Appendices

Chapter 13

"The Paddock to Reef program will inform research, development and innovation initiatives established under Reef Plan 2009."

Photo courtesy of Great Barrier Reef Marine Park Authority

Appendix 1 Continuous improvement

The Paddock to Reef program will inform research, development and innovation initiatives established under Reef Plan 2009, including the Reef Plan Research, Development and Innovation Strategy, Annual Research, Development and Innovation Plan and the Research and Development component of Caring for our Country Reef Rescue.

The Paddock to Reef Program also links to broader research and development initiatives such as the National Environmental Research Program Tropical Ecosystems hub. It is recognised that some knowledge gaps exist within the Paddock to Reef program. These include:

- effectiveness of management practices in improving water quality
- the contribution of gullies to transported sediments
- techniques to monitor riparian and wetland condition
- improved pollutant load estimates through catchment water quality modelling
- receiving water quality modelling to improve understanding of the impact of pollutants on the health of Great Barrier Reef ecosystems.

Further information on these knowledge gaps and approaches to address these are outlined in the following sections.

Improving our understanding of practice effectiveness

Paddock scale monitoring and modelling is a key component of the Paddock to Reef program. It provides information on the water quality changes related to specific management practices on specific land types and climatic regions. Paddock models are used to corroborate this information. The program consists of three monitoring and modelling activities:

1. Paddock monitoring—collecting runoff during actual rainfall events from a uniform portion of a paddock. Over time, the paddock monitoring provides temporal data to capture variability in rainfall and other climatic factors, changes in management and changes in system responses.
2. Rainfall simulation—collecting runoff from a simulated rainfall event from a plot within a paddock. Over time, the rainfall simulation work progressively extends the spatial coverage by capturing the variation in response at sites with different soil or land type characteristics.
3. Paddock modelling—over time, the paddock modelling progressively develops spatial coverage across soil and land types with improved estimations from using paddock monitoring and rainfall simulation information.

Paddock monitoring is undertaken on sets of rows (cane and horticulture), contour bays (grains), hillslopes (grazing) and multi-farm catchments up to 30,000 hectares (cane, grain and grazing). Monitored parameters include runoff and leachate volumes, total suspended solids, electrical conductivity, total nitrogen, total phosphorus, nutrient species (i.e. dissolved and particulate forms) and pesticides (where used) from rainfall and irrigation. Field equipment and laboratory methods have been standardised. Runoff is collected as discrete or composite samples through time, using automated refrigerated pumping samplers, to provide event mean concentrations. Leachate is measured using suction lysimeters or solute samplers.

Samples for nutrient and pesticides are collected from soils and trash. Soils at each site are characterised (morphology, chemical and physical properties). Farm operations that affect water quality (including tillage, nutrient and pesticide applications) and agronomic data are recorded. This allows paddock sites to be modelled using soil water balance and water quality models that can then be applied to other time periods and conditions. Data generated is used to calibrate and verify the paddock scale models used in the Paddock to Reef program.

Figure 13.1 – Automated sampler in the Burdekin (Image: Zoe Bainbridge, Australian Centre for Tropical Freshwater Research).

Sugarcane

Management systems include current farming practice (single cane row on 1.5 metre-wide beds and uncontrolled traffic) and the new farming system (dual row cane on approximately 1.8 metre beds, controlled traffic and legume crop rotation). Nutrient management includes practices such as following general recommended application rates, the Six Easy Steps program and the nitrogen replacement approach. Pesticide management focuses on decreasing the reliance on residual herbicides (e.g. atrazine, diuron) and greater use of low persistence knockdown herbicides, integrated weed management planning and precision application (i.e. shielded sprayers).

In the Mackay Whitsunday region, a multi-block monitoring site is installed at North Eton (area approximately 54 hectares) with 100 per cent sugarcane. A multi-farm site (approximately 2965 and approximately 95 per cent sugarcane) is also being monitored. Improved management practices are being implemented within a large proportion of these areas and the level of implementation of these practices will also be monitored.

Figure 13.2 – Flume at paddock monitoring site, Mackay Whitsunday (Image: Ken Rohde).

Grazing

Paddock scale monitoring for grazing land use compares practices that manage hillslope (sheet and rill) erosion in pastures, riparian areas (off-stream watering and fencing) and gully rehabilitation. Existing pasture monitoring sites in the Fitzroy and Burdekin regions will continue to investigate runoff impacts of grazing pressures (percentage of use/stocking rate), spelling, patchiness and fire management. Limited pesticide monitoring will be conducted. Monitoring will continue at the sub-catchment scale near Bauhinia Downs, with three sites (4000, 6000 and 27,000 hectares) in Muddy and Spottswood Creeks where grazing is the dominant land use (approximately 95 per cent of catchment). Similarly, monitoring will continue in the Gordonstone nested catchments (see Grains section) with a 300 hectare grazing catchment (Neilsen et al., 2010). Other sites in the Fitzroy region have been established to assess the use of off-stream watering in an attempt to reduce cattle pressure on riparian zones and river bank frontage.

Sediment yields from gully rehabilitation practices is monitored in the Burdekin region. Sites are located in the Upper Burdekin and Bowen/Bogie catchments, which contain the areas identified in the Burdekin Water Quality Improvement Plan (Dight, 2009) and Reef Rescue Program as high-priority sediment source areas. Gully erosion rates under different practices are compared using a range of techniques including vegetation monitoring, erosion pins and catchment sediment yields. This data is linked to mapping of gully extent over time using historic air photos and remote sensing (where available) to determine the gully behaviour relative to the whole property and surrounding landscapes. Sediment loads from the sub-catchments containing gully monitoring sites are also monitored.

Figure 13.3 – Grazing in a creek bed, Fitzroy catchment (Image: Mark Silburn, DERM).

Grains

Dryland grains cropping is monitored in the Gordonstone Creek catchment, Capella. At the paddock scale, there are three contour bays (approximately 10 to 45 hectares), while at the sub-catchment scale there are five monitoring sites at increasing scales (approximately 300, 500, 5000, 8000 and 30,000 hectares). Monitoring at the paddock scale focus is on zero till controlled traffic farming within single, double or triple spaced contour bays (i.e. cutting-edge (A) or best management (B) practice). A site using common practices (C), such as conventional/reduced tillage with controlled traffic, is used for rainfall simulation experiments. Data for practices considered unacceptable by industry and community standards (D) will be generated through analysis and modelling of historical data from Capella (Carroll et al., 1997).

Horticulture

Horticulture management practices are monitored at the paddock scale in the Wet Tropics and Burnett Mary regions. The Wet Tropics site focuses on a comparison of nutrient management and inter-row management (bare versus vegetated inter-rows) strategies in bananas. The Burnett Mary site assesses both horticulture (vegetables under plastic mulch) and sugarcane cultivation in rotation, where monitoring is focused on soil and nutrient management and comparing nutrient and pesticide management when returning to cane.

Monitoring wetland (lakes and swamps) condition in the Great Barrier Reef

Wetlands filter out nutrients, sediments and pesticides from waterways. In addition, wetlands are high in biodiversity, have important recreational values and play a vital role in Queensland's primary industries, especially grazing and fisheries. Wetlands can also mitigate the effects of extreme climate events such as storm surges and floods.

The highly variable nature of wetlands, makes them difficult to monitor as the natural variability in the system needs to be separated from those changes caused by human effects.

The Queensland Wetlands Program has developed and implemented several projects to increase the capacity to monitor the wetland extent, risk and condition of Queensland's lakes and vegetated fresh water swamps. In the Great Barrier Reef catchments, coastal wetlands of one hectare or more, and those above five hectares further inland, have been identified, and mapping updates have provided an effective mechanism for reporting on wetland extent changes over time.

In addition to the mapping, wetlands have been classified into different wetland habitat types and conceptual models describing scientific understanding of their components and processes have been developed.

Methods for monitoring the condition of and risk to different wetland types and wetland regions are being developed and tested. An assessment and reporting framework has also been developed, together with a software tool that enables integrated assessment of all wetlands within an area (e.g. catchment) or an individual wetland.

Improved catchment water quality modelling

Using catchment water quality models to report on pollutant load reductions

Reef Plan 2009 has set water quality catchment load targets, with a combination of monitoring and modelling to inform progress on achieving these targets by 2013. Catchment modelling will be used to report catchment pollutant loads for each catchment in the Great Barrier Reef for a revised baseline (2008–2009) and changes relative to the baseline for 2010 to 2013.

The overall approach involves monitoring and modelling a range of attributes including management practices at paddock scale and upscaling to sub-catchment and basin scales.

Current catchment models such as SedNet/ANNEX generate long term average annual sediment and nutrient loads. The transition to Source Catchments will provide a finer resolution time step that will facilitate the link between catchment and receiving water models. The project will establish a 2008–2009 baseline, with the impact on current investments assessed against human loads for subsequent report cards.

Source Catchments modelling framework

Source Catchments is a water quality and quantity modelling framework that supports decision-making and a whole-of-catchment management approach. It allows modelling on the amounts of water and contaminants flowing through an unregulated catchment and into major rivers, wetlands, lakes, or estuaries. Source Catchments is the software evolution of the E2 Modelling Framework, which was released in 2005 through the eWater Toolkit.

Source Catchments can be used to predict the flow and load of constituents at any location in the catchment over time, usually at daily time steps, and can produce reports at varying temporal scales (from daily to annual) and spatial scales (from a single sub-catchment to whole-of-catchment). Scenarios can include actual or planned changes in land use, land management, climate variability and climate change.

This software gives access to a collection of models, data and knowledge that simulate the effects of climatic characteristics (such as rainfall and evaporation) and catchment characteristics (such as land use or vegetation cover) on runoff and contaminant loads from unregulated catchments.

The Source Catchments modelling framework was designed to allow modellers and researchers to construct models by selecting and linking component models from a range of available choices. The model structure and algorithms are not fixed but can be defined by the user who can choose from a suite of available options. As a result, Source Catchments enables a flexible modelling approach, allowing the attributes and detail of the model to vary in accordance with modelling objectives.

Receiving water quality models

A receiving water quality modelling framework is a critical link between catchment models (which describe how management impacts on the delivery of nutrients and sediments to the ends of catchments) and the fate and impacts of these pollutants as they pass through estuaries and into the Great Barrier Reef lagoon.

Receiving water quality model

The marine receiving water model inputs catchment loads of fresh water, sediments, nutrients and pesticides derived from catchment modelling or from measurement, and simulates the transport and transformation of these substances in the receiving waters, including their impact on primary production. The foundation model for the development of materials transport is a Great Barrier Reef-wide hydrodynamic model, capable of simulating currents and mixing that are important for transporting contaminants, as well as water temperature and salinity.

Current work

A Marine and Tropical Science Research Facility and Great Barrier Reef Marine Park Authority funded project undertaken by the Australian Institute for Marine Science and the CSIRO has developed a hydrodynamic model of the entire Great Barrier Reef that includes all the important factors affecting currents, mixing, temperature and salinity within the lagoon and exchanges with the adjacent Coral Sea. A pilot four-kilometre resolution regional model has been established, including river inflows for a number of real-time gauged rivers, and is running in near real-time. Comparisons between observed and predicted tidal sea levels, which drive the general circulation, are a powerful verification of a model's performance. The general agreement of both magnitude and phasing of tidal water level fluctuations at coastal stations throughout the Great Barrier Reef gives confidence in the accuracy of the model's simulation of a dominant hydrodynamic process. Qualitative assessment of a pilot 2009 wet season hindcast of this model indicates general agreement in extent and timing of the predicted surface fresh water plume and the remotely sensed plume distribution. Predicted and observed sub-surface salinities also show good agreement. In addition, a pilot one-kilometre resolution model is undergoing preliminary evaluation.

Appendix 2 Evidence of the effectiveness of improved management practices

This section summarises knowledge of the effectiveness of management practices in providing improved water quality in surface runoff at the paddock scale. Information is presented according to the major pollutants of concern: sediments, nutrients and pesticides. An overview of the economic implications of water quality improvements is also provided.

Results are organised according to management practices that are designed to reduce the runoff of:

- sediment
- nutrients
- pesticides.

Sediments

Most soil conservation practices necessary to reduce erosion and sediment loss from agricultural lands are widely understood (Freebairn et al., 1996) by landholders. General principles include:

- controlling runoff to avoid concentrated flow (e.g. contour banks and waterways in cropping, road management in grazing and forestry)
- maintaining groundcover (stubble in grains, trash in sugarcane, pasture in grazing)
- minimising tillage and maintain soil strength (resistance to erosion)
- use of land within its capabilities (e.g. avoiding steep slopes)
- maximising infiltration but also maximising use of this water by plants (e.g. opportunity cropping in grains)
- controlled machinery traffic to reduce soil compaction
- prevention and repair of gully erosion
- maintaining vegetative cover in riparian areas and flow pathways (e.g. sediment trapping).

These practices aim to maximise water use for plant production, minimise the amount of runoff, slow and spread that runoff and protect the soil surface from raindrops and flowing water. These principles are well supported by field studies. Other practices such as sediment traps (Connolly et al., 1999, 2002), vegetative filters and buffers (USDA-NRCS 2000), grassed headlands, constructed wetlands (reviewed by McJannet, 2007) and riparian management (Lovett and Price, 2001) aim to remove sediment from runoff water after it leaves the paddock. These off-paddock practices are not a substitute for careful paddock management but are tools to further improve water quality.

Data from studies in sugarcane indicate rates of soil erosion are highest under burnt cane, intensive tillage practices (Prove et al., 1995; Sallaway et al., 1979, 1980). Green cane trash blanketing and minimum tillage reduced sediment movement off paddocks by up to 90 per cent (Prove et al., 1995; Rayment, 2002) in steeper, particularly high rainfall areas. Avoiding tillage has a major impact on soil erosion as it reduces rill erosion in the inter-rows (Prove et al., 1995). On low slopes (e.g. less than 1 per cent), rill erosion does not occur and the inter-rows become a site for sediment deposition. In these cases, groundcover is very effective in reducing soil erosion (Waters, 2001; Silburn and Glanville, 2002; Masters et al., 2008). In sugarcane (with trash blankets retained on the soil surface) and bananas, fallows and plant crops (as opposed to ratoon crops) are susceptible to erosion and require management.

These general principles are supported by studies in grains and anecdotal evidence from horticulture cropping areas. Maintenance of groundcover is crucial for managing water quality (Figures 13.4, 13.5, 13.6 and 13.7). A 12-year study of grain cropping on Vertosol (black clay) at Capella found a significant reduction in erosion with greater than 30 per cent surface cover (Carroll et al., 1997). Opportunity cropping using zero tillage was the most effective cropping system for producing consistently high groundcover and reduced runoff and soil loss. These findings are supported by a review of studies in Queensland grain growing areas over the past 40 years (Thomas et al., 2007), which showed that no-till/reduced till and conservation farming dramatically reduces soil loss. Controlled traffic farming has been shown to be effective in enhancing infiltration and reducing runoff and thereby reducing soil loss, especially when combined with maintenance of groundcover (Tullberg et al., 2001, 2007; Li et al., 2001; Silburn and Glanville, 2002; Rohde and Yule, 2003; Masters et al., 2008).

Figure 13.4 – Green cane trash blanket provides good control of soil erosion, Mackay, Queensland (Image: Bronwyn Masters, DERM).

Figure 13.5 – Mulch crop sown in the interspaces in horticulture to prevent erosion (Image: Neil Halpin, DEEDI).

Figure 13.6 – Surface cover and sediment concentrations at Gregory Highway site, Gordonstone, for two similar rainstorm events (100 millimetres and 127 millimetres) with contrasting levels of cover (low cover shown in red; high cover shown in green).

Figure 13.7 – Annual average soil loss from hillslope plots with different pasture cover, in semi-arid Central Queensland (means of seven years data) (Source: Silburn et al., in press) (Image: David Waters, DERM).

High erosion rates have been measured in bananas grown on steeper slopes with little groundcover when rainfall intensity was high (McKergow et al., 2004). Sediment, total nitrogen and total phosphorus losses from banana fields to streams were reduced by 25 to 65 per cent by grass buffer strips, but only where runoff did not become concentrated (McKergow et al., 2004). In horticulture, planting of cover crops in the interspaces between vegetable beds covered with plastic mulch is seen as a way of minimising sediment losses. The water quality benefits of management practices such as bio-mulches in horticultural crops have not been quantified in Queensland.

Groundcover has a strong effect on hillslope runoff and sediment losses in extensively grazed pastures in Queensland (Miles, 1993; McIvor et al., 1995; Scanlan et al., 1996; Connolly et al., 1997; Carroll et al., 2000; Waters, 2004; Bartley, et al., 2006; Silburn et al., in press).

Groundcover depends on pasture growth and grazing utilisation. However, climatic events outside management control may affect cover and soil erosion. For example, during drought, cover can degrade even in the absence of commercial grazing though not as quickly as with grazing (Pressland and Graham, 1989).

Gully erosion is a significant source of sediment in grazing lands (Cogle et al., 2006). Management can influence gully sediment yield via four mechanisms:

- Reducing the amount of runoff water from the hillslope draining into the gully. There are too many gullies to treat individually and improving cover levels is the most common management practice change that will potentially affect gully erosion rates.
- Increasing vegetation cover on the gully walls to reduce local erosion (rain-splash, sheet-wash and rill processes).
- Reducing sediment transport capacity of the gully channel (e.g. more roughness).
- Fencing to exclude disturbance to the fringes of the gully and gully edges by cattle.

Little data exists on the net contribution of gullies to transported sediments. For example, sediment sourced at the top of the gully may be deposited within the gully channel. The Paddock to Reef program seeks to provide data of this nature in Great Barrier Reef catchments. In particular, natural chemical tracers can assist in differentiating hillslope from gully and riverbank sediments.

Nutrients

The main approaches for nutrient management in reef catchments focus on nitrogen and phosphorus. Higham et al., (2009) provide rankings of the relative effectiveness of practices in the ABCD framework in managing nutrient losses. Common principles to reduce nutrients in runoff and deep drainage are:

- minimising the rate of nutrient inputs
- accounting for all nutrient sources (e.g. from legumes, mill mud and irrigation water, etc)
- matching application rates and timing with soil nutrient levels and yield goals
- managing soil water to reduce nitrate losses below the root zone
- reducing the amount of runoff by various soil management practices
- reducing sediment movement to reduce phosphorus and some nitrogen in runoff.

Potential nutrient losses in runoff and drainage will be related to the amount of the nutrient in the soil, which is a result of the rate of application, placement and rates of removal (e.g. crop use, losses). This emphasises the importance of minimising excess inputs of fertiliser.

In sugarcane, research and industry consultation resulted in the Six Easy Steps nutrient management program, which is considered best practice across the industry (Schroeder et al., 2005, 2010). Crop, water and nitrogen balances in sugarcane in the Burdekin (Thorburn et al., 2009) were used to calibrate the APSIM crop model and then predict losses for different management practice classes (Figure 13.8). The results provide increased confidence that A and B class nitrogen management practices identified in the ABCD framework will improve water quality over current (C) and dated (D) management practices.

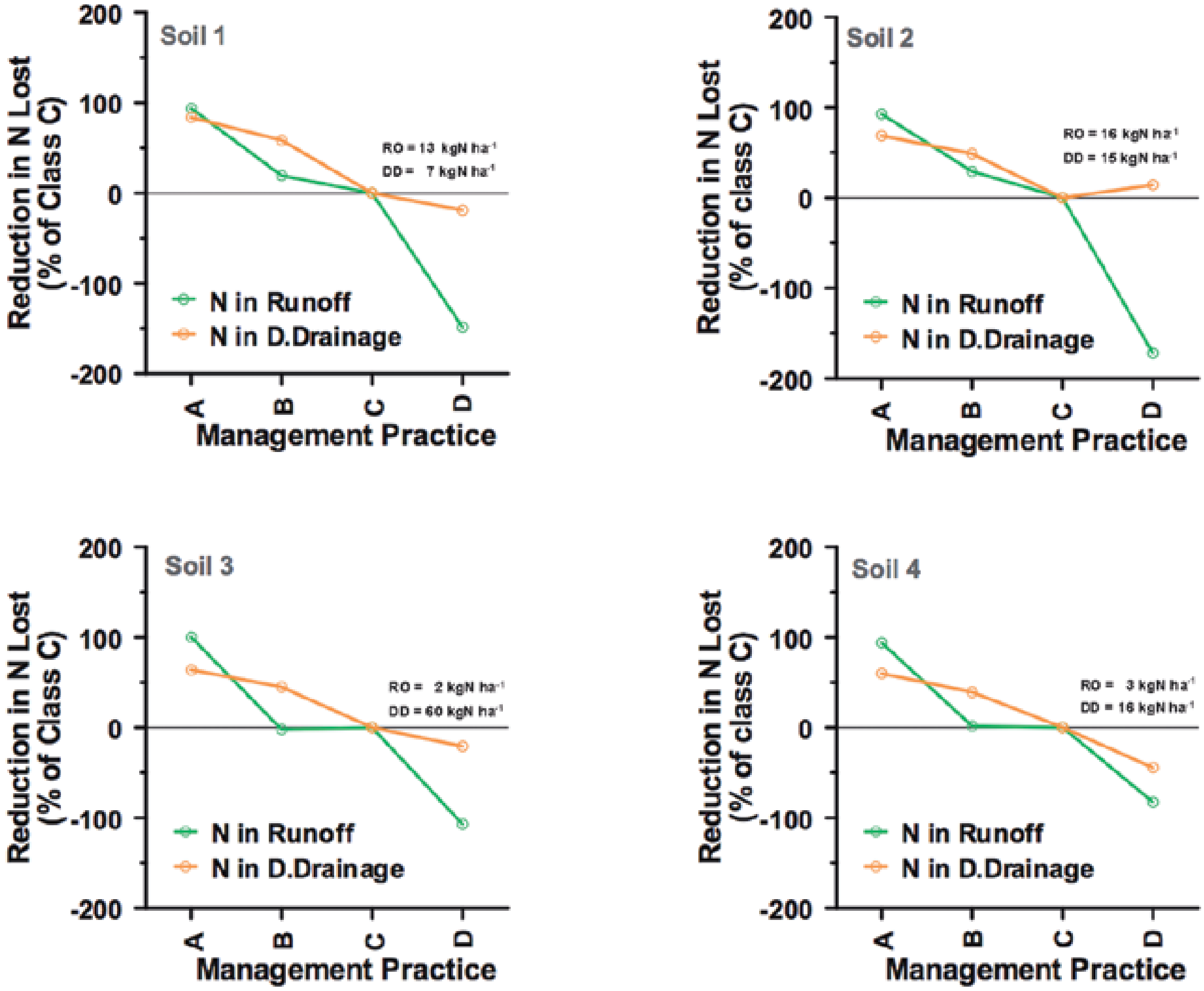

Figure 13.8 – Improving water quality associated with decreasing nitrogen application rates on four Burdekin soils, relative to C management class (Source: Thorburn et al., 2009).

In recent years, use of legume crops in sugarcane rotations has increased. While legume crops improve soil health, reduce sediment loss and provide organic fertiliser (Garside and Bell, 2001; Reghenzani and Armour, 2000), little is known of their potential impacts on water quality. However, it is possible that inputs of nitrogen from the legume may be greater than crop uptake and so leak to the environment over subsequent crops. Other management practices, for example fertiliser placement, are more likely to change the nitrogen loss pathways than the amount that is lost (Prove et al., 1997, Masters et al., 2008, Thorburn et al., 2010). Reducing nitrogen lost by one loss pathway such as runoff, may be countered by an increase in the loss through another pathway, such as deep drainage and to the atmosphere, reinforcing the need for a holistic approach to managing the overall nitrogen surplus. The elevated soil phosphorus status of most sugarcane soils, particularly those receiving mill by-products, such as mill mud (Rayment and Bloesch, 2006) suggests that the environmental significance of dissolved inorganic phosphorus in both drainage and runoff needs to be tested.

In bananas, Armour and Daniells (2001) showed that nitrogen fertiliser rates could be reduced by more than 50 per cent, from 520 kilograms of nitrogen per hectare per year to 150 and 225 kilograms per hectare per year for plant and ratoon crops respectively. This was based on matching application rates to crop demand with fortnightly applications under favourable weather conditions. Application rates of nitrogen in the Queensland banana industry have already been reduced by as much as 40 per cent over the past 12 years. The contribution made by excess nutrient addition to nutrient loads entering runoff or groundwater from banana and other horticultural crops is unclear and there have been few detailed studies. However, Mitchell et al., (2007) found clear relationships between the proportion of land in tropical catchments where fertilisers were used (cane and bananas) and the average nitrate nitrogen (NO_3-N) concentration in runoff.

The main nutrient runoff losses from low input, extensive grazing lands are those attached to sediment (particulate nitrogen and phosphorus) (O'Reagain et al., 2005; Cogle et al., 2006). Managing erosion should limit nutrient losses attached to sediment. However, there is little data available on nutrient losses from grazing lands and their management, particularly for dissolved nutrients. Data from Mount Mort shows that cover had a large effect in reducing runoff, sediment and total nitrogen and total phosphorus loads (Finlayson and Silburn, 1996).

Pesticides

The main pesticides of interest are herbicides, in particular residual herbicides that inhibit photosynthesis, referred to as PSII herbicides (e.g. atrazine, diuron). Pesticide transport off-field and off-farm in runoff can be controlled by:

- minimising the rate of pesticide applications
- improving application efficiency (spray nozzle technology, banded spraying, controlled traffic farming)
- carefully selecting pesticides with particular properties (e.g. pesticides that dissipate more rapidly [shorter half-life] and are more sorbed to soil)
- timing applications to avoid periods with higher risk of large rainfall events
- adhering to labelling (appropriate use, storage and disposal of chemicals)
- reducing the amount of runoff by various soil management practices
- management of off-paddock water through collection drains and sumps.

Minimising pesticide movement in runoff is primarily achieved by reducing pesticide inputs (getting the best control with lowest application rates) (Simpson, 2007; Silburn and Kennedy, 2007). The ultimate way to reduce runoff of residual herbicides is to not use them at all (A or B practice) or to use them much less, for example for plant cane only.

There is a clear relationship between the concentration of pesticides in runoff and that in the soil (Leonard et al., 1979; Silburn, 2003; Silburn and Kennedy, 2007; Rattray et al., 2007) and some evidence that pesticide runoff is proportional to the concentration in trash (Masters et al., 2008). Thus, any practices that reduce these surface stores of pesticide should reduce losses in runoff. Time of application through the year has a large effect on potential for pesticide runoff, with a more than 10-fold difference between the wettest and driest months (Rattray et al., 2004; Simpson, 2007).

The properties (half-life, solubility, soil sorption, volatility etc.) of pesticides are a useful guide to their behaviour in the environment. These properties will influence how quickly the pesticides break down in the soil and how likely they are to be transported off-site in runoff water or attached to eroding sediments (Simpson, 2007; Silburn and Kennedy, 2007).

The rainfall simulation work of Masters et al. (2008) provides some of the only paddock scale data comparing pesticide dissipation and runoff for older-conventional and new farming system sugarcane farming practices (i.e. C versus B class). This work found significant reductions in herbicide losses under new farming system practices (controlled traffic, banded pesticide application) compared to conventional broadcast application (100 per cent coverage). These results have broad relevance to much of the sugar industry, particularly for areas totally reliant on rainfall. Soil management practices have also been shown to be effective in reducing pesticide runoff indirectly by reducing water and sediment movement (e.g. Silburn et al., 2002; Masters et al., 2008).

For pesticides used in grazing lands, such as tebuthiuron (Graslan), there is poor understanding of use and how the pelletised product behaves in the environment. However, tebuthiuron is regularly detected in Great Barrier Reef streams (Lewis et al., 2009; Packett et al., 2009).

Mackay Whitsunday rainfall simulator—sediment, nutrient and herbicide in runoff from cane farming practices (Masters et al., 2008).

Key results from the rainfall simulation study were:

Soil management—Control traffic farming had significantly less runoff (43 per cent) and sediment loss (44 per cent) than current practice under storm rainfall.

Nutrient management—Total nitrogen loss from surface applications of Dunder fertiliser and sub-surface applications of granular fertiliser were similar, as both were applied at the same rate (160 kilograms of nitrogen per hectare). Nitrate losses were greater from granular applications than from Dunder, with losses being reduced on Control Traffic Farming compared to current practice. However, Dunder had greater amounts of ammonia in runoff compared with granular treatments.

Herbicide management—Reducing applied amounts by 50 to 60 per cent reduced event mean concentrations in runoff for all herbicides (ametryn, atrazine, diuron, and hexazinone) by more than 50 per cent, when rainfall was one day after application. Further reductions in runoff loads were made on Control Traffic Farming compared with current practice. There were strong relationships between herbicide concentration on the trash, event mean concentration in runoff and time after application, for all herbicides.

Recommended best practice for management of water quality in cane is no-till green harvested control traffic farming, with fertilisers and herbicides applied as early as possible before the onset of the wet season. Residual herbicides should be banded on centres of beds and fertilisers applied sub-surface.

Economics of best management practices

The potential economic benefits of adoption of management practices that lead to improved water quality outcomes have been demonstrated in sugarcane (Van Grieken et al., 2010), grains (Strahan and Hoffman, 2009) and grazing systems. Strahan and Hoffman (2009) modelled adoption of the Grains Best Management Program in the Fitzroy Basin and concluded that:

“By comparing the results achieved for the farm management practices assessed it is evident that very significant dollar per hectare benefits may be achieved from the adoption of more sustainable farm management practices. Improved management practices are cost effective, improve the efficiency of production and increase farm viability. Furthermore, improved management practices that also increase crop yields and/or cropping frequency will improve farm viability substantially.”

In grazing lands it is clear there are situations where investments in improved management are worthwhile for the landholders and others that provide mainly a public benefit in terms of minimising sediment loss.

Analysis of the direct costs and benefits related to changing cane management practices according to the ABCD framework (Van Grieken et al., 2010a) in multiple regions shows that cost reductions are substantial and yield responses are marginal (Van Grieken et al., 2010b,c). This suggests there are good opportunities for landholders to improve financial viability at the same time as reducing pollutant export to the Great Barrier Reef.

Appendix 3 Description of the methods for estimating the extent of riparian vegetation

Creating a spatial layer to represent riparian areas

There is a great diversity of river types within the Great Barrier Reef catchments from small, first order streams in upland areas to large coastal rivers. Riparian areas may range in size from small pockets between the streambed and the upper stream bank to lower parts of the river system that include extensive floodplains. A standardised approach was used to define riparian watercourse boundaries or stream centre lines and then buffer these by 50 metres on each side to create the riparian areas spatial layer extent. This spatial extent is likely to cover most riparian areas. In the case of some smaller streams, this layer is likely to include some adjacent land.

For this report, a standard buffer of 50 metres was considered a reasonable representation of riparian areas across the 35 catchments, based on visual interpretation and expert knowledge.

Several datasets were used to define riparian watercourse boundaries and stream mid-lines. The primary data set was the 1:100,000 Geoscience Australia drainage layer (2009). A 50 metre buffer margin around the linear features in this layer includes the streambed but also proportions of, or all of, the adjacent riparian areas. This, however, inadequately represents large streams where a defined buffer may not extend outside the water body due to the size of the river itself. To resolve this, the riverine water body and lacustrine water body data from the Wetlands Mapping Project (EPA, 2005) was used to define the width of large rivers. The riverine wetlands class from this project was, therefore, included to better define the riparian width.

The drainage layer, riverine wetlands and water body layers were all buffered by 50 metre margins and then merged into a single geographic information system mapping layer to represent the riparian areas of Great Barrier Reef catchments. Estuarine water bodies from the Wetlands Mapping Project were buffered by 100 metres and excluded from the riparian areas as these areas are reported on in the wetlands component of this chapter.

Riparian forest extent mapping and groundcover for the baseline

The National Forest Inventory has defined the minimum crown cover for forests as 20 per cent (Montreal Process Implementation Group for Australia, 2008). Scarth et al. (2008) showed that foliage projective cover of 11 per cent is equivalent to 20 per cent crown cover. Therefore, areas with foliage projective cover of at least 11 per cent are considered forested in this study. Foliage projective cover data was generated using satellite imagery from 1986 to 2009 using the method described by Armston et al. (2009). Groundcover estimates were generated from satellite imagery for 2009 based on the method described by Scarth et al. (2006). With the current methodology, reliable groundcover estimates can only be produced for both cleared areas and open woodlands.

Within the extent of the buffers, the foliage projective cover and groundcover were analysed. The foliage projective cover analysis included statistics on the extent of woody vegetation (greater than or equal to 11 per cent foliage projective cover). Where woody vegetation is absent, the groundcover data was analysed and separated into areas of low cover (less than 50 per cent cover) and high cover (greater than or equal to 50 per cent). The groundcover estimates are based on the dry season mean from 1986 to 2009.

Monitoring forest extent change from 2004 to 2008

Changes in forest extent from 2004 to 2008 were also reported. Forest extent changes include loss of forests through tree clearing and gains in forest extent through regrowth or new plantings. The monitoring of forest extent for this project, however, is restricted to tree clearing only. It is expected that the reduction in forest extent as a result of tree clearing is significantly larger than the potential forest gains through regrowth or new plantations.

In Queensland, landcover change mapping has been in progress since 1995, as part of the Statewide Landcover and Trees Study (SLATS; www.nrw.qld.gov.au/slats). The primary objective for this program is to detect and map changes in woody vegetation as a result of tree clearing. Statewide Landcover and Trees Study data from 2004 to 2008 was analysed within the riparian areas and statistics generated for Great Barrier Reef catchments and sub-catchments. At the time of publication, the change detection from 2008 to 2009 has not been completed.

Limitations

Several limitations need to be considered when using this data. Initially, the area statements on the extent of forests within riparian areas were based on foliage projective cover estimates derived from satellite imagery with a pixel size of 30 metres (re-sampled to 25 metres). Higher quality (SPOT 5) imagery for 2009 will be available for the majority of the Great Barrier Reef catchments for future reports. Following geometric and radiometric corrections of this imagery, foliage projective cover estimates will be generated at higher spatial resolution (10 metres). It is likely the baseline information will be updated to reflect the new estimates. Field data will also be collected to validate these foliage projective cover estimates and the derived forest extent mapping.

Monitoring of tree clearing within riparian areas can be conducted using Statewide Landcover and Trees Study data. It is likely, however, that some regrowth has since occurred. It was not possible to reliably map regrowth using existing imagery for the short period of 2004 to 2008. Further research is required before detection of regrowth can be undertaken within riparian areas.

Other limitations include the accuracy of the drainage layer and the Wetlands Mapping Project. These data sets have been mapped at a scale of 1:100,000. The satellite imagery used (Landsat) is only suitable for producing maps at a scale of 1:100,000 or coarser. However, the overall accuracy of the riparian buffer areas will be restricted by the drainage layer and Wetlands Mapping Project.

Missing data in the summary statistics is mostly due to cloud and cloud shadow cover in the groundcover data. However, it may also be due to topographic shading and water areas within the buffered riparian extents. It is not possible to map tree or groundcover using remote sensing in these areas.

The riparian results in this report were limited to two indicators of riparian vegetation: forest extent and groundcover. For example, forest extent may include woody weed infestations. Although woody weeds species have a lower ecological value than native vegetation, they can provide higher bank stability compared to banks with no vegetation at all. Groundcover may give an indication of stream bank stability in non-forested areas, but groundcover is difficult to assess under forest canopies. Other indicators could be developed in the future to assess the ecological function of riparian zones, including connectivity of riparian vegetation.

Appendix 4 Description of the method to estimate catchment loads

The following information is from Kroon et al. (2010).

Use of different methods to estimate catchment loads

To estimate natural and total catchment loads in the Great Barrier Reef, generally two different methods are used:

- A (deterministic) process-based model (e.g. SedNet, Source Catchments) that incorporates mapped information about different sources of pollutants, and takes into account the hydrology and contaminant transport characteristics of the system (Wilkinson et al., 2004). This information is used to route the pollutants through a river network and to estimate a load.
- A statistical modelling framework (e.g. Load Regression Estimator methodology), which makes use of monitoring data collected at a site within a catchment over a specified time frame (e.g. this report, also Kuhnert et al., 2009; Wang et al., 2009).

The choice between using a (deterministic) process-based model or a statistical modelling framework to estimate catchment pollutant loads depends on the resolution and representativeness of the monitoring data captured, and how well the process model is believed to mimic the underlying hydrological processes and variability of the system. Where the monitoring data is representative of the river system, statistical approaches tend to be applied. When monitoring data is sparse or unavailable, process-based models are typically used. In addition, some parameters in process based models are calibrated using the same monitoring data that is used as a means for calculating loads, ignoring uncertainty in the model structure as well as on the data that is used for calibration purposes.

Effect on total pollutant load estimates

The results show that the total load estimates of total suspended solids, dissolved inorganic nitrogen, dissolved organic nitrogen, dissolved inorganic phosphorus and dissolved organic phosphorus for individual basins derived from the two methods are in general agreement. For basins where long term monitoring records provided good temporal coverage, this is to be expected as SedNet model runs have been adjusted with validated sediment rating curves (total suspended solids) and are driven by stream concentration monitoring data (dissolved inorganic nitrogen, dissolved organic nitrogen, dissolved inorganic phosphorus and dissolved organic phosphorus). Differences between the two methods can arise from the fact that the mean-annual Load Regression Estimator loads are valid for the monitoring periods, which may cover on average a wetter or drier period than the long term average.

The SedNet total particulate phosphorus and particulate nitrogen loads, and consequently total phosphorus and total nitrogen loads, were greater than the 80 per cent confidence interval for the Load Regression Estimator load estimates in several basins (Barron, Herbert and Pioneer) and not smaller than the 80 per cent confidence interval in any basins. In the Pioneer, this mismatch is consistent with that for total suspended solids on which SedNet particulate nutrient load estimates are based. Over-estimation of particulate nutrient loads in SedNet modelling has been previously identified, and estimates have been halved in some previous reporting to match monitoring-derived load estimates (Cogle et al., 2006). In the Barron and Herbert basins, over-estimating particulate nutrient loads in SedNet is likely due to the soil nutrient concentration data used in SedNet modelling being an over-estimate of the concentrations of material delivered to streams, or the predicted mix of hillslope and sub-surface erosion was biased towards hillslope erosion.

Effect on baseline pollutant load estimates

The baseline pollutant load for each basin was calculated based on the most recent estimates for natural catchment pollutant loads derived from catchment modelling, and total pollutants loads derived from a combination of catchment modelling and monitoring. For some basins, results from different catchment model runs were used as the most recent available estimates for natural and total catchment loads, as not all studies modelled natural and total catchment loads, or modelled total catchment loads for all constituents. This has resulted, in a few cases, in the following discrepancies in baseline load estimates:

- Total nitrogen and total phosphorus baseline loads do not always correspond with the sum of baseline loads of all nitrogen and phosphorus constituents, respectively (e.g. Wet Tropics, Burdekin and Mackay Whitsundays Natural Resource Management regions, and Great Barrier Reef region).
- Out of the 350 baseline load estimates for the individual basins, 13 had negative values:
  - Four of these are attributed to pollutant trapping and processing within reservoirs that outweighs the load increases associated with land use changes from natural.
  - Five of the remaining nine were derived from subtracting modelled natural loads from modelled total loads. Most of these can be attributed to the higher dissolved organic nitrogen and dissolved organic phosphorus concentrations assigned to rainforest in natural pollutant load estimates (e.g. McKergow et al., 2005b) compared with those in more recent total pollutant load estimates (e.g. Cogle et al., 2006; Armour et al., 2009; Post et al., 2006)[1].
  - The final four were derived from subtracting modelled natural loads from monitored total loads. The Tully dissolved organic nitrogen and dissolved organic phosphorus total load estimates were not smaller than the most recent modelled estimates, which were themselves based on lower rainforest concentrations of dissolved organic nitrogen and dissolved organic phosphorus than those used to estimate natural loads. Similarly, the negative baseline dissolved organic nitrogen load for the

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[1] The higher dissolved organic nitrogen and dissolved organic phosphorus concentrations assigned to rainforest affects the natural loads from all basins with significant rainforest to varying degrees (all basins in Cape York and Wet Tropics regions, Black, Proserpine, O'Connell, Pioneer), and the total loads from the Cape York basins (excluding Normanby).

Johnstone may be due to higher rainforest concentrations in the modelled natural loads (McKergow et al., 2005b). The total dissolved inorganic nitrogen load for the Barron is similar to previous estimates (e.g. Furnas, 2003; McKergow et al., 2005b), but 10 times lower than the best modelled estimate (Cogle et al., 2006).

To ensure that future estimates of catchment loads to the Great Barrier Reef are beyond reproach, it is recommended that:

- Improvements in the quality of model inputs be made in future catchment modelling, including terrain slope, gully extent and activity, hydrographic gauging[2], riverbank height and the network extent over which bank erosion is represented, reservoir sediment trapping, c-factor associated with closed/rainforest (e.g. Armour et al., 2009)[3], and the nutrient concentrations of soil and dissolved runoff.
- The natural pollutant load estimates for all basins be revised in parallel with revision of total catchment loads, ensuring consistency in data inputs and modelling methods (Source Catchments), and improving the robustness of the baseline load estimates to the Great Barrier Reef, and all sources of uncertainty (parameter, model and data) associated with load estimates are propagated through the catchment models, resulting in transparent, objective and repeatable estimates of end-of-catchment loads.

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[2] Floodplain hydrodymanic modelling can also be used to reduce uncertainties by explicitly representing flow velocity across a floodplain.

[3] SedNet estimates for total suspended solids (and PN and PP) from basins that contain significant closed/rainforest are most likely overestimates, as total suspended solids monitoring data indicates that lower USLE cover factors should be applied in rainforest areas. This will have resulted in SedNet over-estimating total suspended solids loads in basins with closed/rainforest (natural loads: all basins in Cape York and Wet Tropics regions, Black, Proserpine, O'Connell, Pioneer; total loads: Lockhart, Russell-Mulgrave, Murray, O'Connell (possibly), Plane Creek basin (possibly), and Mary (possibly)).