tully WQIP area, against current condition of water quality during flood events in 2006/2007.

Indicator		Unit	Draft WQO		Current condition	
			Mouth of estuary to marine waters	All marine waters ≤ 15km off the coast		
Nutrients	Inorganic N TAN NO ₂ N NO ₃ N NO _x N	µg/l	15	2	1.6	
			10	910	0.2	
			135	2	99	
	160		135	102		
	5		140	2.2		
	20		3	12		
Organic N Total N FRP Total P						
Microalgal Growth	Chl-a		2.0	0.5	1.3	
Water Clarity	Turbidity	NTU	10	1		
	Secchi	m	1.0			
	TSS	mg/L			4.5	
Pesticides	Diuron	µg/l		1.0	0.011	
	Atrazine			6.6	0.004	
	Chlorpyrifos			0.02		
	Endosulfan			0.005		
	Ametryn			0.2	< dl	
	Simazine			11	< dl	
	Hexazinone			0.9	0.004	
	2,4-D				52.6	
	Tebuthiuron				17.5	
	MEMC				0.002	
	Diazinon				0.06	
	Tributyltin				0.001	
	Irgarol				0.02	

Sustainable load targets and current status of pollutant loads

The Tully WQIP has estimated sustainable load targets based on the draft WQOs for marine waters and based on estimates of pre-1850 loads. Sustainable load targets based on draft WQOs were estimated for flood events when the majority of pollutants are transported to the marine receiving waters.

To reduce Chl-a concentrations in the open coastal lagoon to meet the draft WQO of 0.5 µg/L (Table 1), the outcomes of the modeling indicate that DIN concentrations at Euramo bridge (Tully River), or nitrate that is lost from the land, would need to be reduced by at least 80%. Receiving water models and local water quality guidelines for suspended sediment, phosphorus and pesticides are needed before sustainable load targets can be estimated.

Estimates of pre-1850 loads suggest that sustainable loads are 940 tonnes/year for total nitrogen; and 110 tonnes/year for total phosphorus.

Current status of sediment and nutrient loads was determined using a combination of monitoring (and associated modelling), and were subsequently compared with sustainable loads. Estimated annual average pollutant loads delivered to receiving waters by streams and rivers in the Tully WQIP area are:

- 119,000 tonnes of total suspended sediment per year;

- 2,300 tonnes of total nitrogen per year, comprising of 1,200 tonnes (52%) dissolved inorganic nitrogen, 500 tonnes (22%) of dissolved organic nitrogen, and 600 tonnes (26%) of particulate nitrogen; and
- 240 tonnes of total phosphorus per year, comprising of 50 tonnes (22%) of filterable reactive phosphorus, 30 tonnes (13%) of dissolved organic phosphorus, and 160 tonnes (65%) of particulate phosphorus.

Compared to pre-1850 loads, the current TSS load appears to have increased by a factor of around 4, the current TN load by a factor of around 3, and the current TP load by a factor of 2. This increase in TN load corresponds well with the estimated 80% reduction required in DIN concentrations at Euramo bridge (Tully River) to reduce Chl-a concentrations in the open coastal lagoon to meet the draft WQO of 0.5 µg/L.

Outcomes of new research in the Tully and Murray catchments indicate that significant sediment and nutrient loads are being delivered to marine waters by over bank floods, *in addition to* loads delivered by streams and rivers. The additional amounts range from 10 - 60% depending on pollutant type and flood size.

Because pesticides are toxicants, herbicide concentrations were compared against draft WQOs in the freshwater reaches of the Tully WQIP area. Atrazine, diuron and hexazinone concentrations in 30 of the 102 samples analysed equalled or exceeded draft WQOs in the catchment (and exceeded National Water Quality Guidelines for drinking water, stock water and freshwater ecosystems).

Based on the best available science to estimate sustainable load targets and current pollutant loads, the following list of key pollutants and critical source categories was developed:

1. **nitrate** and **particulate nitrogen** are considered the priority pollutants. Over 85% of nitrate is sourced from agricultural land uses, primarily sugarcane and bananas, while particulate nitrogen is sourced from eroding soils, especially those exposed during land development activities, and those enriched in nitrogen through a history of fertiliser use;
2. **herbicide residues**, including ametryn, atrazine, diuron, hexazinone and simazine, are ranked second due to their widespread detection in both fresh and marine waters where they can have impacts at very low concentrations. Ametryn, atrazine, diuron and hexazinone are used in sugarcane, while simazine is used in plantation forestry;
3. **suspended sediment** and **particulate phosphorus** are ranked third, reflecting the relatively low generation and delivery of sediment in the catchment, particularly compared to data from other GBR catchments. Residual sediment (and associated particulate phosphorus) sources are present in all agricultural land uses, plantation forestry, along waterways, as well as in urban development, roads and drains in all land uses;
4. **dissolved organic nitrogen** is ranked fourth due to its relatively high contribution to nitrogen loads in overbank flows. Preliminary research results indicate that this dissolved organic nitrogen originates almost completely from the upper catchment rainforest. Increased run-off rates and amount, due to removal of wetlands and the installation of land drainage systems in coastal floodplains, may result in higher dissolved organic nitrogen loads now reaching receiving waters.

Assessment of management scenarios to reduce loads

The Tully WQIP has assessed the cost-effectiveness of changes in land management to reduce key pollutant loads from critical sources, using scenario modelling. These scenarios investigated the potential of land management practices in current land uses to reduce nitrate, herbicide and suspended sediment loads to the marine receiving waters. The outcomes of the scenario modelling were discussed with CSFP Steering Committee.

Nitrate

Results from scenario modelling indicate that reduced DIN delivery at end-of-river can be achieved in sugarcane and banana, with both financial-economic and water quality benefits:

- in sugarcane, the models show that complete adoption of the Bureau of Sugar Experiment Stations (BSES) '**Six Easy Steps**' program reduces the total DIN load to end-of-river by 23%. This plan recommends 100% adoption of Six Easy Steps by sugarcane farmers by 2010.
- a reduction of 45% in the total DIN load to end-of-river is achievable with complete uptake of **nitrogen (N) replacement** in sugarcane. N replacement is still in a research 'proof of concept' stage and this plan recommends R&D investment to further this technology.
- a reduction of 66% in the total DIN load to end-of-river would be achievable with complete adoption of **N fixing sugarcane**, assuming that this reduced the requirement for N fertiliser applications to 30 kg N per ha. Significant local research will be required to determine whether this technique is viable in sugarcane, and potentially in bananas, as well as the potential impact and spread of such bacteria beyond the intended crops.
- in bananas, complete adoption of a 30% **reduction in nitrogen application** to 225 kg N per ha reduced DIN contribution from the banana industry by 27%. Previous research determined that nitrogen application may be reduced to 250 kg N/ha without measurable loss of yield. This plan recommends further research and accelerated extension on key nutrient management practices in horticulture by 2013.

These scenarios do not result in the 80% reduction in nitrate concentration required. Consequently, additional management actions need to be implemented to reduce nitrate concentrations.

- modelling has demonstrated that **riparian restoration**, for the purpose of denitrification of groundwater delivered to streams, should target streams with specific characteristics in the central catchment. This plan recommends restoration of key riparian locations as identified in this analysis by 2013.
- the Tully WQIP further recommends (i) more accurate and precise estimates of fertiliser usage, (ii) long-term monitoring of nitrate loads at end-of-river and, (iii) if current recommended management actions do not achieve progress towards an 80% reduction in nitrate concentrations by 2013, socio-economic assessment of land use change.

Herbicides

Results from scenario modelling indicate that the most cost-effective option for water quality improvement is uptake of reduced rates of herbicide application in sugarcane:

- the use of a **hooded sprayer** could lead to a 50% decrease in herbicide delivery to the end-of-river and only a slight decrease in gross margin. However, potential yield impacts need to be validated under local conditions.

Fewer than 20% of farmers and growers are estimated to have current **ChemCert® accreditation**. This plan recommends, as a start, complete adoption and/or renewal of ChemCert® accreditation (or equivalent) by all farmers and growers by 2010.

This plan proposes that further R&D is required to (i) explore viable alternatives to problematic herbicides, (ii) assess herbicide use in grazing, plantation forestry and urban environments, and (iii) examine usage and detection of other pesticides assessed as relatively high risk for the aquatic environment.

Suspended sediment, particulate nitrogen and particulate phosphorus

Results from scenario modelling indicate that reduced suspended sediment loads, and associated particulate nitrogen and particulate phosphorus loads, at end-of-river can be achieved in sugarcane and banana, with both financial-economic and water quality benefits:

- in sugarcane, uptake of **zero tillage** reduces total suspended sediment contribution to end-of-river by 10%, and is attractive from a financial-economic perspective. This plan recommends accelerated extension on zero tillage in sugarcane by 2013.
- in bananas, complete uptake of **zonal tillage** reduces total suspended sediment contribution to end-of-river by 3%; the financial-economic effects are currently unknown and strategies are proposed to address this. This plan recommends further research and accelerated extension on zonal tillage in bananas by 2013.

- moreover, **targeted restoration of riparian buffer zones** at large scales reduces total suspended sediment loads to end-of-river (e.g. 124 km results in 5% reduction), while simultaneously enhancing EVs identified by the community. This plan recommends restoration of key riparian locations as identified in the analysis by 2013.

Management action targets to achieve sustainable load targets

The Tully WQIP has developed management action targets (MAT), based on the outcomes of the comparison between sustainable load targets and current pollutant loads, estimates of target loads and assessment of management scenarios, and four stakeholder workshops (Table 2). The MATs have been set for 2013 (or earlier) to ensure progress against the goal and objectives of Reef Plan.

To meet the MATs, *management actions* were developed that identify strategic, prioritised and achievable actions. The implementation of these actions will result in progressive (quantified) reductions in pollutant loads from both diffuse and point sources towards achieving draft WQOs that are currently not met.

The implementation of these management actions is estimated to reduce by 2013 (Table 3):

- total nitrate load from 1,160 tonnes/year to 870 tonnes/year;
- total suspended sediment load from 119,000 tonnes/year to 97,500 tonnes/year, and
- herbicide concentrations to meet Australian and Great Barrier Reef water quality guidelines in freshwater and marine environments.

Implementation and monitoring and evaluation

At a regional and catchment level, the regional NRM board (Terrain NRM) will play a lead role in the ongoing coordination of WQIP planning and implementation. In this task, it will be supported through long-term partnerships with the CSFP Steering Committee and associated partners.

At a cross Regional, State and Federal level, the Reef Water Quality Partnership (RWQP) provides a framework to support links between Australian and Queensland Government Agencies and GBR regional NRM bodies to implement the Tully WQIP.

In addition to the public consultation process currently underway, several steps are still required to finalise the Tully WQIP implementation arrangements:

1. partnership and implementation workshops, focussed on developing commitment to and resources for critical management actions, need to be held with industry and indigenous groups, Cardwell Shire Council, and State and Federal Government sectors, and
2. targeted effort is needed at a higher level within industry organisations and State and Federal Government Agencies, (i) to determine the funding needed for management actions, (ii) to discuss program, policy and budget alignments among the lead agencies and partner organisations committed to management actions, and (iii) to consider any additional funding required to achieve management actions.

Ultimately, the draft Tully WQIP will be finalised by taking the outcomes of these processes into account. It is intended that the final Tully WQIP be signed-off for implementation by Terrain NRM, CSFP Steering Committee, and State and Federal Government Agencies.

The Tully WQIP recommends that monitoring and evaluation be progressed in a formalised State of the Catchment reporting, with progressive updates by all partners on an annual basis. To ensure consistency in the GBR region, the plan recommends building on a monitoring and modelling strategy and reporting framework strategy currently being finalised by the RWQP. Significant review of the Tully WQIP is intended within a five-year time frame to coincide with the end of Reef Plan (2013).

Table 2. Management action targets (MATs) developed for the Tully WQIP, placed in the asset framework advocated by the National CCI and NRM programs, and used by the regional NRM plan. The MATs have been developed based on the outcomes of current and future land management scenarios and four stakeholder workshops, and have been set for 2013 (or earlier) to ensure progress against the goal and objectives of Reef Plan.

CRITICAL AREAS FOR ACTION	ASSET			
	Water resources		Sustainable industries	Riparian zones and wetlands
Nutrient management	W1. Incorporate land use planning and pollutant offsetting mechanisms into the FNQ 2025 Regional Plan by 2008	WR2. Reduce total DIN loads delivered to receiving waters by streams and rivers by 25% to 870 tonnes/year by 2013	SI1. Reduce nitrate loss by 50% from contributing land uses by 2013	RW1. Undertake 285.5 km of riparian rehabilitation in identified areas to denitrify groundwater delivered to streams by 2013
Herbicide management		WR3. Meet the Australian and GBR water quality guidelines for pesticides by 2013	SI2. Reduce herbicide losses by 50% from contributing land uses by 2013	RW2. Minimise impact of invasive species that threaten inland aquatic and terrestrial ecosystems by 2013
Sediment management		WR3. Reduce total TSS loads delivered to receiving waters by streams and rivers by 18% to 97,500 tonnes/year by 2013	SI3. Reduce sediment loss by 10% from contributing hot spots by 2013	RW3. Undertake 124 km of riparian rehabilitation in identified areas to minimise bank erosion by 2013
Restoration of floodplain function		WR4. Identify floodplain retentation areas that can contribute to filtering function by 2013	SI4. All main land uses have implemented, and are continuously updating, current recommended practices by 2013	RW4. No further degradation or fragmentation of aquatic ecosystems by 2013

Table 3. Estimated reduction in current loads with implementation of priority management actions by 2013. Only those management actions are given for which estimates in load reductions could be quantified using SedNet/Annex. Note that additional proposed management actions are expected to contribute to a reduction in current loads, but quantification of their effects has not been possible with currently available models.

Current pollutant loads		MAT (2013)	Management actions	Reduction		Loads in 2013		
Pollutant	tonnes	tonnes		tonnes	%			
TSS	119,000	97,500	Promote adoption of zero tillage in sugarcane	13,000	10	96,350		
			Promote adoption of zonal tillage in horticulture	3,700	3			
			Revegetate key locations as identified by SedNet and other methods	5,950	5			
			TOTAL	22,650	18			
DIN	1,159	870	Complete uptake of Six Easy Steps in sugarcane, including nutrient management plans Implement detailed nutrient management strategy for horticulture	261 25	23 2			
DON	529	n/a	n/a	Total	286		25	
PN	630	n/a	Promote adoption of zero tillage in sugarcane Promote adoption of zonal tillage in horticulture	73 22	12 4			
			Total	95	16			
TN	2,318	2,029	TOTAL	381	16	1,937		
FRP	54	n/a	n/a					
DOP	31	n/a	n/a					
PP	159	n/a	Promote adoption of zero tillage in sugarcane Promote adoption of zonal tillage in horticulture				20 6	13 4
			Total				26	17
TP	244	n/a	TOTAL	26	17	218		

ACKNOWLEDGEMENTS

I am indebted to the Cardwell Shire Floodplain Program (CSFP) Steering Committee for supporting the development and delivery of the Tully Water Quality Improvement Plan. Support and assistance of the CSFP Steering Committee and its partners was instrumental in getting the framework and structures in place for the development and delivery of this plan. Too many individuals have been part of the CSFP Steering Committee in the past and present to thank individually, so I'll limit my thanks to the current Chairs and Facilitators of the Steering Committee and its associated Action Teams, thereby acknowledging the contribution of all their members: Bill Shannon from Mission Beach Local Marine Advisory Committee and Paul Devine from Cardwell Shire River Improvement Trust (Steering Committee), Derrick Finlayson from Tully Sugar Ltd and Peter Lucy from Tully Canegrowers (Production Action Team), Paul Devine and Damon Sydes, both from Cardwell Shire Council (Biodiversity Action Team), and Keith Noble from Growcom and Kate Hensler from Terrain NRM (Socio-Cultural Action Team).

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The Tully WQIP is the third in the Great Barrier Reef region to be delivered and implemented, following the Douglas and Mackay-Whitsunday WQIPs. Coordination of WQIPs in the GBR region has been assisted by the Reef Water Quality Partnership and its Regional Implementation Group. I hope my RWQP and RIG colleagues can learn from and build on the Tully effort.

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ACRONYMS

ABGC – Australian Banana Growers Council

ACTFR – Australian Centre for Tropical Freshwater Research

APSIM – agricultural production systems simulator

AFS – Australian Forestry Standard

BOD – biological oxygen demand

BSES – Bureau of Sugar Experiment Stations

CCI – Coastal Catchment Initiative

Chl-a – chlorophyll-a

CoP – code of practice

CMA – Catchment Management Association

CSIRO – Commonwealth Scientific and Industrial Research Organisation

CSC – Cardwell Shire Council

CS RIT – Cardwell Shire River Improvement Trust

CSFP – Cardwell Shire Floodplain Program

CSFP SC – Cardwell Shire Floodplain Program Steering Committee

DEW – Australian Department of the Environment, Water, Heritage and the Arts

DIN – dissolved inorganic nitrogen

DO – dissolved oxygen

DON – dissolved organic nitrogen

DOP – dissolved organic phosphorus

DPI&F – Queensland Department of Primary Industry and Fisheries

E2 – software product for whole-of-catchment modelling

EMSS – environmental management support system

EPA – Queensland Environmental Protection Agency

ERA – environmentally relevant activity

EV – environmental value

FMS – farm management systems

FNQ – Far North Queensland

FNQ NRM – Far North Queensland Natural Resource Management

FNQ ROC – Far North Queensland Regional Organisation of Councils

FSC – Forest Stewardship Council

FRP – filterable reactive phosphorus

FSS – fine suspended sediment

GCTB – green cane trash blanketing

GBR – Great Barrier Reef

GBRMPA – Great Barrier Reef Marine Park Authority

IOC – Intergovernmental Operational Committee

ISO – International Organisation for Standardisation
ITC – Integrated Tree Cropping
JCU – James Cook University
JSC – Joint Australian and Queensland Governments Natural Resource Management Steering Committee
LMAC – Local Marine Advisory Committee
LUCTOR – land use crop technical coefficient generator
N – nitrogen
NHMRC – National Health and Medical Research Council
NMZ – Nutrient Management Zone
NO₃ – nitrate
NO_x – nitrate and nitrite
NPPWE – National Principles for the Provision of Water for Ecosystems
NRM – Natural Resource Management
NRW – Queensland Department of Natural Resources and Water
NWQMS – National Water Quality Management Strategy
MAT – management action target
PEFC – Pan European Forest Certification Council
PASTOR – pasture and animal system technical coefficient generator
PFNQ – Private Forestry North Queensland
P – phosphorus
PN – particulate organic nitrogen
PP – particulate organic phosphorus
QLUMP – Queensland Land Use Mapping Program
QPWS – Queensland Parks and Wildlife Services
RCT – resource condition target
RE – regional ecosystem
RIG – Regional Implementation Group
ROP – Resource Operations Plan
RUSLE – Revised Universal Soil Loss Equation
RWQP – Reef Water Quality Partnership
RWSS – Regional Water Supply Strategy
SedNet/Annex – Sediment River Network/Annual Nutrient Export
SIIP – Sugar Industry Infrastructure Package
SMART – Specific, Measurable, Achievable, Relevant and Timed
SS – suspended sediment
STP – sewage treatment plant
TN – total nitrogen
TP – total phosphorus
TSS – total suspended sediment

UQ – University of Queensland

WQ – water quality

WQIP – Water Quality Improvement Plan

WQO – water quality objective

WRP – Water Resources Plan

1 BACKGROUND TO THE TULLY WATER QUALITY IMPROVEMENT PLAN

1.1 Introduction

A Water Quality Improvement Plan (WQIP) describes the measures and actions required to achieve an interim pollutant¹ load(s) target, which is on trajectory to a long-term sustainable load target. A WQIP will identify the most cost-effective and timely measures and actions needed by all parties to achieve these targets. Parties include the Australian, State and Local Governments, regional Natural Resource Management (NRM) boards, and community, industry and environment groups.

WQIPs are developed and implemented across Australia in agreed coastal hotspots, such as the Great Barrier Reef (GBR) (Baker 2003). Moreover, the Tully basin has been identified as a high risk catchment under the Reef Water Quality Protection Plan (Reef Plan, Section 1.2), which made the development of a Tully WQIP a high priority. The Tully WQIP is the second WQIP developed in the Wet Tropics region following the Douglas WQIP (Davis 2006), and one of seven WQIPs currently being developed in the GBR region. Reef WQIPs, including the Tully WQIP, are primarily concerned with reducing sediment, nutrient and pesticide loads in the water entering the Great Barrier Reef (GBR) (Figure 1.1). The additional localised benefits of Reef WQIPs implementation may include greater economic efficiencies in the local industries and better water quality and ecological health in the contributing freshwater systems.

A WQIP includes the following components (Figure 1.2):

- it identifies the environmental values (EVs) of water bodies and the water quality objectives (WQOs) that will protect the EVs (Section 2),
- it estimates the sustainable target loads based on the WQOs, and compares these with the estimated current status of pollutant loads (Section 3),
- it assesses management measures and control actions to reduce pollutant loads to receiving waters in order to protect water quality (Section 4),
- it identifies management action targets, and associated management actions, that will result in progressive (quantified) reductions in pollutant loads from both diffuse and point sources required to achieve sustainable loads (Section 5), and
- it identifies the processes and management arrangements to ensure effective implementation (Section 6).

The development of WQIPs is funded by the Coastal Catchment Initiative (CCI) program (Section 1.2), and is consistent with the goals and objectives of regional NRM plans (Section 1.2). A draft WQIP will be submitted for accreditation by the Australian Government, relevant State and/or Local Governments, and the relevant regional NRM board, thereby forming an agreed approach to achieving pollutant reductions. Once developed, a WQIP will be incorporated into regional NRM plans and will be reviewed and renewed at least every seven years.

The development and delivery of the Tully WQIP has been managed by the regional NRM board (Terrain NRM, the business name of FNQ NRM Ltd.), with support from the Cardwell Shire Floodplain Program (CSFP) and Cardwell Shire Council (CSC). Research underpinning the draft Tully WQIP was conducted by the CSIRO's Floodplain Renewal Program along with James Cook University (JCU), DPI&F, NRW, Bureau of Sugar Experiment Stations (BSES), University of Queensland (UQ), and Australasian Groundwater & Environmental Consultancies.

The CSFP framework was established, based on the lessons learnt from the Douglas WQIP (Kroon *et al.* 2006), to manage and support the planning and policy, research, management and extension activities underpinning the development, delivery, and ultimately the implementation, of the Tully WQIP (Figure 1.3a, b). The CSFP forms a partnership between primary industry groups, the Giringun Aboriginal Corporation, conservation groups, CSC, Terrain NRM, State and Federal Government agencies, and research

¹ *Pollution* is defined as 'a deleterious change in the chemical, physical and biological qualities of an ecosystem due to human activity', and *pollutants* as 'the substances, structures and species (biological or chemical) that cause the pollution' (Baker 2003).

organisations (Appendix 1). This partnership aims to improve the long-term socio-economic and biophysical productivity of the Tully WQIP area (Section 1.3) through the effective management of natural and cultural resources (CSFP 2005a). The CSFP became synonymous with the Cardwell Shire Catchment Management Association Inc. in November 2006.

To support the CSFP Steering Committee with day-to-day management and alignment of NRM activities in the greater Tully-Murray catchment area, while focussing on the development and delivery of the Tully WQIP, the CSFP Steering Committee established three Action Teams in August 2005. These Action Teams, in the areas of Biodiversity (BAT 2006), Production (PAT 2006) and Socio-cultural and human capital (SCAT 2006), have members from relevant CSFP partner organisations. The Action Teams have been providing specific information, based on the best available scientific information and local knowledge, to the CSFP Steering Committee. In relation to the development of the Tully WQIP, the CSFP Steering Committee has played a crucial role in discussing, negotiating and making decisions on water quality improvement. To outline responsibilities of all CSFP partners for internal and external communication, a communication strategy was adopted by the CSFP Steering Committee (CSFP 2005b).

1.2 Planning and policy environment of the Tully WQIP

The Tully WQIP has been developed in a broader planning and policy environment, including Regional, State and National plans and policies. The following sections provide a brief summary of each relevant plan and policy, and their linkages to the Tully WQIP.

The Reef Water Quality Protection Plan

In 2005-06, the Great Barrier Reef (GBR) contributed an estimated \$6.9 billion per year (gross product) to the Australian economy (Access Economics 2007). This contribution comprises mostly tourism (\$6 billion), followed by other recreational activities (\$623 million) and commercial fishing (\$251 million), and provides employment for approximately 66,000 (full time equivalent) persons. This economic contribution depends on the maintenance and enhancement of the environmental values of the GBR aquatic ecosystems.

To protect the GBR, and its environmental values, from land based sources of pollution, the Australian and Queensland Governments jointly developed and launched the *Reef Water Quality Protection Plan* (the 'Reef Plan'; The State of Queensland & Commonwealth of Australia 2003). The goal of the Reef Plan is 'to halt and reverse the decline in water quality entering the Reef within 10 years'. To support the achievement of this goal, the Reef Plan has two objectives:

1. reduce the load of pollutants from diffuse sources in the water entering the Reef; and
2. rehabilitate and conserve areas of the Reef catchment that have a role in removing water borne pollutants.

Actions to implement the Reef Plan include the development of local *Water Quality Improvement Plans* (Action D4), and the identification and establishment of *Nutrient Management Zones* (NMZs) (Action D8).

To support the Reef Plan, the Reef Water Quality Partnership (RWQP) was established to bring together Australian and Queensland Government Agencies and GBR regional NRM boards to deliver water quality targets, monitoring and reporting. The organisations involved include Australian Government Agencies (Department of the Environment and Water Resources (DEW), Department of Agriculture, Fisheries and Forestry, and Great Barrier Reef Marine Park Authority (GBRMPA)), Queensland Government Agencies (Department of Premier and Cabinet, Department of Natural Resources and Water (NRW), Department of Primary Industries and Fisheries (DPI&F), and Environmental Protection Agency (EPA)), and GBR regional NRM bodies (Burdekin Dry Tropics Board, Burnett Mary Regional Group, Fitzroy Basin Association, Mackay Whitsunday NRM and Terrain NRM).

The RWQP Management Committee is the core of the RWQP and comprises agency representatives from the Reef Plan Intergovernmental Operational Committee (Reef Plan IOC) and representatives of the GBR regional NRM bodies. The Management Committee coordinates government and regional NRM body water quality target-setting, monitoring and reporting activities. This includes the development and implementation of workplans to deliver coordinated and prioritised activities through this forum. The Management Committee reports to the Reef Plan IOC and the Joint Queensland – Australian Government NRM Steering

Committee (JSC) for regional NRM issues. A Scientific Advisory Panel provides independent science advice to the Management Committee.

Coastal Catchments Initiative

The CCI is a national program under the Natural Heritage Trust, administered by DEW. The CCI, in collaboration with State Environmental Protection Agencies, seeks to achieve and maintain targeted reductions in pollutant discharges to coastal water quality hotspots. The CCI is rolled out in two stages:

1. agreement on the coastal hotspots and preparation of *Water Quality Improvement Plans*. A WQIP is prepared consistent with the *Framework for Marine and Estuarine Water Quality Protection* (Appendix 2) and in collaboration with regional NRM boards; and
2. investment in water quality projects identified through the WQIPs. During WQIP development, CCI funds interim projects that support short-term, cost-effective measures to improve water quality, and build institutional capacity and tools for WQIP implementation.

The *Framework* builds upon key elements of the *National Water Quality Management Strategy* (NWQMS) and the *National Principles for the Provision of Water for Ecosystems* (NPPWE). Both the NWQMS and the NPPWE have been developed by the Australian, State and Territory Governments, and are part of the Council of Australian Governments' Water Reform Framework.

The main policy objective of the NWQMS is 'to achieve sustainable use of the nation's water resources by protecting and enhancing their quality, while maintaining economic and social development' (ANZECC 1994). NWQMS provides policies, a process (Figure 1.2), and a series of national guidelines to help communities manage their water resources to meet current and future needs (ANZECC 1998). NWQMS considers community involvement in water management critical, to (i) identify the preferred uses of local water bodies, and (ii) develop community acceptance in relation to the costs associated with improved water quality. NWQMS has developed 21 national water quality guidelines, including *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC 2000), and *Queensland Water Quality Guidelines* (2006). The *Australian Drinking Water Guidelines* (NHMRC 2004), and *Guidelines for Managing Risks in Recreational Water* (NHMRC 2006) are referred to from the ANZECC guidelines.

The main purpose of the NPPWE is 'to provide policy direction on how the issue of water for the environment should be dealt with in the context of general water allocation decisions' (ANZECC 1996). Similarly to the NWQMS, the NPPWE recognises that 'all relevant environmental, social and economic stakeholders will be involved in water allocation planning and decision-making on environmental water provisions' (ANZECC 1996). In Queensland, water resource planning is conducted through the development of Water Resource Plans (WRP) and resource Operations Plans (ROP) under the Water Act 2000.

Regional NRM Plan

The regional NRM board (Terrain NRM) oversees natural resource management in the Wet Tropics region. Terrain NRM has developed a series of plans, including the regional NRM plan (FNQ NRM Ltd and Rainforest CRC 2004) and companion aboriginal plan (Wet Tropics Aboriginal Plan Project Team 2005), which provide the foundation for Terrain's work. The preparation of a WQIP for each Wet Tropics catchment is identified in the regional NRM plan as a Management Action Target in the water resources asset². The targets identified in the Tully WQIP, and associated management measures and control actions, will be included in the revised regional NRM plan.

Nutrient Management Zones

Reef Plan requires the identification and establishment of nutrient management zones (NMZs) (Action D8), i.e. land areas that contribute significant quantities of nutrients to waterways entering the GBR. These zones will provide a focus for extension services, property resource management planning and NRM funding to minimise impact of nutrients on the GBR. To improve land management practices and reduce nutrient export, ten areas of significant fertiliser use were identified as NMZs in 2007, including the Wet Tropics Coastal area (Brodie 2006, DPI&F 2007).

² See Section 3 for definitions of Management Action Target and asset as used the national CCI and NRM programs.

As measures and actions for achieving improved water quality are being progressed under WQIPs, it is intended that NMZs will add weight to and complement efforts focussed on improving nutrient management, with specific emphasis on those intensively farmed commodities with close proximity to the coast. Through an integrated monitoring and evaluation framework, the success of sector specific management practices in eliciting desired improvements in nutrient management will be assessed. Policies associated with NMZs may give rise to more stringent control actions being considered should preferred voluntary, self management and industry led approaches prove ineffectual (A. West, DPI&F, pers. comm. 2007).

FNQ 2025 Statutory Regional Plan

The Queensland State government (via the Department of Local Government, Sport and Recreation) is currently developing a statutory regional plan for Far North Queensland. The FNQ 2025 planning process is aimed at managing growth and development, and resolving conflicting pressures on land, environment and resources. This planning process will establish critical land use categories for the region, with a particular focus on setting the urban footprint for the region, as well as determining strategically important agricultural land. In setting these land use categories, and in determining critical land use performance indicators within these categories, water quality issues will be one of the key environmental considerations. CCI has recently funded a five month project (June to October 2007) to explore how best to deal with water quality management issues within the context of this emerging regional planning framework.

1.3 Characteristics of the Tully WQIP area

The Tully basin has been identified as a high risk catchment under Reef Plan (The State of Queensland & Commonwealth of Australia 2003). Each GBR catchment was assessed against the following criteria: biophysical risk, social risk, development risk and risk to marine industries. Each criterion included attributes and rankings against which each catchment was rated to determine risk. Based on this risk assessment, the Tully basin was identified as being in the top 10 high risk catchments, making the development of a Tully WQIP a high priority.

The following sections provide a brief summary of the current status of each criterion (see also Appendix 3), preceded by a definition of the area covered by the Tully WQIP.

The Tully WQIP area

The Tully WQIP area refers to the combined geographical area of the Tully and Murray basins (Johnson 1998) and the Cardwell Shire Local Government Area (Figure 1.4) (Bohnet *et al.* 2006 2007). The area contains parts of the Wet Tropics World Heritage Area and discharges into the GBR World Heritage Area. The six major sub-catchments include: (1) Hull River and coastal tributaries; (2) Tully River (comprising Upper Tully River and Nitchaga Creek, Lower Tully River tributaries, Davidson Creek and Echo Creek, Jarra Creek, Banyan Creek, and Lower Tully River); (3) Murray River; (4) Dallachy Creek; (5) Meunga Creek and Kennedy Creek; and (6) coastal creeks draining into Hinchinbrook Channel (including Hinchinbrook Island) (Johnson 1998).

These six sub-catchments discharge into seven wetlands included in the Directory of nationally important wetlands (Miller and Deacon 2005), DPI&F declared Fish Habitat Areas, seagrass meadows, and the GBR Marine Park and World Heritage Area. During flood events, approximately 2,000 km² of marine receiving waters are influenced by this discharge (Figure 1.4), with the exact area depending upon the volume and duration of flow, as well as the direction of currents and winds (Brodie *et al.* 2007a). Based on plumes from several Tully-Murray flood events from 1994 to 1999, the receiving water body includes at least the waters south to Hinchinbrook Island, east to beyond the Brooks and Family Islands, and north to the Barnard Islands and up to near Innisfail. Importantly, this receiving water body is also affected by flood plumes from both the Herbert and Burdekin rivers (Lewis *et al.* 2006). Recent satellite imagery shows that plumes from Wet Tropics rivers, including the Tully, can extend eastwards across the entire reef shelf and beyond into the Coral Sea (Figure 1.5; Brodie *et al.* 2007a).

Current status of biophysical risk

The high rainfall in the Tully-Murray basin, combined with near-coastal steep topography and extensive fertilised land use on the floodplain, provides the potential for erosion and pollutant transport to the receiving waters. Moreover, increased run-off rates and amount, due to removal of wetlands and floodplain vegetation

and the installation of land drainage systems in coastal floodplains, mean that higher sediment and nutrient loads may now reach receiving waters. These loads are likely to have an impact on protected and important habitats in estuarine and marine receiving waters due to their close proximity to the coast.

Climate

The climate in the Tully-Murray basin is characterised by very humid summers and mild, relatively dry winters (Johnson 1988). The basin receives a mean annual rainfall between approximately 2000 and 4000 mm (Bureau of Meteorology 2007). In the upper reaches at Koombooloomba Dam, the mean minimum and maximum monthly rainfalls are 84.9 mm (October) and 474.8 mm (March), respectively, with 500.9 mm (March 1967) being the highest daily rainfall recorded. At this site, the highest mean monthly maximum temperature in summer is 28.1°C (December), while lowest mean monthly minimum temperature in winter is 19.6°C (July). At the southern end of the basin at Cardwell, the mean minimum and maximum monthly rainfalls are 30.1 mm (August) and 467.4 mm (February), respectively, with 527.1 mm (January 1934) being the highest daily rainfall recorded. At this site, highest mean monthly maximum temperature in summer is 31.5°C (January), while lowest mean monthly minimum temperature in winter is 13.6°C (July).

Land use

The Tully-Murray basin comprises 2,787 km², with eight major land uses (Armour *et al.* 2007a; Table 1.1, Figure 1.6). The higher elevations and upper reaches of the rivers and creeks are primarily occupied by tropical rainforest and sclerophyll forests, while the coastal floodplain has largely been cleared and drained for agricultural purposes (sugarcane, grazing, banana, horticulture and plantation forestry) (Johnson 1998). Remnant patches of rainforest are found on the alluvial plains, and in wetlands and estuaries near the alluvial coast.

The total area under sugarcane in the Tully Sugar Mill area has almost doubled from 15,676 ha to 30,001 ha from 1991 to 2001 (McDonald and Weston 2004). From 1990 to 1998, the area cultivated for bananas expanded by approximately 50% in the Tully-Murray catchments (GBRMPA 2001). These expansions were accompanied by an estimated 118% increase in usage of nitrogen (N) fertilisers in sugarcane and banana production in the Tully-Murray catchments from 1990 to 1999 (GBRMPA 2001). Surveys indicate that N fertiliser usage *per ha* has declined in both industries, by 25% in sugarcane (from 200 kg N / ha yr in 2000 to 150 kg N/ha yr in 2007; McMahan 2007), and by 40% in bananas (from 520 kg N/ha yr in 1995 to 313 kg N/ha yr in 2007; Lindsay 2007b), respectively. Plantation forestry has expanded from 6,828 ha in 2004 to 10,314 in 2007 (based on QLUMP 2004 and recent sales information).

Ecosystem communities

Most of the natural forest in the Tully-Murray basin is protected, and is located in the Wet Tropics World Heritage Area, in National Parks or State Forests, and in Nature refuges (Figure 1.7). The area of floodplain vegetation in the basin is approximately 20.8 km², and has decreased by approximately 80% compared to pre-European areas (Furnas 2003). These changes in vegetation communities reflect clearing for agricultural development and an increase in tussock grassland or sedgeland, with a decrease in open and closed forest (Furnas 2003). In contrast to the other vegetation types, the areas of mangrove vegetation do not currently differ from their pre-European extent (Furnas 2003).

The riparian area in the basin is approximately 59 km², and has decreased by approximately 60% since European development (Furnas 2003). The last survey in 1997 indicated that riparian condition varied from very good (28%) to very poor (28%), with the remainder in good (10%), moderate (18%) and poor (16%) condition (Johnson 1998).

The Tully Province contains 68 regional ecosystems (REs) that are classified, based on vegetation management and biodiversity status, as endangered (13 REs, 6,907 ha) and of concern (55 REs, 68,575 ha) (EPA 2005a). Many of these 68 REs have been exploited for their grazing and timber values and have been extensively cleared and changed hydrologically for agricultural purposes. Current threatening processes include further changes to hydrology and drainage, fragmentation (including wind exposure), residential and industrial development, agricultural and ponded pasture development, grazing pressure, change in fire regimes, invasions of weeds, vines and/or rainforest, feral pigs, and recreational and vehicular disturbances (EPA 2005a).

Most of the receiving waters in the Tully-Murray basin are protected and/or considered to be of national importance (Figure 1.8). These include the GBR World Heritage Area, the GBR Coast Marine Park, seven wetlands included in the Directory of Nationally Important Wetlands, DPI&F declared Fish Habitat Areas, and seagrass meadows. The basin contains 9,536 ha of palustrine wetlands and 63,230 ha of estuarine wetlands (EPA wetland mapping, version 1, August 2006). Compared to pre-European wetland areas approximately 69% have been lost (Furnas 2003). The seven wetlands listed in the Directory of Nationally Important Wetlands include Licuala Palm Forest (233 ha), Tully River - Murray River Floodplains (39,171 ha), Edmund Kennedy Wetlands (11,033 ha), Herbert River gorge (21,542 ha), Hinchinbrook Channel (30,718 ha), Missionary Bay (11,072 ha), Sunday Creek Broad-leaved Paperbark Site (39 ha), and the GBR Marine Park (34,108,876 ha) (Miller and Deacon 2005). The DPI&F Fish Habitat Areas protect inshore and estuarine fish habitats in the Hull, Tully and Murray Rivers and Dallachy Creek, and were declared in 1983 to sustain local and regional fish stocks and fisheries.

The receiving water body (Figure 1.4) contains five of the 70 bioregions within the GBR Marine Park, including high nutrients coastal strip, inner shelf seagrass, inner mid-shelf lagoon, coastal central reefs, and northern open lagoon reefs (GBRMPA 2004). These regions contain seagrass beds, nursery areas for juvenile fish, prawns and other animals, dugong protection areas, and foraging areas for turtles and dugongs, and reefs. Water quality in these regions is affected by agriculture, aquaculture, coastal development and shipping, as well as the loss of wetlands and vegetation including riparian zones (Baker 2003).

Current status of social risk

The capacity to change practices that (potentially) cause land-based pollution is, to a certain extent, determined by major economic drivers. In the Wet Tropics region, the major drivers of the economy are tourism, followed by agriculture and grazing, and to a lesser extent, mineral production (McDonald and Weston 2004) (Table 1.2). In contrast, the economy of the Cardwell Shire is almost completely reliant on agricultural production. In 2007, regional agricultural income totalled \$126.7 million (Roebeling *et al.* 2007b). Both the sugarcane and banana industry have demonstrated capacity to change practices that reduce land-based pollution (Section 4).

Capacity to effect change is also determined by NRM infrastructure. In the Tully-Murray basin, NRM infrastructure has been enhanced by the establishment of the CSFP (Section 1.1) and by financial support for the Shire's Parks, Gardens and Revegetation Unit. NRM infrastructure could be further enhanced by strengthening local capacity of State Agencies with NRM responsibilities.

Improvement of water quality is likely to be supported by the local community. In a recent wellbeing and livelihoods survey conducted in the Cardwell Shire water quality was identified as *the most* important ecological wellbeing factor (Larson 2007). Other ecological wellbeing factors identified as important by more than 50% of respondents included (in order of ranking): air quality (78%); condition of landscape/beaches (77%); beauty of landscape/beaches (76%); access to natural areas (74%); soil quality (64%); swimming and bushwalking (62%); and fishing and collection (57%).

The Wet Tropics Aboriginal Plan outlines strategies and actions for water resources to deal with issues of concern, including water pollution (Wet Tropics Aboriginal Plan Project Team 2005). Three Aboriginal Traditional Owner groups live in the area covered by the Tully WQIP, including the Girramay, Jirrbal and Gulnay people. In 2001, 716 persons (6.3% of total population) stated Aboriginal and/or Torres Strait Islander origin (OESR 2007a). Current families continue associations with country that stretch back more than 1500 generations, and today's elders continue their oral history traditions. The Giringun Aboriginal Corporation, representing the three Aboriginal Traditional Owner groups, has been involved in the development of the Tully WQIP as a partner of the CSFP.

Current status of development risk

The Cardwell Shire Local Government Area is 3,062 km², and encompasses most of the Tully-Murray catchment (Figure 1.4). The Cardwell Shire has recently been usurped into Cassowary Coast Shire Council together with Johnston Shire. Major townships and their (preliminary) estimated resident populations are Tully (2,533), Cardwell (1,438), and Wongaling Beach (1,159) (OESR 2007b). Smaller townships and settlements include Bilyana, Cardstone, Carmoo, Euramo, Feluga, Hull Heads, Jumbun, Kennedy, Lower Tully, Murray Upper, Murrigal, Silky Oak, South Mission Beach, and Tully Heads.

The Cardwell Shire Local Government Area had an estimated resident population of 10,084 in 2006, with a projected population of 15,155 in 2026 (OESR 2007a). Increased population growth and urbanisation provides the potential for erosion and pollutant transport to the receiving waters.

Current status of risk to marine industries

Commercial tourism visits to the marine receiving waters averaged ~12,000 a year from 2003 to 2005 (C. Honchin, GBRMPA, pers. comm. 2007), and contributed to the \$10.6 million spent on tourism accommodation in Cardwell Shire in 2006 (OESR 2007b). Tourism resorts at Dunk, Bedarra and Hinchinbrook Islands provide focal points for accessing the marine environments, with >70% of commercial tourism visits going to Dunk Island and the surrounding Stingaree Reefs. Commercial fisheries earnings in the coastal and marine waters off the Tully-Murray basin were over \$3.0 million in 2005. Both the tourism and commercial fisheries industries could be at risk from the progressive decline in water quality of the waterways entering the GBR (The State of Queensland & Commonwealth of Australia 2003).

Table 1.1: Major land uses in the Tully-Murray basin based on the draft QLUMP 2004 data for the Tully and Murray catchments (from Armour *et al.* 2007a).

Tully-Murray	Area (ha)	Area (km2)	% of catchment
Natural forest	198,200	1,982	71.2
Sugar Cane	36,700	367	13.2
Grazing	14,900	149	5.3
Forestry plantation	10,300	103	3.7
Waterways	7,700	77	2.7
Banana	7,500	75	2.7
Urban	3,000	30	1.1
Other horticulture	400	4	0.1
Total	278,700	2,787	100

Table 2.2: Contributions of major economies in the Wet Tropics region and Cardwell Shire, based on the most recently available data. Note that contributions of different economies may have been calculated during different years, making absolute comparisons difficult.

Economy	Wet Tropics	Cardwell Shire
Tourism	\$2 billion ¹	n/a
Tourism accomodation	\$355.7 million ²	\$10.6 million ²
Commercial fishing	\$200 million ³	>\$3 million ⁴
Sugar Cane		\$65.4 million ⁶
Grazing	\$754.2 million ⁵	\$8.4 million ⁶
Forestry plantation		\$4.7 million ⁶
Banana / horticulture		\$48.2 million ⁶

¹ = Prideaux and Falco-Mammone (2007), ² = OESR (2007b), ³ = FNQ NRM Ltd and Rainforest CRC (2007), ⁴ = DPI&F <http://chrisweb.dpi.qld.gov.au/chris/>, ⁵ = McDonald and Weston (2004), ⁶ = Roebeling *et al.* (2007b)

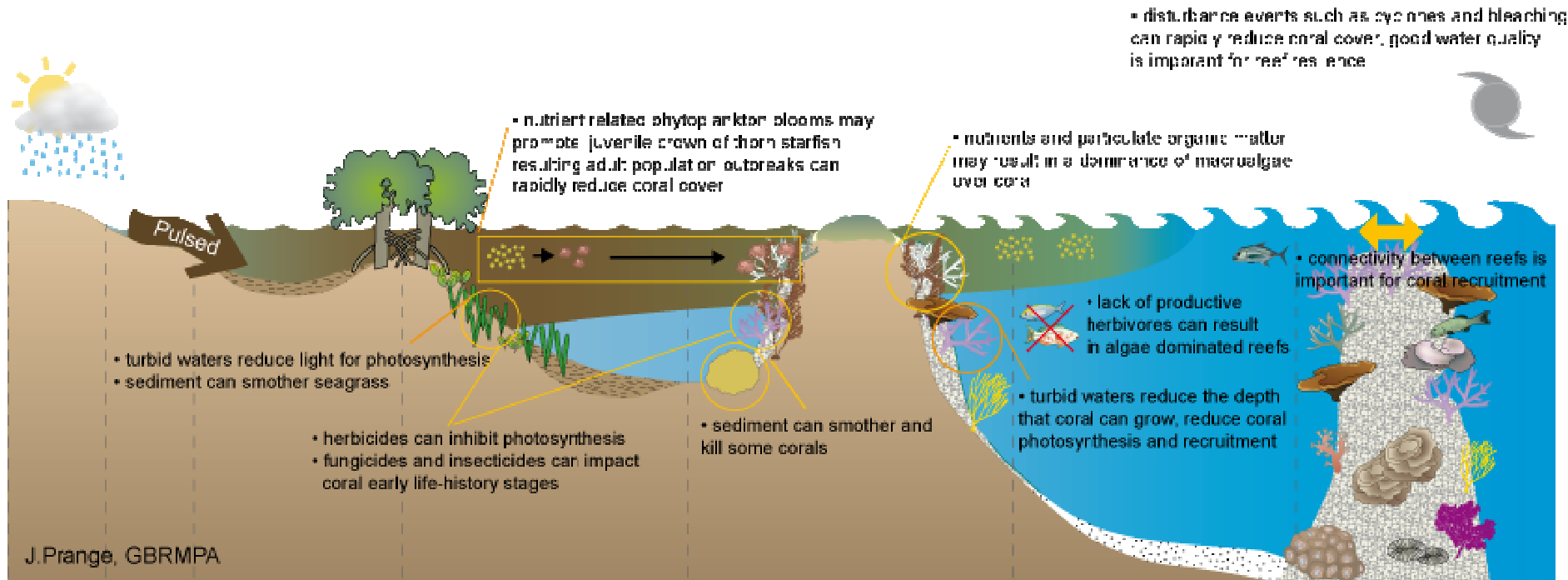


Figure 1.1. Conceptual diagram showing some key ecological responses to sediment, nutrients and pesticides in the inshore marine environment (from J. Prange, GBRMPA, 2007).

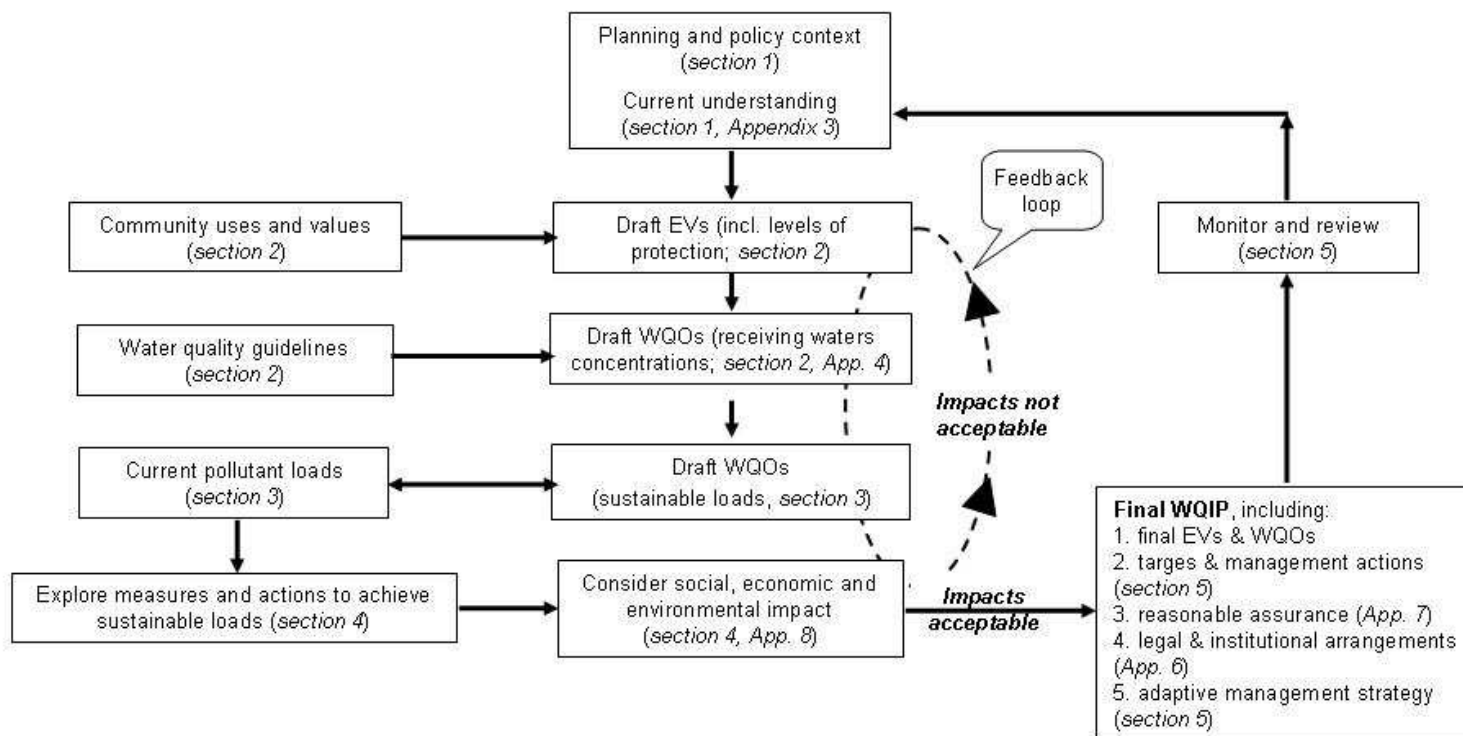
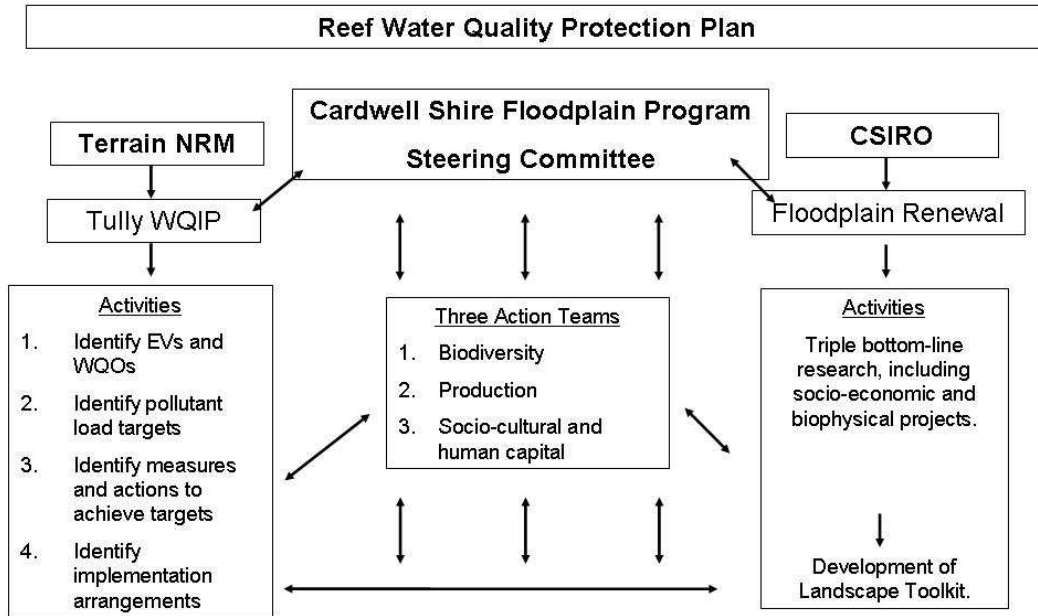


Figure 1.2. Process for developing a Water Quality Improvement Plan, adapted by the Queensland Environmental Protection Agency from the National Water Quality Management Strategy (NWQMS). The relevant sections of the Tully WQIP are outlined for each component of this framework.

a.



b.

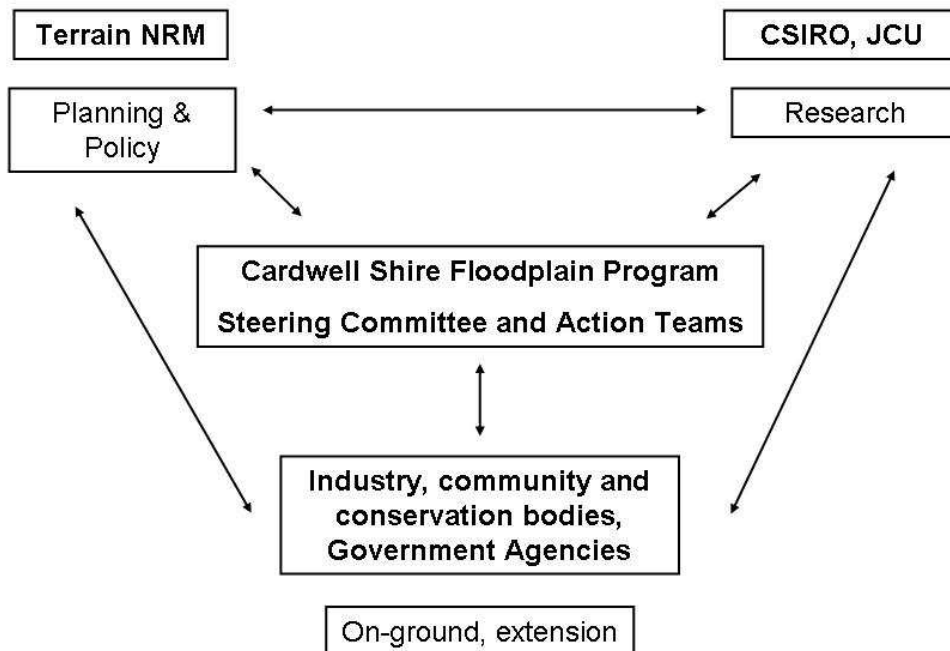


Figure 1.3. Participatory planning, research, and engagement framework established to develop and deliver the Tully WQIP, showing the central role of the CSFP Steering Committee. (a) a side view of the CSFP framework showing the two main programs, the development of the Tully WQIP and CSIRO Floodplain Renewal Program, in relation to CSFP, and (b) a top-down view of the CSFP framework showing linkages between planning & policy, research, and on-ground and extension activities (CSFP 2005a).

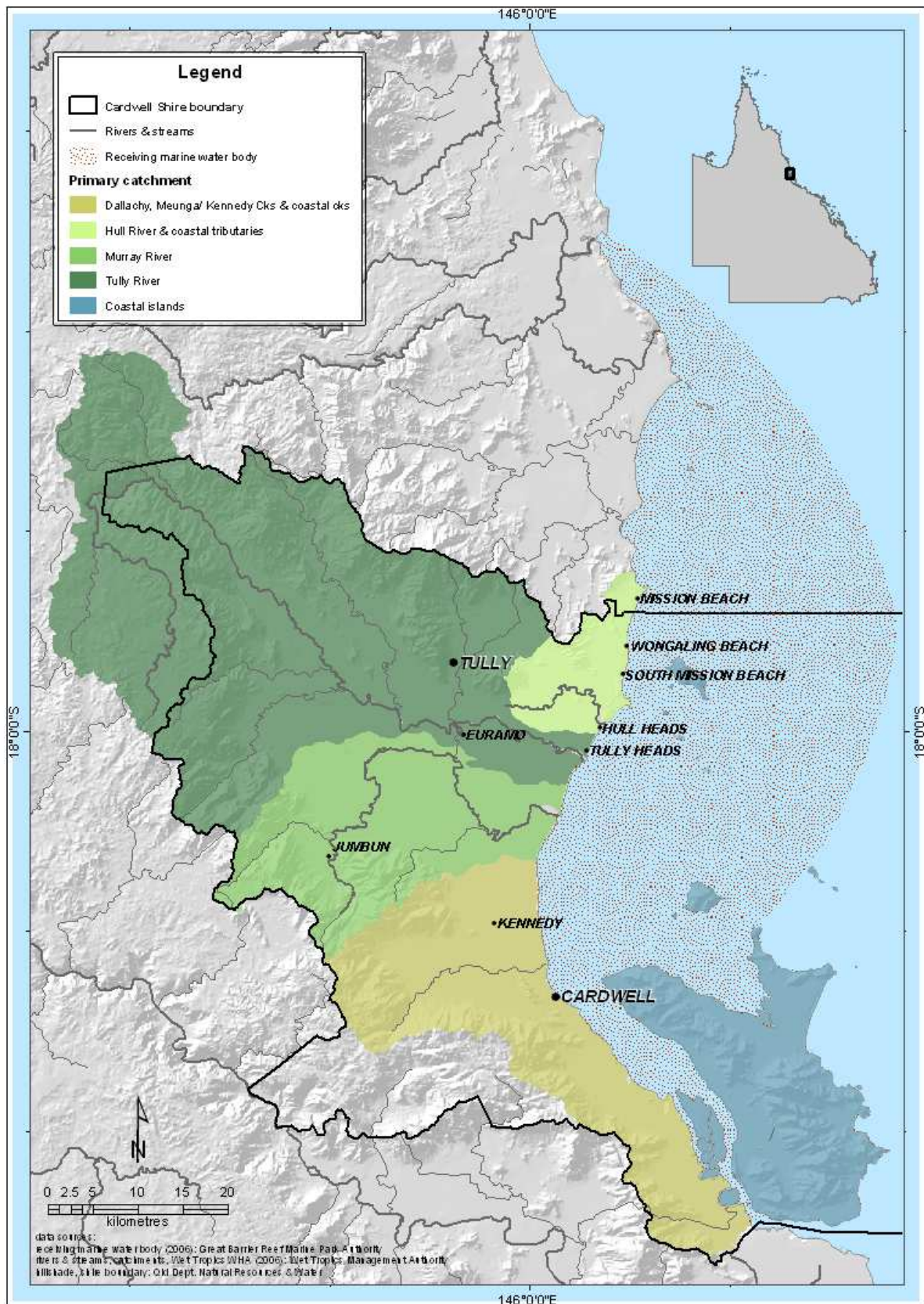


Figure 1.4. The Tully WQIP area (Tully-Murray basin and Cardwell Shire Local Government Area overlay), and marine area of influence.

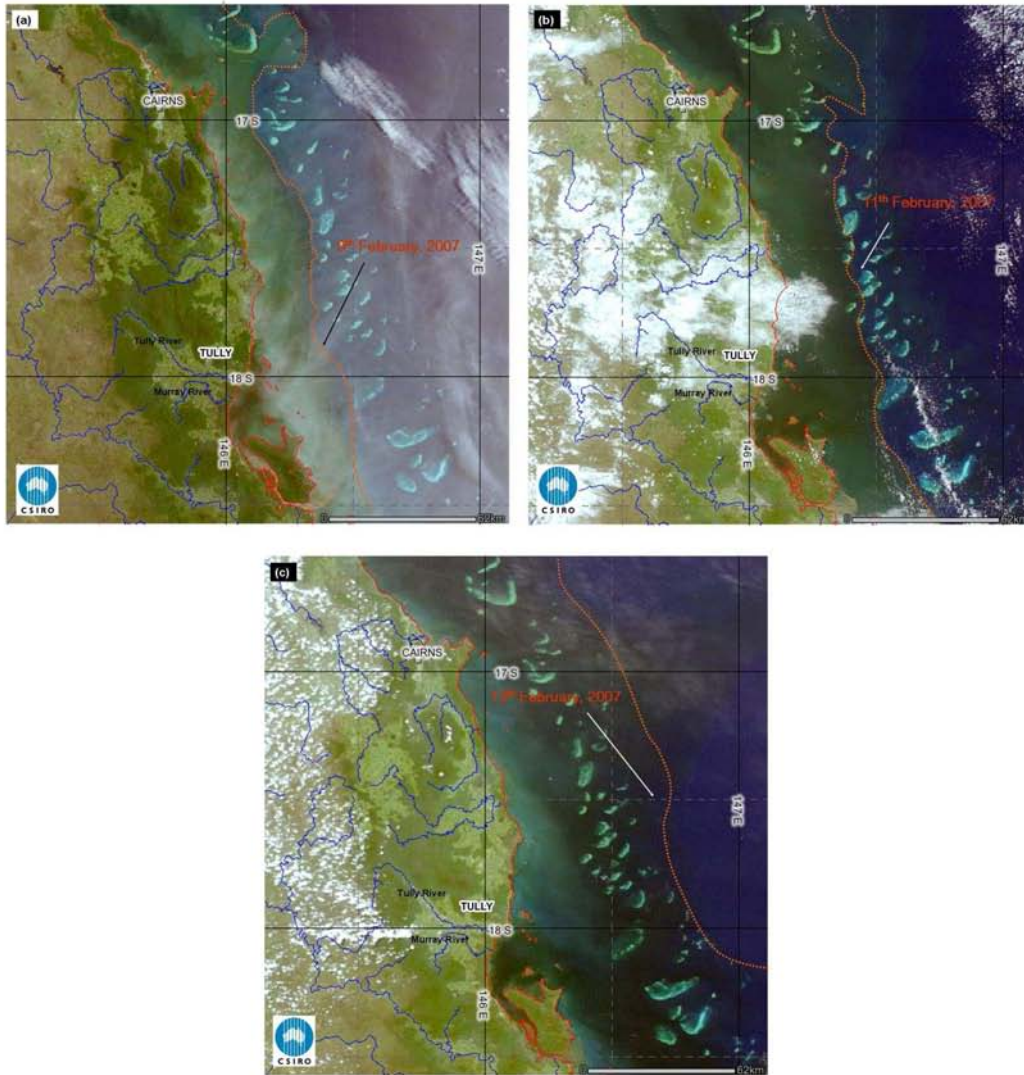


Figure 1.5. Flood plumes from the Wet Tropics rivers, including the Tully and Murray Rivers, following heavy rainfall and flooding in February 2007, on (a) 9 February 2007, (b) 11 February 2007 and (c) 13 February 2007. Note that the flood plumes extend eastwards across the entire reef shelf and beyond into the Coral Sea. MODIS-Terra satellite imagery, developed for/by CSIRO, NASA EOS

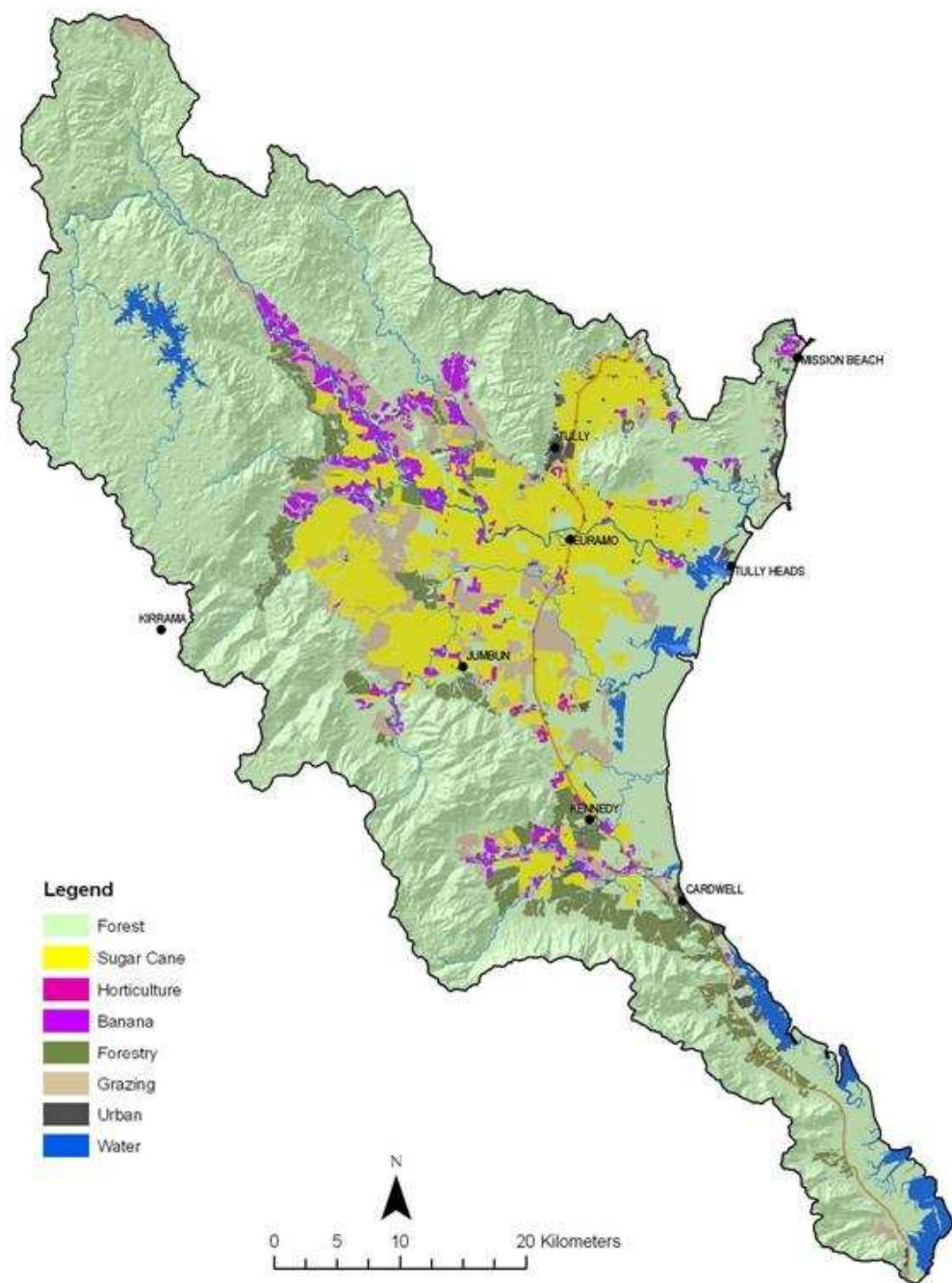


Figure 1.6. Major land uses in the Tully-Murray basin based on the draft QLUMP 2004 data for the Tully and Murray catchments (from Armour et al. 2007a).

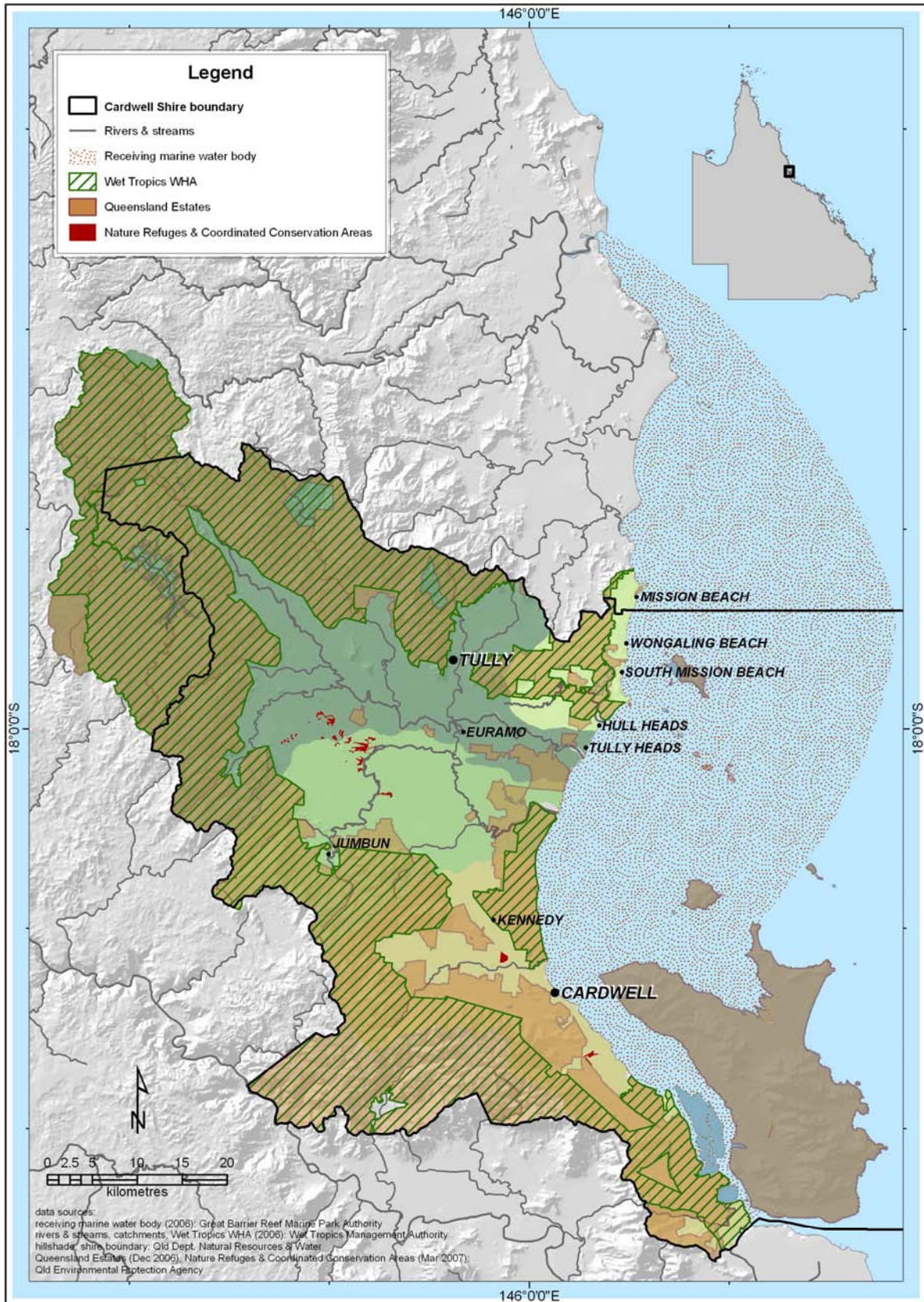


Figure 1.7. Protected terrestrial ecosystems in the Tully WQIP area, including the Wet Tropics World Heritage Area, Queensland Estates (gazetted National Parks Scientific, National Park, National Park Recovery, Conservation Park, Resources Reserve, Forest Reserve, State Forest and Timber Reserve), and Nature refuges and coordinated conservation areas.

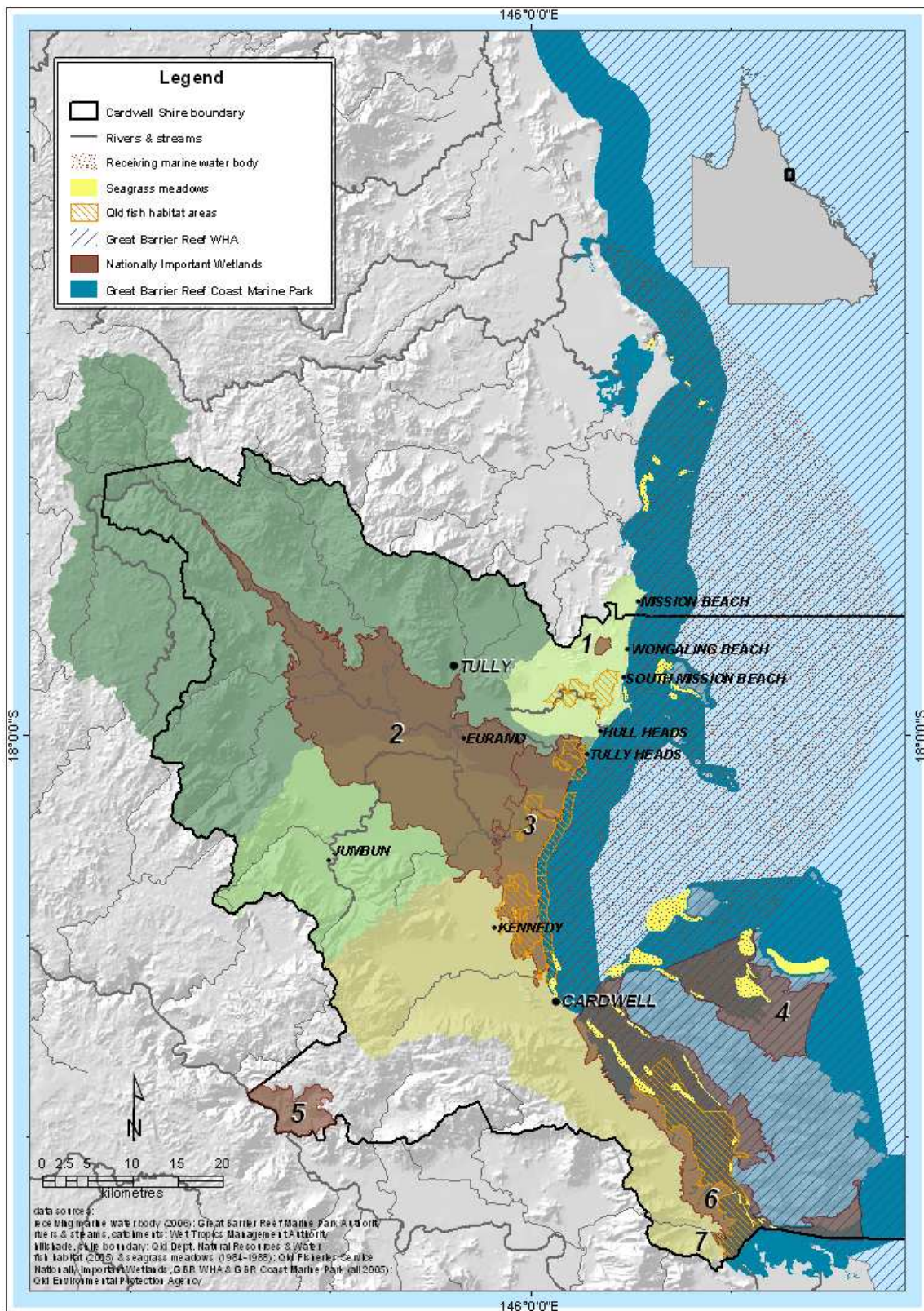


Figure 1.8. Freshwater, estuarine and marine ecosystems in the Tully WQIP area that are protected and/or considered to be of national importance, including the GBR World Heritage Area, GBR Coast Marine Park, Directory of nationally important wetlands, DPI&F fish habitat areas, and seagrass meadows. Numbers refer to the Directory of nationally important wetlands: (1) Licuala Palm Forest; (2) Tully River - Murray River Floodplains; (3) Edmund Kennedy Wetlands; (4) Missionary Bay; (5) Herbert River gorge; (6) Hinchinbrook Channel; and (7) Sunday Creek Broad-leaved Paperbark Site.

2 DRAFT ENVIRONMENTAL VALUES AND WATER QUALITY OBJECTIVES

2.1 Introduction

The Tully WQIP will establish environmental values (EVs) and water quality objectives (WQOs) for freshwaters, estuarine and marine reaches of the Tully WQIP area that are consistent with the *National Water Quality Management Strategy* (NWQMS) framework (Section 1.2). This framework is embedded in the *Queensland Environmental Protection (Water) Policy 1997* (EPPW). Using this process, the preferred (environmental) values and uses of local water bodies (both surface and groundwater) are determined by identifying the current and future values or uses of the waterways which contribute to public or private benefits (i.e. EVs; Table 2.1). Draft WQOs are based on the community's choices for EVs, and the existing water quality guidelines and standards intended to protect them (EPA 2006, Honchin *et al.* 2008). Water quality guidelines define desirable ranges and maximum levels for certain parameters that should be achieved (based on scientific evidence and judgement) to maintain specific EVs. Thus, WQOs are measurable indicators of the characteristics needed to protect the EVs of particular waterways, and may be defined for a range of physical, chemical and biological parameters, as well as other measures of catchment condition. By being consistent with the EPPW processes, the established WQOs will assist the EPA in undertaking licensing of Environmentally Relevant Activities (ERAs), in working with Local Government on urban stormwater management, and in guiding overall investments in critical improvements in rural and diffuse water quality issues. Moreover, Regional NRM bodies are encouraged to use this process to establish EVs and determine draft WQOs that they can adopt as water quality targets in their NRM plans (EPA 2006). For the Tully WQIP, this framework has been used to identify the draft EVs and WQOs using processes developed with and agreed to by the EPA and the GBRMPA.

2.2 Process for establishing EVs

The established EVs are the values and uses of the waterways that the management actions outlined in the draft Tully WQIP will try to protect. Therefore, the first step in a water quality management program is to determine the preferred values and uses of local water bodies (ie identify the EVs). EVs are those qualities of the waterway that make it suitable to support particular aquatic ecosystems and human uses (EPA 2005). Specifically, EVs are categorised into aquatic ecosystems, primary industries, recreation and aesthetics, drinking water, industrial uses, and cultural and spiritual values, with further stratification for some categories (Table 2.1; ANZECC 2000, EPA 2006). These qualities require protection from the effects of pollution such as waste discharges, siltation and runoff to ensure healthy aquatic ecosystems and waterways that are safe and suitable for community use (EPA 2005). All water reaches will possess at least one of the EVs listed (ie protection of aquatic ecosystems), and more than one EV may be designated for a specific water reach (EPA 2005).

The EVs for the Tully WQIP were established using the following process:

1. interviews with community members in the Tully WQIP area (Bohnet *et al.* 2006);
2. three workshops with community members in the Tully WQIP area (Bohnet *et al.* 2007);
3. discussions with the CSFP Steering Committee; and
4. further meetings with, and input from key stakeholders and the community to enable provision of comments on the draft EVs, during the public consultation phase on the draft WQIP.

The last step is to ensure that (i) the draft EVs accord with the inputs provided to date through interviews, workshops and CSFP Steering Committee; and (ii) members of the community, who have not been involved to date, have a chance to provide their input.

Draft EVs from interviews, workshops and CSFP Steering Committee

The following information is from Bohnet *et al.* (2006, 2007), unless otherwise noted.

To identify the draft EVs accorded to waters in the Tully-Murray basin, a two-staged approach was used following a social-ecological framework for sustainable landscape planning (Bohnet and Smith 2007). Stage one comprised qualitative interviews with 49 community members to gain an understanding of the EVs attached to waters in the Tully-Murray basin. Interviews were stratified geographically and socially, with initial contacts established through key informants in the local community and further contacts provided by interviewees.

Stage two comprised the completion of community workshops to identify the EVs of the main rivers and creeks, as well as estuaries, coastal and adjacent marine environments. Workshops were widely advertised through the local media and networks, including CSFP's Socio-cultural Action Team. Based on the community's response, three workshops were held with 29 participants; one at South Mission Beach to cover the Hull River and coastal and marine areas, one at Euramo to cover the Tully-Murray floodplain and one at Cardwell to cover the Kennedy valley and the southern part of the Cardwell Shire including coastal and marine areas. During these workshops, participants placed EVs in a spatially explicit location on catchment maps.

Interviewees and workshop participants included Traditional Owners, other Indigenous peoples, councillors, local (non-farming) residents, sugarcane farmers, tropical fruit growers, banana growers, graziers, foresters, tourism operators and conservation representatives.

Based on the geographic information provided by interviewees and workshop participants, draft EVs identified by the community were assigned to each of the 28 river reaches with common EVs within the Tully-Murray basin. River reaches were defined after the workshops using protocols outlined in EPA (2006) and ANZECC (2000) (see Section 2.5). Additional information on uses and values for wetlands was included based on information obtained through a prioritisation exercise for wetland investments undertaken in the Tully-Murray basin (D. Sydes, CSC, pers. comm. 2007). Participants in the wetland workshops included Traditional Owners, landholders, technical experts, Terrain NRM and State Agency staff, local government and industry representatives. The draft EVs for each of these 28 reaches were presented to and discussed with CSFP Steering Committee (April 2007).

The results for the draft EVs are summarised in Table 2.2 and are provided in more detail in Appendix 4 (Table 4.2). The draft EVs demonstrate that the waterways in the Tully WQIP area are used and valued for a wide range of activities (Table 2.2). All 28 reaches are used and valued for their aquatic ecosystems, for their indigenous and non-indigenous cultural heritage, and for their amenity. Aquatic foods are obtained from 24 out of the 28 reaches; apparently no food is taken from natural wetlands in four out the six catchments (Hull and Murray rivers, Kennedy and Meunga Creeks, and coastal creeks to Hinchinbrook Channel). Primary and secondary recreation were identified as an EV for 15 and 27 reaches, respectively. This difference in reaches used for activities involving direct versus indirect contact reflects the distribution of estuarine crocodiles (*Crocodylus porosus*). Almost all reaches with freshwater were used for drinking (12) and stock water (11), as well as farm supply (11) and irrigation (10). Four brackish reaches are used and valued for aquaculture purposes. The two industry uses in the area are the Tully Sugar Mill and Koombaloo Dam, which is used for hydro-electricity generation.

All user groups use and value the aquatic ecosystems that local waterways provide, as well as their drinking water and aquatic food values. Differences and potential conflict between the various values is often between 'consumptive' (e.g. irrigation) and 'non-consumptive' (e.g. recreational and cultural) uses (Table 2.3). The main consumers of water in the basin are farmers and industry (e.g. Koombaloo Dam, banana farmers, Tully Sugar Mill). In contrast, local residents, Traditional Owners and conservation groups use and value waterways primarily for recreation and aesthetic values, as well as for cultural and spiritual purposes. Such conflict may be further exacerbated by differences in community perceptions regarding the state of water quality and aquatic ecosystems. Specific mention was made that Traditional Owners' values are not taken as seriously as farmers' values. These differences, relating to the weighting of (i) different EVs identified by the local community, and (ii) EVs identified by local, regional, national and international communities, are currently not addressed by the NWQMS framework for setting EVs and WQOs.

2.3 Identification of high ecological value waterways

For the *aquatic ecosystem* EV, the NWQMS identifies three levels of protection for waterways with different ecosystem conditions (high ecological value, slightly to moderately disturbed and highly disturbed). This allows the community to identify those waterways with high ecological value to be protected. The draft Tully WQIP recommends that, similar to the Douglas WQIP, waterways which fall within 'protected' areas under existing legislation (i.e. Wet Tropics World Heritage Area, Queensland Estates (including gazetted 'National Parks Scientific', 'National Park', 'National Park Recovery', 'Conservation Park', 'Resources Reserve', 'Forest Reserve', 'State Forest' and 'Timber Reserve'), Nature Refuges and Coordinated Conservation Areas, Queensland Declared Fish habitat area [Class A], and Marine Park Areas [Preservation Zones and better]) be considered **High Ecological Value** waterways (Figure 2.2). It further recommends that the EPA and Terrain NRM complete a more detailed assessment of the conservation values of the area's waterways. This will allow further consultation with the community on which additional waterways could be recommended for high ecological value status.

2.4 Specific issues and threats identified by the community

Specific issues and threats related to uses and values of waterways were identified in the interviews and workshops. These have been summarised here into pollutants of concern and other issues relevant to water quality, and have been taken into account in the development of management actions (Section 5).

Sediment, nutrients and pesticides were identified as pollutants of concern by the community and CSFP Steering Committee. Specific mention was made of river bank erosion, council (road) works, and the lack of commitment to change practices to minimise or stop the use of agrochemicals. Additional pollutants of concern that were mentioned included acid sulphate soils, bacteria and pathogens, hydrocarbon substances, heavy metals, and dissolved oxygen reducing substances (including sugar, general organic matter, effluent from Tully Sugar Mill and Tully Sewage Treatment Plant (STP), and banana waste).

Issues of concern that were identified by the community and CSFP Steering Committee as relevant to water quality for freshwater reaches include: (i) the safety of drinking water; (ii) limited or no access to areas of cultural and spiritual significance; (iii) the loss of local water bodies including wetlands, lagoons and small streams; (iv) the clearing of native vegetation on the upper reaches of the rivers and creeks and associated agricultural development; (v) the condition of riparian zones; (vi) environmental flow and water quantity; (vii) groundwater quality and quantity; (viii) weed infestations; (ix) feral pigs; (x) increase in distribution and abundance of crocodiles; (xi) litter produced by the banana industry; and (xii) reduction in fish and fisheries species.

For the estuarine and marine waters, additional issues of concern include: (i) coastal erosion; (ii) pollution from marinas; (iii) marina development; (iv) urban and coastal development, including development on land below flood level; (v) sewage treatment plants on islands; and (vi) maintaining healthy reefs, mangroves and wetlands.

The workshop participants identified economics at both farm level and local government level as one of the main drivers causing landscape, land use and environmental change impacting on water quality and quantity. Participants provided a number of suggestions to mitigate these impacts, which is indicative of the importance placed on water quality as a wellbeing factor (Section 1.3), as well as the community's aspirations and commitment to improve water quality in the Tully-Murray basin. These suggestions have been taken into account in the development of management measures and control actions (Section 5).

2.5 Establishing draft WQOs that will protect draft EVs

Process for establishing Draft WQOs

Draft WQOs are based on both the community's choices for EVs as well as the water quality guidelines and standards to protect them. WQOs are measurable indicators of the characteristics needed to protect EVs of particular waterways. They may be defined for a range of physical parameters (e.g. turbidity, suspended sediment and temperature), chemical parameters (e.g. phosphorus, nitrogen, biochemical oxygen demand and toxicants), and biological parameters (e.g. algae, diatoms, macroinvertebrates and fish), as well as other measures of catchment condition (e.g. erosion levels, riparian vegetation and channel morphology). Where more than one EV is identified for a waterway (e.g. water suitable for both irrigation and aquatic

ecosystems), the WQ guidelines to support each value and use should be identified. For each waterway, the most stringent guideline for each water quality indicator is the draft WQO selected, in order to best protect all identified EVs (ANZECC 2000, EPA 2006).

Water Quality Guidelines

WQ Guideline Documents

WQ guideline values depend on the EV being considered. There are a number of WQ guideline documents available for the various environmental values that apply to the Tully WQIP area. Regional specific guidelines can accommodate local conditions and where there is more than one set of applicable guidelines, the most local accredited guideline information shall take precedence over broader guidelines. However, for a number of indicators, notably toxicants, there is little or no local information. For these indicators, the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC 2000) guidelines will remain the principal source of information.

To draft the WQOs for the Tully WQIP, the following water quality guidelines for surface water (and, where applicable, ground water) have been used: *Interim marine water quality guidelines for the Great Barrier Reef Marine Park* (Draft) (Honchin *et al.* 2007), *Queensland Water Quality Guidelines* (EPA 2006), *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZECC 2000), *Australian Drinking Water Guidelines* (NHMRC 2004), and *Guidelines for Managing Risks in Recreational Water* (NHMRC 2006). These guidelines are considered trigger values, that would indicate a potential environmental problem if exceeded, and 'trigger' a management response (e.g. further monitoring, investigation, refinement of guideline according to local conditions, etc.).

The ANZECC guidelines (ANZECC 2000) refer to the *Australian and New Zealand Food Standards Code* (ANZFS 2007) for standards for chemical contaminants in food for the protection of human consumers of aquatic foods; these standards are statutory. For each chemical, standards are set for one or more food items. If a standard for a chemical is not listed for a particular food item, there must be no detectable residue of that chemical in that food. If a chemical is not listed, there must be no detectable residue of (metabolites of) that chemical in food. Note that food standards are set for many non-aquatic food items, including sugarcane, bananas and beef.

Identification of reaches with common water types

WQ guidelines for aquatic ecosystems and some other EVs also depend on the type of water being considered (e.g. fresh water, estuary). The Queensland Water Quality Guidelines (EPA 2006) define water types to 'create areas within which water quality is sufficiently homogenous that a single water quality guideline value can be applied to all waters within each water type'. The seven water types defined by EPA (2006) for the Wet Tropics region were used for the Tully WQIP, and adjusted as follows:

1. *upland freshwater*: streams and major rivers above 150 m.
2. *lowland freshwater*: streams and major rivers below 150 m.
3. *lakes*: deepwater habitat situated in dammed river channel, with total area >8 ha.
4. *wetlands*: 'palustrine' wetlands as per EPA wetland mapping (version 1, August 2006).
5. *mid-estuary*:
 - upstream limit = 'estuarine' wetlands as per EPA wetland mapping (version 1, August 2006).
 - downstream limit = mouth of estuary = coastline.
6. *enclosed coastal/lower estuary*:
 - upstream limit = mouth of estuary = coastline.
 - downstream limit = lower limit of 'estuarine' wetlands as per EPA wetland mapping (version 1, August 2006).
7. *open coastal*: 15 km buffer from combined coastline/island coasts.

An eighth water type, *offshore marine*, is outside the limit of Queensland Waters (3 nautical miles from the coast) and is defined by the National Water Quality Guidelines (ANZECC 2000):

8. *marine offshore*: all marine waters >15 km off the coast, that is beyond the 15 km buffer.

Future spatial analysis may assist in refinement in the location of these water types in the Tully WQIP area.

The presence of each water type (Figure 2.1) was checked within each of the six sub-catchments in the Tully WQIP area (Johnson 1988) and considered in conjunction with the 28 reaches with common EVs (Table 2.2). This led to the establishment of draft WQOs for all these reaches in the Tully WQIP area (see Draft WQOs section below).

WQ Guidelines Used for the Tully WQIP

Using the relevant guidelines and standards for the particular EVs and the water types that they apply to, water quality guidelines and standards for sediment, nutrients and pesticides were assigned to each potential environmental value (Appendix 4, Table 4.1a, b).

Draft WQOs for reaches with common EVs

To protect the draft EVs identified by the community, the relevant National, State and Regional level water quality guidelines and standards for each of the EVs identified were used to establish draft WQOs (Appendix 4, Tables 4.2a,b). In cases where more than one EV was identified for a particular water reach, the most stringent water quality guideline was applied as the draft WQO for that water reach, to ensure protection of all EVs. Because the Tully WQIP is primarily concerned with reducing sediment, nutrient and pesticide loads in the water entering the GBR, draft WQOs were established for associated parameters. The draft WQO for waterways with high ecological value is 'maintain and improve existing water quality'.

These draft WQOs for the 28 water reaches serve as water quality targets which, if achieved, would protect the EVs that the community would like to see protected. Conversely, these draft WQOs should be considered trigger values that would indicate a potential problem if exceeded, and 'trigger' a management response. The standards for chemical contaminants in food for the protection of human consumers of aquatic foods (ANZFSC 2007) are '*no detectable residues*' for any of the pesticides assessed. Note that these standards are statutory, unlike water quality guidelines. Consequently, the draft WQOs for human consumption should be '*no detectable residues*' of these pesticides in aquatic foods.

Further consultation is required to finalise the *Interim marine water quality guidelines for the Great Barrier Reef Marine Park* (Draft) (Honchin *et al.* 2007), and further research is required to develop locally and regionally specific water quality guidelines for pesticides for the Wet Tropics region (including the Tully WQIP area). Consequently, the draft Tully WQIP has defined aspirational targets for all water quality parameters as the draft WQOs in marine waters, and aspirational targets for herbicides as the draft WQOs in all waters. When this information becomes available, draft WQOs may be changed in the near future into (more short-term) resource condition targets.

To determine whether the current water quality in marine receiving waters achieves the draft WQOs set for these waters, the draft WQOs of two water types in inshore marine waters ('enclosed coastal/lower estuary', and 'all marine waters \leq 15 km off the coast') were compared against available data on current condition of water quality in these waters in 2005/2006 and 2006/2007 (J. Prange, GBRMPA, pers. comm. 2007). This comparison shows that, for pollutants for which draft WQOs have been set (i.e. water quality guidelines were available) and/or current condition was monitored, draft WQOs are met except for chlorophyll-a (Table 2.3).

Sustainable load targets and current pollutant loads were also estimated using a combination of monitoring and modelling which is discussed in Section 3.

The Tully WQIP developed under the Coastal Catchment Initiative (CCI) had a downstream focus aimed at protection of the Great Barrier Reef. The draft WQOs set for other waterways in the Tully WQIP area, except those for pesticides, will not be further considered in the Tully WQIP. Management Actions for the rest of the waterways will be developed in the regional NRM Plan.

Table 2.1. Potential environmental values (EPA 2006).



Environmental values	Supporting details	Questions
AQUATIC ECOSYSTEMS		
Aquatic ecosystems	 Pristine (see HEV systems below) or modified Aquatic Ecosystems –	
High conservation / ecological value systems (HEV)	Systems are largely unmodified or have undergone little change. Often found within national parks, conservation reserves or inaccessible locations. Targets aim to maintain and improve existing water quality.	Are any waterways largely unmodified or changed very little? Where are they?
Modified systems	Freshwater	What components of ecosystems do you want to protect e.g. turtles, fish, macroinvertebrates, riparian vegetation, instream habitats, flows?
Modified systems	Estuarine/Coastal/Marine	What components of ecosystems do you want to protect e.g. reefs, seagrasses, mangroves, dugongs, turtles, fish, shellfish?
HUMAN USES		
Primary industries	 Irrigating crops such as sugar cane, lucerne, etc	Where is the water used for irrigation? What crops, etc are irrigated?
	 Water for Farm Use such as in fruit packing or milking sheds, etc	Where is the water used around farms for washing down areas or fruit packing?
	 Stock Watering	Where is the water used for watering stock? What type of stock?
	 Water for Aquaculture such as barramundi, prawn or red claw farming	Where is the water used in aquaculture operations and what species are cultivated?
	 Human Consumption of wild or stocked fish or crustaceans	Where is there consumption of wild or stocked fish or crustaceans?
Recreation and aesthetics	 Primary recreation with direct contact with water such as swimming or snorkelling	Are there any recreational activities where people are fully immersed in the water e.g. swimming, snorkelling? If so, where?
	 Secondary recreation with indirect contact with water such as boating, canoeing or sailing	Are there any recreational activities where people are possibly splashed with water e.g. fishing, boating, sailing? If so, where?
	 Visual appreciation but no contact with water such as picnicking, bushwalking, sightseeing	What areas of waterways are regularly used by people who enjoy looking at and being near the waterway?
Drinking Water	 Raw Drinking Water supplies	Where do people or local governments take water from the river for water supplies?
Industrial uses	 Water for Industrial Use such as power generation, manufacturing plants	What are the industries that take water from the river for their operations and where does this occur?
Cultural and spiritual values	 Cultural and spiritual values	What are the cultural and spiritual values associated with these waterways?

Table 2.2. Draft environmental values (EVs) for each of the 28 water reaches in the Tully WQIP area. Draft EVs were identified based on (i) interviews with 49 community members (Bohnet *et al.* 2006), (ii) three community workshops with 29 participants (Bohnet *et al.* 2007), and (iii) feedback from CSFP Steering Committee. Empty cells indicate that a particular EV was not identified for a particular reach. Water types correspond to those presented in Figure 2.1.

Catchment	Reaches with common Environmental Values ¹	Aquatic ecosystems	Human uses									Drinking water	Industrial uses	Cultural and spiritual values
			Primary industries					Recreation and aesthetics						
			Irrigation	Farm supply	Stock watering	Aquaculture	Human consumption	Primary recreation	Secondary recreation	Visual appreciation				
Hull River and coastal tributaries	Freshwater in natural areas	y				y	y	y	y	y			y	
	Freshwater in developed areas	y	y	y	y		y	y	y	y			y	
	Natural wetlands	y							y				y	
	Upstream limit of tidal influence to mouth of estuary	y			y	y		y	y				y	
Tully River	Freshwater in natural areas	y				y	y	y	y	y			y	
	Freshwater in developed areas	y	y	y	y		y	y	y	y	y	y	y	
	Koombooloomba Dam	y				y	y	y	y	y	y	y	y	
	Natural and constructed wetlands	y	y	y	y		y	y	y	y			y	
	Upstream limit of tidal influence to mouth of estuary	y			y	y		y	y				y	
Murray River	Freshwater in natural areas	y				y	y	y	y	y			y	
	Freshwaters in developed areas	y	y	y	y		y	y	y	y	y		y	
	Natural and constructed wetlands	y	y	y	y		y	y	y				y	
	Upstream limit of tidal influence to mouth of estuary	y				y		y	y				y	
Dallachy Creek	Freshwater in natural areas	y				y	y	y	y	y			y	
	Freshwaters in developed areas	y	y	y	y		y	y	y	y	y		y	
	Natural and constructed wetlands	y	y	y	y		y	y	y				y	
	Upstream limit of tidal influence to mouth of estuary	y				y		y	y				y	
Kennedy & Meunga Creeks	Freshwater in natural areas	y				y	y	y	y	y			y	
	Freshwaters in developed areas	y	y	y	y		y	y	y	y	y		y	
	Natural wetlands	y	y	y	y			y	y				y	
	Upstream limit of tidal influence to mouth of estuary	y				y		y	y				y	
Coastal creeks to Hinchinbrook Channel (including Hinchinbrook Island)	Freshwater in natural areas	y				y	y	y	y	y			y	
	Freshwaters in developed areas	y		y	y		y	y	y	y	y		y	
	Natural wetlands	y	y	y	y			y	y				y	
	Upstream limit of tidal influence to mouth of estuary	y			y	y	y	y	y				y	
Inshore marine	Mouth of estuary to marine waters	y			y	y	y	y	y				y	
	All marine waters ≤ 15km off the coast	y				y	y	y	y				y	
Offshore marine	All marine waters >15km off the coast	y				y	y	y	y				y	

Notes: ¹ See text and EPA (2006, Appendix B) for definitions. Definitions for marine waters differ between EPA (2006) and GBRMPA. Coastal water = low water to 10 m isobath (GBRMPA) or ≤15 km (EPA), open water = seaward of 10 m isobath (GBRMPA) or >15 km (EPA); here the EPA definitions are used. ² Outside the limit of Qld waters (3 nautical miles). Note that the 3 nautical mile boundary applies around Qld islands.

Table 2.3. Summary of different uses and values of waterways by groups of people in the Tully WQIP area. ++ represents the main use/value, + represents a reasonably common use/value, and – represents minimal or no use. The green colour indicates non-consumptive uses of water, whereas the yellow colour indicates primarily consumptive uses of water (from Bohnet *et al.* 2007).













Environmental values	Aquatic ecosystems	Human uses										
		Primary industries					Recreation and aesthetics			Drinking water	Industrial uses	Cultural and spiritual values
		Irrigation	Farm supply	Stock watering	Aquaculture	Human consumption	Primary recreation	Secondary recreation	Visual appreciation			
Who values what?												
Farmers												
Sugarcane	+	-	+	-	-	-	+	+	+	++	+	-
Banana	+	++	++	-	-	-	+	+	+	++	+	-
Tropical fruit	+	++	++	-	-	-	+	+	+	++	+	-
Small crops	+	++	++	-	-	-	+	+	+	++	+	-
Graziers	+	-	+	++	-	-	+	+	+	++	-	-
Foresters	+	++	-	-	-	-	+	+	+	++	+	-
Industry institutions												
Sugar	+	-	-	-	-	-	-	-	-	-	++	-
Banana	+	++	++	-	-	-	-	-	-	-	++	-
Tropical fruit	+	++	++	-	-	-	-	-	-	-	++	-
Tourism	++	-	-	-	-	-	++	++	++	+	-	+
Aquaculture	+	-	-	-	++	-	-	-	-	-	++	-
Commercial fishing	+	-	-	-	-	++	-	-	-	-	++	-
Traditional Owners	++	-	-	-	-	-	++	++	++	++	-	++
Conservation groups	++	-	-	-	-	-	++	++	++	++	-	+
Local (non-farming) residents	+	-	-	-	-	-	++	++	++	++	+	+

Table 2.4. Comparison of draft water quality objectives (WQO) for nutrients, sediment and pesticides in two water types in inshore marine waters in the Tully WQIP area (from Appendix 4; Table 4.2), against current condition of water quality during flood events in 2006/2007 (J. Prange, GBRMPA, pers. comm. 2007). Nutrient, suspended sediment and chlorophyll-a data are median values of three inshore reef sites (two sample events at each Dunk Island, King Reef and North Barnard Islands) collected in January 2006/April 2007. Herbicide data area median values of seven grab water samples collected between the Tully River and Dunk Island in the flood event post Cyclone Larry in 2006. TAN = Total ammonia N, NO₂N = nitrite, NO₃N = nitrate, NO_xN = oxides of nitrogen, FRP = filterable reactive phosphorus, Chl-a = chlorophyll-a, TSS = total suspended sediments. Empty cells = no (or insufficient) data available, < dl = below detectable limit.

Indicator		Unit	Draft WQO		Current condition	
			Mouth of estuary to marine waters	All marine waters ? 15km off the coast		
Nutrients	Inorganic N	TAN	µg/L	15	2	1.6
		NO ₂ N				
		NO ₃ N			910	
		NO _x N		10	2	0.2
	Organic N		135	135	99	
	Total N		160	140	102	
	FRP		5	3	2.2	
	Total P		20	20	12	
Microalgal Growth	Chl-a		2.0	0.5	1.3	
Water Clarity	Turbidity	NTU	10	1		
	Secchi	m	1.0	>10	5	
	TSS	mg/L	<5	<2	4.5	
Pesticides	Diuron	µg/L		0.9	0.011	
	Atrazine			0.4	0.004	
	Chlorpyrifos			0.005	<dl	
	Endosulfan			0.005	<dl	
	Ametryn			0.5	< dl	
	Simazine			0.2	< dl	
	Hexazinone			75	0.004	
	2,4-D				0.8	
	Tebuthiuron				0.02	
	MEMC				0.002	
	Diazinon				0.06	
	Tributyltin				0.001	
	Irgarol				0.02	

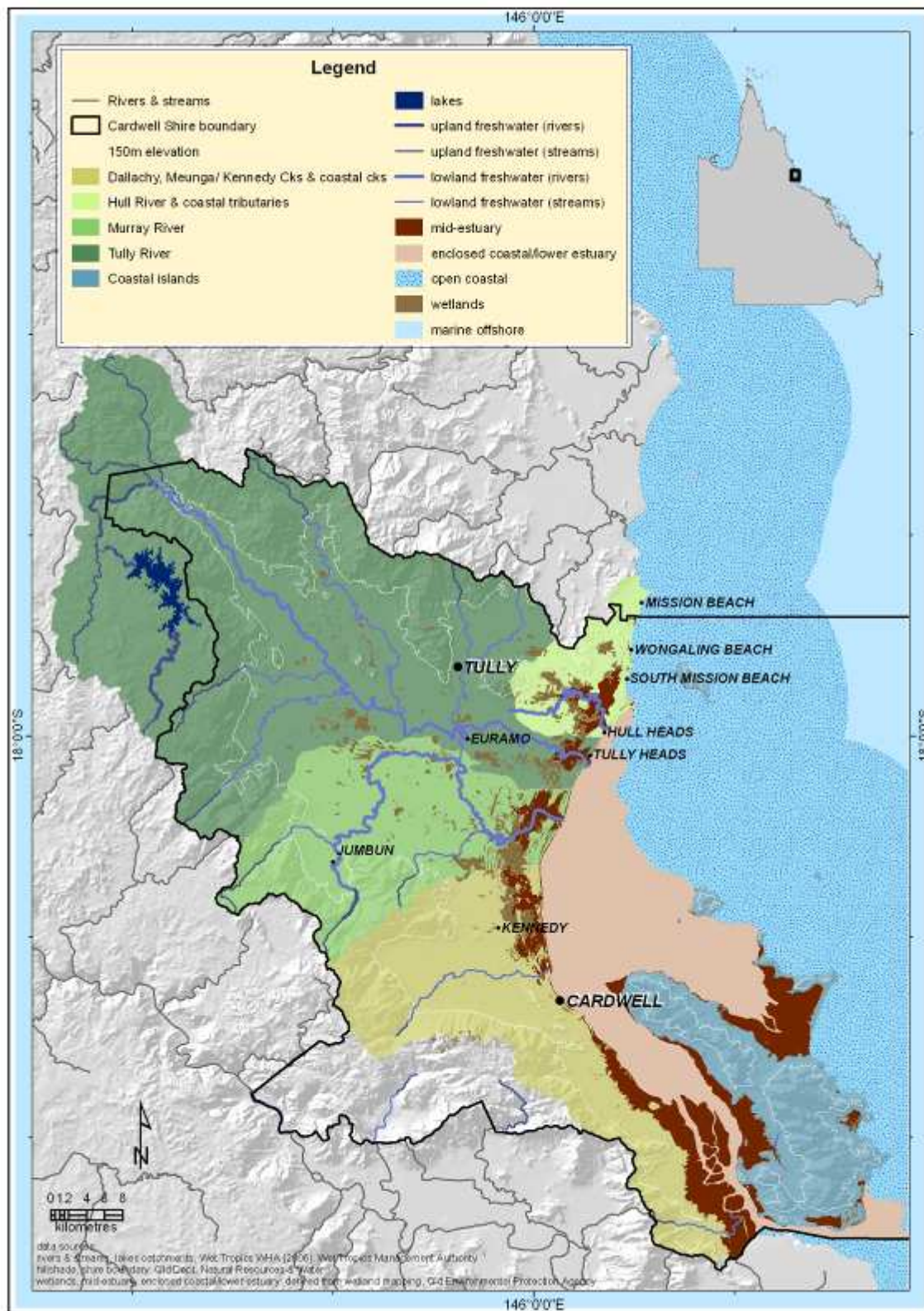


Figure 2.1. The spatial location of eight water types within each of the six sub-catchments in the Tully WQIP area. For clarity only major rivers and streams are shown. See text and EPA (2006, Appendix B) for definitions. Definitions for *marine* water types differ between EPA (2006) and GBRPMA. *Coastal water* = low water to 10 m isobath (GBRMPA) or ≤ 15 km (EPA), *open water* = seaward of 10 m isobath (GBRMPA) or > 15 km (EPA); here the EPA definitions are used. *Marine offshore* is outside the limit of Qld waters (3 nautical miles). Note that the 3 nautical mile boundary applies around Qld islands.

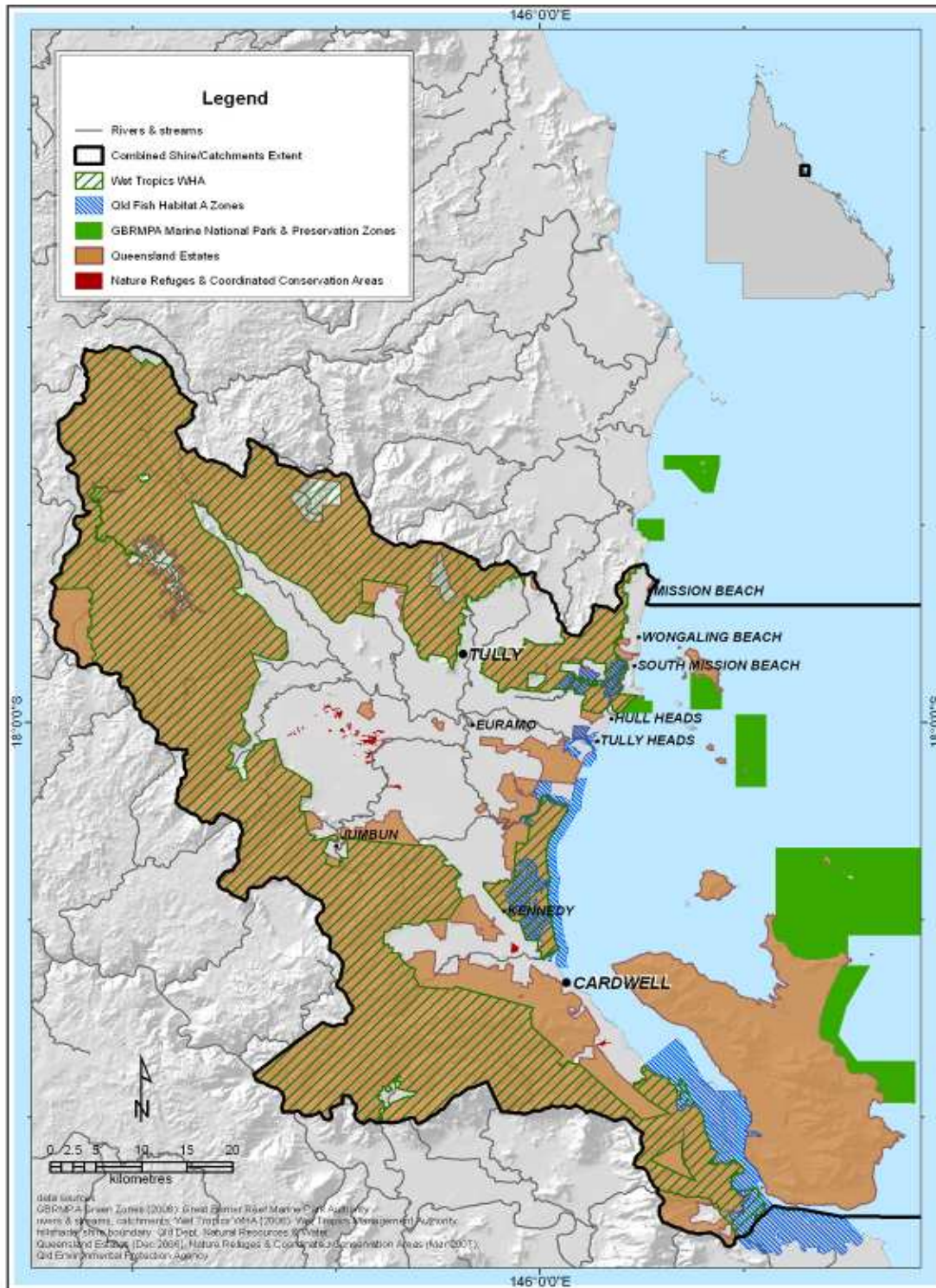


Figure 2.2. Proposed High Ecological Value waterways (i.e. waterways which fall within 'protected' areas under existing legislation, (i.e. Wet Tropics World Heritage Area, Queensland Estates (including gazetted 'National Parks Scientific', 'National Park', 'National Park Recovery', 'Conservation Park', 'Resources Reserve', 'Forest Reserve', 'State Forest' and 'Timber Reserve'), Nature Refuges and Coordinated Conservation Areas, Queensland Declared Fish habitat area [Class A], and Marine Park Areas [Preservation Zones and better]).

3 SUSTAINABLE LOAD TARGETS AND CURRENT STATUS OF POLLUTANT LOADS

3.1 Introduction

The Tully WQIP has set targets (i.e. WQOs) to protect critical waterway assets (i.e. EVs) (Section 2). Targets are defined as '*quantifiable performance levels or changes in level to be attained at a specific future date*'. The following hierarchy of targets has been used to structurally align the Tully WQIP with the regional NRM plan:

- *aspirational target* = Aspirational statements about desired condition of natural resources in the longer term (50+ years);
- *resource condition target* (RCT) = Specific, time-bound and measurable targets, relating largely to resource condition, against the minimum set of matters for regional targets (timeframe 10-20 years); and
- *management action target* (MAT) = Short term targets (1-5 years), relating mainly to management actions or capacity-building. These targets must contribute to progress towards the longer-term resource condition targets.

The Tully WQIP is primarily concerned with reducing sediment, nutrient and pesticide loads in the water entering the GBR (The State of Queensland & Commonwealth of Australia 2003). Consequently, aspirational targets have been defined based on the draft WQOs for marine waters (Section 2.4).

Specific resource condition targets (RCTs) have not been defined due to a current lack of available science to determine definite quantitative relationships between (improvements in) water quality and the (change in) condition of a resource. Draft WQOs may be changed in the near future into RCTs, with finalisation of *Interim marine water quality guidelines for the Great Barrier Reef Marine Park* (Draft) (Honchin *et al.* 2007), and development of locally and regionally specific water quality guidelines for pesticides for the Wet Tropics region (Section 2.4).

This section describes the process used: (i) to estimate sustainable load targets based on the draft WQOs for marine waters (i.e. aspirational target); and (ii) to compare these estimates with current pollutant loads. These results were subsequently used to develop management action targets to progress towards achieving sustainable loads.

3.2 Pollutants of interest

The Tully WQIP is primarily concerned with reducing sediment, nutrient and pesticide loads in the water entering the GBR (Figure 1.1). Hence, sustainable and current pollutant loads were estimated for flood events when the majority of pollutants are transported to the marine receiving waters (Mitchell *et al.* 2007). A brief description of each of these pollutants and their potential impact on the GBR is provided below. The following information is from Furnas (2003), GBRMPA (2007a,b) and Brodie *et al.* (2007a), unless otherwise noted.

Suspended sediment is usually measured as *total suspended sediment* (TSS), which can be further divided up into *fine* (<2 µm), *medium* (2-63 µm) and *coarse* (>63 µm) *sediment*. Fine sediment is carried widely over the GBR shelf, while medium and coarse sediment are carried over only relatively short distances, accumulating in river channels and forming delta fans. For receiving waters, fine sediments are of particular concern because these particles can increase turbidity levels, smother corals and seagrass, irritate fish gills and absorb and transport other pollutants such as nutrients and pesticides.

The main nutrients of concern for the GBR are nitrogen and phosphorus. In water, both are found naturally as both as inorganic and organic species and in dissolved and particulate forms. Common measurements of nitrogen are *dissolved inorganic nitrogen* (DIN), *dissolved organic nitrogen* (DON), and *particulate organic nitrogen* (PN). DIN is the summed concentration of nitrate (NO₃⁻), nitrite (NO₂⁻) and ammonium (NH₄⁺) and is biologically available in fresh and marine waters. Concentrations for nitrate and nitrite are sometimes presented combined as NO_x. Increased DIN concentrations can promote growth of bacteria, phytoplankton, algae and weeds. DON is a form of nitrogen that is incorporated into dissolved organic matter and includes amino acids, proteins and urea. It has generally been assumed that DON is not directly bio-available and thus of minimal concern for receiving waters. However, recent work cited by Wallace *et al.* (2007a,b) suggests

that particular forms of DON may be more bio-available than commonly assumed and further research is being conducted to examine this possibility. PN is a form of nitrogen in biomass and dead organic matter, or attached to mineral particles and suspended sediment; most components of PN are biologically available.

Common measurements of phosphorus are *filterable reactive phosphorus* (FRP), *dissolved organic phosphorus* (DOP) and *particulate organic phosphorus* (PP). FRP (or phosphate) is the principal soluble inorganic form of phosphorus, can include orthophosphates (H_2PO_4^- , HPO_4^{2-} , PO_4^{3-}) and readily binds to sediment particles. DOP is a form of phosphorus that is incorporated into organic and inorganic matter. Both FRP and DOP are readily available for and utilised by plants and bacteria. PP is a form of phosphorus in biomass and dead organic matter, or attached to mineral particles and suspended sediment; some components of PP are biologically available.

Pesticides include a range of chemicals that are used to manage pests, such as weeds (herbicides), insects (insecticides), mites (miticides), nematodes (nematocides) and fungus (fungicides). In the GBR region, pesticide use has increased, particularly in agricultural and urban areas, and shifted from chemicals such as DDT, dieldrin and heptachlor to modern triazine, organophosphate and urea-based pesticides. Both historically used and current agricultural pesticides have been widely detected in both fresh and marine waters of the GBR region (Haynes *et al.* 2000, Kapernick *et al.* 2006, Lewis *et al.* 2006, Rohde *et al.* 2006; see also Honchin *et al.* 2007), including the Tully region (e.g. Kapernick *et al.* 2006, Faithful *et al.* 2007, Honchin *et al.* 2007). Pesticides can harm freshwater and marine plants and animals and may progressively accumulate in sediments or in biological tissues (Negri *et al.* 2007, Honchin *et al.* 2007).

3.3 Sustainable sediment, nutrient and pesticide loads

To estimate sustainable load targets the draft WQOs for marine waters (Section 2) were linked to existing monitoring and modelling information on water quality in the GBR lagoon. Sustainable load targets were estimated for flood events when the majority of pollutants are transported to the marine receiving waters (Mitchell *et al.* 2007).

Nitrate

A sustainable load for nitrate was estimated using a combined hydrodynamic / chlorophyll-a (Chl-a) - nitrate correlation model for the GBR (Wooldridge *et al.* 2006). This model links a quantitative river discharge parameter (dissolved inorganic nitrogen (DIN) concentration in event flows) with a quantitative indicator of health in the marine environment (Chl-a concentration). Chl-a, a photosynthetic pigment, is an indicator of phytoplankton biomass and is widely used as a proxy for nutrient availability (GBRMPA 2007). Such a relationship has been confirmed for the GBR north of the Burdekin River, where observed summer Chl-a concentrations in the inner-shelf areas increase significantly with event flow DIN concentrations of rivers that discharge into it (Wooldridge *et al.* 2006).

The Wooldridge model estimated the degree of improvement in river water quality (i.e., % reduction in DIN concentration) that is necessary to ensure that Chl-a $< 0.6 \mu\text{g/L}^3$ for all locations within the northern GBR lagoon. Specifically, to estimate sustainable loads for nitrate for the Tully River the Wooldridge model used: (i) modelled spatial extent of runoff–seawater dilution ratios; (ii) observed runoff-induced lagoon Chl-a concentrations (Brodie *et al.* 2007d); and (iii) observed flood-induced river nutrient concentrations (Furnas 2003) (Wooldridge *et al.* 2006). The observations are based on monthly summer records of Chl-a concentrations across lagoonal waters since 1992 (Brodie *et al.* 2007d), and NO_x (nitrate and nitrite) data collected over 12 years (1988-2000) at the Euramo bridge (Furnas 2003).

The outcomes of the Wooldridge model suggest that DIN concentrations at Euramo bridge (Tully River), or nitrate that is lost from the land, would need to be reduced by at least 80% to $34 \mu\text{g/L}$ to reduce Chl-a concentrations in the open coastal lagoon to meet the aspirational target of $0.5 \mu\text{g/L}$ (draft WQO; Appendix 4, Table 4.2a). The mean NO_x concentration at Euramo bridge over these 12 years ($170 \mu\text{g/L}$) is comparable with the 2006 wet season average ($\sim 190 \mu\text{g/L}$) (J. Prange, GBRMPA, pers. comm. 2007). This suggests that

³ The Chl-a concentration of $0.6 \mu\text{g/L}$ represented the upper limit water quality target in GBR inshore coastal waters when the Wooldridge model was run (Wooldridge *et al.* 2006). Since then, the interim marine water quality guidelines for the Great Barrier Reef Marine Park have reduced this to $0.5 \mu\text{g/L}$ for open coastal waters and $0.3 \mu\text{g/L}$ for marine offshore waters (GBRMPA 2007). These concentrations have also been established as the draft WQO for Chl-a in marine waters (Table 2.2a).

NO_x concentrations at Euramo bridge need to be reduced to 34 µg/L to achieve draft WQOs for marine receiving waters⁴. This value corresponds to the concentration suggested for NO_x in Wet Tropics freshwater lowland streams (30 µg/L, EPA 2006).

Sediment, nitrogen, phosphorus and pesticides

Receiving water models and local water quality guidelines for suspended sediment, forms of nitrogen other than nitrate, phosphorus and pesticides are needed before sustainable load targets (i.e. a link between concentrations in rivers and draft WQOs for marine waters) can be estimated. In the interim, while these model are being developed, CSFP Steering Committee has agreed that every attempt should be made to halt and reverse the decline of water quality entering the GBR lagoon, based on the assessment of management scenarios (Section 4).

Pre-1850 loads

An assessment of the estimated change in delivery of SS, TN and TP to the GBR from the pre-development period (i.e. pre-1850) to current conditions may contribute to the development of sustainable load targets. For wet catchments, such as the Tully WQIP area, TSS estimates were based on 2,500 tonnes per km³ of discharge (2.5 mg SS/L). The average nutrient loading coefficients were assumed to be equivalent to the median concentrations calculated for samples collected at a site just below the rainforest on Dalrymple Creek (Herbert River) (Brodie *et al.* 2003). Export estimates were subsequently calculated by multiplying the annual freshwater discharge from the basin by the loading coefficient.

For the Tully WQIP area, Brodie *et al.* (2003) estimated that pre-1850 loads were:

- TN = 940 tonnes/year; and
- TP = 110 tonnes/year.

Brodie *et al.* (2003) mention the considerable uncertainty in the results and suggest that confidence to two significant figures is reasonable. Because of their uncertainty these figures are indicative only, but could be used as interim aspirational targets for the Tully WQIP. The estimate for pre-1850 TSS loads are considered not reliable due to the use of the RUSLE in closed forest situations on steep slopes in tropical environments, and the relative uncertainty of pre-1850 vegetation composition and its erosive potential in the Tully-Murray basin (Brodie, ACTFR, pers. comm. 2008), and is not included here.

3.4 Current status of pollutant loads and critical sources

To determine the current status of pollutant loads, and identify critical sources, a combination of monitoring (and associated modelling) was used. Monitoring focussed around flood events in 2006 and 2007, when the majority of pollutants are transported to the marine receiving waters.

Sediment, nutrient and pesticide loads in waterways

Current sediment and nutrient loads delivered to marine receiving waters by rivers and creeks in the Tully-Murray basin were estimated using SedNet/Annex (Sediment River Network/Annual Nutrient Export) (Armour *et al.* 2007a). This model estimates a long-term, annual average load, rather than predicting short-term events. Major improvements compared to the Short Term Modelling project for Wet Tropics catchments (Hateley *et al.* 2006) include the use of a 25 m digital elevation model, the use of more recent land use data (QLUMP 2004 and recent expansion of plantation forestry), the recalculation of the C (vegetation cover) factor and K (soil erodibility) factor of the Revised Universal Soil Loss Equation (RUSLE) based on improved data, and revised soil nitrogen and phosphorus concentrations from published soil surveys.

Importantly, the potential contribution of constructed drains to sediment and nutrient delivery to streams (e.g. Bartley *et al.* 2004) was not included in the SedNet/Annex modelling. Approximately 1,100 km of constructed drains are present in the Tully WQIP area (Armour *et al.* 2007a). However, catchment-wide data

⁴ Marine receiving waters of the Tully WQIP area are affected by flood plumes from both the Herbert and Burdekin Rivers. The Wooldridge model indicates that similar reductions in DIN loads need to be achieved in these two catchments to meet the aspirational target of 0.5 µg/L Chl-a in the open coastal waters of the GBR.

required for incorporating these structures into the modelling, such as an artificial drainage layer, classification into major and minor drains, and information on actively eroding drains and stable drains, were not available (Armour *et al.* 2007a). Estimates of sediment budgets for the Douglas WQIP suggest that cane drains can contribute significantly to total sediment (and nutrient) loads (Bartley *et al.* 2004). This plan recommends that the information required to include constructed drains into catchment models be collected, and that their total and proportional contribution to sediment and nutrient loads be estimated.

Where possible, the relative contribution of individual sources of pollution to sediment and nutrient loads was estimated, based on SedNet/Annex modelling (diffuse sources) or discharge information (point sources). Potential sources of pollution considered include:

- *diffuse sources* (natural forests in protected areas, sugarcane, grazing, plantation forestry, banana and horticulture, urban run-off and development sites, and waterways, including river and stream banks);
- point sources, including:
 - *licensed* (Tully Sugar Mill, Tully Sewage Treatment Plant, sewage treatment at resorts, caravan parks and holiday villages, aquaculture facilities, extractive industries, other environmentally relevant activities, and boat discharges); and
 - *unlicensed* (unsewered residential areas).

To estimate current status of pollutant loads, current management practices were included for all major industries, based on the most recent surveys (Table 3.1) and research (Hateley *et al.* 2006, Roebeling and Webster 2007). In sugarcane, 48 growers were surveyed covering a total area of 9,189 ha (25% of Tully WQIP area) (McMahon 2007). In banana, an unknown number of growers was surveyed covering a total area of 868 ha (10.8% of Tully WQIP area) (Lindsay *et al.* 2007a). At the time of writing, survey results for grazing, and current uptake management practices for natural forests in protected areas, urban land uses and waterways, were not available. Current status of all potential sources of pollution in the Tully WQIP area are summarised in Appendix 3.

Currently, models to estimate total pesticide catchment loads in the Tully-Murray basin are not available. However, monitoring programs did measure pesticide export from several diffuse sources.

The relative contribution of six diffuse sources (natural forest, sugarcane, grazing, plantation forestry, bananas and urban) to current pollutant loads of sediment and nutrients was monitored in rivers and streams in the Tully-Murray basin during two wet seasons (2006/2007 and 2007/2008) (Faithful *et al.* 2007). Water samples were also analysed for ten herbicide residues (ametryn, atrazine, desethyl atrazine, desisopropyl atrazine, diuron, fluometuron, hexazinone, prometryn, simazine and tebuthiuron). Other pesticides were not included because of uncertainty surrounding the time at which pesticides were used in the area, and/or due to the unavailability or costs of the analyses required.

The following information is from Armour *et al.* (2007a) and Faithfull *et al.* (2007), unless otherwise noted.

Sediments

Modeling estimates of total catchment loads

SedNet/Annex modelling estimated that:

- a total of 183,000 tonnes TSS/year is supplied to waterways in the Tully-Murray basin, consisting of hillslope erosion (116,000 tonnes TSS/year), bank erosion (57,000 tonnes TSS/year) and gully erosion (10,000 tonnes TSS/year);
- 119,000 tonnes TSS/ year is transported to end-of-river (Table 3.2; Figure 3.1); and
- adoption of Green Cane Trash Blanketing in sugarcane has reduced the TSS contribution by sugarcane from 173,000 tonnes/year in 1970 to 29,000 tonnes/year under current conditions.⁵

⁵ Note that this is an over-estimate of the reduction in TSS contribution by sugarcane, as this comparison assumes that the area of sugarcane production and other crops is the same as the current condition (Armour *et al.* 2007a). This assumption is not valid (see Section 1.3).

The modelled proportional contribution of each land use to the total TSS (and associated PN and PP) loads exported to the end-of-river contradicted direct observations from monitoring and sediment fingerprinting (Hateley 2007), and are not further considered. This discrepancy is associated with the use of the RUSLE in closed forest situations on steep slopes in tropical environments (Armour *et al.* 2007a).

Point sources for which annual TSS loads could be estimated contribute an additional <4% to the average annual TSS load delivered to receiving waters (Appendix 3):

- 0.13% (Tully Sugar Mill);
- 0.001% (sewage treatment plant); and
- 3.2% (aquaculture).

Compared to pre-1850 loads, the current TSS load appears to have increased by a factor of around 4 (Brodie *et al.* 2003).

Monitoring estimates of contribution by land use and total catchment load

Catchment monitoring results showed that TSS concentrations from all sub-catchment sites were relatively low, particularly compared to data from other GBR catchments. Median TSS concentrations from natural forest sub-catchment sites were consistently lower than those from other land uses, indicating that catchment disturbances in the latter resulted in minor increases in sediment losses. Sediment tracing work in Davidson Creek, Jarra Creek and Tully River demonstrated that on average 75% of suspended sediments were derived from surface erosion (sugarcane, grazing and banana), with the remainder contributed by bank erosion (Hateley 2007). In this study, no suspended sediment was detected in Davidson Creek, Jarra Creek and Tully River that could be traced to natural forests in the respective upper catchments (Hateley 2007).

The average suspended sediment transport *from the Tully River catchment only*, based on: (i) three years of logger estimations at Euramo bridge (Tully), is 144,000 tonnes/year (range: 79,000 – 237,000 tonnes/year), and on (ii) on four years of water quality monitoring at Euramo bridge (Tully), is 125,000 tonnes/year (Mitchell *et al.* 2007). The logger-derived estimates are considered to be based on measurements of fine, well-suspended sediment. This suggests that the SedNet/Annex modelled estimates of TSS loads are conservative.

Nitrogen

Modeling estimates of total catchment loads

SedNet/Annex modelling estimated that:

- a total of 2,300 tonnes of TN is exported to the end-of-river per year, comprising 1,160 tonnes (50%) DIN, 529 tonnes (23%) of DON, and 630 tonnes (27%) of PN (Table 3.2, Figure 3.1); and
- sugarcane contributes most to this DIN load, followed by banana and horticulture, both as a proportion of total and per ha (Table 3.2, Figure 3.2).

Modelled and monitored DIN concentrations at six sampling locations were in general agreement, providing confidence in the outcomes of the SedNet/Annex model.

Point sources for which annual TN loads could be estimated contribute an additional ~4% to the average total TN load per year delivered to receiving waters (Appendix 3):

- 0.3% (STP), consisting of approximately 75% DIN and 25% DON; and
- 3.5% (aquaculture).

Compared to pre-1850 loads, the current TN load appears to have increased by a factor of around 3 (Brodie *et al.* 2003). This corresponds with the estimated 80% reduction required in DIN concentrations at Euramo bridge (Tully River), to reduce Chl-a concentrations in the open coastal lagoon to meet the aspirational target of 0.5 µg/L (Section 3.3).

Monitoring estimates of contribution by land use and total catchment load

Catchment monitoring indicates that DIN, DON and PN from sub-catchment sites with fertilised land use (particularly sugarcane and bananas) were elevated compared to natural forest sites. Results from nitrate monitoring in the Tully catchment during wet seasons over a total period of 16 years (1987-2000; 2004-2007) show that mean NO_x concentration at a site increases significantly with the proportion of fertiliser-additive land use above that site (Figure 3.3; Mitchell *et al.* 2007). Specifically, mean NO_x concentrations increase by a factor of 35 with an increase in fertilised land use above the sampling site from 0% to 100%.

The approximate doubling in area cultivated for bananas and sugarcane in the 1990-ies was accompanied by an estimated increase in N fertiliser usage by 118% in the Tully-Murray catchments (GBRMPA 2001, McDonald and Weston 2004). This most likely contributed to the continuing increase in nitrate, PN and PP concentrations at Euramo bridge, Tully River, from 1988 to 2000 (Mitchell *et al.* 2007). Since then, surveys have indicated that N fertiliser usage *per ha* has declined in both industries (Section 1.3), but this decline has not been reflected in a decrease in DIN loads or concentrations at end-of-river. This suggests that either fertiliser usage is underestimated in surveys, and/or the existence of a time-lag between decrease in N fertiliser usage and DIN loads or concentrations at end-of-rivers.

The average total nitrogen transport *from the Tully River catchment only*, based on 13 years of water quality monitoring at Euramo bridge (Tully), is 1,250 tonnes of TN, comprising of 570 tonnes (46%) DIN, 200 tonnes (16%) of DON, and 440 tonnes (35%) of PN (Mitchell *et al.* 2007). Mitchell *et al.* (2007) suggest that SedNet/Annex derived values, particularly those for DON, may be closer to real values due to issues with the analytical methodology.

Phosphorus

Modeling estimates of total catchment loads

SedNet/Annex modelling estimated that:

- a total of 240 tonnes TP/year is exported to the end of river, comprising of 50 tonnes (22%) of FRP, 30 tonnes (13%) of DOP, and 160 tonnes (65%) of PP (Table 3.2, Figure 3.1); and
- contribution of FRP *per ha* is highest in urban, followed by banana and grazing, while contribution of DOP per area is highest in sugarcane, banana and grazing (Table 3.2).

Point sources for which annual TP loads could be estimated contribute an additional ~8% to the average total TP load per year delivered to receiving waters (Appendix 3):

- 0.3% (STP), consisting almost completely of FRP; and
- 7.5% (aquaculture), consisting almost completely (>90%) of PP, and is sourced from feeds, phytoplankton and detritus (Preston *et al.* 2000).

Compared to pre-1850 loads, the current TP load appears to have increased by a factor of around 2 (Brodie *et al.* 2003).

Monitoring estimates of contribution by land use and total catchment load

Catchment monitoring results indicated that concentrations of the three forms of phosphorus were higher in run-off from sub-catchments with fertilised land use (cane, grazing) and urban areas, compared to natural forest sub-catchments. Sediment fingerprinting showed that phosphorus concentrations in banana soils were two to three times higher than in natural forest, grazing and sugarcane soils (Hateley 2007). Over a 12 to 13 year period, PP concentrations at Euramo bridge have increased significantly with increases in areas of fertilised land use in the catchment (Mitchell *et al.* 2007).

The average total phosphorus transport *from the Tully River catchment only*, based on 13 years of water quality monitoring at Euramo bridge (Tully), is 97 tonnes of TP, comprising of 15 tonnes (16%) FRP, 12 tonnes (12%) of DOP, and 68 tonnes (70%) of PP (Mitchell *et al.* 2007). Mitchell *et al.* (2007) suggest that SedNet/Annex derived values, particularly those for DOP, may be closer to real values due to issues with the analytical methodology.

Pesticides

Monitoring estimates

Catchment monitoring detected seven herbicide residues in waterways of the Tully WQIP area: ametryn (range from 0.01 to 0.05 µg/L), atrazine (0.01 to 1.0 µg/L) and its decay products desethyl atrazine (0.01 to 0.08 µg/L) and desisopropyl atrazine (0.01 to 0.05 µg/L), diuron (0.02 to 19 µg/L), hexazinone (0.1 to 3.6 µg/L), and simazine (0.03 to 0.06 µg/L). Fluometuron, prometryn, and tebuthiuron were not detected at all. Four of these five herbicide residues detected (ametryn, atrazine, diuron, hexazinone) are used in sugarcane, two are decay products of atrazine, while the seventh (simazine) is used in plantation forestry operations.

Because of their potential toxicity, the observed concentrations of herbicides were compared against draft WQOs in the freshwater reaches of the Tully WQIP. Under the national water quality guidelines, herbicides are considered toxicants, that is, 'chemical contaminants that have the potential to exert toxic effects at concentrations that might be encountered in the environment' (ANZECC 2000).

Herbicide concentrations equalled or exceeded draft WQOs (and national water quality guidelines for drinking water, stock water and freshwater ecosystems; ANZECC 2000) (Appendix 4, Table 4.1, 4.2) in 30 of the 102 samples analysed (Table 3.3). The main land uses upstream of the sampling locations are natural forest, sugarcane and grazing:

- atrazine was detected in 41 samples, with concentrations equalling or exceeding drinking water and stock water guidelines (both 0.1 µg/L) in 20 samples;
- diuron was detected in 44 samples, with concentrations equalling or exceeding guidelines for freshwater ecosystems (0.2 µg/L) in 26 samples; but not for drinking water and stock water (30 µg/L);
- hexazinone was detected in 48 samples, with concentrations exceeding guidelines for drinking water and stock water (2 µg/L) in two samples;
- ametryn concentrations did not exceed guidelines for drinking water and stock water (5 µg/L), guidelines for freshwater ecosystems do not exist; and
- simazine was only detected twice, both times in the Murray River, but well below guidelines for drinking water and stock water (0.5 µg/L) and guidelines for freshwater ecosystems (3.2 µg/L).

Draft WQOs, derived from water quality guidelines (EPA 2006, ANZECC 2000) are considered trigger values, that would indicate a potential environmental problem if exceeded, and 'trigger' a management response. Given the results, Terrain NRM informed EPA of the detection of herbicide levels above water quality guidelines for drinking water, stock water and freshwater ecosystems. Additional management responses need to include a further risk assessment of these herbicides for the specific conditions of tropical freshwater environments. Further action may be required to inform changes in the regulatory system, as current recommended practices for pesticide use are determined by label recommendations and permit conditions under the National Registration Framework, managed by the Australian Pesticides and Veterinary Medicines Authority.

No herbicide residues were detected in the 36 samples collected immediately below natural forest, except two with levels at or just above detection level. These were collected at Tully Gorge (hexazinone; 0.01 µg/L) and Davidson Creek (diuron; 0.02 µg/L), and may reflect a sample contamination problem. Alternatively, land use above the Tully Gorge sampling location, and the location of a sugarcane field next to the Davidson Creek collection site may have contributed to these two detections.

Monitoring in receiving waters in April 2006 detected atrazine, diuron, hexazinone and simazine at the Euramo bridge (Tully River), and from the Tully River to Dunk Island; tebuthiuron was not detected at all (Kapernick *et al.* 2006). Further, marine monitoring at Bedarra Island from June to October 2005 detected diuron and simazine; no sampling was conducted during the wet season. In 2007, atrazine, diuron, hexazinone and simazine were detected at the Euramo bridge (J. Prange, GBRMPA, pers. comm. 2007).

Analyses of mud crabs (*Scylla serrata*), collected in the Tully River mouth in 2005 and 2006, did not indicate any pesticides (polychlorinated biphenyls, polycyclic aromatic hydrocarbons, chlorpyrifos, endosulfan, DDTs, dieldrin, trans-chlordane, trans-nonachlor, and heptachlor-epoxide) or herbicides (diuron and atrazine) (Negri *et al.* 2007).

An additional 21 pesticides used in bananas were assessed according to their relative risk to the aquatic environment (Gauss *et al.* 2007). This included five insecticides, three nematicides, two miticides, six fungicides, and five herbicides. Pesticides were ranked according to their application rates, for their potential to enter the aquatic environment and with respect to their toxicity to aquatic organisms. Priority group one,

representing pesticides with relatively high aquatic risk indices, include all insecticides (chlorpyrifos, prothiofos, diazinon, fipronil, and bifenthrin), two nematicides (fenamiphos, cadusafos), and one herbicide (paraquat). This ranking needs to be used by the banana industry and Terrain NRM to prioritise management strategies that minimise off-site impacts of pesticides used in bananas, to guide water quality monitoring programs, and to compare risk indices to those being obtained for other land uses (e.g. plantation forestry, grazing).

Herbicide use in grazing, plantation forestry and urban environments is currently not well documented (Appendix 3), and could not be assessed.

Sediment and nutrient loads in over bank floods

Sediment and nutrient loads estimated by SedNet/Annex are annual averages that would be delivered to the ocean by flows from rivers and creeks in the Tully-Murray basin. However, the Tully and Murray catchments are subject to frequent flooding, where water runs over-bank and discharges into the estuarine and marine environment without re-entering the main river channel. During such floods, the Tully and Murray river gauges do not record the discharge very well. For example, the Tully river gauge at Euramo only records 73% to 86% of the flood discharge and the Upper Murray gauge only records 5% to 12% of the flood discharge (Wallace *et al.* 2007b). Consequently, during over-bank floods large amounts of water leave the Tully and Murray catchments that are not recorded by the catchment river gauges.

As part of the Tully WQIP, sediment, nitrogen and phosphorus loads were estimated in over-bank floods, based on total flood discharge estimates and sediment and nutrient concentrations during floods (Wallace *et al.* 2007a,b). The results clearly demonstrate the significant contributions that over-bank flood events make to pollutant loads delivered to receiving waters (Figure 3.1a,b,c). For example, during the 2007 wet season the three flood events alone carried sediment and nutrient loads that were similar to the annual average loads exported by rivers and creeks in the Tully-Murray basin. Since most of the flood discharge is not measured by the river gauges, much of this flood load is *in addition to* the currently estimated annual riverine load. Per over bank flood, these additional amounts range from 2% to 99% of annual river loads, depending on pollutant type and flood size.

A second important feature emerges from the over-bank flow water quality data. The largest fraction of the nitrogen load in flood waters is in the form of DON (Wallace *et al.* 2007a,b). This contrasts markedly with the nitrogen species reported for river waters, where DIN is the dominant form. It is believed that the main source of DIN is from agricultural land, whereas the main source of DON is likely to be from upper catchment rainforest. It is generally assumed that these DON loads may not contribute to marine eutrophication, because DON loads to receiving waters may not have changed or are not biologically available (ref?). However, runoff to the GBR lagoon may have increased due to land drainage (e.g. McCulloch 2006), resulting in an enhanced DON load to the ocean. Furthermore, this extra DON may be directly assimilated by macrophytes, seagrasses and algae, albeit at lower (10% to 20%) rates than DIN is assimilated (see Wallace *et al.* 2007a,b). Consequently, the biologically available nitrogen load to the ocean may also have been enhanced by elevated DON loads arising from the upper catchment rainforest.

The implications of the flood water quality studies in the Tully WQIP area, and potentially for other Wet Tropics WQIPs, are as follows (Wallace *et al.* 2007b):

- over-bank floods make a significant contribution to the marine load of TSS and nutrients and much of this load is not recorded by catchment river gauges;
- on average, the annual TSS load, delivered by the Tully WQIP area to the GBR, may be 60% greater than that estimated from river data alone (Armour *et al.* 2007a);
- on average, the annual nutrient loads, delivered by the Tully WQIP area to the GBR, may be double that estimated from river data alone (Armour *et al.* 2007a);
- these data suggest that current marine load estimates of TSS, TN and TP (and associated species of N and P) from wet tropical catchments with frequent over-bank flooding (based on gauged flows, measured river concentrations and SedNet modelling) are probably too low;
- the size of these underestimates in any catchment in any year will depend on the number and size of over-bank flood events in that catchment in that year. In wet years, such as 2007, the over-bank load of nutrients can be similar to the annual average river load;

- this will make the monitoring of any trends in ocean loads difficult unless they are made over long enough periods to remove inter-annual variability;
- previous WQIPs that centre around on-farm interventions in agriculture will potentially reduce DIN loads (e.g. for Douglas Shire); and
- reductions in DON (and sediment) loads that arise outside the floodplain require different interventions; e.g. those that slow down and reduce drainage.

3.5 Annual and seasonal variation in sediment and nutrient loads

Annual discharge in the Tully River is amongst the least variable between years of all Australian river catchments (Mitchell *et al.* 2007). This is in sharp contrast to most other rivers in Queensland, which generally show huge year-to-year variability in discharge. In contrast, monthly discharges vary significantly, with a clear 'wet season' from December to May and 'dry season' from June to November. Records for three years (1996, 1997, 2000) show that the dry season discharge contributed only 20% to 24% to the total discharge volume. Hence, the majority of pollutants of concern are most likely transported to the GBR during the wet season, in particular around flood events.

Mitchell *et al.* (2007) showed that concentrations of most pollutants increased with increasing discharge, however, concentrations of particulate and dissolved forms responded differently during higher discharges. In general, concentrations of particulate forms such as TSS, PN and PP increased with flow and were highest during the wet-season, as heavy rains mobilise particulate material. Phosphate showed a similar, but slightly weaker relationship with discharge, presumably linked to its adsorption to particulate material. In contrast, concentrations of dissolved forms such as nitrate initially increased with increasing flow, but subsequently decreased with increasing dilution. Nitrate concentrations were highest in January, reflecting first-flush elevations. Responses of other dissolved forms such as DOP and DON to variation in discharge could not be reliably analysed.

Combined, these data indicate that sediment and nutrient loads to receiving waters are highest during the wet season. Input from most point sources would be relatively constant throughout the year, however, these contributions are likely to be highly localised and in some cases seasonal (e.g. Tully Sugar Mill).

3.6 Key pollutants and critical sources

A list of key pollutants and critical source categories was developed, based on the best available science to estimate sustainable load targets and current pollutant loads (Brodie *et al.* 2007a). This list was presented to, and discussed with, the CSFP Steering Committee. The Steering Committee accepted this list and agreed that it be used to develop scenarios to examine the effect of changes in land management on water quality (Section 4).

1. **Nitrate and particulate nitrogen** are considered the priority pollutants. The generation and delivery of DIN in the catchment is extremely high compared to pristine catchments, especially in sub-catchments with fertilised land use (Figure 3.3). Over 85% of DIN is sourced from agricultural land uses, primarily sugarcane and bananas. Particulate nitrogen is sourced from eroding soils, especially those exposed during land development activities, and those enriched in nitrogen through a history of fertiliser use. Models show that DIN concentrations at Euramo bridge (Tully River) are much higher than would meet draft WQOs for chlorophyll-a in the open coastal lagoon. This DIN concentration corresponds to *nitrate that is lost from the land*, and the models suggest this loss would need to be reduced by as much as 80%. In practical terms, this translates into an 80% reduction in nitrate losses from farms to surface run-off and groundwater, *not* necessarily into an 80% reduction in fertiliser application rates.
2. **Herbicide residues**, including ametryn, atrazine, diuron, hexazinone and simazine, are ranked second due to their widespread detection in both fresh and marine waters where they can have impacts at very low concentrations. Atrazine, diuron and hexazinone concentrations in 30 of the 102 samples analysed, equalled or exceeded draft WQOs in the catchment (and exceeded national water quality guidelines for drinking water, stock water and freshwater ecosystems) (Table 3.3). Unlike DIN, a receiving water model is still needed to link herbicide concentrations in rivers to draft WQOs in the GBR lagoon. No pesticides or herbicides were found in mudcrabs collected in the Tully estuary in 2005 and 2006.

Ametryn, atrazine, diuron and hexazinone are used in sugarcane; while simazine is used in plantation forestry. Moreover, a pesticide risk assessment ranked eight out of the 21 pesticides used in bananas as a high relative aquatic risk. In contrast to sugarcane and bananas, pesticide use in grazing, plantation forestry and urban environments is currently not well documented and requires further research.

3. **Suspended sediment** and **particulate phosphorus** are ranked third, reflecting the relatively low generation and delivery of sediment in the catchment, particularly compared to data from other GBR catchments. The catchment results for suspended sediment could also not be linked to draft WQOs in marine receiving waters, due to the unavailability of (i) local water quality guidelines for suspended sediments, and (ii) a receiving water model to link suspended sediments concentrations in rivers to draft WQOs in the GBR lagoon. Residual sediment sources are present in sugarcane cultivation (plant cane stage), horticulture (fallow management, inter-row management), grazing (carrying capacity, river and stream bank management including cattle access), plantation forestry (establishment stage, inter-row management) and waterways (river and stream bank erosion), as well as urban development, roads and drains in all land uses.
4. **DON** is ranked fourth due to their relatively high contribution to nitrogen loads in over-bank flows. This high load of potentially bio-available nitrogen to receiving waters is *in addition to* nitrogen loads delivered by river flows. Preliminary research results indicate that the majority of DON in these over-bank flows originates almost completely from the upper catchment rainforest (largely because of their much greater area). Increased run-off rates and amount, due to removal of wetlands and the installation of land drainage systems in coastal floodplains, may result in higher DON loads now reaching receiving waters. Further research is being conducted to confirm these results, and to assess potential management actions to reduce total DON load exports to marine waters.

Monitoring and modelling indicated that, based on the currently available information, point sources contribute a small proportion ($\leq 7.5\%$) to the total annual sediment, nutrient and pesticide loads. Generally, point sources are regulated activities, meaning that they have been assessed, deemed to have met environmental management considerations and conditioned accordingly. While most contributions of point sources are small compared to those by diffuse sources, these contributions are likely to be highly localised and in some cases seasonal.

Table 3.1. Summary of current (a) soil, (b) nutrient and (c) pest management practices in sugarcane and banana in the Tully WQIP area. R = ratoon, F= fallow, P = plant stage (from Lindsay 2007a, McMahon 2007).

(a)

Land use and survey parameters	Soil management		
	Practice	Area (%)	Growers (%)
Sugarcane 48 growers (14%) 9,189 ha (25%)	Annual soil testing	n/a	68
	Legume fallow	59 (F)	60
	Zonal tillage	0	0
	Zero tillage	0	0
	Green cane trash blanketing	93	n/a
	Row width (1.52m - 1.68m)	83	n/a
	Planting in single rows	76	n/a
	Drains stable and vegetated	n/a	n/a
	Wetlands	n/a	52
	Silt traps	n/a	24
	Riparian zones vegetated (trees, shrubs, grass)	All	n/a
	Slashing headland vegetation	n/a	79
	Horticulture/banana Growers (n/a) 868 ha (10.8 %)	Annual soil testing	n/a
Use soil analysis		100 (P), 94 (R)	n/a
Crop eradication: herbicide & cultivation		42	71
Crop eradication: cultivation		58	29
Crop eradication: dry season only		45	86
Land preparation: dry season only		100	100
Groundcover during fallow		94	86
Interrow vegetation		100	100
Difficulty maintaining interrow vegetation in ratoon		85	71
Trash residues on row areas		100	100
Drains stable and vegetated		100	100
Silt traps		45	86

(b)

Land use and survey parameters	Nutrient management		
	Practice	Area (%)	Growers (%)
Sugarcane 48 growers (14%) 9,189 ha (25%)	Annual leaf testing	0	0
	Fert application tailored to soil types & varieties	n/a	78
	Fert application: subsurface - beside row (R)	33 (R)	n/a
	Fert application: subsurface - split stool (R)	67 (R)	n/a
	Annual mud application	8	67
Horticulture/banana Growers (n/a) 868 ha (10.8 %)	Annual leaf testing	n/a	n/a
	Use leaf analysis	38 (P), 38 (R)	71 (P), 71 (R)
	N application: broadcast (P)	91 (P)	n/a
	N application: Fertigation (P)	83 (P)	n/a
	N application: Broadcast (R)	97 (R)	n/a
	N application: Fertigation (R)	83 (R)	n/a
	Monthly N application	43	n/a
	P application: Broadcast (P)	57 (P)	n/a
	P application: Fertigation (P)	43 (P)	n/a
	P application: Broadcast (R)	94 (R)	n/a
	P application: Fertigation (R)	22 (R)	n/a
Monthly P application	25	57	

(c)

Land use and survey parameters	Pest management		
	Practice	Area (%)	Growers (%)
Sugarcane <i>48 growers (14%)</i> <i>9,189 ha (25%)</i>	Formal monitoring for weeds	n/a	n/a
	Spray headland vegetation	n/a	52
	Herbicide (glyphosate) (F)	58 (F)	42
	Herbicide (Diuron) (P)	11 (P)	23
	Herbicide (Diuron) (R)	56 (R)	60
	Herbicide (Diuron & hexazanone) (P)	42 (P)	42
	Herbicide (Diuron & hexazanone) (R)	36 (R)	35
	Herbicide (Atrazine) (P)	42 (P)	48
	Herbicide (Atrazine) (R)	14 (R)	27
	Herbicide (Paraquat) (P)	66 (P)	67
	Herbicide (Paraquat) (R)	93 (R)	85
	Herbicide (2,4-D) (P)	39 (P)	52
	Herbicide (2,4-D) (R)	87 (R)	85
	Herbicide (Pendimethalin) (P)	43 (P)	46
	Herbicide (Atrazine & ametryn) (P)	15 (P)	17
Horticulture/banana <i>Growers (n/a)</i> <i>868 ha (10.8 %)</i>	Formal monitoring for lead pests & diseases	33	43
	Formal monitoring for soil pests & diseases	88	57
	Formal monitoring for weeds	0	0
	Nematicide use (P)	0	n/a
	Nematicide use (R)	36	n/a
	Insecticide (P)	78	n/a
	Insecticide (R)	100	n/a
	Fungicide (P)	100	n/a
	Fungicide (R)	100	n/a
	Miticide (P)	67	n/a
	Miticide (R)	67	n/a
	Herbicide (Pre-emergent) (P)	71	n/a
	Herbicide (Pre-emergent) (R)	0	n/a
	Herbicide (Pre-emergent) (Headland & drains)	0	n/a
	Herbicide (Knock-down) (P)	98	n/a
	Herbicide (Knock-down) (R)	100	n/a
Herbicide (Knock-down) (Headland & drains)	100	n/a	

Table 3.2. Current river loads for suspended sediment and nutrients, and relative contribution of seven diffuse sources of pollution in the Tully-Murray basin, derived from SedNet/Annex models (from Armour *et al.* 2007a).

Land use	Total	Natural forest			Sugarcane			Grazing			Plantation forestry			Bananas			Urban			Horticulture		
Area (ha, %)	278,700	198,200	71.2%		36,700	13.2%		14,900	5.3%		10,300	3.7%		7,500	2.7%		3,000	1.1%		400	0.1%	
Pollutant loads	tonnes	tonnes	%	kg/ha	tonnes	%	kg/ha	tonnes	%	kg/ha	tonnes	%	kg/ha	tonnes	%	kg/ha	tonnes	%	kg/ha	tonnes	%	kg/ha
TSS	119,000	n/a	-	-	n/a	-	-	n/a	-	-	n/a	-	-	n/a	-	-	n/a	-	-	n/a	-	-
DIN	1,159	104	9.0	0.5	888	76.6	24.2	44	3.8	3.0	20	1.7	1.9	91	7.9	12.1	10	0.9	3.3	2	0.2	5.0
DON	529	211	39.9	1.1	189	35.7	5.1	55	10.4	3.7	20	3.8	1.9	38	7.2	5.1	15	2.8	5.0	1	0.2	2.5
PN	630	n/a	-	-	n/a	-	-	n/a	-	-	n/a	-	-	n/a	-	-	n/a	-	-	n/a	-	-
FRP	54	16	29.6	0.1	8	14.8	0.2	6	11.1	0.4	1	1.9	0.1	12	22.2	1.6	11	20.4	3.7	-	-	-
DOP	31	13	41.9	0.1	11	35.5	0.3	3	9.7	0.2	1	3.2	0.1	2	6.5	0.3	-	-	-	-	-	-
PP	159	n/a	-	-	n/a	-	-	n/a	-	-	n/a	-	-	n/a	-	-	n/a	-	-	n/a	-	-

Note: The modelled proportional contribution of different land uses to the total TSS, PN and PP load are not presented, as the results contradict direct observations from monitoring and sediment fingerprinting. This discrepancy is associated with the use of the RUSLE in closed forest situations on steep slopes in tropical environments (Armour *et al.* 2007).

Table 3.3. Number of water quality samples in which atrazine, diuron and hexazinone were detected, and equalled and/or exceeded National water quality guidelines, at various waterways and locations in the Tully-Murray basin. The total number of samples collected at each location is given (from Faithful *et al.* 2007). Herbicide concentrations in a total of 30 out of 102 samples analysed equalled or exceeded draft WQOs in the catchment (note that herbicide concentrations in some samples equalled or exceeded more than one guideline value).

Waterway	Banyan Creek		Davidson Crk	Kyambul		Murray River	Tully River	Warrami Crk
	Dean Rd	Highway	Davidson Rd	Copperhead Rd	K1	Highway	Euramo	Blackman Rd
Sample location								
Total number of samples	10	8	9	7	4	8	2	7
Atrazine								
Number of samples detected	9	7	1	7	4	8	2	3
Number of samples equalled or exceeded ¹	2	2	0	7	4	3	1	1
Diuron								
Number of samples detected	7	8	4	7	4	8	1	5
Number of samples equalled or exceeded ²	3	5	2	5	4	6	0	1
Hexazinone								
Number of samples detected	7	8	5	7	4	8	2	7
Number of samples equalled or exceeded ³	0	0	0	0	2	0	0	0

¹ drinking water and stock water quality guidelines (both 0.1 µg/L)

² aquatic ecosystem guidelines (0.2 µg/L)

³ drinking water and stock water quality guidelines (both 2 µg/L)

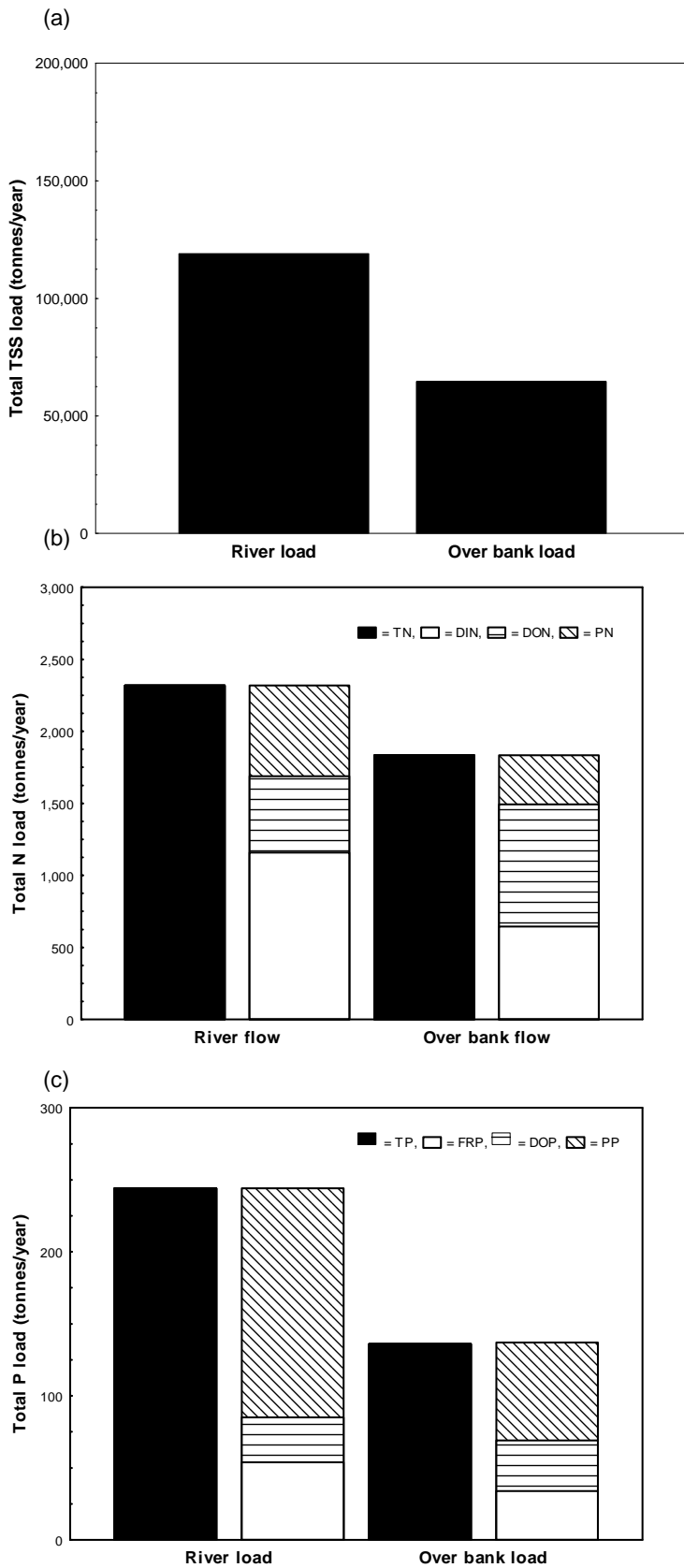


Figure 3.1. Total estimated annual loads of (a) total suspended sediment (TSS), (b) nitrogen (N) and (c) phosphorus (P), in tonnes per year, delivered to receiving waters by rivers and by over-bank floods in the Tully WQIP area. Contributions of different N and P species to total N and P loads are given (from Armour *et al.* 2007a, Wallace *et al.* 2007b).

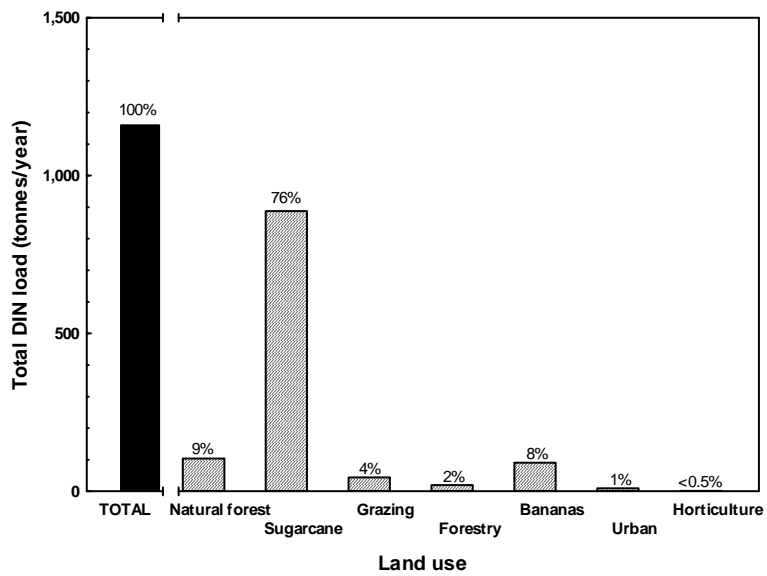


Figure 3.2. Total DIN load in tonnes per year delivered to the end-of-river by river loads, and relative contributions of main land uses in the Tully WQIP area (from Armour *et al.* 2007a).

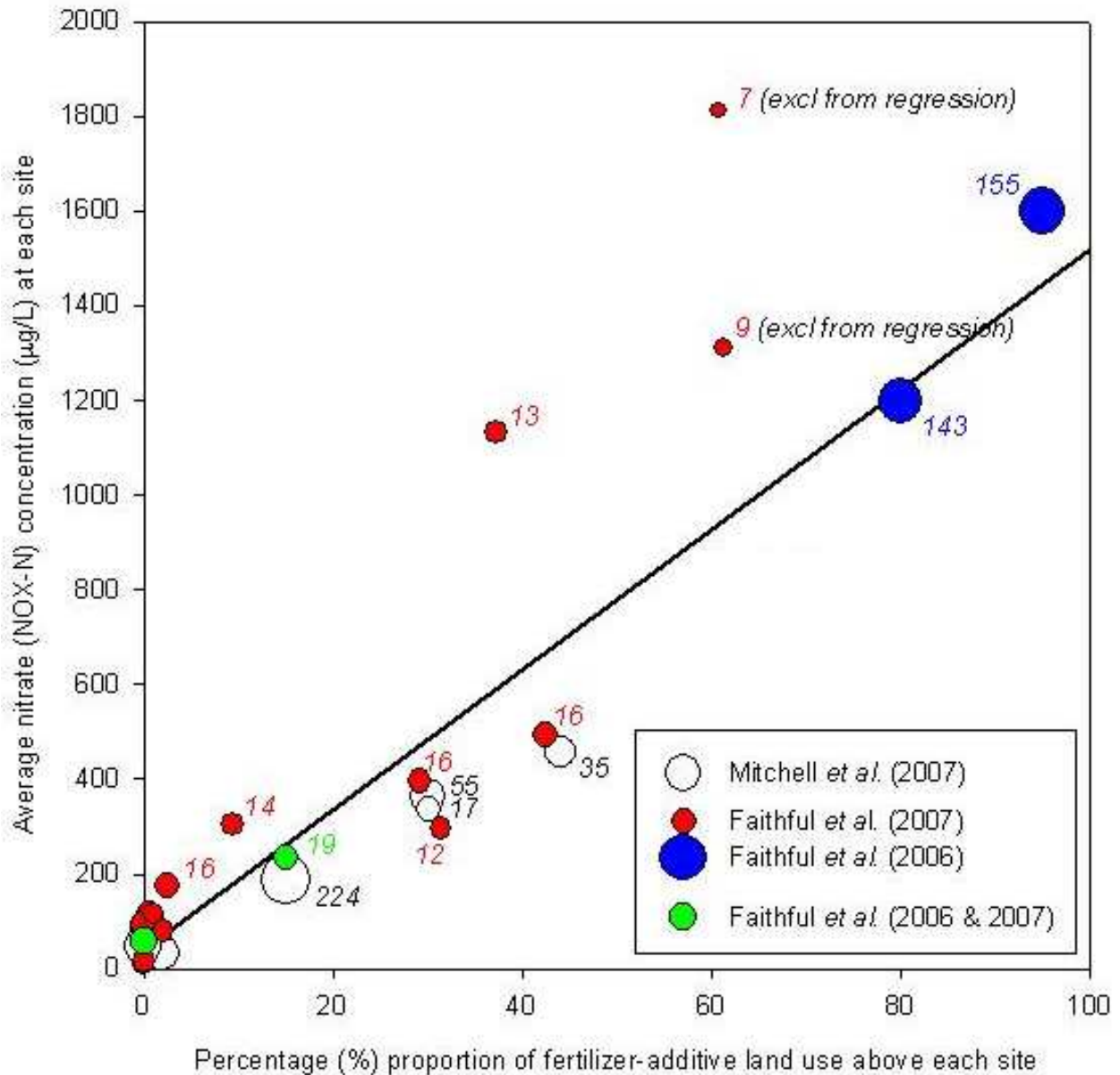


Figure 3.3. Relationship between mean nitrate concentration (µg/L) in streams and rivers during events and proportion of fertiliser-additive land use above each sampling point (from Mitchell *et al.* 2007). Mean nitrate concentration at a site increases significantly with an increase in proportion of fertiliser-additive land use above that site. This relationship is statistically significant, with 86% of the variation in nitrate concentration explained by the proportion of fertiliser-additive land use ($R^2 = 0.86$). The results are based on nitrate monitoring in the Tully catchment during wet seasons over a total period of 16 years (1987-2000; 2004-2007). Sample numbers are given next to each symbol (except for cluster near zero); different-sized symbols are indicative of total number of samples. Data sources given in legend.

4 ASSESSMENT OF MANAGEMENT SCENARIOS TO REDUCE LOADS

4.1 Introduction

To effectively contribute to the objectives of Reef Plan, the Tully WQIP needs to contribute to the halting and reversing of the decline in water quality entering the GBR by 2013. A number of modelled scenarios were used to examine the cost-effectiveness⁶ of changes in land management to reduce key pollutant loads from critical sources. These scenarios investigated the potential of land management practices in current land uses to reduce nitrate, herbicide and suspended sediment loads to the marine receiving waters. The scenarios did not consider land use changes between industries, as initial modelling suggests that significant improvements in water quality can be made through targeted change in management practices in combination with large-scale riparian restoration. However, the improvements in land management practices are dependent on the development *and* implementation of new technologies, and associated management actions have been proposed to further this. The outcomes of these modelling scenarios were subsequently discussed with CSFP Steering Committee in March and April 2007, to commence the development of aspirational and management action targets, and associated management actions (Section 5) and to achieve progress towards sustainable target loads (Section 3).

4.2 Methodology used to model scenarios

The most promising land management practices for water quality improvement in the four major agricultural industries were identified from recent industry surveys (Lindsay 2007a, b, McMahon 2007) and outcomes of industry workshops and expert opinion (Roebeling and Webster 2007). The cost-effectiveness of these management practices for water quality improvement was analysed in sugarcane, banana/horticulture, grazing and plantation forestry production in the Tully-Murray catchment, both at a plot-scale (Roebeling *et al.* 2007a) and a catchment-scale (Roebeling *et al.* 2007b, see also Armour *et al.* 2007a).

Modelled scenarios were developed to examine the effect of changes in land management and compared to current land use and management (Appendix 3), on:

1. Sediment, nutrient and pesticide generation, transport and delivery (Armour *et al.* 2007a, Roebeling *et al.* 2007a,b). Changes in water quality were examined using SedNet/Annex for sediment and nutrients, and expert opinion for herbicides;
2. (Plot level) financial-economic consequences (Roebeling *et al.* 2007a). These were examined using production system simulation models for sugarcane (Agricultural Production Systems sIMulator, APSIM), banana and plantation forestry (land use crop technical coefficient generator, LUCTOR) and grazing (pasture and animal system technical coefficient generator, PASTOR). Cost-benefit analyses were used to determine the annuity gross margins of land uses and management practices; and
3. (Catchment-scale) environmental-economic consequences (Roebeling *et al.* 2007b). These were examined using an environmental-economic spatial investment prioritisation model (Roebeling *et al.* 2007b). This model integrates a land use and value chain model with the water quality model SedNet/Annex (Smith *et al.* 2005), to explore cost-efficient industry-specific land management arrangements for water quality improvement.

Scenario outcomes of (1) and (2) were presented to, and discussed with, the CSFP Steering Committee in March and April 2007. The CSFP Steering Committee agreed to a list of key actions for water quality improvement (Section 4.6), and to proceed with more detailed discussions on implementation (including project leaders and partners, budgets and timelines) (Section 5).

The following information is from Armour *et al.* (2007) and Roebeling *et al.* (2007a, b), unless otherwise noted.

⁶ Cost-effectiveness is defined here as a comparison of the costs and benefits (i.e. financial-economic consequences) of different land management strategies to improve water quality.

4.3 Assessing management scenarios for agriculture and forestry plantations

Nitrate

To estimate potential reductions in nitrate loads at the end-of-river, five future scenarios were modelled that specifically targeted continual improvement of nitrogen management in sugarcane and bananas, and assessed the denitrification potential of riparian zones. The outcomes indicate that the most cost-effective reduction in DIN delivery at end-of-river can be achieved with adoption of management practices in sugarcane and bananas, including improved matching of N application rates to crop and soil requirements in sugarcane and bananas, and re-composition of fertiliser application ratios in bananas (Table 4.1).

In sugarcane, the models show that complete adoption of the BSES 'Six Easy Steps' program reduces the average total DIN load per year to end-of-river by 23% to 898 tonnes (Figure 4.1). The models set the mean fertiliser application at 140 kg N/ha per year, based on a preliminary estimate prior to the development of BSES' 'Six Easy Steps' process for Tully (Schroeder *et al.* 2005). Moreover, plot-scale financial economic analyses indicated that the economic optimum rate of N application in sugarcane varies with soil type, and ranges from 90 to 150 kg N/ha per year. This supports the implementation of 'Six Easy Steps', as three of the six components of this process deal with soil assessment, testing and associated fertiliser recommendations (Schroeder *et al.* 2005). 'Six Easy Steps' is a component of the draft program for NMZs in the Wet Tropics, and is currently being calibrated for implementation in Tully.

Using the CSIRO based 'N replacement' management guidelines and modelling complete uptake in sugarcane reduces the average total DIN load per year to end-of-river by 45% to 637 tonnes (Figure 4.1). The models set mean fertiliser application at 110 kg N/ha per year, based on results of N replacement experiments for sugarcane (Thorburn *et al.* 2007, Webster and Brodie 2007). At the plot-scale, implementation of 'N replacement' leads to gross margins at or just below the economic optimum. 'N replacement' is an emerging methodology that applies N in the order of 1 kg N for every tonne harvested in the previous crop. Experiments in the Wet Tropics (Innisfail, Mossman) have shown little yield penalty in comparison with current N application rates (Webster and Brodie 2007). 'N replacement' is still in a research 'proof of concept' stage.

Modelling complete uptake of 'N fixation' in sugarcane reduces the average total DIN load per year to end-of-river by 66% to 391 tonnes (Figure 4.1). The models set mean fertiliser application at 30 kg N/ha per year based on experimental results (J. Reghenzani, Terrain NRM Ltd, pers. comm. 2007). Plot-scale financial economic impacts of N fixation could not be analysed due to the unavailability of financial data. 'N fixation' utilises free-living, nitrogen-fixing bacteria to supply most of the crop's nitrogen needs. Significant local research will be required to determine whether this technique is viable in sugarcane, and potentially in bananas, as well as the potential impact and spread of such bacteria beyond the intended crops.

In bananas, complete adoption of a 30% reduction in N application to 225 kg N/ha reduced DIN contribution from the banana industry by 27%, from 91 to 66 tonnes DIN per year. Moreover, N application may be reduced to 250 kg N/ha without measurable loss of yield (Armour and Daniells 2002). Plot-scale financial economic analyses indicate that largest gross margins are attained at around 308 kg N/ha, 21 kg P/ha and 728 kg K/ha, with exact nutrient requirements and ratios varying with soil type.

The current modelled scenarios do not achieve the 80% reduction in nitrate concentration that models estimate is required to meet aspirational targets (Section 2.4). This may be due in part to uncertainties in the models, and the predicted effects of approved management actions will need to be validated in monitoring programs. With improved understanding of system response to implementation of management actions, additional management actions that need to be undertaken can be determined. Two options for additional management actions to reduce nitrate concentrations are further discussed here.

First, a riparian mapping tool was applied to the Tully WQIP area, to assess the potential of riparian buffers to reduce nitrate loads delivered to streams via baseflow, and to identify potential denitrification 'hotspots' (Rassam and Pagendam 2007). The results demonstrate that riparian restoration in the Tully WQIP area, for the purpose of denitrification of groundwater delivered to streams, should target 285.5 km of streams in the central catchment, and include low areas, flat areas, regions of medium hydraulic conductivity soils, and areas where current land use results in maximum nitrate delivery to streams. Based on a 10 m riparian strip on either side of a stream, a 285.5 km riparian restoration project would cost approximately \$10.0M (D

Sydes, CSC, pers. comm. 2007)⁷. Thus, restoration of riparian zones can reduce nitrate contribution to the coast when implemented over larger scales, while simultaneously enhancing identified environmental values such as aquatic ecosystems, indigenous and non-indigenous cultural heritage, and amenity (Section 2).

Second, a continuing increase in nitrate, as well as particulate nitrogen and particulate phosphorus concentrations, at Euramo bridge from 1987 to 2000, coincided with an approximate doubling in area of fertiliser-additive land use during that period (Mitchell *et al.* 2007). A decline in nitrogen fertiliser usage *per ha* by both sugarcane (25%, from 200 kg N/ha per year in 2000 to 150 kg N/ha per year in 2007; McMahon 2007) and bananas (40%, from 520 kg N/ha per year in 1995 to 313 kg N/ha per year in 2007; Lindsay 2007b), has not been reflected in a DIN load reduction at Euramo bridge. This suggests that either fertiliser usage is underestimated in surveys, and/or the existence of a time-lag between decrease in N fertiliser usage and DIN loads or concentrations at end-of-rivers. Moreover, if current recommended management actions do not achieve the 80% reduction in nitrate concentrations, these results suggest that changes in land use may need to be assessed to further reduce DIN loads towards achieving a sustainable targets load (e.g. Roebeling *et al.* 2007b).

Herbicides

To estimate potential reductions in herbicide delivery rate, one scenario was modelled that specifically targeted herbicide management in sugarcane. In this scenario, residual herbicide use is halved using a hooded sprayer. Based on expert opinion, it was assumed that 5% of the plot level rate of herbicide application is delivered to the end-of-river (J. Brodie, ACTFR, pers. comm. 2006; Green and Young 2006).

The outcome suggests that complete adoption of a hooded sprayer leads to a 50% decrease in herbicide delivery to the end-of-river and only a slight decrease in gross margin (~\$50/ha) (Table 4.1). However, it is assumed that the reduction in herbicide application has no yield impacts, which needs to be validated under local conditions. Additional scenarios could not be run, due to the lack of (i) water quality and economic information of different herbicide management practices, and (ii) a hydrological model that describes the relationship between farm level herbicide concentrations and total herbicide load to end-of-river.

Suspended sediment, PN and PP

To estimate potential reductions in suspended sediment loads at the end-of-river, four future scenarios were modelled that specifically targeted continual improvement of soil management in sugarcane and bananas, and reduced bank erosion in waterways: TSS, PN and PP were modelled together, given that PN and PP are generally attached to inorganic particles. The outcomes indicate that the most cost-effective reduction in TSS delivery at end-of-river can be achieved with complete adoption of reduced and zero tillage in sugarcane (Table 4.1), while large-scale restoration of riparian buffer zones also significantly reduces bank erosion. Additional soil management practices, including grassed inter-rows in bananas and forestry and optimum stocking rates in grazing, reduce delivery of suspended sediment but may result in a small decrease in gross margin (Table 4.1).

In sugarcane, complete uptake of zero tillage reduces TSS contribution from this land use by 44%, from 29,000 tonnes/year to 16,000 tonnes/year (and TSS contribution to end-of-river by 10% to 107,100 tonnes/year). Zero tillage refers to spraying (instead of ploughing) out the sugarcane by applying glyphosate in sugarcane. Plot-scale financial economic analyses indicated that a change-over from actual to zero tillage in sugarcane results in a small increase (up to 3%) in gross margin, due to a combination of reduced costs in soil preparation and slight increases in yield. A recent survey indicates that no growers use zero tillage (Table 3.1, McMahon 2007), suggesting that complete adoption of this practice would contribute significantly to reducing total suspended sediment loads.

In bananas, complete uptake of zonal tillage reduces TSS contribution by the industry from 5,700 tonnes/year to 2,000 tonnes/year (and TSS contribution to end-of-river by 3% to 115,430 tonnes/year). Note that the reductions in TSS contribution per hectare are much larger. Zonal tillage refers to only cultivating the top of the mound. The financial-economic effects are currently unknown and strategies are proposed to address this.

⁷ Note that Rassam and Pagendam (2007) considered a riparian zone of 50m width either side of the stream network in their analysis. This would increase the costs of riparian rehabilitation up to approximately \$50M, without considering costs of potential land acquisitions.

Bank erosion was reduced in the models by restoring riparian buffer zones on (i) Dallachy, Whitfield, Meunga and Kennedy Creeks (primarily the downstream sections), based on concerns expressed by the local community (Bohnet *et al.* 2007), and (ii) on the worst 20% degraded stream links (124 km of mainly 3rd and 4th order streams) in the area, based on an assessment of riparian condition by Johnson (1998). Bank erosion was reduced by 4,000 tonnes TSS (or 7%), and 14,000 tonnes TSS (or 24%), respectively. Total TSS delivery to end-of-river was reduced by 3% to 115,430 tonnes, and by 5% to 113,050 tonnes, respectively. Based on an average estimate of \$15,000 per hectare (D Sydes, CSC, pers. comm. 2007), a 124 km riparian restoration project would cost \$3.72M. Thus, restoration of riparian zones can reduce sediment contribution to the coast when implemented over larger scales, while simultaneously enhancing identified environmental values such as aquatic ecosystems, indigenous and non-indigenous cultural heritage, and amenity (Section 2).

Combined DIN and TSS scenario

Compared to the current condition, complete adoption of (i) ‘Six Easy Steps’ and zero tillage in sugarcane, and (ii) 30% reduction of fertiliser use and zonal tillage in bananas, in combination with restoration of the worst 20% degraded stream links, reduced total annual DIN loads with 25% to 869 tonnes, and TSS loads with 18% to 97,580 tonnes (with a concurrent reduction in PN and PP).

Overall, the outcomes of these scenarios for agricultural land uses and forestry plantations demonstrate that significant improvements in water quality can be made with complete adoption of practical and achievable management practices in all land uses (given current land use), and implementation of large riparian restoration programs.

4.4 Assessing management scenarios in sugarcane for climate change

Cost-effectiveness of key management practices in sugarcane, including tillage management, fallow management, and nitrogen (N) application rate and method, were assessed using APSIM for the least and most favourable 2070 climate scenarios (Roebeling *et al.* 2007a). Under both the least and most favourable climate scenarios, reduced N application and, in particular ‘N replacement’, remain cost-effective in managing DIN delivery. Similarly, split N application remains equally cost-effective in managing DIN delivery compared to single N application. Moreover, both zero tillage and legume fallow remain cost-effective in managing sediment delivery, compared to actual and minimum tillage and bare fallow, respectively. Overall, cost-effectiveness of management practices is generally not affected by climate change, that is, management practices remain proportionally equally effective in reducing water pollutant delivery. Levels of water pollutant (DIN) delivery may, however, increase significantly under climate change projections for 2070 (up to 20% increase in DIN delivery), thus potentially jeopardizing the attainment of water quality targets.

4.5 Assessing management scenario for urban land use and population growth

Specific land use patterns for population size, generated for a case study in Douglas Shire, indicate that (i) residential development first takes place near urban centres, waterways and hillside areas, (ii) the rate of land use conversion increases with population size, and (iii) the rate of nitrogen water pollution increases with population size (Roebeling *et al.* 2007a). The changes in land use from agricultural to residential means that the potential for water quality improvement with uptake of recommended agricultural practices will be reduced. Moreover, assuming that pollution per unit area of residential land use exceeds that of agricultural land use (Table 4.1), water pollution increases with population size because of the increased pollutant export rate.

To achieve and maintain water quality targets with population growth, implementation of recommended management practices for both residential and agricultural land uses is critical. In Cardwell Shire, the projected population growth and its potential impact on water quality emphasises the urgency and importance of adoption of water sensitive urban design practices for residential land uses. Alternatively, population growth and associated residential development may be constrained; this provides welfare gains when downstream costs from water pollution are taken into account (Roebeling *et al.* 2007c).

4.6 Management actions for implementation

The outcomes of the modelling scenarios demonstrate that targeted change in management practice in current land use, in combination with large-scale floodplain restoration, will achieve significant water quality improvements towards draft WQOs identified for the marine receiving waters. The additional localised benefits may include greater economic efficiencies in the local industries and better water quality and ecological health in the contributing freshwater systems.

The outcomes of the modelling scenarios were discussed with CSFP Steering Committee in March and April 2007. Key management practices identified in the scenarios and supported by the CSFP Steering Committee focus on:

- continual improvement of nutrient management by reducing fertiliser loss and improving applications, particularly in sugarcane and banana/horticulture;
- continual improvement of pesticide management by reducing loss and improving applications (e.g. Calcino and Hurney 2007), replacing residual herbicides with knockdowns wherever practicable and undertaking risk-assessment of pesticides used in grazing and plantation forestry;
- continual improvement in soil management by targeting erosion hot-spot areas and high-risk activities such as constructed drains, agriculture, urban development, roads and degraded low order streams; and
- targeted large-scale rehabilitation of riparian zones, wetlands and general floodplain function, for the purpose of (i) denitrification of groundwater delivered to streams, (ii) reduction of bank erosion, and (iii) enhancing floodwater retention.

The final step of the Tully WQIP was to develop targets for implementation, based on the outcomes of the scientific research and four sector workshops. To structurally align the implementation of the Tully WQIP with the regional NRM plan, these targets were placed in the asset framework advocated by the national CCI and NRM programs, and used in the regional NRM plan.

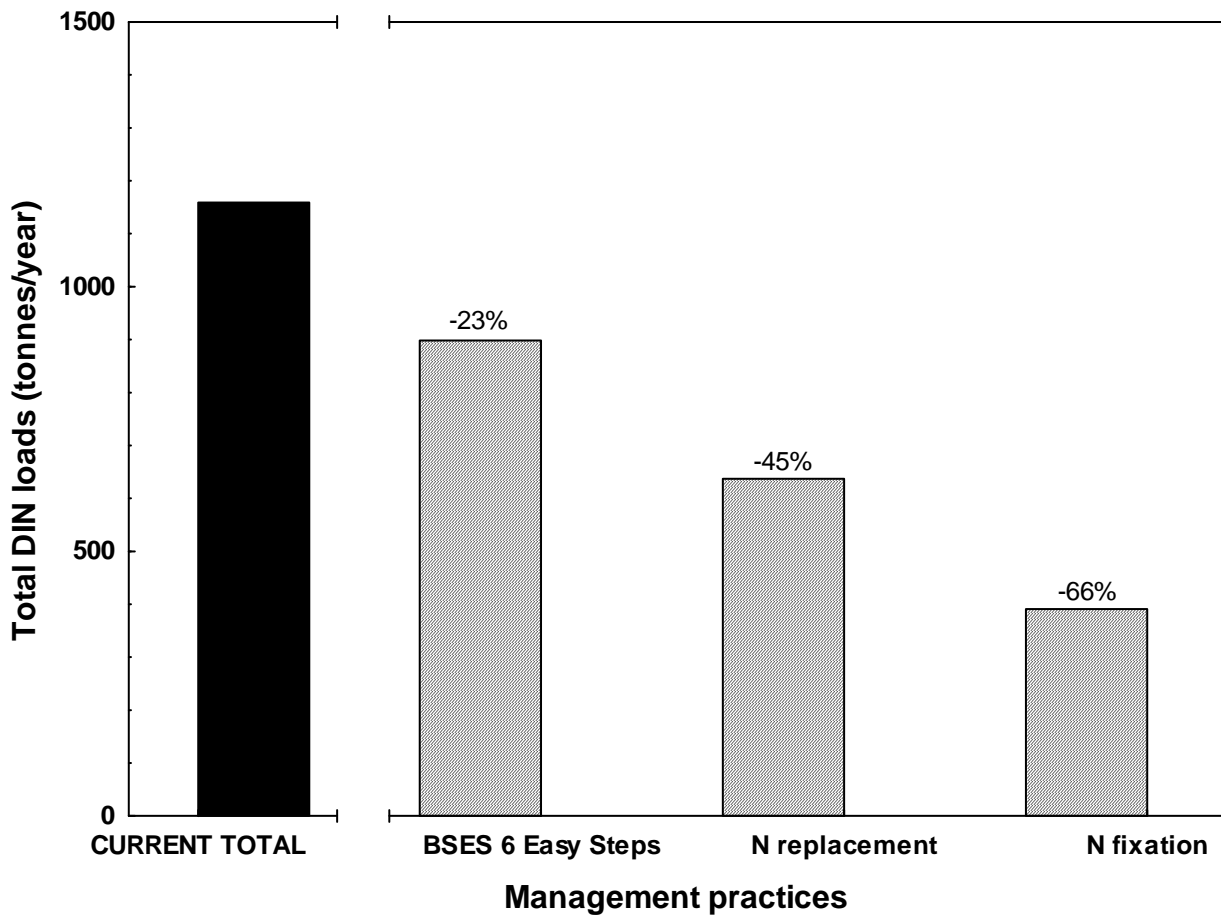


Figure 4.1. Results of three scenarios, modelling the effect of improved nutrient management in sugarcane on total DIN export to end-of-river (from Armour *et al.* 2007). Total DIN export (tonnes/year) and reduction in total DIN export (%) are given for each scenario. Note that the % reduction in DIN export are for each scenario separately (i.e. not additive). 'N replacement' and 'N fixation' are still experimental management practices and need to be validated under local conditions.

Table 4.1. Results of scenarios, modelling the cost-effectiveness of management-practices for water quality improvement in sugarcane, horticulture, grazing and plantation forestry production systems. Management practices were identified from outcomes of industry workshops and expert opinion (Roebeling and Webster 2006), and were examined for their consequences on (plot-level) gross margin and their effectiveness in reducing (plot-scale) delivery of dissolved inorganic nitrogen (DIN), herbicide and fine suspended sediment (FSS). ++ = positive effect, + = moderately positive effect, (+) = slightly positive effect, 0 = no effect, (-) slightly negative effect, - = moderately negative effect, and -- = negative effect (from Roebeling *et al.* 2007a).

Production system	Management practice	Gross margin	Reduction in delivery		
			DIN	Herbicide	FSS
Sugarcane	N application match crop requirements	+	++	0	0
	Split N application	0	(+)	0	0
	Legume fallow	+	-	0	0
	Reduced herbicide application rate	(-)	0	++	0
	Zero tillage	(+)	0	0	++
Horticulture	Fertiliser application match crop requirements	-	+	0	0
	Grassed interrows	(-)	0	0	++
Grazing	N application match crop requirements	+	(+)	0	0
	Stocking rate match carrying capacity	+	0	0	(+)
Plantation forestry	Grassed interrows	(-)	0	0	(+)

Note: In horticulture/banana, efficiency gains through re-composition of fertiliser application ratios can off-set the slight decrease in gross margin. Armour and Daniels (2002) demonstrated that N application may be reduced to 250 kg N/ha without measurable loss of yield.

5 MANAGEMENT ACTION TARGETS TO ACHIEVE SUSTAINABLE LOAD TARGETS

5.1 Introduction

The Tully WQIP has developed aspirational and management action targets that are *SMART*, that is, targets that are Specific, Measurable, Achievable, Relevant and Time-bound. The use of *SMART* targets will aid in monitoring whether progress towards quantified water quality improvements is being achieved. To structurally align the Tully WQIP with the regional NRM plan, these targets are placed in the asset framework advocated by the national CCI and NRM programs, and used in the regional NRM plan. Targets and actions have been developed within the water resources asset, sustainable industries and community assets, and a riparian and wetland asset (a subset of the biodiversity asset)⁸. Progressive improvement in the capacity of the local community to set and evaluate *SMART* targets is anticipated with further investment in research and development, modelling and monitoring, evaluation and reporting.

5.2 Targets

The draft Tully WQIP has defined *aspirational targets* for all water quality parameters as the draft WQOs in marine waters, and *aspirational targets* for herbicides as the draft WQOs in all waters (Section 2). Moreover, pre-European pollutant loads have been set as interim *aspirational targets* (i.e. sustainable load targets) (Section 3).

Specific RCTs have not been defined due to a current lack of available science to determine definite quantitative relationships between (improvements in) water quality and the (change in) condition of a resource. As outlined in Section 2.4, draft WQOs may be changed in the near future into RCTs, with finalisation of *Interim marine water quality guidelines for the Great Barrier Reef Marine Park* (Draft) (Honchin *et al.* 2007), and development of locally and regionally specific water quality guidelines for pesticides for the Wet Tropics region.

Management action targets (MATs) were developed based on the outcomes of the comparison between sustainable load targets and current pollutant loads (Section 3)⁹, assessments of management scenarios to reduce loads (Section 4), and four workshops conducted in May 2007 (Robinson *et al.* 2007) (Table 5.1). These workshops gathered detailed perspectives from industry (sugarcane, banana), Cardwell Shire Council and CSFP Steering Committee on Tully WQIP partnership and implementation design. The MATs have been set for 2013 (or earlier) to ensure progress against the goal and objectives of Reef Plan (Section 1).

To meet the MATs, *management actions* have been developed that identify strategic, prioritised and achievable actions, which will result in progressive (quantified) reductions in pollutant loads from both diffuse and point sources. Within each MAT, management actions address the full adaptive management cycle, including *Policy development and planning*, *Resource assessment*, *Research and development*, *On ground action*, *Capacity building and engagement*, and *Monitoring and evaluation*. Implementation of these identified management actions for each diffuse and point source of pollution (Appendix 5) will make progress towards achieving draft WQOs that are currently not met.

Prioritisation of management actions

Following their development, all *management actions* identified were further prioritised using seven specific criteria that were equally weighted, including:

- significance of action to water quality;
- urgency of water quality improvement;
- level of certainty of positive outcomes from actions;

⁸ These assets are reflected in the current CSFP structure, with Production, Biodiversity and Socio-cultural Action Teams (Figure 1.3).

⁹ Target loads are set based on reduction in river loads, **not** based on total loads (i.e. river loads and over-bank flood loads). Further research is required to estimate sustainable loads for over-bank flows. However, it is expected that some of the management actions in the nutrient and sediment management areas are likely to contribute to reducing these loads (e.g. riparian revegetation, fencing of wetlands, etc.).

- cost-effectiveness of action to individuals and government;
- level of increased adoption rate required;
- acceptance of action by landholders (Roebeling and Webster 2007); and
- availability of practical method of action.

This resulted in a set of high priority management actions (Table 5.2 a,b,c). The implementation of these management actions is estimated to reduce by 2013:

- total nitrate load from 1,159 tonnes/year to 870 tonnes/year (Table 5.3a);
- total suspended sediment load from 119,000 tonnes/year to 97,5000 tonnes/year (Table 5.3a); and
- herbicide concentrations to meet Australian water quality guidelines in freshwater and marine environments.

Moreover, implementation of more aspirational management actions beyond 2013 is estimated to reduce total nitrate load further to 522-786 tonnes/year (Table 5.3 b). Note that these recommended management actions are dependent on significant further R&D prior to implement on-ground.

5.3 Critical areas of intervention

Nutrient management in intensive agriculture

Diffuse sources contribute the largest amounts to the total annual nutrient loads in waterways, with most agricultural industries contributing a disproportionately large amount per unit area (Section 3). Significant improvements in *nutrient management* in agricultural industries will need to be made to demonstrate progress towards achieving the goal of the Reef Plan by 2013 (Section 1). Scenario modelling demonstrates that reducing fertiliser application rates to match crop and soil requirements will lead to improvements in both water quality and gross margins (Section 4). Importantly, current management actions recommended for implementation are likely to achieve a 25% reduction in nitrate concentrations at Euramo bridge. To achieve the 80% reduction in nitrate concentrations required, further intervention, targeted riparian restoration and an assessment of different land uses are also required (Section 4).

Herbicide management

The widespread detection of herbicides, including concentrations above water quality guidelines for aquatic ecosystems, drinking water and stock water, combined with documented community concern about pesticide use, indicates that all industries need to immediately address *herbicide management*. All industries need to ensure complete uptake of recommended practices for pesticides, complete uptake of Chemcert® accreditation (or equivalent) by all farmers and growers, as well as exploring alternative options such as development of new crop/pasture varieties and/or testing the use of weed sensors. Sugarcane and banana industries need to use the outcomes of recent (Calcino and Hurney 2007, Gaus *et al.* 2007) and current pesticide risk assessments to prioritise and implement management strategies that minimise off-site impacts of pesticides, and to guide water quality monitoring programs. Moreover, it is recommended that the potential of volatilisation, atmospheric transport and wet deposition of pesticides from agriculture to protected areas and beyond be examined (e.g. Daly *et al.* 2007).

Sediment (and PN and PP) management

Improvements in *soil management* in localised erosion hot-spots and targeting residual sources, including roads and drains in all land uses, is the most effective way to further minimise soil loss. Moreover, targeted river and stream bank stabilisation, including large-scale riparian rehabilitation, can significantly reduce sediment loads.

Protection and restoration of floodplain function, including priority riparian zones and wetland areas

Substantially enhanced nitrogen loads (DON) from natural forest may now reach and be available in receiving waters, due to removal of wetlands and the installation of land drainage systems in the coastal floodplains (Wallace *et al.* 2007). Due to the different causes, management practices and control actions to

reduce these particular loads are quite different from those to control nutrient loads, and may include re-establishing the filter function of coastal floodplains. It is recommended that this includes restoration of priority riparian zones, wetland areas and other floodplain retention areas (e.g. Van Der Lee *et al.* 2004). Moreover, continued improvements in *floodplain management* will need to be made to demonstrate progress towards achieving the goal of the Reef Plan by 2013 (Section 1). It is recommended that CSFP leads a debate about a long-term river management program, to discuss strategies for both flood risk management and ecological rehabilitation of the coastal floodplains.

Table 5.1. Management actions targets (MATs) developed for the Tully WQIP, placed in the asset framework advocated by the national CCI and NRM programs, and used by the regional NRM plan. The MATs have been developed based on the outcomes of current and future land management scenarios (Section 4), and four workshops conducted in May 2007, and have been set for 2013 (or earlier) to ensure progress against the goal and objectives of Reef Plan (Section 1).

CRITICAL AREAS FOR ACTION	ASSET			
	Water resources		Sustainable industries	Riparian zones and wetlands
Nutrient management	W1. Incorporate land use planning and pollutant offsetting mechanisms into the FNQ 2025 Regional Plan by 2008	WR2. Reduce total DIN loads delivered to receiving waters by streams and rivers by 25% to 870 tonnes/year by 2013	SI1. Reduce nitrate loss by 50% from contributing land uses by 2013	RW1. Undertake 285.5 km of riparian rehabilitation in identified areas to denitrify groundwater delivered to streams by 2013
Herbicide management		WR3. Meet the Australian and GBR water quality guidelines for pesticides by 2013	SI2. Reduce herbicide losses by 50% from contributing land uses by 2013	RW2. Minimise impact of invasive species that threaten inland aquatic and terrestrial ecosystems by 2013
Sediment management		WR3. Reduce total TSS loads delivered to receiving waters by streams and rivers by 18% to 97,500 tonnes/year by 2013	SI3. Reduce sediment loss by 10% from contributing hot spots by 2013	RW3. Undertake 124 km of riparian rehabilitation in identified areas to minimise bank erosion by 2013
Restoration of floodplain function		WR4. Identify floodplain retention areas that can contribute to filtering function by 2013	SI4. All main land uses have implemented, and are continuously updating, current recommended practices by 2013	RW4. No further degradation or fragmentation of aquatic ecosystems by 2013

Table 5.2. High priority management actions developed for the Tully WQIP, for (a) nutrient management, (b) herbicide management, and (c) sediment management. Codes in MAT column refer to those in Table 6.1. P = Policy development and planning, RA = Resource assessment, RD = Research and development, O = On-ground action, C = Capacity building and engagement, and ME = Monitoring and evaluation. Implementation workshops, focussed on developing commitment to, and resources for these management actions, will be held with partner organisations during the public consultation phase.

(a)

MAT	Management actions	Action type	Timelines	
			Start	Finish
Nutrient management				
WR2	Ensure magement action targets for WQIP and NMZ are the same	P	2008	2008
WR2	Finalise NMZ policy, including clear articulation of implications of WQIP and NMZ alignment	P	2008	2008
SI1	Develop "Wet Tropics" grazing land management, including optimum nitrogen management strategy	P	2008	2010
WR2	Calibrate BSES Six Easy Steps for sugarcane	RD	2008	2008
WR2	Test nitrogen replacement methodology in sugarcane	RD	2008	2013
WR2	Progress reseach into nitrogen fixation in sugarcane	RD	2008	2013
SI1	Determine nitrogen contributions and losses from legumes in sugarcane	RD	2008	2013
SI1	Cost-benefit analysis of application of mill mud in sugarcane	RD	2008	2013
WR2	Determine optimum nitrogen management strategy for sugarcane growers and receiving waters	RD	2008	2013
WR2	Develop detailed nutrient management process for horticulture	RD	2008	2013
WR2	Develop nutrient decision support system for horticulture	RD	2008	2008
WR2	Determine optimum nitrogen management strategy for horticulture growers and receiving waters	RD	2008	2013
SI1	Determine nitrogen requirements of plantation forestry	RD	2008	2013
SI1	Develop slow release fertiliser technologies	RD	2008	2013
SI4	Ensure complete uptake of current nutrient recommended management practices, across sugarcane, horticulture, grazing and plantation forestry industries, as per industries' Codes of Practices and/or (more recent) industry recommendations	O	2008	2013
SI1	Sugarcane, horticulture, grazing and plantation forestry industries to take a coordinated approach to nutrient management strategies and investment	O	2008	2008
WR2	Complete uptake of Six Easy Steps in sugarcane, including nutrient management plans	O	2008	2010
WR2	Implement detailed nutrient management strategy for horticulture	O	2008	2013
SI1	Extension on legumes in sugarcane	O	2008	2008
SI1	Extend results from phosphorus reduction research in horticulture	O	2008	2013
SI1	Implement plantation forestry establishment procedures that minimise erosion	O	2008	2013
SI1	Establish Model farm project ("Systematic implementation of nutrient and sediment source controls on wet tropical cane farms")	O	2008	2008
RW1	Revegetate key locations as determined in nitrate removal model	O	2008	2013

SI1	Compile, present, and extend nitrogen budget work conducted in Johnstone	C	2008	2008
WR2	Large-scale demonstration trials of nitrogen replacement trials in sugarcane	C	2008	2013
WR2	Maintain and expand the use of key nutrient management practices in horticulture influencing water quality	C	2008	2013
WR2	Report on coordinated approach to nutrient management across sugarcane, horticulture, grazing and plantation forestry industries	ME	2008	2010
WR2	Establish effective reporting frameworks across sugarcane, horticulture, grazing and plantation forestry industries	ME	2008	2008
WR2	Build on and maintain regular benchmark surveys to monitor progress in nutrient recommended management practices uptake in sugarcane, horticulture, grazing and plantation forestry industries	ME	2008	2010
WR2	Plot and farm-scale monitoring of Six Easy Steps and nitrogen replacement (in model farm)	ME	2008	2013
WR2	Field-scale monitoring of nitrogen fixation in sugarcane	ME	2008	2013
WR2	Monitor nutrient concentrations in riverine environment, including loads at end-of-river	ME	2008	2013
WR2	Monitor nutrient concentrations in Tully River flood plumes	ME	2008	2011
WR2	Monitor nutrient and chlorophyll a concentrations in marine receiving waters	ME	2008	2011
WR2	Compare existing water quality data against draft WQOs for nutrients in 28 water reaches	ME	2008	2010

(b)

MAT	Management actions	Action type	Timelines	
			Start	Finish
Herbicide management				
WR3	On-going review of (residual) pesticides registration	P	2008	2010
WR3	Improve pesticides application guidelines to reflect local environmental condition	RD	2008	2010
WR3	Improve Chemcert® accreditation to reflect local environmental condition	RD	2008	2010
SI2	Cost-benefit of hooded sprayer in sugarcane (model farm)	RD	2008	2010
SI2	Precision Agriculture research in sugarcane, horticulture, grazing and plantation forestry industries	RD	2008	2010
SI2	Explore new crop / pasture varieties	RD	2008	2010
SI2	Expand integrated pest management strategies for local properties, for large-scale application in sugarcane, horticulture, grazing and plantation forestry industries	O	2008	2010
SI4	Ensure complete uptake of current pesticide recommended management practices across sugarcane, horticulture, grazing and plantation forestry industries, as per industries' Codes of Practices and/or (more recent) industry recommendations	O	2008	2008
SI2	Ensure complete uptake of Chemcert (or equivalent) accreditation in sugarcane, horticulture, grazing and plantation forestry industries	O	2008	2008
WR3	Sugarcane, horticulture, grazing and plantation forestry industries to take a coordinated approach to pesticide management strategies and investment	O	2008	2008
RW2	Strategic control of Hymenachne in priority areas as identified in control plan	O	2008	2013
WR3	Extend BSES revised and recommended herbicide application strategies to sugarcane growers	O	2008	2008
WR3	Report on Chemcert® accreditation in sugarcane, horticulture, grazing and plantation forestry industries	ME	2008	2010
SI2	Plot and farm-scale monitoring of hooded sprayer in sugarcane (model farm)	ME	2008	2013
WR3	Establish effective reporting frameworks across sugarcane, horticulture, grazing and plantation forestry industries	ME	2008	2008
WR3	Report on coordinated approach to pesticide management across sugarcane, horticulture, grazing and plantation forestry industries	ME	2008	2010
WR3	Build on and maintain regular benchmark surveys to monitor progress in pesticide recommended management practices uptake in sugarcane, horticulture, grazing and plantation forestry industries	ME	2008	2010
WR3	Monitor pesticide concentrations in riverine environment, including at end-of-river	ME	2008	2010
WR3	Monitor pesticide concentrations in marine receiving waters	ME	2008	2010
WR3	Assess bio-accumulation of pesticides in freshwater, estuarine and marine environment	ME	2008	2010
WR3	Monitor pesticide levels in aquatic food	ME	2008	2010
WR3	Compare existing water quality data against draft WQOs for pesticides in 28 water reaches	ME	2008	2010

(c)

MAT	Management actions	Action type	Timelines	
			Start	Finish
Sediment management				
WR4	Review and reform institutional arrangements for drain management	P	2008	2008
WR4	Collate spatial information on drainage network, including drain capacity, location, current structure and audit of crossings	RA	2008	2008
SI3	Assess eroding drainage and road networks	RA	2008	2010
WR4	Examine zero tillage in sugarcane	RD	2008	2010
WR4	Examine zonal tillage in horticulture	RD	2008	2010
WR4	Examine stocking rate estimates in grazing	RD	2008	2010
WR4	Examine cost-effective options for grassed interrows in forestry	RD	2008	2010
SI3	Cost-benefit of drain design and stabilisation in sugarcane and horticulture	RD	2008	2013
RW3	Determine key locations for riparian revegetation, using SedNet and other methods	RD	2008	2007
SI4	Ensure complete uptake of current sediment recommended management practices across sugarcane, horticulture, grazing and plantation forestry, as per industries' Code of Practices and/or (more recent) industry recommendations	O	2008	2013
WR4	Sugarcane, horticulture, grazing and plantation forestry to take a coordinated approach to sediment management strategies and investment	O	2008	2008
WR4	Promote adoption of zero tillage in sugarcane	O	2008	2013
WR4	Promote adoption of zonal tillage in horticulture	O	2008	2013
WR4	Promote adoption of zonal tillage during forestry establishment	O	2008	2010
SI3	Promote recommended management practice for riparian zones through sugarcane, horticulture, grazing and plantation forestry industry groups	O	2008	2013
SI3	Extend information on sustainable drain management through sugarcane, horticulture and plantation forestry industry groups	O	2008	2008
SI3	Modify farm drain shapes to reduce erosion	O	2008	2013
RW4	Fence "key wetland" areas, with particular focus on Upper Murray area	O	2008	2010
RW4	Implement key recommendations of river management plans	O	2008	2013
RW3	Revegetate key locations as identified by SedNet and other methods	O	2008	2013
RW4	Revegetate key riparian sites across shire as identified in regional and catchment rehabilitation plans	O	2008	2013
RW4	Develop incentives program to fence all creeks and provide off stream water points adjacent to grazing lands (Echo and Davidson Creek catchments)	O	2008	2013
RW4	Develop incentives program to fence all creeks and provide off stream water points adjacent to grazing land (Ropers Creek)	O	2008	2013
RW4	Develop incentives program to fence all creeks and provide off stream water points (Murray River Catchment)	O	2008	2013

WR4	Identify degraded grazing areas, discuss rehabilitation options with landholders and develop cost-sharing solutions.	C	2008	2010
RW4	Provide technical advice, support and extension to the community on the management and rehabilitation of riparian areas and key aquatic habitats	C	2008	2013
SI3	Benchmark current sediment management BMPs for drains and roads	ME	2008	2008
WR4	Plot and farm-scale monitoring of zero tillage in sugarcane (model farm)	ME	2008	2013
WR4	Plot and farm-scale monitoring of zonal tillage in horticulture	ME	2008	2013
WR4	Report on coordinated approach to sediment management across sugarcane, horticulture, grazing and plantation forestry industries	ME	2008	2010
WR4	Establish effective reporting frameworks across across sugarcane, horticulture, grazing and plantation forestry industries	ME	2008	2008
WR4	Build on and maintain regular benchmark surveys to monitor progress in sediment BMP uptake	ME	2008	2010
WR4	Monitor sediment concentrations in riverine environments, including loads at end-of-river	ME	2008	2013
WR4	Monitor sediment concentrations in Tully River flood plumes	ME	2008	2011
WR4	Monitor sediment concentrations in marine receiving waters	ME	2008	2011
WR4	Compare existing water quality data against draft WQOs for sediment in 28 water reaches	ME	2008	2010

Table 5.3. Estimated reduction in current loads with implementation of (a) priority management actions by 2013, and (b) aspirational management actions in 50+ years. Only those management actions are given for which estimates in load reductions could be quantified using SedNet/Annex (Armour *et al.* 2007a). Note that additional proposed management actions are expected to contribute to a reduction in current loads, but quantification of their effects has not been possible with currently available models. Aspirational targets (AT) are based on pre-1850 load estimates, and should be considered indicative only due to their uncertainty (Brodie *et al.* 2003).

(a)

Current pollutant loads		MAT (2013)	Management actions	Reduction		Loads in 2013
Pollutant	tonnes	tonnes		tonnes	%	
TSS	119,000	97,500	Promote adoption of zero tillage in sugarcane	13,000	10	96,350
			Promote adoption of zonal tillage in horticulture	3,700	3	
			Revegetate key locations as identified by SedNet and other methods	5,950	5	
			TOTAL	22,650	18	
DIN	1,159	870	Complete uptake of Six Easy Steps in sugarcane, including nutrient management plans	261	23	
			Implement detailed nutrient management strategy for horticulture	25	2	
			Total	286	25	
DON	529	n/a	n/a			
PN	630	n/a	Promote adoption of zero tillage in sugarcane	73	12	
			Promote adoption of zonal tillage in horticulture	22	4	
			Total	95	16	
TN	2,318	2,029	TOTAL	381	16	1,937
FRP	54	n/a	n/a			
DOP	31	n/a	n/a			
PP	159	n/a	Promote adoption of zero tillage in sugarcane	20	13	
			Promote adoption of zonal tillage in horticulture	6	4	
			Total	26	17	
TP	244	n/a	TOTAL	26	17	218

(b)

Current pollutant loads		AT (50+ yrs)	Management actions	Reduction		Loads (50+ yrs)
Pollutant	tonnes	tonnes		tonnes	%	
TSS	119,000	n/a	n/a			
			TOTAL	0	0	119,000
DIN	1,159	232	Complete uptake of N replacement in sugarcane, and/or Complete uptake of N fixation in sugarcane	522 768	45 66	
			Total	522-768	45-66	
DON	529	n/a	n/a			
PN	630	n/a	n/a			
TN	2,318	943	TOTAL	522-768	45-66	1,550-1,796
FRP	54	n/a	n/a			
DOP	31	n/a	n/a			
PP	159	n/a	n/a			
TP	244	107	TOTAL	26	17	218

6 IMPLEMENTATION AND MONITORING AND EVALUATION

6.1 Implementation framework

At the catchment level, CSFP Steering Committee will support the implementation of the Tully WQIP. To progress from development to implementation, the CSFP Steering Committee proposes that implementation workshops be held during the public consultation phase to determine project leaders, timelines, budgets and partners. These workshops, to be organised by Terrain NRM, will focus on the technical detail of the management actions that need to be developed. This will ensure that all information relating to current and future management actions is captured in implementation tables. Second, targeted effort is needed at a higher level within industry organisations and State and Australian Government agencies to: (i) determine the funding needed for implementation; (ii) discuss program, policy and budget alignments among the lead agencies and partner organisations committed to management actions; and (iii) consider any additional funding required to achieve implementation.

At a regional and catchment level, Terrain NRM will play a lead role in the ongoing coordination of WQIP planning and implementation. In this task, it will be supported through long-term partnerships with the CSFP Steering Committee. Terrain NRM will carry out this role by continuing to build strong partnerships with Government Agencies, Council, industry groups, Traditional Owners and the general community.

At a cross Regional, State and Federal level, the RWQP (Section 1.2) provides a framework to support links between Australian and Queensland Government Agencies and GBR regional NRM bodies to implement the Tully WQIP. The RWQP was established to bring together Australian and Queensland Government Agencies and GBR regional NRM boards to deliver water quality targets, monitoring and reporting.

Ultimately, the draft Tully WQIP will be finalised by taking the outcomes of these processes into account. It is intended that the final Tully WQIP be signed-off for implementation by Terrain NRM, CSFP Steering Committee, State and Australian Government agencies.

Roles and partnerships for implementation

The Tully WQIP will be implemented by Terrain NRM Ltd in collaboration with the CSFP and its partner organisations (Section 1.1). Key partners of Terrain NRM in the major packages of intervention are (in alphabetical order):

- *nutrient management*: ABGC, BSES, Canegrowers, CSIRO, DPI&F, Growcom, ITC Forestry Ltd, JCU, PFNQ and Rewards Group Forestry Ltd.
- *herbicide/pesticide management*: AgForce, ABGC, BSES, Canegrowers, CSC, CSIRO, DPI&F, NRW, EPA, Growcom, ITC Forestry Ltd, JCU, PFNQ, Rewards Group Forestry Ltd and UQ.
- *sediment management*: AgForce, ABGC, BSES Canegrowers, CSC, CS RIT, CSIRO, DPI&F, NRW, EPA, Growcom, ITC Forestry Ltd, JCU, PFNQ and Rewards Group Forestry Ltd.
- *restoration of floodplain function, including protection and restoration of priority riparian zones and wetland areas*: Aboriginal Traditional Owners supported through Giringun Aboriginal Corporation, AgForce, ABGC, Canegrowers, CSC, CS RIT, CSIRO, DPI&F, NRW, EPA, GBRMPA, Growcom, ITC Forestry Ltd, JCU, PFNQ, Rewards Group Forestry Ltd and Stanwell Corporation Ltd.

Role of CSFP Steering Committee and Action Teams

Detailed perspectives on partnership and implementation design were gathered in a workshop with CSFP Steering Committee in May 2007 (Robinson *et al.* 2007). Here, the outcomes of this workshop are summarised as it relates to Tully WQIP implementation.

The CSFP Steering Committee has agreed on three core principals, namely to:

1. streamline the project endorsement and priority setting process while maintaining a forum for representation at catchment level (by the Catchment Management Association (CMA) as the revised Steering Committee);

2. maintain the Action Teams as formal teams or engagement networks to maintain ownership of projects and actions at sector/stakeholder level; and
3. reduce the time, administration and management burden from Action Teams by appointing a full time coordinator to manage the implementation program, provide support to Action Teams and liaise with CMA.

The outcomes of the workshop also highlighted several discrete and important actions to be undertaken by, or through, the CMA/Steering Committee, to support the move from Tully WQIP development into Tully WQIP sign-up and implementation phases (Robinson *et al.* 2007):

1. clarify preferred stakeholder sign-up/endorsement process sought by Australian Government funders, the CMA, and local stakeholder groups;
2. address absence of key technical and compliance agencies (e.g. EPA, NRW, DPI&F) in clarifying contribution to monitoring and regulatory functions, including providing locally-based officers in the catchment;
3. consider emerging pressures or processes in the catchment from new implementation arrangements e.g. expansion in plantation forestry
4. clarify employment arrangements for full time implementation manager/coordinator including funds (e.g. Terrain NRM), and hosting arrangements (e.g. centralise role within the new committee structure or embed this role within sectors such as Local Government);
5. identify resources individual sectors and stakeholders need to stay engaged in CMA/Steering Committee level discussions or in Action Teams ;
6. clarify reporting arrangements (both for accountability and adaptive management) between Action Teams, Steering Committee and Regional Body; and,
7. clarify by what means Action Teams implement their endorsed projects –
 - a. contracts with sectors or organisations administered through Terrain NRM (on behalf of the CMA);
 - b. direct tendering process or fee for service managed through the Action Teams themselves and/or coordinator, or,
 - c. Mixture of the two strategies.

Broader institutional arrangements to support implementation

The Tully WQIP has been developed in a broader planning and policy environment, including Regional, State and National plans and policies (Section 1). CCI has recently developed a project proposal to review and analyse legislative and administrative arrangements to support WQIP implementation at a statewide, regional or local level (Appendix 6). The project aims to review and analyse state and local government legislation that supports WQIP implementation, in particular environment protection, land use planning, water resource, coastal zone management legislation, and local government by-laws. Regional NRM groups (including Terrain NRM) and local governments preparing WQIPs in the GBR region will act as contact groups for this project. The findings of this project will be included in the Tully WQIP in 2008/2009.

State and Federal Government

Currently, the relationship between the Tully WQIP and decision-making related to ERAs under Queensland's *Environment Protection Act 1994* is of most significance. The draft EVs and WQOs for the Tully WQIP were established through processes consistent with schedulable EVs and WQOs. Through the CSFP Steering Committee, the catchment community has focussed on the development of voluntary targets at this stage, to improve scientific confidence in, and achievability of, the proposed targets through an adaptive management approach. This has enabled the CSFP Steering Committee to establish meaningful and robust targets. By being consistent with *Environment Protection Act 1994* processes, however, these draft WQOs will assist EPA in undertaking licensing of ERAs, in working with Local government on urban

stormwater management, and in guiding overall investments in critical improvements in rural and diffuse water quality issues.

Moreover, the Queensland State government (via the Department of Local Government and Planning) is currently developing a statutory regional land use plan for FNQ (Section 1.2). CCI has recently funded a five month project (June to October 2007) to explore how best to deal with water quality management issues within the context of this emerging regional planning framework.

Local Government

CCI has recently funded a one-year project to identify practices that may be undertaken by local governments to contribute to the achievement of Reef Plan objectives. Specifically, to protect and improve water quality through WQIPs, the project will review and assess local government activities (i) to identify the current best standards of local government practice in natural resource and water quality management, and (ii) to scope additional statutory, land planning and management opportunities. Key focus areas include:

- community engagement (promotion and education for NRM and water quality issues),
- land and waste management (for example, through local government management plans, policies, local laws and best environmental practice), and
- water actions (including water quality monitoring and waterway biodiversity retention).

This project will identify the cost-effective, practicable and timely measures available to local governments to protect and improve the quality of water entering the GBR Marine Park. A priority will be given to maintaining the integrity of the Reef Guardian Council program, which will assist local government in contributing to development and implementation of WQIPs. CSC is (currently) not one of the councils in the benchmarking project, but it is anticipated that this project will identify potential roles of local government in WQIP implementation. Relevant outcomes will be included in the Tully WQIP in 2008/2009.

6.2 Monitoring and evaluation framework

To ensure consistency in the GBR region, the RWQP is finalising a strategy for WQIP monitoring and modelling, as well as a reporting framework. These strategies aim to support the evaluation and reporting of progress against management action targets. The Tully WQIP recommends that monitoring and evaluation be progressed using this strategy and framework in a formalised State of the Catchment reporting, with progressive updates on an annual basis. State of the Catchment reporting will also feed into broader approaches to reporting on resource condition and trend at the regional and reef-wide level. Significant review of the Tully WQIP, however, is intended within a five-year time frame to coincide with the end of Reef Plan (2013). This should give the community a chance to make the management actions within the Tully WQIP work, to adapt actions as an outcome of research currently underway, and to monitor the progressive effects of improvements.

A specific water quality monitoring strategy for the Tully WQIP has been developed (Brodie *et al.* 2007c). Moreover, water quality monitoring and modelling in the Wet Tropics region, including the Tully WQIP area, is coordinated through the North Queensland Regional Alliance. This alliance is a sub-group of the RWQP, and brings together regional representatives of Federal and Queensland Government Agencies (GBRMPA, EPA, NRW), Terrain NRM and research organisations (CSIRO, JCU), to deliver water quality targets, monitoring and reporting.

Current *monitoring* activities in the Tully WQIP area include:

- plot-scale monitoring of ‘Six Easy Steps’ and ‘N replacement’ (BSES, CSIRO, DPI&F)
- filter function of a tropical wetland (CSIRO)
- catchment-scale and end-of-river load monitoring (NRW)
- GBR Marine Monitoring (GBRMPA)

Monitoring of the receiving waters is currently overseen by GBRMPA for the Reef Plan Marine Monitoring Program, conducted under ReefPlan (GBRMPA 2007). Some activities of this program are located in or near the Tully WQIP area. To evaluate changes in water quality against Tully WQIP implementation, it is recommended that this program continues to monitor the Tully River floodplume and inshore marine area

(including concentrations of nutrients, sediments, Chl-a, and pesticides), the health of inshore coral reefs and seagrass beds, as well as socio-economic indicators, for at least the next four years.

To track uptake or problems with use of sustainable practices, from productivity and environmental perspectives, the Tully WQIP recommends that all partners report regularly on progress of management actions, and build on recent benchmark reports (e.g. Lindsay 2007a,b, McMahon 2007, Roebeling and Webster 2007). An independent audit process should be established as a support to self-regulation of all sectors. Moreover, each sector needs to ensure that a large enough area is covered to ensure that survey data are statistically representative of their sector. Proposed mechanisms are to (i) target those landholders who manage most of the land for each sector, and (ii) link the Tully Sugar Mill's intake of sugarcane with the lodging of a survey by individual farmers. Such reports are critical for industries to report on water quality improvements prior to the end of ReefPlan (2013), to target extension efforts, and will help to raise the profile of positive (industry) performance by communicating progress to communities and governments. A case in point is the (previously undocumented) improvements in soil and nutrient management quantified for this Tully WQIP.

Current *modelling* activities include:

- catchment-scale and end-of-river load modelling (NRW)
- estimates of sediment and nutrient loads in over bank floods (CSIRO)

CCI recently funded a three-month (June to August 2007) project to conduct a review and gap analysis of receiving-water water quality modelling in the GBR. The project will provide basic background on (i) the conceptual basis of models, (ii) model capabilities and limitations, (iii) the opportunities for linking catchment delivery of pollutants to ecological outcomes through modelling frameworks, and (iv) providing a gap analysis on model frameworks and knowledge. This will include an analysis of how model capability and linked modelling frameworks might be achieved in a technical sense (and institutionally), including estimates of the scale of effort required to achieve such capability and frameworks. The project will recommend a strategy (or possibly alternative strategies) that could be implemented for model development and application for supporting the management of the GBR.

CCI has recently funded a 15-month project to prepare a Reef Plan reporting strategy and pilot report card. Reef Plan requires reporting to evaluate the effectiveness of actions in halting and reversing the decline of water quality to the GBR. This project is intended to assist the Queensland Government in ensuring that a reporting strategy is developed and a 2006/2007 prototype report card is produced with existing data, by May 2008, to maximise the long term utility of reef water quality reporting and report card development. This project will develop and deliver a reporting strategy and pilot report card. The prototype report card will not be comprehensive for all catchments given the limited current available catchment data. The FNQ region (through Terrain NRM) will contribute to the development of the reporting strategy and pilot report card. The findings of this project will be included in the Tully WQIP in 2008/2009.

Adaptive management strategy

WQIPs need to prepare an adaptive management strategy for the life of the WQIP that ensures a regular and predictable review of management practices and control actions based on:

- additional information from monitoring including improved understanding of the effectiveness of different management actions;
- improvements in predictive modelling capacity; and
- revised water quality objectives, load targets or environmental flow objectives and regimes.

CCI has recently agreed to fund a short project (proposed September to December 2007), to develop a protocol for developing adaptive management strategies for WQIPs. The project will agree on a conceptual framework for adaptive management, and work with the Tully WQIP as a case study to develop and test a protocol for adaptive management strategies. The RWQP Scientific Advisory Panel will provide advice on the science implications of this for the Tully WQIP and other Reef WQIPs. The adaptive management strategy for the Tully WQIP will be developed through this process, which will be incorporated into the WQIP in 2008.

6.3 Finalising the Tully WQIP

The WQIPs currently being prepared in the GBR region have various tasks in common. Some of these tasks have been coordinated into cross-regional projects by the RWQP's Regional Implementation Group. The following projects have not been finalised, however, their outcomes will be included in the Tully WQIP in 2008/2009.

Socio-economic assessment of improving GBR water quality

Management actions need to include an evaluation of the wider social, economic and environmental impacts of such actions, and of any actions needed to address such impacts. The socio-economic impact of improving water quality for the Tully WQIP area has been assessed by Bohnet (*et al.* 2006, 2007) and Roebeling *et al.* (2007a,b). Specifically, Roebeling *et al.* (2007a, b) demonstrated that significant improvements in water quality can be made through the adoption of management practices that provide a benefit to the industry as well as to the wider community. The information from these assessments has been used for stakeholder consultation on deciding priorities for, and acceptability of, proposed management practices and/or control actions.

CCI has also funded a six month project (April to September 2007) to assess the social and economic impacts (benefits and costs) of protecting the EVs (values and uses) of GBR waterways by achieving water quality targets/objectives established in Reef WQIPs (Appendix 8). The Tully WQIP is a component study for this project, and the findings of this project will be included in the Tully WQIP in 2008/2009.

Margin of safety and reasonable assurance

All WQIPs need to demonstrate that a margin of safety has been applied to account for uncertainty in estimating the total maximum pollutant loads. This should account for the accuracy limits of available tools and information.

All WQIPs also need to prepare a reasonable assurance statement that substantiates with a high degree of confidence that (i) projected reductions in the loads of pollutants to the receiving water body and of key pollutants to priority estuaries and beaches, and (ii) attainment of river flow regimes (expressed as flow exceedence curves) for estuaries, will be achieved with WQIP implementation. The reasonable assurance statement will substantiate with a moderate to high degree of confidence that the WQOs, total maximum loads and environmental flow objectives are achievable, and that the WQIP targets are appropriate in timing and extent for achievement of those targets.

CCI has recently funded a one-year project (July 2007 to June 2008) to prepare protocols for addressing margin of safety and reasonable assurance in Reef WQIPs (Appendix 7). The project will prepare protocols for the use of margin of safety concept in specifying the ecologically sustainable load, and the provision of reasonable assurance statements for Reef WQIPs. The project will consider pollutant loads, specifically sediment and nutrient loads, but does not consider river flow objectives. The FNQ region will be used as one of two case studies for the project, and the findings of this project will be included in the Tully WQIP in 2008/2009.

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APPENDICES

APPENDIX 1. Cardwell Shire Floodplain Program

Table 1.1 Member and partner organisations of the Cardwell Shire Floodplain Program Steering Committee, and its three Action Teams (Production, Biodiversity, Socio-cultural). Organisations and persons are presented in alphabetical order. Current Chairs and Facilitators are Bill Shannon and Paul Devine (Steering Committee), Derrick Finlayson and Peter Lucy (Production Action Team), Paul Devine and Damon Sydes (Biodiversity Action Team), and Keith Noble and Kate Hensler (Socio-Cultural Action Team). Current Program Manager and Officer are Frederieke Kroon and Damon Sydes, respectively.

Organisation	Person	Steering Committee	Production Action Team	Biodiversity Action Team	Socio-cultural Action Team
Girringun Aboriginal Corporation	Claude Berron	x		x	
	Clarence Kinjun	x			x
	Leigh Pentecoast	x			x
AgForce	Norm Kippin	x	x		
Australian Banana Growers Council	Mark Jackson	x			
BSES	Alan Hurney		x		
	Matt McMahon		x		
Canegrowers	Peter Lucy	x	x	x	x
	Nick Stipis (p)	x	x		
Cardwell Shire Council	Paul Devine (RIT)	x		x	
	Jim Nicholson	x			
	Damon Sydes (Terrain NRM)	x		x	x
Chamber of Commerce	Jean Vallianos	x			
Conservation Volunteers Australia	David Hudson			x	
CSIRO	Iris Bohnet				x
	Frederieke Kroon (Terrain NRM)	x	x	x	x
	Jim Wallace	x			
	Tony Webster		x		
Department of Primary Industries and Fisheries	David Westcott			x	
	Alf Hogan			x	
	Stewart Lindsay	x	x		
	Diana O'Donnell (p)			x	
	Terry Reid (p)		x		
	Neil Sing		x		
Department of Natural Resources and Water	Jim Turnour (p)	x	x		x
	Adam West	x			
	John Armour		x		
	Steve Bertocchi	x		x	
Environmental Protection Agency	David Green (Terrain NRM) (p)		x	x	
	Niall Connolly	x		x	
	Peter Morisson (p)	x	x	x	x
GBRMPA	Donna Audas	x		x	
	David Briggs				x
	Carol Honchin	x			
	Karen Lawrence (p)				x
GrowCom	Karen Vella (p)				x
	Graham Cripps (p)		x		
	Keith Noble	x			x
	Joe Rhodes (p)		x		
	George Russell		x		
ITC	Mark Warmington		x		
	Darryl Killin	x			
JCU	Jon Brodie	x	x		
	Brian Roberts	x	x	x	x
Local Marine Advisory Committee	Bill Shannon	x			
Private Forestry North Queensland	Max Bell	x	x		
	David Skelton	x			
	Tony Sturre	x			
Rewards Group	Kim Forde (p)			x	
Stanwell Corporation	Allan Dale	x			
	Rowena Grace			x	
Terrain Ltd	Kate Hensler				x
	Steve McDermott			x	
	John Reghenzani		x		
	Joann Schmider				x
	Jessica Stainley		x		
	Rachel Wicks				x
	Dick Camilleri (p)	x	x		
Tully Sugar Ltd	Derrick Finlayson	x	x		
Wildlife Preservation Society Queensland	Ron Zamora (p)			x	

APPENDIX 2. The Framework for Marine and Estuarine Water Quality Protection

A Water Quality Improvement Plan will as a minimum:

- a. delineate the marine and estuarine waters to which the plan applies and the catchment which contributes pollutants to those waters;
- b. identify the environmental values of those marine and estuarine waters;
- c. set out the water quality issues, pollutants of concern, and water quality objectives for those waters, and:
 - o the estimated total maximum pollutant loads to achieve and maintain the water quality objectives, and how this differs from the current estimated pollutant loads (assumptions used for the basis of these estimates shall be detailed);
 - o the estimated constituent point and diffuse source allocations of the total maximum pollutant loads (including from marine activities, e.g. aquaculture);
 - o the estimated point source allocations to each licensed point source, and the allocations to non-point sources of contaminants, including atmospheric deposition or natural background sources;
 - o the margin of safety used in establishing the total maximum pollutant load which accounts for uncertainty, including that associated with estimating pollutant loads, water quality monitoring, ecosystem processes and modelling;
 - o how decision support systems will be developed and applied to appraise the likelihood of success of the plan, and the degree and timeliness of reductions in pollutant loads, including provision for future growth which accounts for reasonably foreseeable increases in pollutant loads (e.g. approved industrial point sources, urban expansion); and
 - o seasonal variation in pollutant load inputs, such that the water quality objectives will be met all year round.
- d. set out the river flow objectives for those waters, having regard for ecological and geomorphic processes relating to, but not limited to:
 - o protecting natural low flows;
 - o protecting important rises in water levels;
 - o maintaining wetland and floodplain inundation;
 - o maintaining natural flow variability; and
 - o maintaining or rehabilitating estuarine processes and habitats.
- e. estimate the time required to attain and maintain water quality and river flow objectives, and the basis to those estimates;
- f. describe the control actions and/or management measures which will be implemented to ensure:
 - o discharges of pollutants to coastal waters are less than the total maximum pollutant loads, for all sources irrespective of category or land use activity; and
 - o environmental flow provisions will achieve the identified river flow objectives.
- g. set out a timeline, including interim targets and milestones, for implementing the control actions and/or management measures and attainment of water quality and river flow objectives, including a schedule for revising the regulatory and management arrangements, as appropriate;
- h. identify accountabilities for implementing the various source control measures, as well as strategies for the maintenance of effort over time;
- i. identify strategies for adaptive environmental management, recognising the implications to environmental monitoring programs of management interventions over time;

- j. set out the processes for monitoring and/or modelling and reporting on the effectiveness of the control actions and/or management measures, and whether pollutant loads and environmental water provisions are being met;
- k. provide time lines and costs for plan implementation;
- l. identify opportunities for market based approaches to implement the plan;
- m. provide for the periodic review of water quality objectives, total maximum pollutant loads, river flow objectives and environmental water provisions;
- n. set out the means for public involvement and public reporting; and
- o. identify the process and timing for revising the plan.

As an Appendix to the water quality improvement plan, the plan will also contain:

- a. legal advice stating and describing the jurisdiction's statutory capacity to implement the plan and commitments for legislative reform, as appropriate;
- b. the programs and funding committed by the jurisdiction to implementing the plan; and
- c. a "reasonable assurance" i.e. a high degree of confidence that projected reductions in the total pollutant load and attainment of environmental water provisions will be achieved. The grounds to the "reasonable assurance" should be substantiated.

APPENDIX 3. Current status of pollutant sources

Diffuse sources of pollution

Diffuse sources of pollution are not regulated, meaning that they have not been assessed, and do not require an environmental authority under the *Environmental Protection Act 1994*. The main land uses considered as diffuse sources of pollution in the Tully WQIP area include natural forests in protected areas, sugarcane, grazing, plantation forestry, banana and other horticulture, urban run-off and development sites, and waterways including river and stream banks (Table 2.1). For each land use, relevant legislations, Code of Practices, and current practices for sediment, nutrient and pesticide management are summarised below.

The contribution of each land use to the total sediment, nutrients and pesticides loads were estimated based on monitoring and modelling information (Section 3.4; Table 3.2). A variety of modelling scenarios were run to examine the cost-effectiveness of changes in land management on reducing key pollutant loads from critical sources (Section 4). Identified management actions were subsequently prioritised using seven specific criteria that were equally weighted (Section 5)

Natural forests in protected areas

Natural forest is the largest land use in the Tully-Murray basin (>70%, Table 2.1), and comprises mostly protected areas (Wet Tropics World Heritage Area, National Park or State Forest), but also includes defence lands. Management of protected areas is the responsibility of the Wet Tropics Management Authority and the Environmental Protection Agency/Queensland Parks and Wildlife Service (EPA/QPWS), and is prescribed in legislation (and associated regulations). These include the *Environmental Protection Act 1994*, the *Environmental Protection and Biodiversity Conservation Act 1999*, the *Nature Conservation Act 1992*, the *Integrated Planning Act 1997*, and the *Water Act 2000*, as well as various internal Management Plans, Code of Practices and Manuals (EPA 2007a). Practices for protected area management in the Tully-Murray catchment area are described in EPA (2007).

Similarly to the GBR, these protected areas provide a range of ecosystem uses and values to communities at local, regional, national and international scales. This includes uses and values associated with aquatic ecosystems, indigenous and non-indigenous cultural heritage, and amenity (Section 2), as well as the provision of a valuable tourism economy (Prideaux and Falco-Mammone 2007) and the supply of clean water to perennial streams. The latter is critical in maintaining water quality in tributaries and rivers, and diluting pollutant input further downstream. Because natural forests cover a large area in the Tully WQIP area, activities in these areas may impact on water quality in the Tully-Murray waterways and receiving waters.

Sugarcane

The sugarcane industry in Queensland has established a Code of Practice, entitled '*Sustainable Cane Growing in Queensland*'. In Cardwell Shire, 348 properties are rated predominantly as sugarcane. The following information on management practices in sugarcane in the Tully WQIP area is from Sing (2005), Roebeling and Webster (2007) and McMahon (2007). The most recent survey of management practices, as relevant to water quality, included 48 growers (14% of total) and covered 9,189 ha (~25% in Tully WQP area) of the total production area in the Tully and Kennedy districts (McMahon 2007). Estimated adoption rates reflect (the range of) industry and expert opinions on uptake by proportion of farmers (Roebeling and Webster 2007).

The main soil conservation practices in sugarcane are green cane trash blanketing (GCTB), reduced, zero or zonal tillage, grassed headlands, well designed drains, sediment traps and riparian plantings. GCTB is used on 93% of the response area, while 6% is burnt before or after harvest. In addition, moderate tillage is used by 87% of the growers surveyed, while the estimated proportion of growers practicing minimum/zero tillage is less than 30%. An estimated 70-90% of the growers have grassed headlands which are managed by slashing (48%), spraying (21%) or combinations thereof (31%). Estimated adoption rates of improved drains (shallow, spoon-shaped and well grassed) are between 30-60%. Over 50% of growers surveyed use wetlands (52%), silt traps (24%) or drop structures (18%) to manage water flows. All riparian zones in the survey area are vegetated with either trees and shrubs (85%) or grass (15%), which appears to be in contrast with an

estimated 20-60% of farmers using a combination of rocks, groins, netting and vegetation to reduce the erosion of stream and river banks.

Effective nutrient management takes into account all sources of nutrients, including the soil, legume crops, cane trash, carry over from previous cash crops such as bananas, mill mud, and synthetic sources such as fertiliser. Estimated adoption of nitrogen management ranges from 30% to 90%. Soil and leaf analysis are conducted by 94% and 11% of the growers surveyed, respectively. Nearly all growers surveyed practice fallow rotation, with more than half the fallow area (59%) planted to legumes (mainly soybean, cowpea, and lablab). As far as fertiliser management is concerned, nutrient management involves matching fertiliser application to crop requirements with regards to quantity, timing, placement and form. Seventy-eight percent of the surveyed growers tailor fertiliser applications to soil types and varieties. On average, N and P fertilisers are applied at 115 kg/ha and 50 kg/ha, respectively, during plant stage, and at 146 kg/ha and 16 kg/ha, respectively, during ratoon stage. These rates are below current BSES recommended application rates, but may still be more than the plants need given that 59% of the area uses legume fallow (Webster and Brodie 2007). Almost all surveyed growers apply fertiliser to ratoon subsurface in a single application, with 67% using split-stool application, and 33% apply beside the row. In addition, 67% of the responders (8% of area surveyed) apply mill mud annually to both fallow/replant and ratoon.

The following herbicides are applied during plant, ratoon and fallow stage: glyphosate, paraquat, and 2,4-D (knock-down herbicides), and atrazine, ametryn, diuron, hexazinone, and pendimethalin (residual herbicides) (see Calcino and Hurney 2007 for detailed information on application rates and areas). Chlorpyrifos was used by some growers to control cane grubs. Thirty-five sugarcane farmers are currently Chemcert® accredited (C. Summersell, pers. comm., Chemcert Training Queensland, Sept 2007).

Grazing

The Queensland grazing industry has not developed a Code of Practice. In Cardwell Shire, 84 properties are rated solely as grazing. The following information on management practices in grazing in the Tully WQIP area is from Turnour (2005) and Roebeling and Webster (2007). Survey information on current management practices in grazing in the Tully-Murray basin, as relevant to water quality, was not available at the time of writing (S. Lindsay, DPI&F, pers. comm. 2007). Estimated adoption rates reflect (the range of) industry and expert opinions on uptake by proportion of farmers (Roebeling and Webster 2007).

The main soil conservation practices in grazing are maintaining good ground cover, exclusion of cattle from water courses and river banks, and riparian management for cattle and weeds. In the wet coastal grazing system, little if any risk exists of paddock erosion due to extremely good ground cover. Stock access to water courses and river banks appears to be limited, with an estimated 75% of graziers excluding cattle from river and stream banks. An estimated 30% of graziers use a combination of rocks, groins, netting and vegetation to reduce the erosion of stream and river banks.

Grazing in the wet tropics coastal area is based on improved pastures. Turnour (2005) suggests that little, if any, nitrogen fertiliser is applied to wet tropics' pastures, based on discussions with AgForce and DPI&F. However, this is not supported by anecdotal evidence from the CSFP Steering Committee, and nutrient management in the wet tropics' grazing industry should be further examined.

Grazing uses ponded pasture species, such as hymenachne, paragrass and aleman grass. All three are present in the Tully-Murray basin, with hymenachne originally introduced as ponded pasture into the area in the late 1980s (DNRMW 2006). Hymenachne adversely impacts on water quality and aquatic ecosystem health and has now been declared a weed of national significance (DNRMW 2006).

At the time of writing, no information was available on the type, use and application rates of pesticides by the grazing industry. Three graziers are currently Chemcert® accredited (C. Summersell, pers. comm., Chemcert Training Queensland, Sept 2007).

Plantation forestry

Plantation forestry in the Tully-Murray basin includes pine plantations managed by Forest Plantations Queensland (formerly DPI Forestry), hardwood plantations managed by forestry companies (Great Southern Ltd., ITC Forestry Ltd. and Rewards Group Forestry Ltd.), and smaller farm forestry plantations, generally established with the aid of Private Forestry North Queensland (PFNQ). In Cardwell Shire, five properties are rated as plantation forestry, but this is likely to be more as many plantation forestry properties still contain,

and are rated as sugarcane or bananas. The following information on management practices in plantation forestry in the Tully WQIP area, as relevant to water quality, is from Bell (2005), Roebeling and Webster (2007) and Lindsay (2007a), unless otherwise noted. Estimated adoption rates reflect (the range of) industry and expert opinions on uptake by proportion of farmers (Roebeling and Webster 2007).

Management practices in plantation forestry are generally derived from two areas: (i) Forest Certification Programs and (ii) Codes of Practice. The main forestry certification programs in use are the Australian Forestry Standard (AFS), the Forest Stewardship Council (FSC) and the Pan European Forest Certification Council (PEFC). The AFS is now a certified standard under the PEFC. Forest Plantations Queensland's operations are now certified to AFS, while ITC's operations are certified under FSC. Moreover, ISO 14001 requires forestry companies to define and implement a specific set of responsibilities and processes for dealing with environmental and related issues. The Queensland Government has established Code of Practices for native forest timber production across the Queensland State forest estates (EPA 2002), and for native forest practice on freehold land (NRW 2005), but not for native and non-native forest plantation production on freehold land.

Soil conservation practices in plantation forestry include site cultivation outside wet season, minimum tillage, maintaining ground cover, maintaining drainage and drains, hard surfacing of roads and riparian management. Cultivation, land preparation and planting generally takes place during the period May to September, however, site preparation during the wet season was observed in 2007. Indeed, proposed planting times range from January to September. According to the industry, 75% of the growers restrict tillage to localised deep ripping of the plant row when preparing for planting, while 45% maintain grass inter-rows through regular slashing. An estimated 100% of growers develop integrated drainage plans for plantation forestry farms, with specifications for broad, shallow and vegetated drains. The major forestry companies anticipate that they will hard-surface roads to prevent erosion. Headlands are formed and stabilised with sand and gravel to prevent wash.

Fertiliser is applied around planting, followed by subsequent fertilisation as required in the next two or three years, with rates of approximately 50-100 kg NPK/ha/year (NPK = nitrogen, phosphorus and potassium fertiliser; ratio unknown). Foliar analysis is used to determine whether re-fertilisation is required or whether nutrition appears to be a cause of poor performance in the early years. Estimated adoption of effective nitrogen management is 75%.

Chemicals are used for weed control, with simazine and glyphosate being the most generally used herbicides in plantation forestry. Specific information on the use and application rates of these herbicides, and potential other pesticides, by plantation forestry was not available. Zero growers are currently Chemcert® accredited (C. Summersell, pers. comm., Chemcert Training Queensland, Sept 2007).

Banana and other horticulture

The horticulture industry in Queensland has established a Code of Practice of sustainable fruit and vegetable production in Queensland, entitled '*Farmcare – Cultivating a Better Future*'. In Tully WQIP area, banana comprises the biggest component of horticulture. Information on banana and other horticulture is combined, as other horticultural industries cover only a small area (Table 2.1) and management practices are similar. In Cardwell Shire, 167 properties are rated for mixed use, including bananas, lychees, etc. The following information on management practices in banana in the Tully WQIP area is from Lindsay (2005, 2007c) and Roebeling and Webster (2007). The most recent survey of management practices, as relevant to water quality, covered 868 ha (~22%) of the banana production area in Tully (Lindsay 2007b). Estimated adoption rates reflect (the range of) industry and expert opinions on uptake by proportion of farmers (Roebeling and Webster 2007).

The main soil conservation practices in bananas are ground cover management, farm layout and design, drainage design and maintenance, and river and stream bank management. Ground cover was actively encouraged during the fallow period by growers (94% of area), and crop eradication is restricted to the May to October period (45% of area). Moreover all growers surveyed, time their land preparation for the May to October period, retain trash residue on the row area, and encourage and retain inter-row vegetation. Run-off is managed through farm lay-out and design, including adopting soil conservation structures on blocks with >5% slope (100% of area), installing silt traps (45% of area), and stabilising and regularly maintaining headlands and roads to prevent wash (100% of area). Drainage design and maintenance practices by all growers surveyed include (i) primary drains that are broad, shallow and vegetated, (ii) maintaining

vegetation cover on steep sided drains November to March period, (iii) regularly checking drains for erosion and slumping, and (iv) timing maintenance for May to October period. Note that estimated uptake of adoption of some soil conservation practices is significantly lower, including fallow management (65-75%) and inter-row management (50-60%) (Roebeling and Webster 2007). An estimated 95% of growers use a combination of rocks, groins, netting and vegetation to reduce the erosion of stream and river banks.

Nutrient management in bananas takes into account the soil, trash and fertiliser. On average, nitrogen and phosphorus fertilizer are applied at 262 kg/ha and 75 kg/ha, respectively, during plant stage, and at 313 kg/ha and 71 kg/ha, respectively, during ratoon stage. Typical banana cropping cycles have one plant crop and up to six ratoon crops before a block is replanted, resulting in 15-20% of blocks in any one year being in the plant crop phase (Lindsay 2007b). Most producers use soil and leaf analysis to guide nutrient management. Three different application methods are used in both plant and ratoon crop, including pre-plant, broadcast and fertigation.

The banana industry uses the following pesticides for leaf, pest and disease management during plant and ratoon crop: bifenthrin, chlorpyrifos, diazinon, fipronil, and prothlofos (insecticides), cadusafos, fenamiphos, and oxamyl (nematicides), epoxiconazole, mancozeb, propiconazole, pyraclostrobin, tebuconazole, and trifloxystrobin (fungicides), and clofentezine and fenbutatin-oxide (miticides). The following herbicides are used during plant and ratoon crop, and management of headlands and drains: diquat, glufosinate-ammonium, glyphosate, paraquat, and pendimethalin (see Lindsay 2007b for detailed information on application rates and areas). Diazinon has been detected in waterways in the region. Twenty-eight horticulture growers are currently Chemcert® accredited (C. Summersell, pers. comm., Chemcert Training Queensland, Sept 2007).

The banana production system produces additional waste streams which can affect water quality (see also Brodie *et al.* 2007a). Most growers (90-99%) dispose of vegetative packing shed waste by using it as fodder or by placing it on fallow grounds and plant rows. An estimated 50% to 75% of growers dispose of non-vegetative waste (e.g. fertiliser bags, bunch covers, polypropylene string, and chemical containers, and machinery products like batteries, tyres, filters, fuel and oil) through registered contractors or services. An estimated 30% of growers treat water used in packing sheds prior to release into natural waterways

Urban run-off and development sites

CSC refers to the Far North Queensland Regional Organisation of Councils (FNQROC) Regional Development Manual (2004) for 'comprehensive, structured and practical guidelines to promote consistency in development standards'. These guidelines contain construction and development procedures, including (i) design guidelines on road geometry, site regrading, stormwater drainage and quality, water reticulation, sewerage system, utilities and landscaping, and (ii) specifications for earthworks, road pavements, segmental paving, stormwater drainage, water reticulation, sewerage reticulation, concrete works and landscaping (FNQROC 2004). Specific requirements for CSC are provided for some construction procedures and design guidelines. Compliance rates with the FNQROC Regional Development Manual (2004) are unknown at the time of writing.

At the time of writing, no information was available on the type, use and application rates of fertilisers and pesticides by the urban population.

Waterways, including river and stream banks

The statutory and policy obligations with regards to the Queensland aquatic environment were reviewed by Kroon *et al.* (2004). This review summarised relevant Queensland Acts, Commonwealth Acts and Agreements (in particular Agreements between the Commonwealth and Queensland governments), and International Treaties joined by Australia.

At a national level, the NPPWE provides 'policy direction on how the issue of water for the environment should be dealt with in the context of general water allocation decisions' (ANZECC 1996; Section 1.2). In Queensland, environmental flow requirements, allocations and monitoring are explicitly included in Water Resource Plans under the *Water Act 2000*. Currently, the Barron River is the only Wet Tropics catchment with a Water Resource Plan and associated Resource Operation Plan (DNRM 2005).

The *Water Act 2000* further regulates water licences and permits. Apparently, irrigation licenses in the Tully-Murray basin are currently neither capped nor gauged, and many of the bores in the floodplain are unlicensed (Bohnet *et al.* 2006, 2007). If this is indeed the case, these regulated activities (and their environmental

management) have not been assessed and may detrimentally impact on water quality and environmental flows in the basin.

Under the *Water Act 2000*, the Tully-Murray catchment is the only regulated catchment in Queensland with declared embankments and drainage areas. In February 2006, NRW reported to CSFP Steering Committee that it had surveyed 35 levees and 400 plus unlicensed drainage outlets, informed relevant land holders how outlets may be validated, approved four other levees, and had reduced the Byrne, Dore, Cavallaro levee to licensed height. NRW suggested that some of the works completed under the Sugar Industry Infrastructure Package (SIIP) may need some clarification regarding validation; however, requests to this effect have not been received by SIIP. NRW stated an interest in seeking the views of major stakeholders to assess whether the present situation should continue or regulation should be removed.

The ecological and physical condition of rivers, creeks and tributaries in the Tully-Murray basin are described in the Tully State of the River report (Johnson 1998). The condition of the catchment and sub-catchments were assessed for bank stability; bed and bar stability; channel diversity, habitat types and dimensions; riparian vegetation; aquatic vegetation; aquatic habitat; scenic, recreation and conservation values; and overall condition. Johnson (1998) concluded that condition ratings for the reach environs within and between sub-catchments varied widely from very poor to very good. Generally, overall condition of reaches in the upper catchments was good, while that of reaches in the lower catchments was poor. Lower ratings were associated with sugarcane and grazing land uses.

Subsequent to Johnson (1998), additional and more detailed management plans have been developed for Tully (Middle Reach), Jarra Creek, and Meunga Creek (AGEC 2001, 2002, 2003), and partially implemented, by the Cardwell Shire River Improvement Trust (CS RIT) in association with CSC and private landholders. As of February 2006, the CS RIT had an asset register of \$3M, and was developing detailed management plans for Davidson Creek, Echo Creek and Murray River.

Management recommendations for natural habitats in the lowlands, including wetlands, were provided by Tait (1994) as part of the SIIP planning in the Tully and Murray River catchments. These recommendations concerned status of habitats, conservation issues, habitat protection, habitat rehabilitation and drainage design. While significant acquisitions and protection have been put in place since Tait's report (P. Lucy, Canegrowers, pers. comm. 2007), progress against Tait's recommendations has not been documented in an accessible manner by SIIP.

More recently, 28 wetlands in the Tully Murray catchment have been evaluated and prioritised for restoration using a wetland decision support system, developed under the GBR Coastal Wetland Protection Program (D. Sydes, CSC, pers. comm. 2007). Following rapid, on-ground assessment, individual wetlands were prioritised for management action and development of investment areas, on the basis of their habitat values, assimilative capacity, ecosystem functioning, tenure, as well as Traditional Owner and landholder willingness to participate in restoration works. This information has complemented and provided more local detail to the state-wide wetland mapping recently conducted by EPA.

Overall, since European settlement, the filtering role of the floodplain has been substantially altered, due to removal of wetlands and the installation of land drainage systems in the coastal floodplains. Rehabilitation of waterways, including river and stream banks and wetlands, will improve water quality, restore uses and values that have been lost over time (Bohnet *et al.* 2007b), as well as enhance the resilience of the coastal floodplain ecosystem. Uncontrolled drainage and levee banks results in inequitable off-site impacts (Drummond 1993), including impacts on water quality in catchment and receiving waters.

Point sources of pollution

Large point sources of pollution are generally regulated activities, meaning that they have been assessed, deemed to have met environmental management considerations and conditioned accordingly. Licensed environmentally relevant activities (ERAs) in the Tully WQIP area include the Tully Sugar Mill, the Tully Sewage Treatment Plant, sewage treatment plants at resorts, aquaculture facilities, extractive industries and urban industries (Roberts 2007). ERAs are regulated under the *Environmental Protection Regulation 1998* which is legally binding and subordinate to the *Environmental Protection Act 1994*; both are administered by the EPA. Other point sources of pollution considered here include ship-sourced sewage and residential (unlicensed) septic tanks.

For each regulated point source of pollution, sediment, nutrients and pesticides loads have been estimated if monitoring and permit information was available to do so. The proportional contribution of each point source to the total sediment, nutrient and pesticide loads are considered where possible (Section 3.4), and potential management measures and control actions are discussed (Section 5).

The following information is from Roberts (2007) and EPA, unless otherwise noted.

Tully Sugar Mill

Sugar mills need to hold an environmental authority for wastewater treatment and disposal. The Tully Sugar Mill is licensed to discharge into Banyan Creek a maximum of 62,000 m³ per day during the crushing season, which generally lasts 24 weeks. The four effluent ponds are emptied once a year and have no discharge limit; but have an approximate maximum annual volume of 156,000 m³ (L. Cripps, Tully Sugar Mill, pers. comm. July 2007). The license further specifies that discharges must (i) be within certain limits for TSS, pH, dissolved oxygen (DO), biological oxygen demand (BOD) and oil and grease, and, (ii) not produce visible floating oil, scum or other objectionable matter, nor contain any organisms or other contaminants in concentrations capable of causing 'unlawful' harm.

The effluent is analysed by the mill, including those parameters as required by the license, as well as conductivity, carbohydrates, and temperature. In the 2005 crushing season, analyses of effluent water quality indicated that the mill complied with all license conditions except for two pH readings (above limit) and ten BOD (5 day incubation) readings (four above and six below permitted DO range). In addition, conductivity showed a rise of approximately 30 units (in µS/cm) above ambient, while carbohydrate was always below detectable levels. Oil and grease concentrations have not exceeded licence limits since 1999. From 2000 to 2005, mean temperature in effluent ranged from 33 to 37°C and maximum temperatures from 39 to 43°C (42°C in 2005), with recordings between 1 and 17°C above ambient (+10°C in November 2005). Overall, the results demonstrate that the mill meets most of its license requirements and continually improves its discharge water quality.

The nutrient content of most mill effluent is considered not significant and the impact on water quality could be considered negligible (E. Gustavsen, EPA, pers. comm. in Roberts 2007). However, this was disputed by Pearson and Penridge (1992), and outbreaks of 'sewage fungus' (an excessive greyish filamentous growth) have been consistently observed in creeks below sugar mill outlets during crushing season, including the Tully Sugar Mill (N. Connolly, EPA, pers. comm. 2007). Moreover, Mitchell *et al.* (2007) report elevated levels of nutrients immediately downstream from the Tully Sugar Mill and STP, compared to further upstream in Banyan Creek. The mill is currently involved in a study with Bundaberg Sugar and Queensland University of Technology on the formation and impacts of sewage fungus in Banyan Creek (J. King, General Manager TSM, pers. comm. 2007).

The Tully Sugar Mill contributes an estimated maximum of 150 tonnes of TSS to the sediment loads into Banyan Creek per year. This is based on (i) actual maximum TSS in mill discharge over five years (14 mg TSS/L) and permitted volumetric discharge during a 24 week crushing season (10.4 million m³), and (ii) permitted maximum TSS in effluent discharge (30 mg TSS/L) and approximate maximum annual discharge from the four effluent ponds (156,000 m³). This contribution by the mill is most likely an over-estimate, as the actual maximum discharge TSS concentration has ranged between 6 and 14 mg TSS/L over five years (11 mg TSS/L in 2005), while ambient TSS concentration ranged from 5 and 26 mg TSS/L.

Tully Sewage Treatment Plant

STPs need to hold a valid environmental authority for sewage treatment (ERA 15). ERA 15 includes one special and seven standard sewage treatment works categories; the seven standard categories are further divided up into categories relating to capacity to treat sewage for ranges of 'equivalent persons' (i.e. likely demand placed on the licensed system).

The Tully STP, completed in 2005 and fully commissioned in mid-2006, treats sewage effluent from Tully and Mission Beach. The maximum allowable daily discharge for the Tully STP during dry weather is 1,200 m³ per day. During high intensity rainfall events the STP is permitted to discharge three to five times dry weather flow. In May 2007, the STP discharged 1,800 m³ per day into Banyan Creek. The license further specifies that discharges must be within certain limits for TSS, total nitrogen (TN), ammonia, total phosphorus (TP), pH, DO, faecal coliform and BOD. The effluent is analysed weekly by Cairns Water, while in the future water samples will be taken at the Banyan Creek bridge and 100 metres above and below the

STP. In May 2007, the STP was meeting all license conditions for liquid effluent (B. Barrat, CSC, pers. comm. 2007).

Sewage is treated by a tertiary process and the effluent is sterilized with ultra-violet light beams. After flocculation with polymer, the solids are dewatered to a moisture content of 12-26%. This biowaste is currently stockpiled on level land nearby, with a view to future use as fertiliser and soil ameliorant on turf farms, golf courses and parks. Current regulations on solids application to soils requires EPA approval based on guidelines (NSW EPA 1997). While CSC commissioned a report on the suitability of the solids for disposal options (GHD 2005, in Roberts 2007), no records are available to indicate whether or not requirements of receiving soils (NWQMS 2004, NSW EPA 1997) are being met. In May 2007, all solids were being removed by a local landholder for application to cattle pastures (B. Barrat, CSC, pers. comm.).

The Tully STP contributes an estimated maximum of 1.3 tonnes of TSS ($2 \text{ mg TSS/L} \times 0.7 \text{ million m}^3$), 5.9 tonnes of TN ($9 \text{ mg TN/L} \times 0.7 \text{ million m}^3$), and 0.4 tonnes of TP ($0.55 \text{ mg TP/L} \times 0.7 \text{ million m}^3$) to the overall sediment and nutrient loads into Banyan Creek per year (based on actual TSS, TN and TP in treated effluent, and actual daily volumetric discharge). The potential contribution of solids disposal on land to overall pollutant loads is unknown and will not be further considered.

Resorts, caravan parks and holiday villages

Licensed septic systems are utilised by (remote) tourist accommodation facilities, such as resorts, caravan parks, and holiday villages. Permit holders are required to hold a valid environmental authority for sewage treatment (ERA 15). ERA 15 licenses specify conditions of treated effluent release to land, and do not allow direct or indirect release of contaminants to (the bed and banks of) any waters, unless specifically permitted. Nine sewage treatment permits and development approvals are currently approved in the Tully WQIP area, including three in marine receiving waters (Dunk and Hinchinbrook Islands). Eight permits are active; three are category ERA 15a (21 to <100 eps; eps = equivalent persons) and five are ERA 15b (100 to <1500 eps). None of these facilities have any marine outfall.

Provided that licensed septic systems are operated, sited and maintained properly, including regular monitoring and recording of groundwater, they are unlikely to impact on water quality. Their contribution to overall pollutant loads will not be further considered.

Aquaculture facilities

Aquaculture facilities need to hold a valid environmental authority for aquaculture activities (ERA 1). ERA 1 (Aquaculture) relates to 'cultivating or holding marine, estuarine or freshwater organisms (other than molluscs) in ponds or tanks or in enclosures in waters (*impoundments*)'. ERA 1 (Aquaculture) includes five categories related to (i) the total area of the impoundments, and (ii) whether wastes are released to waters.

Five authorised aquaculture operations are operational near Cardwell in Cardwell Shire, including two ≥ 20 ha (ERA 1e), one 10-20 ha (ERA 1d), and one <5 ha (1b), while the fifth operates seacages. The four land operations are licensed to release into water; combined discharge of the three large operations is a maximum of 56.4 million m^3 per year. Discharge volume for the smaller operation, and proportion of prawn farm ponds that utilise recirculation technology, were unknown at the time of writing. Licenses specify limits for TSS, TN, TP, chlorophyll-a (Chl a), pH and DO in release water. In addition, the release must not produce any slick or other visible evidence of oil or grease, nor contain visible floating oil, grease, scum, litter or other objectionable matter. The use of antibiotics is approved under permit by EPA, while pesticides are not used in these operations (C. Robertson, DPI&F, pers. comm. 2007).

The three aquaculture operations contribute an estimated maximum of 3,770 tonnes of TSS, 82 tonnes of TN and 12 tonnes of TP to the loads into receiving waters per year. This is based on permitted maxima of TSS, TN and TP in aquaculture discharges, observed annual volumetric discharge at one farm (2.8 million m^3 ; McKinnon *et al.* 2002), and permitted volumetric discharge at the two other farms (18.1 million m^3). This contribution by the aquaculture operations is most likely an over-estimate, as the actual maximum discharge TSS concentration has ranged between 6 and 14 mg TSS/L over five years (11 mg TSS/L in 2005), while ambient TSS concentration ranged from 5 and 26 mg TSS/L.

Extractive industries (including dredging and quarries)

Operators are required to hold a valid environmental authority for carrying out dredging activities in freshwater (ERA 19), for higher levels of quarrying (ERA 20), and for screening, washing, crushing, grinding, milling, sizing or separating material extracted from the earth or by dredging (ERA 22). All three ERAs include three categories specifying the licensed amount of material per year. In tidal reaches (e.g. below the Euramo bridge), operators are also required to hold valid Allocations issued by EPA under the *Coastal Protection and Management Act 1995*. Allocations and development approvals complement each other.

Eleven extraction licenses are active in the Tully WQIP area; six ERA 19 licenses, four ERA 20 licenses and one ERA 22 licence. Under the *Coastal Protection and Management Act 1995*, eight valid development approvals, and seven valid allocations (total of 18,600 m³/year) exist.

Applicants are advised by EPA to seek input from DPI&F on their proposed sand extraction (Adam West, DPI&F, pers. comm. 2007). While DPI&F is not required to provide this input, DPI&F has a statutory responsibility to protect declared fish habitats and marine plants under the *Fisheries Act 1994*. By requesting input, EPA wants to ensure that the proposed activity does not adversely affect fish habitats and marine plants. For example, the Tully River contains a declared fish habitat downstream of several extraction sites.

At the time of writing, permit information for extraction in the Tully WQIP area under the *Water Act 2000* was not available. However, there are at least a few operators extracting from the freshwater reaches of the Tully River.

CSC has issued seven current extraction licenses on freehold land (CSC Local Law No. 23); however, these are located away from major streams.

Extraction operations in or adjacent to streams may contribute to sediment loads due to channel and bank disturbance, as well as to nutrient loads in areas with high concentrations of nitrogen and phosphorus. Nutrient and sediment loads from extractive industries, however, are difficult to estimate as volumetric discharge information is generally not available. The contributions of these industries to overall pollutant loads are not further considered.

Other Environmentally Relevant Activities

Eight additional ERAs, as well as those already described, are located within the Tully WQIP area. These include crude oil storing (ERA 11, 2x), motor vehicle workshop (ERA 28), marina or seaplane mooring (ERA 73), general waste disposal (ERA 75) and three unspecified ERAs. The contributions of these industries to sediment, nutrient and pesticide loads are not further considered.

Boat discharges

The discharge of vessel sewage is regulated by the Australian Maritime Safety Authority, the GBR Marine Park Authority and Maritime Safety Queensland. These regulations provide a range of sewage management options for vessel owners and operators to help maintain the environmental, health and aesthetic values of Queensland and GBR Marine Park waters.

Within the Tully WQIP area no vessel sewage discharges (whether treated or untreated) are permitted within a boat harbour, a canal, a marina (e.g. Port Hinchinbrook Marina), and a Marine National Park B, Preservation or Scientific Research zones (e.g. Hinchinbrook Channel). Moreover, all Class 1 Commercial vessels must have a sewage holding tank fitted. Additionally, untreated vessel sewage cannot be discharged within one nautical mile (1852 metres) of an aquaculture fisheries resource. For a vessel with 16 or more passengers, no discharge of vessel sewage is permitted within one nautical mile of a reef, the low water mark of an island or the mainland.

Discharge of vessel sewage can result in increased levels of nutrient and pathogen loadings, particularly in poorly flushed areas such as embayments and lagoons. Localised effects on coral reefs include reduced species diversity, lower coral cover and suppressed coral recruitment. Vessel sewage is, however, only a minor contributor to the overall nutrient load in the GBR region relative to the run-off derived from rural and urban sources (L. Gray, GBRMPA, pers. comm. 2007) and as an appropriately regulated activity is not further considered.

Unsewered residential areas

An unknown number of unlicensed septic systems are utilised by rural residential and agricultural households. These systems may contribute nutrients and pathogens to ground and surface water, particularly if they are not sited and maintained properly. Given the small rural population in the Tully WQIP area, these contributions are likely to be low but could be highly localised. For example, before Mission Beach was connected to the Tully STP, the composition of septic tank effluent was estimated at 50-60 mg N/L and 10-15 mg P/L in the sandy coastal strip (Sinclair Knight Merz 2000). A survey of groundwater nitrate concentrations in investigation wells in the Tully-Murray area showed that levels were within national drinking water guidelines (Thorburn *et al.* 2003).

In general, the rate and spatial extent of nutrient leaching depends largely on soil texture, trench size, aquifer configuration and rainfall. CSC has encouraged a change to aerated systems which treat sewage to secondary treatment level. These installations require a service contract that ensures regular maintenance and inspections of treatment effectiveness.

As no data is available on the number of septic tanks in the area, the contributions of septic tanks to pollutant loads are not further considered.

APPENDIX 4. Draft EVs and WQOs

Table 4.1. Water quality guidelines for each potential environmental value, based on State and National water quality guidelines, for (a) nutrients and sediment, and (b) pesticides. TAN = Total ammonia N, NO₂N = nitrite, NO₃N = nitrate, NO_xN = oxides of nitrogen, FRP = filterable reactive phosphorus, Chl-a = chlorophyll-a, TSS = total suspended sediments; guidelines for particulate nitrogen and phosphorus are not available. * See EPA (2006), Appendix B, for definitions of water types. ¹ = EPA (2006), ² = GBRMPA (2007), ³ = ANZECC (2000), ⁴ = NHMRC (2004), ⁵ = NHMRC (2006), ⁶ = ANZFSC (2007), na = not applicable, nd = no (or insufficient) data, ndr = no detectable residue.

a.

Environmental Values		Water quality guidelines for each potential environmental value												
		Water Type*	Indicator											
			Nutrients								Micro-algal growth	Water Clarity		
			Inorganic N				Organic N	Total N	FRP	Total P		Chl-a	Turbidity	Secchi
			TAN	NO ₂ N	NO ₃ N	NO _x N								
			µg/l								NTU	m	mg/L	
Aquatic Ecosystems	High Conservation Value Systems	Freshwater	Assess existing conditions in individual rivers or reaches. WQ objectives are set based on no change from existing values: i.e. no change in median and no change in outlying upper and lower percentiles.											
	Slightly to Moderately Disturbed systems	Upland freshwater	6 ¹	nd ¹	17 ³	30 ¹	125 ¹	150 ¹	5 ¹	10 ¹	0.6 ¹	6 ¹	na ¹	nd ¹
		Lowland freshwater	10 ¹	nd ¹	17 ³	30 ¹	200 ¹	240 ¹	4 ¹	10 ¹	1.5 ¹	15 ¹	na ¹	nd ¹
		Lakes	10 ¹	nd ¹	17 ³	10 ¹	330 ¹	350 ¹	5 ¹	10 ¹	3 ¹	2-200 ¹	nd ¹	nd ¹
		Wetlands	10 ¹	nd ¹	17 ³	10 ¹	330-1180 ¹	350-1200 ¹	5-25 ¹	10-50 ¹	10 ¹	2-200 ¹	na ¹	nd ¹
		Mid-estuary	15 ¹	nd ¹	nd ¹	30 ¹	200 ¹	250 ¹	5 ¹	20 ¹	3 ¹	10 ¹	1 ¹	nd ¹
		Enclosed coastal / lower estuary	15 ¹	nd ¹	nd ¹	10 ¹	135 ¹	160 ¹	5 ¹	20 ¹	2 ¹	10 ¹	1 ¹	nd ¹
		Open coastal	2 ¹	nd ¹	nd ¹	2 ¹	135 ¹	140 ¹	3 ¹	20 ¹	0.5 ²	1 ¹	nd ¹	nd ¹
	Marine offshore	1-6 ³	nd ³	nd ³	1-4 ³	nd ³	100 ³	2-5 ³	10 ³	0.3 ²	nd ³	nd ³	nd ³	
Highly Disturbed Systems	All	Assess existing WQ at the highly disturbed test site. Initial objective is to ensure no deterioration from this. Long-term objective is to attain the slightly to moderately disturbed objective value. Intermediate objectives can be set based on (a) 95%ile of reference values from a slightly disturbed reference site or (b) on references values from another site that is highly disturbed but that is nevertheless in measurably better condition than the test site												

Environmental Values		Water quality guidelines for each potential environmental value													
		Water Type*	Indicator												
			Nutrients									Micro-algal growth	Water Clarity		
			Inorganic N				Organic N	Total N	FRP	Total P	Chl-a	Turbidity	Secchi	TSS	
			TAN	NO ₂ N	NO ₃ N	NO _x N									
			µg/l									NTU	m	mg/L	
Primary Industries	Irrigation		nd	nd	nd	nd	nd	5,000 ³	nd	50 ³	nd	nd	nd	nd	
	Farm Use		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	
	Stock Water		nd	400,000 ³	30,000 ³	nd	nd	nd	nd	nd	nd	nd	nd	nd	
	Aquaculture	Upland & Lowland freshwater		1,000 ¹	<100 ¹	1,000-100,000 ¹	nd ¹	nd ¹	nd ¹	100 ³	nd ¹	nd ¹	80 ¹	nd ¹	40 ³
		Mid-estuary		1,000 ¹	<1,000 ¹	1,000-100,000 ¹	nd ¹	nd ¹	nd ¹	100 ³	nd ¹	nd ¹	nd ¹	nd ¹	75 ³
		Enclosed coastal / lower estuary		1,000 ¹	<1,000 ¹	1,000-100,000 ¹	nd ¹	nd ¹	nd ¹	100 ³	nd ¹	nd ¹	nd ¹	nd ¹	75 ³
		Open coastal		1,000 ¹	<1,000 ¹	1,000-100,000 ¹	nd ¹	nd ¹	nd ¹	50 ³	nd ¹	nd ¹	nd ¹	nd ¹	10 ³
Human Consumption		na	na	na	na	na	na	na	na	na	na	na	na	na	
Recreation & Aesthetics	Primary recreation		10 ³	3,000 ⁵	50,000 ⁵	nd ⁵	nd ⁵	nd ⁵	nd ⁵	nd ⁵	nd ⁵	nd ⁵	>1.6 ³	nd ⁵	
	Secondary Recreation		nd ⁵	nd ⁵	nd ⁵	nd ⁵	nd ⁵	nd ⁵	nd ⁵	nd ⁵	nd ⁵	nd ⁵	nd ⁵	nd ⁵	
	Visual Appreciation		na	na	na	na	na	na	na	na	nd ⁵	< 20% change ³	< 20% change ³	nd ⁵	
Drinking Water	Raw water supply		nd ⁴	3,000 ⁴	50,000 ⁴	nd ⁴	nd ⁴	nd ⁴	nd ⁴	nd ⁴	nd ⁴	5 ⁴	nd ⁴	<500 ⁴	
Industrial Uses	Industrial uses		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	
Cultural & Spiritual	Cultural and spiritual values		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	

b.

Environmental Values		Water quality guidelines for each potential environmental value											
		Water Type*	Indicator										
			Diuron	Atrazine	Chlor-pyrifos	Endo-sulfan	Ametryn	Simazine	Hexa-zinone	2,4-D	Tebu-thiuron	MEMC	Diazinon
µg/l													
Aquatic Ecosystems	High Conservation Value Systems	All	WQ objectives are set based on no detection of pesticides.										
	Slightly to Moderately Disturbed systems	Upland freshwater	0.2 ³	13 ³	0.01 ³	0.03 ³	nd ³	3.2 ³	75 ³	280 ³	2.2 ³	nd ³	0.01 ³
		Lowland freshwater	0.2 ³	13 ³	0.01 ³	0.03 ³	nd ³	3.2 ³	75 ³	280 ³	2.2 ³	nd ³	0.01 ³
		Lakes	0.2 ³	13 ³	0.01 ³	0.03 ³	nd ³	3.2 ³	75 ³	280 ³	2.2 ³	nd ³	0.01 ³
		Wetlands	0.2 ³	13 ³	0.01 ³	0.03 ³	nd ³	3.2 ³	75 ³	280 ³	2.2 ³	nd ³	0.01 ³
		Mid-estuary	nd ³	nd ³	nd ³	nd ³	nd ³	nd ³	nd ³	nd ³	nd ³	nd ³	nd ³
		Enclosed coastal / lower estuary	nd ³	nd ³	nd ³	nd ³	nd ³	nd ³	nd ³	nd ³	nd ³	nd ³	nd ³
		Open coastal	1.0 ²	6.6 ²	0.02 ²	0.005 ²	0.2 ²	11 ²	0.9 ²	52.6 ²	17.5 ²	0.002 ²	0.06 ²
	Marine offshore	1.0 ²	6.6 ²	0.02 ²	0.005 ²	0.2 ²	11 ²	0.9 ²	52.6 ²	17.5 ²	0.002 ²	0.06 ²	
Highly Disturbed Systems	All	Assess existing WQ at the highly disturbed test site. Initial objective is to ensure no deterioration from this. Long-term objective is to attain the slightly to moderately disturbed objective value. Intermediate objectives can be set based on (a) 95% <i>i</i>											

Environmental Values		Water quality guidelines for each potential environmental value												
		Water Type*	Indicator											
			Diuron	Atrazine	Chlor-pyrifos	Endo-sulfan	Ametryn	Simazine	Hexa-zinone	2,4-D	Tebu-thiuron	MEMC	Diazinon	
µg/l														
Primary Industries	Irrigation		2 ³	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	
	Farm Use		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	
	Stock Water		30 ⁴	0.1 ⁴	10 ⁴	0.05 ⁴	5 ⁴	0.5 ⁴	2 ⁴	0.1 ⁴	nd ⁴	nd ⁴	1 ⁴	
	Aquaculture #	Upland & Lowland freshwater		1.5 ³	nd ³	0.001 ³	0.003 ³	nd ³	10.0 ³	nd ³	0.004 ³	nd ³	nd ³	0.002 ³
		Mid-estuary		1.5 ³	nd ³	nd ³	nd ³	nd ³	10.0 ³	nd ³	0.004 ³	nd ³	nd ³	0.002 ³
		Enclosed coastal / lower estuary		1.5 ³	nd ³	nd ³	nd ³	nd ³	10.0 ³	nd ³	0.004 ³	nd ³	nd ³	0.002 ³
		Open coastal		1.5 ³	nd ³	nd ³	0.001 ³	nd ³	10.0 ³	nd ³	0.004 ³	nd ³	nd ³	0.002 ³
Human Consumption		ndr ⁶	ndr ⁶	ndr ⁶	ndr ⁶	ndr ⁶	ndr ⁶	ndr ⁶	ndr ⁶	ndr ⁶	ndr ⁶	ndr ⁶		
Recreation & Aesthetics	Primary recreation		30 ⁵	40 ⁵	10 ⁵	30 ⁵	50 ⁵	20 ⁵	300 ⁵	30 ⁵	nd ⁵	nd ⁵	3 ⁵	
	Secondary Recreation		nd ⁵	nd ⁵	nd ⁵	nd ⁵	nd ⁵	nd ⁵	nd ⁵	nd ⁵	nd ⁵	nd ⁵	nd ⁵	
	Visual Appreciation		na	na	na	na	na	na	na	na	na	na	na	
Drinking Water	Raw water supply		30 ⁴	0.1 ⁴	10 ⁴	0.05 ⁴	5 ⁴	0.5 ⁴	2 ⁴	0.1 ⁴	nd ⁴	nd ⁴	1 ⁴	
Industrial Uses	Industrial uses		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	
Cultural & Spiritual	Cultural and spiritual values		nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	

Table 4.2. Summary of draft environmental values and draft water quality objectives for each water type in catchments and coastal waters of the Tully WQIP area, for (a) nutrients and sediment, and (b) pesticides. TAN = Total ammonia N, NO₂N = nitrite, NO₃N = nitrate, NO_xN = oxides of nitrogen, FRP = filterable reactive phosphorus, Chl-a = chlorophyll-a, TSS = total suspended sediments. * See EPA (2006), Appendix B, for definitions of water types. ¹ = EPA (2006), ² = GBRMPA (2007), ³ = ANZECC (2000), ⁴ = NHMRC (2004), ⁵ = NHMRC (2006), ⁶ = ANZSC (2007); empty cells = no (or insufficient) data available to set draft WQOs (see Table 2).

a.

Segment of water body	Draft EV *	Draft water quality objectives											
		Indicator											
		Nutrients								Micro-algal Growth	Water Clarity		
		Inorganic N				Organic N	Total N	FRP	Total P	Chl-a	Turbidity	Secchi	TSS
		TAN	NO ₂ N	NO ₃ N	NO _x N								
µg/l								NTU	m	mg/L			
Hull River and coastal tributaries													
Freshwater in natural areas	Aquatic ecosystems Human consumption Primary recreation Secondary recreation Visual appreciation Drinking water Cultural and spiritual values	Existing water quality											
Freshwater in developed areas	Aquatic ecosystems Irrigation Farm supply Stock water Human consumption Secondary recreation Visual appreciation Cultural and spiritual values	10		17	30	200	240	4	10	1.5	15		
Natural wetlands	Aquatic ecosystems Visual appreciation Cultural and spiritual values	10		17	10	330-1180	350-1200	5-25	10-50	10	2-200		
Upstream limit of tidal influence to mouth of estuary	Aquatic ecosystems Aquaculture Human consumption Secondary recreation Visual appreciation Cultural and spiritual values	15			30	200	250	5	20	3.0	10	1	

Segment of water body	Draft EV *	Draft water quality objectives											
		Indicator											
		Nutrients								Micro-algal Growth	Water Clarity		
		Inorganic N				Organic N	Total N	FRP	Total P	Chl-a	Turbidity	Secchi	TSS
		TAN	NO ₂ N	NO ₃ N	NO _x N								
		µg/l								NTU	m	mg/L	
Tully River													
Freshwater in natural areas	Aquatic ecosystems Human consumption Primary recreation Secondary recreation Visual appreciation Drinking water Cultural and spiritual values	Existing water quality											
Freshwaters in developed areas	Aquatic ecosystems Irrigation Farm supply Stock water Human consumption Primary recreation Secondary recreation Visual appreciation Drinking water Industrial use Cultural and spiritual values	10		17	30	200	240	4	10	1.5	5		
Koombooloomba Dam	Aquatic ecosystems Human consumption Primary recreation Secondary recreation Visual appreciation Drinking water Industrial use Cultural and spiritual values	10			10	330	350	5	10	3.0	5		
Natural and constructed wetlands	Aquatic ecosystems Irrigation Farm supply Stock water Human consumption Primary recreation Secondary recreation Visual appreciation Cultural and spiritual values	10		17	10	330-1180	350-1200	5-25	10-50	10	2-200		
Upstream limit of tidal influence to mouth of estuary	Aquatic ecosystems Aquaculture Human consumption Secondary recreation Visual appreciation Cultural and spiritual values	15			30	200	250	5	20	3.0	10	1	

Segment of water body	Draft EV *	Draft water quality objectives											
		Indicator											
		Nutrients								Micro-algal Growth	Water Clarity		
		Inorganic N				Organic N	Total N	FRP	Total P	Chl-a	Turbidity	Secchi	TSS
		TAN	NO ₂ N	NO ₃ N	NO _x N								
		µg/l								NTU	m	mg/L	
Murray River													
Freshwater in natural areas	Aquatic ecosystems Human consumption Primary recreation Secondary recreation Visual appreciation Drinking water Cultural and spiritual values	Existing water quality											
Freshwaters in developed areas	Aquatic ecosystems Irrigation Farm supply Stock water Human consumption Secondary recreation Visual appreciation Drinking water Cultural and spiritual values	10		17	30	200	240	4	10	1.5	5		
Natural and constructed wetlands	Aquatic ecosystems Irrigation Farm supply Stock water Primary recreation Secondary recreation Visual appreciation Cultural and spiritual values	10		17	10	330-1180	350-1200	5-25	10-50	10	2-200		
Upstream limit of tidal influence to mouth of estuary	Aquatic ecosystems Human consumption Secondary recreation Visual appreciation Cultural and spiritual values	15			30	200	250	5	20	3.0	10	1	

Segment of water body	Draft EV *	Draft water quality objectives											
		Indicator											
		Nutrients								Micro-algal Growth	Water Clarity		
		Inorganic N				Organic N	Total N	FRP	Total P	Chl-a	Turbidity	Secchi	TSS
		TAN	NO ₂ N	NO ₃ N	NO _x N								
		µg/l								NTU	m	mg/L	
Dallachy Creek													
Freshwater in natural areas	Aquatic ecosystems Human consumption Primary recreation Secondary recreation Visual appreciation Drinking water Cultural and spiritual values	Existing water quality											
Freshwaters in developed areas	Aquatic ecosystems Irrigation Farm supply Stock water Human consumption Secondary recreation Visual appreciation Drinking water Cultural and spiritual values	10		17	30	200	240	4	10	1.5	5		
Natural wetlands	Aquatic ecosystems Irrigation Farm supply Stock water Human consumption Secondary recreation Visual appreciation Cultural and spiritual values	10		17	10	330-1180	350-1200	5-25	10-50	10	2-200		
Upstream limit of tidal influence to mouth of estuary	Aquatic ecosystems Human consumption Secondary recreation Visual appreciation Cultural and spiritual values	15			30	200	250	5	20	3.0	10	1	

Segment of water body	Draft EV *	Draft water quality objectives											
		Indicator											
		Nutrients								Micro-algal Growth	Water Clarity		
		Inorganic N				Organic N	Total N	FRP	Total P	Chl-a	Turbidity	Secchi	TSS
		TAN	NO ₂ N	NO ₃ N	NO _x N								
		µg/l								NTU	m	mg/L	
Kennedy & Meunga Creeks													
Freshwater in natural areas	Aquatic ecosystems Human consumption Primary recreation Secondary recreation Visual appreciation Drinking water Cultural and spiritual values	Existing water quality											
Freshwaters in developed areas	Aquatic ecosystems Irrigation Farm supply Stock water Human consumption Secondary recreation Visual appreciation Drinking water Cultural and spiritual values	10		17	30	200	240	4	10	1.5	5		
Natural wetlands	Aquatic ecosystems Irrigation Farm supply Stock water Secondary recreation Visual appreciation Cultural and spiritual values	10		17	10	330-1180	350-1200	5-25	10-50	10	2-200		
Upstream limit of tidal influence to mouth of estuary	Aquatic ecosystems Human consumption Secondary recreation Visual appreciation Cultural and spiritual values	15			30	200	250	5	20	3.0	10	1	

Segment of water body	Draft EV *	Draft water quality objectives											
		Indicator											
		Nutrients								Micro-algal Growth	Water Clarity		
		Inorganic N				Organic N	Total N	FRP	Total P	Chl-a	Turbidity	Secchi	TSS
		TAN	NO ₂ N	NO ₃ N	NO _x N								
		µg/l								NTU	m	mg/L	
Coastal creeks to Hinchinbrook Channel													
Freshwater in natural areas	Aquatic ecosystems Human consumption Primary recreation Secondary recreation Visual appreciation Drinking water Cultural and spiritual values	Existing water quality											
Freshwaters in developed areas	Aquatic ecosystems Farm supply Stock water Human consumption Primary recreation Secondary recreation Visual appreciation Drinking water Cultural and spiritual values	10		17	30	200	240	4	10	1.5	5		
Natural wetlands	Aquatic ecosystems Irrigation Farm supply Stock water Secondary recreation Visual appreciation Cultural and spiritual values	10		17	10	330-1180	350-1200	5-25	10-50	10	2-200		
Upstream limit of tidal influence to mouth of estuary	Aquatic ecosystems Aquaculture Human consumption Primary recreation Secondary recreation Visual appreciation Cultural and spiritual values	10			30	200	250	5	20	3.0	10	1	

Segment of water body	Draft EV *	Draft water quality objectives											
		Indicator											
		Nutrients								Micro-algal Growth	Water Clarity		
		Inorganic N				Organic N	Total N	FRP	Total P	Chl-a	Turbidity	Secchi	TSS
		TAN	NO ₂ N	NO ₃ N	NO _x N								
		µg/l								NTU	m	mg/L	
Inshore marine													
Mouth of estuary to marine waters	Aquatic ecosystems Aquaculture Human consumption Primary recreation Secondary recreation Visual appreciation Cultural and spiritual values	15			10	135	160	5	20	2.0	10	1.0	
All marine waters ≤ 15km off the coast	Aquatic ecosystems Human consumption Primary recreation Secondary recreation Visual appreciation Cultural and spiritual values	2		910	2	135	140	3	20	0.5	1		
Offshore marine													
All marine waters >15km off the coast	Aquatic ecosystems Human consumption Primary recreation Secondary recreation Visual appreciation Cultural and spiritual values	1-6			1-4		100	2-5	10	0.3			

b.

Segment of water body	Draft EV *	Draft water quality objectives										
		Indicator										
		Diuron	Atrazine	Chlorpyrofos	Endo-sulfan	Ametryn	Simazine	Hexa-zinone	2,4-D	Tebu-thiuron	MEMC	Diazinon
µg/l												
Hull River and coastal tributaries												
Freshwater in natural areas	Aquatic ecosystems Human consumption Primary recreation Secondary recreation Visual appreciation Drinking water Cultural and spiritual values	No detection of pesticides.										
Freshwater in developed areas	Aquatic ecosystems Irrigation Farm supply Stock water Human consumption Secondary recreation Visual appreciation Cultural and spiritual values	0.2	0.1	0.01	0.03	5	0.5	2.0	0.1	2.2	nd	0.01
Natural wetlands	Aquatic ecosystems Visual appreciation Cultural and spiritual values	0.2	13	0.01	0.03	nd	3.2	75.0	280	2.2	nd	0.01
Upstream limit of tidal influence to mouth of estuary	Aquatic ecosystems Aquaculture Human consumption Secondary recreation Visual appreciation Cultural and spiritual values											

Segment of water body	Draft EV *	Draft water quality objectives										
		Indicator										
		Diuron	Atrazine	Chlor-pyros	Endo-sulfan	Ametryn	Simazine	Hexa-zinone	2,4-D	Tebu-thiuron	MEMC	Diazinon
		µg/l										
Tully River												
Freshwater in natural areas	Aquatic ecosystems Human consumption Primary recreation Secondary recreation Visual appreciation Drinking water Cultural and spiritual values	No detection of pesticides.										
Freshwaters in developed areas	Aquatic ecosystems Irrigation Farm supply Stock water Human consumption Primary recreation Secondary recreation Visual appreciation Drinking water Industrial use Cultural and spiritual values	0.2	0.1	0.01	0.03	5	0.5	2.0	0.1	2.2	nd	0.01
Koombooloomba Dam	Aquatic ecosystems Human consumption Primary recreation Secondary recreation Visual appreciation Drinking water Industrial use Cultural and spiritual values	0.2	0.1	0.01	0.03	5	0.5	2.0	0.1	2.2	nd	0.01
Natural and constructed wetlands	Aquatic ecosystems Irrigation Farm supply Stock water Human consumption Primary recreation Secondary recreation Visual appreciation Cultural and spiritual values	0.2	0.1	0.01	0.03	5	0.5	2.0	0.1	2.2	nd	0.01
Upstream limit of tidal influence to mouth of estuary	Aquatic ecosystems Aquaculture Human consumption Secondary recreation Visual appreciation Cultural and spiritual values											

Segment of water body	Draft EV *	Draft water quality objectives										
		Indicator										
		Diuron	Atrazine	Chlorpyrifos	Endosulfan	Ametryn	Simazine	Hexazinone	2,4-D	Tebu-thiuron	MEMC	Diazinon
		µg/l										
Murray River												
Freshwater in natural areas	Aquatic ecosystems Human consumption Primary recreation Secondary recreation Visual appreciation Drinking water Cultural and spiritual values	No detection of pesticides.										
Freshwaters in developed areas	Aquatic ecosystems Irrigation Farm supply Stock water Human consumption Secondary recreation Visual appreciation Drinking water Cultural and spiritual values	0.2	0.1	0.01	0.03	5	0.5	2.0	0.1	2.2	nd	0.01
Natural and constructed wetlands	Aquatic ecosystems Irrigation Farm supply Stock water Primary recreation Secondary recreation Visual appreciation Cultural and spiritual values	0.2	0.1	0.01	0.03	5	0.5	2.0	0.1	2.2	nd	0.01
Upstream limit of tidal influence to mouth of estuary	Aquatic ecosystems Human consumption Secondary recreation Visual appreciation Cultural and spiritual values											

Segment of water body	Draft EV *	Draft water quality objectives										
		Indicator										
		Diuron	Atrazine	Chlorpyrifos	Endosulfan	Ametryn	Simazine	Hexazinone	2,4-D	Tebu-thiuron	MEMC	Diazinon
		µg/l										
Dallachy Creek												
Freshwater in natural areas	Aquatic ecosystems Human consumption Primary recreation Secondary recreation Visual appreciation Drinking water Cultural and spiritual values	No detection of pesticides.										
Freshwaters in developed areas	Aquatic ecosystems Irrigation Farm supply Stock water Human consumption Secondary recreation Visual appreciation Drinking water Cultural and spiritual values	0.2	0.1	0.01	0.03	5	0.5	2.0	0.1	2.2	nd	0.01
Natural wetlands	Aquatic ecosystems Irrigation Farm supply Stock water Human consumption Secondary recreation Visual appreciation Cultural and spiritual values	0.2	0.1	0.01	0.03	5	0.5	2.0	0.1	2.2	nd	0.01
Upstream limit of tidal influence to mouth of estuary	Aquatic ecosystems Human consumption Secondary recreation Visual appreciation Cultural and spiritual values											

Segment of water body	Draft EV *	Draft water quality objectives										
		Indicator										
		Diuron	Atrazine	Chlorpyrifos	Endosulfan	Ametryn	Simazine	Hexazinone	2,4-D	Tebu-thiuron	MEMC	Diazinon
		µg/l										
Kennedy & Meunga Creeks												
Freshwater in natural areas	Aquatic ecosystems Human consumption Primary recreation Secondary recreation Visual appreciation Drinking water Cultural and spiritual values	No detection of pesticides.										
Freshwaters in developed areas	Aquatic ecosystems Irrigation Farm supply Stock water Human consumption Secondary recreation Visual appreciation Drinking water Cultural and spiritual values	0.2	0.1	0.01	0.03	5	0.5	2.0	0.1	2.2	nd	0.01
Natural wetlands	Aquatic ecosystems Irrigation Farm supply Stock water Secondary recreation Visual appreciation Cultural and spiritual values	0.2	0.1	0.01	0.03	5	0.5	2.0	0.1	2.2	nd	0.01
Upstream limit of tidal influence to mouth of estuary	Aquatic ecosystems Human consumption Secondary recreation Visual appreciation Cultural and spiritual values											

Segment of water body	Draft EV *	Draft water quality objectives										
		Indicator										
		Diuron	Atrazine	Chlorpyrifos	Endosulfan	Ametryn	Simazine	Hexazinone	2,4-D	Tebu-thiuron	MEMC	Diazinon
		µg/l										
Coastal creeks to Hinchinbrook Channel												
Freshwater in natural areas	Aquatic ecosystems Human consumption Primary recreation Secondary recreation Visual appreciation Drinking water Cultural and spiritual values	No detection of pesticides.										
Freshwaters in developed areas	Aquatic ecosystems Farm supply Stock water Human consumption Primary recreation Secondary recreation Visual appreciation Drinking water Cultural and spiritual values	0.2	0.1	0.01	0.03	5	0.5	2.0	0.1	2.2	nd	0.01
Natural wetlands	Aquatic ecosystems Irrigation Farm supply Stock water Secondary recreation Visual appreciation Cultural and spiritual values	0.2	0.1	0.01	0.03	5	0.5	2.0	0.1	2.2	nd	0.01
Upstream limit of tidal influence to mouth of estuary	Aquatic ecosystems Aquaculture Human consumption Primary recreation Secondary recreation Visual appreciation Cultural and spiritual values											

Segment of water body	Draft EV *	Draft water quality objectives										
		Indicator										
		Diuron	Atrazine	Chlor-pyrosfos	Endo-sulfan	Ametryn	Simazine	Hexa-zinone	2,4-D	Tebu-thiuron	MEMC	Diazinon
		µg/l										
Inshore marine												
Mouth of estuary to marine waters	Aquatic ecosystems Aquaculture Human consumption Primary recreation Secondary recreation Visual appreciation Cultural and spiritual values											
All marine waters ≤ 15km off the coast	Aquatic ecosystems Human consumption Primary recreation Secondary recreation Visual appreciation Cultural and spiritual values	1.0	6.6	0.02	0.005	0.2	11	0.9	52.6	17.5	0.002	0.06
Offshore marine												
All marine waters >15km off the coast	Aquatic ecosystems Human consumption Primary recreation Secondary recreation Visual appreciation Cultural and spiritual values	1.0	6.6	0.02	0.005	0.2	11	0.9	52.6	17.5	0.002	0.06

APPENDIX 5. Measures and actions for pollutant sources

Diffuse sources of pollution

The diffuse sources contribute the largest amounts to the total annual sediment and nutrient loads, with most agricultural industries contributing a disproportionately large amount per unit area (Section 3.4). In addition to increased areas of fertiliser-additive land use, the nitrogen load to receiving waters has most likely increased due to removal of wetlands and the installation of land drainage systems in the coastal floodplains. The widespread detection of herbicides, including concentrations above water quality guidelines for aquatic ecosystems, drinking water and stock water, combined with documented community concern about pesticides use, indicates that all users also need to immediately address herbicide management.

Natural forests in protected areas

Potential sources of increased *sediment* (and associated *nutrients*) run-off in natural forest areas are roads (including old logging roads), walking trails, camping areas and pigs. While current load contributions could be considered 'natural'; agencies need to report on current uptake of management practices against relevant Acts and Regulations to demonstrate that sediment and nutrient contributions from protected areas are minimised. Increased loads from protected areas may now reach receiving waters, particularly during over bank flows, due to clearance and drainage of the coastal floodplain (see 'Waterways').

Management of feral pigs in protected areas is a particularly sensitive issue in the catchment, in part because feral pigs are perceived as contributing to water quality problems (Bohnet *et al.* 2007). It is recommended that the contribution of pigs to sediment and nutrient loads is quantified to ensure cost-effective distribution of resources to water quality improvement.

Importantly, since protected areas are the largest land use in the Tully-Murray basin, it is critical for agencies responsible for its management to become active partners in the CSFP, to ensure successful implementation of the Tully WQIP.

Sugarcane

The 'Six Easy Steps' process is recommended to be delivered immediately to all Tully-Murray growers, for improved N management, resulting in improved cost efficiencies for farmers and a 23% reduction in DIN delivery to end-of-river. This process will complement delivery of the draft program for NMZs in the Wet Tropics (DPI&F 2007).

Concurrently, the development of the 'N replacement' concept is being supported and tested for Tully conditions. Progress needs to be closely monitored over a number of seasons, to validate the modelled reduction in DIN delivery to end-of-river (45%) and associated cost efficiencies. Once validated, an implementation program of N replacement is supported.

Other N management programs, such as 'N fixation', could provide benefits to growers and receiving waters, but need to be validated and assessed, requiring significant investment. Modelled reduction in DIN delivery to end-of river (66%) is promising.

To determine the optimum N management strategy for sugarcane growers and receiving waters, interactions between all available N management practices should be investigated and extended. This needs to include cost-benefit analyses of legume fallow, and mill mud and split-nitrogen applications.

To improve retention of herbicides on-site and reduce herbicides levels in off-site waterways, BSES will extend revised and recommended herbicide application strategies to sugarcane growers in September 2007, and has employed a weeds agronomist to revise their Herbicide Manual (Calcino and Hurney 2007). Herbicide reduction strategies need to focus on ratoon crops, as these occupy ~70% of the cane production area and are mostly sprayed during the wet season (Calcino and Hurney, 2007). Chemcert® accreditation and application guidelines need to be improved to reflect local (rather than generic) environmental conditions (including timing, rainfall, etc.) (Robinson *et al.* 2007), and be adopted by all sugarcane farmers. The use of hooded sprayers can significantly reduce herbicide application, but its current uptake and the potential effect on yield costs are unknown, and need to be determined.

Complete uptake of zero tillage is the most cost-effective manner to reduce sediment delivery, both at the plot and catchment-scale (Roebeling 2007a,b). Drain improvement can significantly reduce sediment losses to receiving waters (Davis 2006), however, it is considered costly while potentially leading to a decrease in sugarcane production (Roebeling and Webster 2007). Hence, investment needs to focus on (i) drain improvement in sediment hot-spot areas, and (ii) research into drain design and effects on yields (Roebeling and Webster 2007).

A proposed mechanism for the sugarcane sector to report regularly on management practices uptake and adoption, is to link the mill's intake of sugarcane with the lodging of a survey by individual farmers. The Tully Sugar Mill, as well as other FNQ mills, could thus play a critical role in collating management practices information on behalf of their constituents, as well as progressively ensuring that farmers adopt sustainable practices.

Grazing

The Queensland grazing industry and DPI&F need to accelerate the development and implementation of 'Wet Grazing' Grazing Land Management for the Wet Tropics.

Information on management practice uptake in grazing was not available at the time of writing, and needs to be reported upon by DPI&F. This benchmark needs to be used to prioritise nutrient, sediment and pesticide management strategies in grazing.

Residual sources of increased *sediment* (and associated *nutrients*) run-off in grazing areas are (i) non-optimal stocking rates, (ii) stream bank erosion associated with cattle access, and (iii) low adoption rates of management practices associated with river and stream stabilisation. Matching stocking rates to pasture carrying capacity is expected to increase production at no extra cost while decreasing sediment run-off, and should be included as a component of the Wet Tropics Grazing Land Management. River and stream bank management, and associated establishment of off-stream or hard surface watering points, requires considerable investment without a direct financial return to the grazier, unless species that can be harvested are planted. In order to reduce recurring fencing costs in flood-prone grazing areas, virtual fencing technology (e.g. laser, GPS) needs to be examined.

Current *pesticide* use and application rates in the grazing industry are unknown, and need to be determined for inclusion in the pesticide risk assessments (Section 3.4). Further, all graziers need to become Chemcert® (or equivalent) accredited.

Plantation forestry

In light of the recent and future expansion of plantation forestry in the Tully-Murray basin, and across FNQ, the relevant agencies need to urgently develop and implement a Code of Practice for native and non-native forest plantation production on freehold land.

It is recommended that NRW and EPA consider the potential impacts on water quantity and quality of conversion of sugarcane and grazing areas into forestry plantations. The current FNQ 2025 planning process, including the establishment of critical land use categories for the region, may ensure that future changes in land use will happen in light of 'land fit for purpose'.

Potential sources of increased *sediment* (and associated *nutrients*) run-off in forestry plantations are (i) site preparation and cultivation during the wet season, (ii) bare inter-rows and (iii) riparian management. Site preparation and cultivation during the wet season needs to be avoided, as it significantly increases the chance of sediment run-off. Inter-row management incurs ongoing, regular maintenance costs while yield benefits are not expected, but could be negated with cattle grazing once seedlings are well established. River and stream bank management require considerable investment without a direct financial return, unless species that can be harvested are planted. Nutrient management in plantation forestry could potentially be improved by including soil analysis.

CSIRO needs to improve the crop growth model used for plantation forestry (LUCTOR) to enable more realistic assessment of cost-effectiveness of management practices, and associated changes in water quality.

Current *pesticide* use and application rates in plantation forestry are not well documented, except that both simazine and glyphosate are used. Pesticides use and application rates need to be determined for inclusion in

the pesticide risk assessments (Section 3.4). Further, all foresters need to become Chemcert® or equivalent accredited.

Bananas and other horticulture

Both monitoring and modelling results demonstrate that current N and P application can be substantially reduced (Armour and Danniells 2001, Armour *et al.* 2007), and are being extended to the banana industry. Efforts should be geared towards the expansion of current nutrient management programs in horticulture into a process that establishes soil-specific recommendation for nutrient application in banana (e.g. Growcom FMS). CCI has recently funded a 14 month project (July 2007 to August 2008) to develop a decision support tool for nutrient management in tropical horticulture, including banana production in the Tully and Johnstone. Moreover, greater on-farm capacity is currently being built through a CCI-funded 15 month project (February 2007 to May 2008) to trial and extend Growcom Farm Management System (FMS) in the Wet Tropics (including Tully). To determine the optimum nutrient management strategy for banana growers and receiving waters, interactions between all available nutrient management practices should be investigated and extended, including cost-benefit analyses of fertigation systems, soil and leaf analysis for N and P, inclusion of organic waste and soil moisture management (Roebeling and Webster 2007).

The banana industry has been identified as a major user of *pesticides*, some of which may possess high risk to the aquatic environment (Section 3.4; Gaus *et al.* 2007). These include all insecticides (chlorpyrifos, prothiofos, diazinon, fipronil, and bifenthrin), two nematicides (fenamiphos, cadusafos), and one herbicide (paraquat). This ranking for banana pesticides needs to be used to prioritise management strategies that minimize off-site impacts of these pesticides, and to guide water quality monitoring programs. Both the economic and biophysical impacts of new pesticide management strategies are recommended to be assessed. Further, all banana growers and other horticulturalists need to become Chemcert® accredited.

Residual *sediment* sources in banana appear to be present in (i) fallow management and (ii) inter-row management. Growing a break crop between cropping cycles is expected to provide benefits for water quality, yields and gross margin (Roebeling and Webster 2007). Complete uptake of zonal tillage can reduce sediment delivery, however, current uptake and effects on yield and gross margin are unknown and need to be determined.

CSIRO needs to improve the crop growth model used for plantation forestry (LUCTOR) to enable more realistic assessment of cost-effectiveness of management practices, and associated changes in water quality. Alternatively, CSIRO need to adjust the sugarcane production model (APSIM) for bananas.

Complete uptake for disposal of inorganic waste through registered contractors or services, and treatment of waste water is recommended. The presence of (highly visible) litter in the catchment (e.g. Brodie *et al.* 2007a) may negate other improvements in banana industry practices as far as community perception is concerned. The development and use of biodegradable bunch covers and strings would at least minimise potential impacts downstream. There is community concern about the (lack of inspection on) quality of waste water being released into the river (Bohnet *et al.* 2006), and the low uptake of waste water treatment. It is recommended that EPA investigate the quality of waste water from banana packing sheds and consider including its release as a licensed Environmentally Relevant Activity under the *Environmental Protection Regulation 1998* if appropriate.

Urban run-off and development sites

Compliance rates with the FNQROC Regional Development Manual (2004) are unknown and it is recommended that they be determined. A partnership between CSC and EPA will strengthen local capacity and improve timely and strategic response to unsustainable urban land and water management practices (Robinson *et al.* 2007). Such a partnership need to drive a full, consistent adoption of water sensitive urban design practices, with certainty this will happen to a high standard, with the policy and regulatory framework in place to ensure desired outcomes. A State Planning Policy is currently being developed under the *Integrated Planning Act 1997* with guidelines for local government urban stormwater planning and development assessment, as well as provisions in Coastal Management Plans under the *Coastal Protection and Management Act 1995* (P. Curley, EPA, pers. comm. 2007). The main water quality issue addressed is urban stormwater quality management for new urban development.

The projected population growth in the area and its potential impact on water quality (Roebeling *et al.* 2007b) emphasises the urgency and importance of adoption of water sensitive urban design practices for

residential land uses in Cardwell Shire. Alternatively, population growth and associated residential development may be constrained at levels that maximise benefits from both terrestrial and marine based economies (Roebeling *et al.* 2007c).

Waterways, including river and stream banks

Currently available data on water quality and aquatic foods needs to be compared with draft WQOs for fresh, estuarine and marine waters. These data can include compliance monitoring data for licensed point sources (EPA), catchment and end-of-river monitoring data (NRW), and end-of-river and marine monitoring data (GBRMPA). As it is unlikely that all 28 reaches will be covered by existing data, it is recommended that a monitoring program be established to assess water quality and aquatic foods in the remaining reaches by EPA.

Management of waterways, including river banks, extraction and drainage, is a political issue in the Tully-Murray basin. Engineering solutions to reduce bank erosion have included the complete rock armouring of the Tully River, which is extremely expensive and their effectiveness in improving overall water quality has not been demonstrated (Lait 2007). Bank erosion, and associated *sediment and nutrient* losses, can be reduced by large-scale riparian rehabilitation (Armour *et al.* 2007a; Rassam and Pagendam 2007). While such works will also require significant investments, implementation will enhance protection of identified environmental values such as aquatic ecosystems, indigenous and non-indigenous cultural heritage, and amenity. Alternative (non-engineering) solutions to reduce bank erosion along large waterways may need to be explored, including progressively buying out sections of neighbouring farmland for complete rehabilitation of waterways, or establishing a 'river-bank' where neighbouring landholders deposit and exchange land gained and lost during floods.

It is recommended that a *Water Resources Plan (WRP)* for the Wet Tropics, developed under the *Water Act 2000*, will be developed for the Tully-Murray area by NRW. This proposed WRP will determine environmental flows within the Tully-Murray system, and should set the foundation for decision making in relation to water extraction within the system. This is particularly important in light of recently proposed schemes and established taskforces, such as the Bradfield scheme and the Northern Australian Land and Water Taskforce. The development of a WRP will need to document and report on location, size and intake of current water extraction operations, to demonstrate that irrigation licenses and bores are sustainable. A strong alignment of this planning process with the Tully WQIP will ensure sustainable management of both water quality and water quantity in the Tully-Murray basin.

Drainage is not coordinated on a catchment-wide scale, despite a key recommendation in Drummond (1993) for the CS RIT to develop and oversee the implementation of a coordinated Drainage Control Plan. Uncontrolled drainage and levee banks will result in inequitable off-site impacts (Drummond 1993), including impacts on water quality in catchment and receiving waters. To manage drainage, and associated water quality issues, at a catchment scale, it is critical that the key recommendation by Drummond is followed up on by NRW together with CS RIT. Specifically, the institutional arrangements of drainage and the current regulated status of the catchment should be clarified and reviewed. A Drainage Review Plan needs to include spatially explicit, catchment-wide data on the approximately 1,100 km of constructed drains present in the area.

It is recommended that drainage management at the farm scale needs to be targeted towards erosion hot spots in the catchment by DPI&F. No duty of care is placed on farmers on existing drains, unless they are declared drains and embankment areas. Appropriate market-based incentives may need to be developed by CSIRO, and targeted towards erosion hot spot areas by DPI&F.

Substantial research effort will need to be directed towards evaluating the filtering role of coastal floodplains, including the filter function of riparian zones and wetland areas, and the role of drainage systems in increasing runoff rates and amounts, with a view to re-establish at least some of this filtering function. This could include the establishment of low lying areas as water retention basins during floods. A current CSIRO study is examining the filtering function of Kyambul lagoon. Results from a monitoring study to assess the effectiveness of silt traps and constructed wetlands in sediment capture in Roper's Creek sub-catchment are not available at the time of writing.

Five wetlands have so far been identified for investment from the GBR Coastal Wetland Protection Program, based on an evaluation and prioritisation for restoration using a wetland decision support system (D. Sydes, CSC, pers. comm. 2007). These are Kyambul, Porters Creek coastal wetlands, Bunta lagoons, Glenbora

wetlands and Domouros swamp. It is recommended that the protection of remaining wetland areas, including swamps and lagoons, be considered.

Research and management of pests (e.g. pigs) and weeds (e.g. hymenachne, paragrass and pond apple) should focus on quantifying and minimising potential impacts on water quality, to ensure cost-effective management of water quality problems. Current work is underway by CSC to assess the effectiveness of riparian restoration in reducing hymenachne infestations in the Upper Murray, and by Boar Busters to manage pig numbers in Mission Beach and surrounding areas.

Point sources of pollution

Point sources of pollution are regulated activities. This means they have been assessed, deemed to have met environmental management considerations and conditioned accordingly. Monitoring information was not obtained for most licensed point sources. This has made it difficult to determine, as accurately as possible, (i) the proportional contribution of point sources to the total annual sediment, nutrient and pesticide loads, as well as (ii) whether current water quality meets the draft WQOs and National and State water quality guidelines for fresh and estuarine waters. Based on the currently available information, point sources contribute a small proportion ($\leq 7.5\%$) to the total annual sediment, nutrient and pesticide loads. While contributions of point sources are small compared to those by diffuse sources, these contributions are likely to be highly localised and in some cases seasonal. It is recommended that EPA works with point source industries to compare their monitoring information against the draft WQOs and State and National water quality guidelines.

To strengthen local capacity and improve timely and strategic response to unsustainable urban land and water management practices, CSC has proposed a partnership between EPA and CSC (Robinson *et al.* 2007). These practices include environmental compliance responsibilities for sewage management, trade waste management, urban storm water quality management, and water conservation activities, as described under the *Environmental Protection Act 1994*. To implement such a partnership CSC proposes to locate, and jointly resource with EPA, an environmental compliance officer in Cardwell Shire. It is recommended that such a partnership is extended to include all point sources in the area, including Tully Sugar Mill, aquaculture and extractive industries.

Tully Sugar Mill

The Mill's license does not specify limits for either nutrient or pesticide concentrations in discharges. However, given the apparent role of the Mill's discharge in promoting outbreaks of 'sewage fungus' (N. Connolly, EPA, pers. comm. 2007), nutrient concentrations in the discharge need to be assessed and compared against draft WQOs and Qld Water Quality Guidelines for fresh and estuarine waters (EPA 2006). Furthermore, to distinguish nutrient inputs from the Tully Sugar Mill and the STP, respectively, it is recommended that a nutrient monitoring program is established in Banyan Creek. The Mill is currently involved in a study with Bundaberg Sugar and Queensland University of Technology on the formation and impacts of 'sewage fungus' in Banyan Creek (J. King, General Manager TSM, pers. comm. 2007). Further, the detection of various herbicides in Banyan Creek (Faithfull *et al.* 2007) warrants an examination of the mill's discharge for these pollutants.

The TSS concentrations in the Tully Sugar Mill's discharges have been consistently within permit conditions. Consequently, no management practices are recommended for this pollutant for the Mill, aside from ensuring that permit conditions continue to be met.

The Tully Sugar Mill does have an issue meeting its BOD conditions (Roberts 2007). Extensive modifications initiated by the Mill have not yet solved the BOD problem, and EPA may need to work with the Tully Sugar Mill to identify a new approach.

Tully Sewage Treatment Plant

The Tully STP currently meets all license conditions (B. Barrat, CSC, pers. comm. 2007), consequently, no management practices are recommended for these pollutants for the STP, aside from ensuring that permit conditions continue to be met.

Various herbicides were detected in Banyan Creek downstream from the STP (Faithful *et al.* 2007), however, it is highly unlikely that the STP would have contributed to those. Analyses of organochlorine

pesticides in solids were inconclusive (GHD 2005, in Roberts 2007), and it is recommended that CSC re-examines concentrations of these pesticides in both effluent and solids.

The STP produces significant amounts of solids (3 m³ / day) that need to be disposed of consistently and sustainably. Due to the detected presence of organochlorine pesticides, the solids are classified as restricted use (i.e. not for domestic or residential use). As no records on use of solids appear to exist, CSC and EPA need to ensure that solid disposal guidelines, outlining conditions and requirements of receiving soils in agriculture, land rehabilitation and plantation forestry (see GHD 2005, in Roberts 2007), are being met.

Resorts, caravan parks and holiday villages

To ensure draft WQOs and other water quality guidelines (EPA 2006, Honchin *et al.* 2007) are being met, EPA and industry need to check and report on monitoring records. In case of non-compliance, appropriate management practices and control actions need to be put in place.

Aquaculture facilities

To ensure draft WQOs and other water quality guidelines (EPA 2006, Honchin *et al.* 2007) are being met, EPA and industry need to check and report on monitoring records. In case of non-compliance, appropriate management practices and control actions need to be put in place. DPI&F can work with industry to assist in technology change (e.g. further uptake of recirculation technology) and environmental compliance under the *Fisheries Act 1994*.

EPA and industry need to examine and report on usage and/or monitoring information for other potential pollutants of concern, such as antibiotics.

Extractive industries (including dredging and quarries)

To ensure draft WQOs and other water quality guidelines (EPA 2006, Honchin *et al.* 2007) are being met, EPA, NRW and industry need to check and report on monitoring records. In case of non-compliance, appropriate management practices and control actions need to be put in place.

To determine a sustainable rate of extraction for the Tully River, EPA needs to commission a fluvial study to examine the relationship between sand available for extraction within the river system, potential erosion of the adjacent bed or banks, longshore transport, and beach nourishment. Based on recommendations by the former Beach Protection Authority that no further permits be issued unless operators could provide information or data in the form of such a fluvial study, the EPA has advised operators to provide them with such data. EPA has also started to explore cost sharing initiatives to undertake such a study amongst stakeholders, including operators, EPA, NRW, and CSC. It is recommended that the undertaking of a fluvial study may be progressed via the CS RIT.

More effective and efficient arrangements for permit applications, as well as for ensuring compliance, need to be explored for sand extraction by licensing agencies (EPA, NRW), council and operators. It is recommended that the lead agency keeps a spatial database on the number, size and state of operation of extractive industries, with a shared agreement for efficiency gains across jurisdictions. This would also facilitate input from DPI&F and other organisations (e.g. RIT) on potential (downstream) impacts of extractive operations.

Other Environmentally Relevant Activities

To ensure draft WQOs and other water quality guidelines (EPA 2006, Honchin *et al.* 2007) are being met, EPA and industry need to check and report on monitoring records. In case of non-compliance, appropriate management practices and control actions need to be put in place.

Boat discharges

Vessel discharges are addressed under existing regulations. In January 2010, existing regulations for vessel sewage discharge will be further strengthened by the inclusion of the following:

- 7 to 15 passengers - nil discharge of untreated sewage within 1 nautical mile of a reef, the low water mark of an island or the mainland; and
- 16 or more passengers - no discharge to open waters.

Emphasis on communicating these changes to both commercial and recreational vessel owners should be a priority for the responsible Government agencies (Australian Maritime Safety Authority, the GBRMPA and Maritime Safety Queensland). Compliance auditing should also be undertaken to ensure that the chances for localised impacts associated with the discharge of vessel sewage are minimised.

Unsewered residential areas

To prevent or mitigate pollution problems in areas not connected to the Tully STP, particularly in areas where bores are used to access drinking water, it is critical that owners ensure regular maintenance and inspections of septic systems. It is recommended that CSC keeps a spatial database on the number, size and state of operation of residential septic systems, and number of bores used to access drinking water (see also 5.3.3.2, Drinking water).

Additional water quality issues and threats identified by the community

Developed under the *Reef Water Quality Protection Plan* (The State of Queensland & Commonwealth of Australia 2003), the Tully WQIP is primarily concerned with reducing sediment, nutrient and pesticide loads in the water entering the GBR. Additional pollutants and issues of concern were identified during community interviews and workshops (Section 2; Bohnet *et al.* 2006, 2007; see also Brodie *et al.* 2007a). Management practices and control actions for some of these have been described above (e.g. sewage treatment on islands, feral pigs, waste from banana production systems, urban development, maintaining healthy mangroves and wetlands, and condition of riparian zone). Management practices and control actions for the remaining pollutants and issues of concern are briefly summarised here.

Additional pollutants of concern

Acid sulfate soils

The State Planning Policy 2/02 '*Planning and managing development involving acid sulfate soils*' is part of the *Integrated Planning Act 1997*, and applies to the Cardwell local government area. This policy has effect when (i) certain development applications are assessed, (ii) planning schemes are made or amended, and (iii) land is designated for community infrastructure. It is unclear whether this includes agriculture development.

Acid sulfate soils are present in the Tully WQIP area (Smith and Ahern 1998); however, their complete extent is unknown. It is recommended that detailed acid sulfate soils mapping in the Tully WQIP area is conducted, as extremely reactive soils have been recently identified in previously unknown acid sulfate soils areas (O'Donnell, DPI&F, pers. comm. 2007). CCI has recently funded a two-year project (July 2007 to May 2009) to map acid sulfate soils, and to establish management strategies for avoiding their disturbance and mitigating disturbed acid sulfate soils, in Far North Queensland. The results will be incorporated into the Tully WQIP in 2009/2010. Moreover, it is recommended that spatially explicit, catchment-wide data on the approximately 1100 km of constructed drains is overlain with detailed acid sulfate soils mapping, to identify and remediate deep drainage issues.

Heavy metals, hydrocarbon substances, and bacteria and pathogens

The following information is from '*The Framework for Marine and Estuarine Water Quality Protection*' (DEW), unless otherwise noted.

Heavy metals can enter marine and estuarine ecosystems through the discharge of industrial waste, treated sewage, stormwater run-off, mining operations and other diffuse sources (such as from vehicles). The most common heavy metal pollutants are arsenic, cadmium, chromium, copper, nickel, lead, and mercury. In the Tully WQIP area, cadmium and mercury could also be sourced from fertiliser and fungicide use (Brodie *et al.* 2007a). Mud crabs (*Scylla serrata*) collected in the Tully River mouth in 2005 and 2006 were found to have detectable levels of various metals and metalloids (Negri *et al.* 2007).

Oil and hydrocarbon pollution of coastal waterways is largely linked to industrial and stormwater discharges. Many of the compounds in crude oil and other petroleum products have been known to smother organisms, lower fertility and cause disease in aquatic organisms. In the Tully WQIP area, oil and hydrocarbons could also be sourced from cane and forest fires (Brodie *et al.* 2007a).

Pathogens such as faecal coliforms and enterococci can enter the marine environment through the downstream flow from discharge of sewage via river outfalls and from stormwater system overflows to rivers and streams. These pathogens pose threats to human health through gastro-enteritis, hepatitis and other diseases. Unacceptable faecal discharges to coastal waters may arise from aging sewage and stormwater infrastructure, combined system overflows after heavy rains or inadequate wastewater treatment. In the Tully WQIP area, pathogens could also be sourced from aquaculture operations (Brodie *et al.* 2007a). Note that many point sources of pollution (Appendix 4) are already required to comply with permit conditions relevant to these pollutants.

In the Tully WQIP area, most of these pollutants have an unknown occurrence or impact, while oil spills are chiefly point or scattered sources (Brodie *et al.* 2007a). It is not recommended that a monitoring program be established to determine the potential occurrence of these pollutants in the area, to ensure cost-effective distribution of resources to water quality improvement.

Additional issues of concern

Drinking water

The local community uses surface waters as drinking water (Bohnet *et al.* 2006), while an unknown number may access groundwater via bores for drinking water.

Terrain NRM has informed EPA of the detection of herbicide levels above water quality guidelines for drinking water (Section 3.4). It is recommended that improved pesticide management practices are implemented immediately by all industries (Section 5), and that the number of bores and/or pumps used to access ground or surface water for drinking water are spatially documented by EPA and CSC. If drinking water is accessed from waterways with herbicide levels above water quality guidelines (Section 3.4), the EPA, sugarcane industry and CSC need to arrange for testing this drinking water for herbicide concentrations immediately.

Nitrate has also been detected in Tully-Murray groundwater, with approximately 30% of all investigation wells surveyed between June and December 1997 containing nitrogen from an industrial source, most likely inorganic fertiliser (Thorburn *et al.* 2003). Nitrate concentrations in most of these wells were low, with none of the wells having nitrate concentrations above drinking water guidelines.

Limited or no access to waterways

Increased access to and use of country is aspired to by Traditional Owners and Indigenous peoples throughout the Wet Tropics region (FNQ NRM and Rainforest CRC 2004, Wet Tropics Aboriginal Plan Project Team 2005). In the community interviews and workshops (Section 2), Traditional Owners and Indigenous peoples indicated that access to the remaining cultural heritage sites, including areas important for traditional indigenous uses of land, estuaries and sea, should be provided (Bohnet *et al.* 2006, 2007). Access to places of cultural and spiritual significance (e.g. story places) has been lost due to private landholdership. This means that these areas are lost for cultural/spiritual practices, unless access to those areas is permitted for those purposes by private landowners. Sometimes this appears to be borne out of a land holder's ignorance of Traditional Owners and Indigenous peoples living in the area, and the significance they place on access and use of country. In such cases, education and awareness raising may help in gaining access. It is recommended that long-term and continued involvement of Girramay, Jirrbal and Gulnay Traditional Owners and their respective clan groups, through the Giringun Aboriginal Corporation, in the CSFP Steering Committee is strongly supported. This will contribute to increasing awareness and understanding of the Tully-Murray basin as a cultural and spiritual landscape for the Traditional Owners and Indigenous peoples.

Groundwater quality

Industry knowledge suggests that ground water (rather than surface water) is a major carrier of pollutants to the receiving waters. Nitrate has been detected in Tully-Murray groundwater, with approximately 30% of all investigation wells surveyed containing nitrogen from an industrial source, most likely inorganic fertiliser (Thorburn *et al.* 2003). To ensure effective management of water quality, it is recommended that the role of groundwater in the production system and water system be examined.

Increase in distribution and abundance of crocodiles

Management of crocodiles is the responsibility of EPA/QPWS. EPA/QPWS recently released its 'DRAFT Management program for *Crocodylus porosus* in Queensland 2007 – 2017' for public comment (EPA 2007b), with written submissions due by 4 May 2007. According to the draft plan, the general aim of management is to retain crocodiles in the wild while improving public safety.

The perceived increase in distribution and abundance of *C. porosus* is not supported by extensive surveys (EPA 2007b). In the area between Cooktown and Tully, crocodile numbers appear to have been kept low by urban, rural residential, and agricultural development, together with clearing of riparian vegetation, disturbance by motor boats, commercial gill netting in estuaries, and removal of crocodiles. Moreover, the population structure of *C. porosus* in Queensland indicates that it may still be recovering from hunting, or that larger animals are still being removed from the population (EPA 2007b).

To elucidate the apparent discrepancy between the community's perceptions and the surveys, it is recommended that EPA/QPWS reports to CFSP on the final management program for crocodiles, with a focus on the Tully WQIP area.

Marina development

New developments in catchments adjacent to the GBR are regulated and require approvals under a number of legislative Acts. They will also fall under the statutory regional land use plan for Far North Queensland (FNQ 2025; Section 1.2). This plan is currently being developed, with a proposed delivery date in 2008. No further actions are considered in the Tully WQIP.

Maintaining healthy reefs

Inshore coral reef communities of the GBR are at risk from impacts caused by cyclonic winds, bleaching, outbreaks of crown-of-thorns starfish as well as being exposed to sediment, nutrients and pesticides from land runoff. An important attribute of a healthy ecological community, is that it should be self-perpetuating and 'resilient', that is, able to recover from disturbance. Adult corals can tolerate poorer levels of water quality than new coral recruits, thus one of the ways in which water quality is likely to impact reef communities is through an effect on coral reproduction and recruitment.

It is anticipated that with improvements in water quality, associated with the implementation of the Tully WQIP, the status of inshore reefs should improve, firstly in terms of reproduction and recruitment and in the long-term the reef community as a whole. In 2005, GBRMPA implemented a long-term water quality and ecosystem health monitoring program under Reef Plan. The monitoring undertaken as part of the program will be used to help assess changes in water quality and the health of inshore reefs and intertidal seagrass meadows. GBRMPA has recently released a report on the data collected in the first 18 months of the program, which provides baseline information on inshore marine water quality, inshore reef and intertidal seagrass health (GBRMPA 2007). To continue to assess changes with implementation of Reef WQIPs (including the Tully WQIP), it is essential that the GBRMPA continues the implementation of the Reef Plan Marine Monitoring Program.

APPENDIX 6. Legal and institutional arrangements

Background

CCI has recently developed a project proposal to review and analyse legislative and administrative arrangements to support WQIP implementation at a statewide, regional or local level. Specifically, the project aims to review and analyse state and local government legislation that supports WQIP implementation, in particular environment protection, land use planning, water resource, coastal zone management legislation, and local government by-laws.

The findings of this project will be included in the Tully WQIP in 2008/2009. Here, a brief summary of the proposed project, including methods, is given.

Project summary

The WQIP planning process includes a review and analysis of legislative and administrative arrangements to support WQIP implementation at a statewide, regional or local level, and on this basis, provides scope for making recommendations on:

1. regulatory reform, including minor and major amendments,
2. administrative reform (e.g. how existing legislation may be better used, what legislation can be used but is not currently being used for this purpose), and
3. addressing barriers to administration of relevant legislation (e.g. what are the information needs of responsible authorities),

to better support WQIP implementation, in a timely and cost-effective manner.

The review and analysis is to be followed by recommendations on Items 1-3 above, amendments to facilitate/give incentive to/require implementation of management measures identified in WQIPs. These are potentially critical 'control action' elements for any 'reasonable assurance' statement for GBR WQIPs.

Methods

The project will be undertaken on behalf of regional NRM groups (including Terrain NRM) and local governments preparing WQIPs in the GBR region.

The project will include the following activities:

1. with input from the contact group, prepare a discussion paper that:
 - o identifies and outlines relevant state-wide, regional or local legislation,
 - o makes suggestions on opportunities for improved administration, and
 - o identifies potential barriers to administration, sympathetic to implementation of WQIPs and achievement of Reef Plan objectives;
2. conduct a workshop with representatives from contact group agencies, and industry and community environmental bodies (including urban development) to explore the discussion paper and the need for/nature of any regulatory and administrative reforms;
3. seek formal agency and industry feedback on workshop outcomes;
4. prepare final report and recommendations on regulatory and administrative reforms (including opportunities and barriers) to implement WQIPs, having regard for agency and industry feedback.

Note environment protection, land use planning, land and water resource and coastal zone management legislation, and local government by-laws are of primary concern to this review.

APPENDIX 7. Margin of safety and reasonable assurance

Background

CCI has recently funded a one-year project (July 2007 to June 2008) to prepare protocols for addressing margin of safety and reasonable assurance in Reef WQIPs. The project will prepare protocols for the use of margin of safety concept in specifying the ecologically sustainable load, and the provision of reasonable assurance statements for Reef WQIPs. The project will consider pollutant loads, specifically sediment and nutrient loads, but does not consider river flow objectives. The FNQ region will be used as one of two case studies for the project.

The findings of this project will be included in the Tully WQIP in 2008/2009. Here, a brief summary of the project, including methods, is given.

Project summary

WQIPs are the primary vehicle for delivering Reef Plan objectives at the catchment scale, with WQIPs prepared in accordance with the Framework for Marine and Estuarine Water Quality Protection (Appendix 1). Important features of the Framework are the need to address margin of safety and reasonable assurance.

This project will develop a protocol for the development of WQIPs to assist regional NRM groups to address margin of safety and reasonable assurance requirements. The protocol will be informed by a review of available literature and experience with model and prediction uncertainties and with policy design, implementation and effectiveness.

The protocol will be applied and assessed in two NRM regions through direct collaboration with the NRM groups. Based on the results, the protocol will be refined to address identified shortcomings or previously unidentified/new/evolving opportunities.

Methods

For the purpose of addressing MoS, this project will:

1. identify and quantify key model uncertainties in catchment models currently employed for Reef WQIPs (e.g. Sednet and EMSS), as well as known/reasonably anticipated uncertainties in future catchment and receiving water quality modelling environments (e.g. E2, Brodie/Devlin receiving water quality model), define what can and cannot be quantified in these models;
2. identify and quantify key prediction uncertainties arising from input data uncertainty (and bias) and its propagation through model predictions;
3. identify and quantify the reduction in input data and model prediction uncertainties arising from aggregation over different spatial scales, i.e. determine the minimum area over which model predictions must be averaged to provide satisfactory levels of uncertainty;
4. review USEPA and other methods for encompassing margin of safety and reasonable assurance to meet the requirements of the Framework for Marine and Estuarine Water Quality Protection, and associated guidelines; and
5. recommend priority areas of investigation to improve the confidence of catchment models.

For the purpose of addressing reasonable assurance statements, this project will:

1. review management policy and adoption benchmarks regarding,
2. impact of alternative treatments on nutrient sources (biophysical effectiveness); and
3. likely adoption and compliance rates with respect to treatments (social and economic effectiveness);
4. in consultation with WQIP agencies, investigate the adoption (and where possible ongoing compliance) of a range of comparative policies. The goal will be to provide a set of broad performance points of references that can be used to assess the potential performance of the suite of policies proposed within

any WQIP. Candidate policies will include those with broadly similar aims or modes of operation, and where possible using similar communities (and ideally existing policies in reef catchments). So far as is practicable these will seek to replicate the range of potential policies under consideration, and (if possible) include compliance and effectiveness pathways for regulatory instruments as well as adoption rates for voluntary information and incentive program. Review current incentives systems (e.g. awareness raising and capacity building, direct/ecosystem service payment, tax-based, market-based, regulatory etc) and incentives frameworks used to encourage adoption of management measures for high risk activities or similar, and estimate the likelihood of adoption under a range of incentives/scenarios.

Develop and test a protocol:

1. provide a protocol for the development of WQIPs that addresses margin of safety and reasonable assurance considerations as informed by 1-7;
2. test the protocol with two NRM groups (1 agriculture dominant, e.g. Mackay Whitsundays or Far North Queensland, 1 grazing dominant, e.g. Fitzroy Basin Association or Burdekin Dry Tropics Board)

APPENDIX 8. Socio-economic assessment of improving GBR water quality

Background

CCI has recently funded a six month project (April to September 2007) to assess the social and economic impacts (benefits and costs) of protecting the environmental values (values and uses) of GBR waterways by achieving water quality targets/objectives established in Reef WQIPs. The Tully WQIP is used as a case study for this project.

Note that the Tully WQIP has conducted its own assessment of socio-economic impacts of improving water quality for the Tully WQIP area (Bohnet *et al.* 2006, 2007, Roebeling *et al.* 2007a,b). The information from these assessments has been used for stakeholder consultation on deciding priorities for and acceptability of proposed measures/actions (Section 5).

The findings of this project will be included in the Tully WQIP in 2008/2009. Here, a brief summary of the project, including methods, is given.

Project summary

The socio-economic assessment and report will be used directly in WQIPs as justification of the benefits and costs to the community of improving water quality and protecting environmental values of the GBR waterways. The draft and final reports from the economic and social assessment would be made available to WQIP coordinators for their reporting and stakeholder consultations on deciding priorities for and acceptability of proposed measures /actions.

Each WQIP is developing management actions to achieve the necessary changes in water quality to achieve the WQOs and these will be inputs to this project. These are the actions that will reduce pollutant loads.

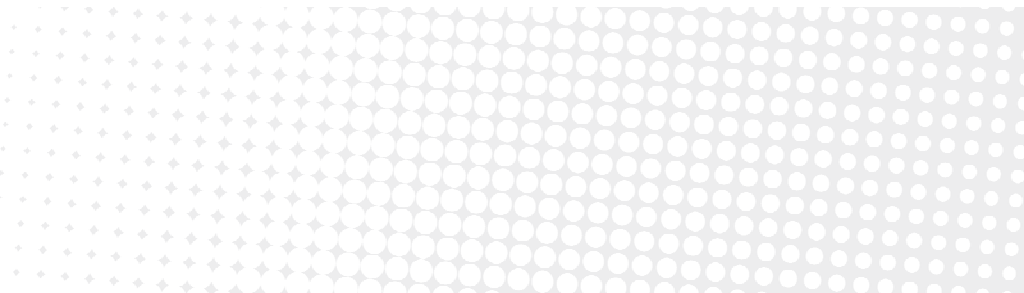
The final report would also be used to assist in scheduling EVs and WQOs from each WQIP project under Queensland legislation if EPA proceeded with this action. Scheduling EVs and WQOs would help the Queensland EPA regulate point sources and, in conjunction with the CCI-funded project “Integrating WQIPs into state planning processes”, could be used to influence urban planning decisions and obtain water quality benefits from urban stormwater management.

Note that diffuse sources of pollution in agricultural and rural areas are more difficult to identify and hence regulate, so the scheduling of EVs and WQOs is intended only to provide overarching ‘head of powers’ and direction to land use planning and natural resource allocation processes. However, this project will help WQIPs to prioritise measures/actions to meet the desired WQOs (e.g. for funding support). It will also assist stakeholder consultations and engagement in order to achieve these actions.

Methods

This project will:

1. Review literature of the relationship between water quality and economic/social activities;
2. Review current socio-economic condition and trend assessment (by each WQIP region) and provide a clear synopsis of the range of activities with direct/indirect reliance on/sensitivity to water quality;
3. Provide an appraisal of the likely effects of changes in water quality/ecosystem health on the primary social and economic use activities (EVs) within each of the WQIP regions, including an assessment of the likely/potential economic and social significance of such changes;
4. Prepare, and if necessary peer review, of report and report released



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