

# 2013 Scientific Consensus Statement

Land use impacts on  
Great Barrier Reef water quality  
and ecosystem condition



Lead authors: Jon Brodie, Jane Waterhouse, Britta Schaffelke, Frederieke Kroon, Peter Thorburn, John Rolfe, Johanna Johnson, Katharina Fabricius, Stephen Lewis, Michelle Devlin, Michael Warne, Len McKenzie

Independent Science Panel: Roger Shaw, Eva Abal, Mike Grundy, Peter Doherty, Neil Byron

© The State of Queensland 2013. Published by the Reef Water Quality Protection Plan Secretariat, July 2013. Copyright protects this publication. Excerpts may be reproduced with acknowledgement to the State of Queensland. Image credits: Tourism Queensland; Queensland Government Department of Agriculture, Fisheries and Forestry; Great Barrier Reef Marine Park Authority; Burnett Mary Regional Group.

This document was prepared by an independent panel of scientists with expertise in Great Barrier Reef water quality. This document does not represent government policy.



# Scientific Consensus in 2013

To support the development of the Reef Water Quality Protection Plan 2013 (Reef Plan) a multidisciplinary group of scientists, with oversight from the Reef Plan Independent Science Panel, was established to review and synthesise the significant advances in scientific knowledge of water quality issues in the Great Barrier Reef and to reach consensus on the current understanding of the system.

The overarching consensus is *that key Great Barrier Reef ecosystems are showing declining trends in condition due to continuing poor water quality, cumulative impacts of climate change and increasing intensity of extreme events.*

The evidence base is synthesised in a series of five supporting chapters and the following conclusions are based on those detailed reviews:

1. The decline of marine water quality associated with terrestrial runoff from the adjacent catchments is a major cause of the current poor state of many of the key marine ecosystems of the Great Barrier Reef.
2. The greatest water quality risks to the Great Barrier Reef are from nitrogen discharge, associated with crown-of-thorns starfish outbreaks and their destructive effects on coral reefs, and fine sediment discharge which reduces the light available to seagrass ecosystems and inshore coral reefs. Pesticides pose a risk to freshwater and some inshore and coastal habitats.
3. Recent extreme weather—heavy rainfall, floods and tropical cyclones—have severely impacted marine water quality and Great Barrier Reef ecosystems. Climate change is predicted to increase the intensity of extreme weather events.
4. The main source of excess nutrients, fine sediments and pesticides from Great Barrier Reef catchments is diffuse source pollution from agriculture.
5. Improved land and agricultural management practices are proven to reduce the runoff of suspended sediment, nutrients and pesticides at the paddock scale.

# Independent Science Panel remarks

The Independent Science Panel (the panel) was established in 2009 to provide multidisciplinary scientific advice to the Australian and Queensland Governments on implementing Reef Plan. The panel also oversaw and reviewed the 2013 Scientific Consensus Statement.

In reviewing the evidence and conclusions of the Consensus Statement, the panel noted:

1. There has been excellent progress over the past four years with greater scientific understanding and measurement of 'catchment to reef' processes and progress by the farming community towards land management practices that reduce pollutant loads to the Great Barrier Reef.
2. Water quality modelling, supported by appropriate validation, indicates that early adopters of best practice land management have reduced total pollutant loads—a significant step towards the goal of halting and reversing the decline in water quality to the reef.
3. The recent relative risk assessment is a major achievement allowing the development of cost-effective, regionally-specific management actions to improve water quality. The leading example is the recommendation to reduce nitrogen loads from northern rivers. This will reduce the frequency and severity of primary outbreaks of crown-of-thorns starfish arising from floods in this area, which propagate to many other reefs in the central Great Barrier Reef over 15 year cycles.
4. While current management interventions are starting to address water quality in the Great Barrier Reef, sustained and greater effort will be needed to achieve the ultimate goal of no detrimental impact on the health and resilience of the reef. In addition to continuous improvement, transformational changes in some farming technologies may be necessary to reach some targets.
5. Conditions in terrestrial catchments are most strongly connected with marine receiving waters during floods but the extreme rainfall causing major floods is often episodic and may be separated by decadal droughts. Consequently, there are inherent and complex lags in this system which must be recognised in performance evaluations of Reef Plan. This challenge is best met by investing in continued development of coupled catchment-reef models and the essential collection of adequate data to calibrate and validate the models.
6. The Consensus Statement has identified new knowledge needed to help achieve the ultimate goal of Reef Plan. These are outlined in the supporting chapters of the Consensus Statement and will assist with identifying future research priorities. Future efforts should focus on synthesising the knowledge gained and communicating the results to landholders and decision makers. The Consensus Statement provides an excellent platform for this work.





## Introduction

Globally, reefs and other coastal marine ecosystems are exposed to a combination of pressures including increased discharge of sediment, nutrients and pesticides, crown-of-thorns starfish outbreaks, increased bleaching associated with global climate change, and increased incidence of and severity of coral diseases, destructive fishing practices, overfishing or loss of herbivorous fish and other grazing organisms. These pressures have led to precipitous declines in coral cover and to persistent shifts away from coral dominance.

On the Great Barrier Reef, recent evidence shows that coral cover has declined from around 50 per cent in the 1960s to around 14 per cent in 2011 with a well-documented decline from 28 per cent in 1985 to 14 per cent in 2013. Coral cover decline in the northern Great Barrier Reef has not shown the consistent downward trend seen along the developed coast of the central and southern Great Barrier Reef. This reflects the limited catchment development in Cape York. The causes of this decline are various and are often region or reef specific for example:

- cyclones can physically destroy coral reefs
- runoff of sediment and nutrients predominantly affects coastal and inshore reefs with evidence linking nutrient inputs with crown-of-thorns starfish outbreaks that impact most of the Great Barrier Reef
- coral bleaching caused by increased temperatures associated with climate change
- coral disease linked to degraded water quality and climate change.

Recent declines in coral calcification have been linked to the combined effects of increases in temperature and the effects of ocean acidification. Similarly, the extent of coastal seagrass meadows has been in severe decline, particularly in the southern Great Barrier Reef, which has had associated impacts on dugongs and green turtles. Southern Great Barrier Reef dugong populations are much smaller than in the mid-1960s, a situation exacerbated by recent extreme weather events which damaged seagrass meadows. Mortality of dugongs and green turtles in the southern Great Barrier Reef in 2011 was higher than in any year since monitoring started in 1998.

Declining marine water quality, influenced by terrestrial runoff, is recognised as one of the most significant threats to the long-term health of the Great Barrier Reef. Management of this issue will improve ecosystem resilience to other pressures including those associated with a changing climate.

## Background

The establishment of Reef Plan in 2003 by the Australian and Queensland Governments was supported by evidence showing a decline in water quality and the associated ecosystem decline on the Great Barrier Reef.

A comprehensive review of the evidence available at the time was prepared by a taskforce of experts. In 2008, an updated Scientific Consensus Statement was prepared as part of the review and updating of Reef Plan 2009. This ensured that Reef Plan 2009 was based on advances in scientific knowledge.

The key finding of the 2008 Scientific Consensus Statement was that water discharged from rivers to the Great Barrier Reef continued to be of poor quality in many locations with land derived contaminants, including suspended sediments, nutrients and pesticides, present at concentrations likely to cause environmental harm. The other main findings were that climate change and major land use change had confounding influences on Great Barrier Reef health and current management interventions were not effectively solving the problem.



# Summary of evidence to support the Scientific Consensus Statement 2013

## 1. The decline of marine water quality associated with terrestrial runoff from the adjacent catchments is a major cause of the current poor state of many of the key marine ecosystems of the Great Barrier Reef.

Great Barrier Reef marine ecosystems and their associated catchments are part of a dynamic, interconnected system. Activities within the catchments affect the condition of coral reefs and seagrass meadows, which have both declined severely in the period since 2008. Marine water quality continues to be negatively affected by the discharge of excess nutrients, fine sediments and pesticides from the adjacent catchments, and poor marine water quality is a major cause for the poor state of many of the key marine ecosystems (coral reefs, seagrass meadows, coastal wetlands and estuaries) of the Great Barrier Reef.

### Summary of evidence:

- 1.1 Great Barrier Reef-wide coral cover has declined by approximately 50 per cent since 1985, while coral cover on inshore reefs has declined by 34 per cent since 2005. Coral cover in the northern Great Barrier Reef has remained stable. Causes of coral loss vary from reef to reef, depending on exposure to tropical cyclones, outbreaks of crown-of-thorns starfish or coral disease, elevated temperatures causing coral bleaching and exposure to flood plumes.
- 1.2 Evidence of the link between poor water quality, specifically nutrients, and crown-of-thorns starfish outbreaks has been greatly strengthened.
- 1.3 Inshore seagrass meadows along the developed Great Barrier Reef coast (i.e. south of Cooktown) have declined over the past three to five years and are in poor condition.
- 1.4 Suspended sediment discharges, especially after extreme weather events, negatively affect turbidity in inshore waters, reduce the light required by corals and seagrass meadows and increase the sedimentation of fine particles and organic rich flocs (muddy marine snow) that can smother marine organisms.
- 1.5 Poor water quality, especially elevated concentrations of and different ratios of nutrients and high turbidity, has been shown to increase the likelihood of bleaching in corals.
- 1.6 There is evidence of increases in seagrass leaf tissue nitrogen concentrations since 2005. Epiphyte loads that reduce light availability and impair seagrass growth have increased, possibly as a consequence of increased nutrient supply.
- 1.7 Pesticides pose a low to moderate risk to inshore coral reefs at current levels, but the consequences of long term exposure at concentrations below those known to affect coral is not understood.
- 1.8 Many coastal and inshore seagrass meadows of the Great Barrier Reef are exposed to herbicide concentrations that adversely affect seagrass productivity. The contribution of herbicides to recent widespread seagrass losses is unknown.
- 1.9 The interactions of poor water quality with other pressures such as climate change are largely unknown, but could increase the risk to Great Barrier Reef ecosystems.
- 1.10 Significant new mangrove stands and landward range expansions in some areas of the Great Barrier Reef are correlated with increased sedimentation due to human activity. However, excessive sedimentation can reduce tree growth, bury seedlings and cause mortality. Increased productivity and growth in response to high nitrogen availability is offset by the increased probability of canopy loss and mortality during periods of drought or storm activity along gradients of increasing salinity. Remaining coastal wetlands are subject to sediment, nutrients and pesticides inputs from rainfall runoff and irrigation tailwater. These inputs and physical modifications to the wetlands contribute to loss of biodiversity and affect wetland structure and function, for example by facilitating weed growth, loss of connectivity between habitats, reduced oxygen levels and flow rate.





**2. The greatest water quality risks to the Great Barrier Reef are from nitrogen discharge, associated with crown-of-thorns starfish outbreaks and their destructive effects on coral reefs, and fine sediment discharge which reduces the light available to seagrass ecosystems and inshore coral reefs. Pesticides pose a risk to freshwater and some inshore and coastal habitats.**

A combination of qualitative and semi-quantitative assessments was used to estimate the relative risk of water quality constituents to Great Barrier Reef ecosystem health from major sources in the catchments, focusing on agricultural land uses. Risk was defined as the area of coral reefs and seagrass meadows within a range of assessment classes (very low to very high relative risk) for several water quality variables in each natural resource management region. The variables included:

- ecologically relevant thresholds for concentrations of total suspended solids and chlorophyll *a* from daily remote sensing observations
- the distribution of key pollutants including total suspended solids, dissolved inorganic nitrogen and photosystem II inhibiting herbicides in the marine environment during flood conditions (based on end-of-catchment loads and plume loading estimates)
- a factor related to water quality influences on crown-of-thorns starfish outbreaks was included for coral reefs.

The main finding was that increased loads of suspended sediments, nutrients (nitrogen and phosphorus) and pesticides all pose a high risk to some parts of the Great Barrier Reef. However, the risk differs between the individual pollutants, the source catchments and the distance from the coast.

**Summary of evidence:**

- 2.1 Overall, nitrogen poses the greatest risk of pollution to coral reefs from catchments between the Daintree and Burdekin Rivers. Runoff from these rivers during extreme and early wet seasons is associated with outbreak cycles of the coral-eating crown-of-thorns starfish on the northern Great Barrier Reef shelf (15 to 17 degrees south) that subsequently generate secondary outbreaks throughout the central Great Barrier Reef. Great Barrier Reef-wide loss of coral cover due to crown-of-thorns starfish is estimated to be 1.4 per cent per year over the past 25 years, and a new outbreak is underway. It is estimated that crown-of-thorns starfish have affected more than 1000 of the approximately 3000 reefs within the Great Barrier Reef over the past 60 years.





2.2 Of equal importance is the risk to seagrass from suspended sediments discharged from rivers in excess of natural erosion rates, especially the fine fractions (clays). Whether carried in flood plumes, or resuspended by waves, suspended solids create a turbid water column that reduces the light available to seagrass and corals. High turbidity affects approximately 200 inshore reefs and most seagrass areas. Seagrass loss severely impacts green turtle and dugong populations. On a regional basis, the Burdekin and Fitzroy regions present the greatest risk to the Great Barrier Reef in terms of sediment loads.

2.3 At smaller scales, particularly in coastal seagrass habitats and freshwater and estuarine wetlands, pesticides can pose a high risk. Concentrations of a range of pesticides exceed water quality guidelines in many fresh and estuarine water bodies downstream of cropping lands. Based on a risk assessment of the six commonly used photosystem II inhibiting herbicides, the Mackay Whitsunday and Burdekin regions are considered to be at highest risk, followed by the Wet Tropics, Fitzroy and Burnett Mary regions. However, the risk of only a fraction of pesticides has been assessed, with only six of the 34 pesticides currently detected included in the assessment, and therefore the effect of pesticides is most likely to have been underestimated.

2.4 The ranking of the relative risk of degraded water quality between the regions in the Great Barrier Reef is (from highest risk to lowest):

- Wet Tropics
- Fitzroy
- Burdekin
- Mackay Whitsunday
- Burnett Mary
- Cape York.

Priority areas for managing degraded water quality in the Great Barrier Reef are Wet Tropics for nitrogen management; Mackay Whitsunday and the lower Burdekin for photosystem II inhibiting herbicide management; and Burdekin and Fitzroy for suspended sediment management.

2.5 From a combined assessment of relative risk of water quality variables in the Great Barrier Reef (using the total area of habitat affected in the areas identified to be of highest relative risk) and end-of-catchment

anthropogenic loads of nutrients, sediments and photosystem II inhibiting herbicides, the regional ranking of water quality risk to coral reefs is (from highest risk to lowest):

- Wet Tropics
- Fitzroy
- Mackay Whitsunday
- Burdekin
- Cape York
- Burnett Mary.

The regional ranking of water quality risk to seagrass is (from highest risk to lowest):

- Burdekin
- Wet Tropics
- Fitzroy
- Mackay Whitsunday
- Burnett Mary
- Cape York.

Importantly in the Mackay Whitsunday region, 40 per cent of the seagrass area is in the highest relative risk class compared to less than 10 per cent for all other regions. The highly valuable seagrass meadows in Hervey Bay, and the importance to associated dugong and turtle populations in the Burnett Mary region, were not included in the ranking analysis, as they are outside the Great Barrier Reef Marine Park boundaries.

2.6 Both dissolved (inorganic and organic) and particulate forms of nutrients discharged into the Great Barrier Reef are important in driving ecological effects. Overall, increased nitrogen inputs are more important than phosphorus inputs. Dissolved inorganic forms of nitrogen and phosphorus are considered to be of greater concern than dissolved organic and particulate forms as they are immediately bioavailable for supporting algal growth. Particulate forms of nitrogen and phosphorus mostly become bioavailable, but over longer time frames. Most dissolved organic nitrogen typically has limited and delayed bioavailability.

2.7 Little is known about the types and concentrations of contaminants bound to sediment discharged by rivers into the Great Barrier Reef and the risk that these pose to marine ecosystems.



**3. Recent extreme weather—heavy rainfall, floods and tropical cyclones—have severely impacted marine water quality and Great Barrier Reef ecosystems. Climate change is predicted to increase the intensity of extreme weather events.**

The prediction that weather events (rainfall variability and tropical storms) may become more intense in the future as a consequence of climate change has severe implications for water quality and Great Barrier Reef ecosystems. Extreme weather events (drought and flooding rain) will increase runoff and physically disturb ecosystems.

**Summary of evidence:**

- 3.1 In 2010, a historically strong La Niña weather pattern developed, replacing an El Niño pattern. Between 2009 and 2012, seven cyclones affected North Queensland which produced substantial physical damage to shallow water ecosystems and record flooding. Extreme rainfall in 2010-2011 and 2012-2013 resulted in extensive flood plumes along most of the coast and across much of the continental shelf in some regions.
- 3.2 Recent loss of seagrass habitat as a result of severe weather events and degraded water quality has led to increased mortality of dugongs and green turtles.
- 3.3 The cumulative pressure of multiple stressors determines the state of marine ecosystems and the trajectory of recovery after disturbance. A 50 per cent decline in Great Barrier Reef coral cover over the past three decades shows that the natural resilience of the ecosystem has been compromised by impacts from extreme rainfall and associated runoff from agriculture, thermal stress, salinity stress, light stress, cyclone damage and crown-of-thorns starfish outbreaks.
- 3.4 Reducing end-of-catchment loads of nutrients, sediments and pesticides will help enhance reef resilience in the face of continuing climate change pressures. For example, if the impacts of crown-of-thorns starfish were reduced following nitrogen load reduction from the Wet Tropics, coral cover is predicted to either recover or at least stabilise.



## 4. The main source of excess nutrients, fine sediments and pesticides from Great Barrier Reef catchments is diffuse source pollution from agriculture.

Estimates of river pollutant loads to the Great Barrier Reef lagoon have greatly improved since the last Consensus Statement. The results confirm that water discharged from the catchments into the lagoon continues to be of poor quality in many locations. Furthermore, enhanced modelling and monitoring of total suspended solids, nitrogen, phosphorus and photosystem II inhibiting herbicides, and provenance tracing of sediment, has significantly enhanced our knowledge of major sources and processes contributing to these river pollutant loads. The main land uses contributing pollutant loads are rangeland grazing for sediment, rangeland grazing and sugarcane for total nitrogen and total phosphorus, and sugarcane for photosystem II inhibiting herbicides. The Wet Tropics, Burdekin and Fitzroy regions contribute most to these river pollutant loads.

### Summary of evidence:

- 4.1 Compared to pre-European conditions, modelled mean-annual river loads to the Great Barrier Reef lagoon have increased 3.2 to 5.5-fold for total suspended solids, 2.0 to 5.7-fold for total nitrogen and 2.5 to 8.9-fold for total phosphorus. However large differences in changed loads exist between rivers due to human factors; e.g. there is almost no change in loading for most pollutants in northern Cape York rivers but much greater changes in rivers in the central and southern Great Barrier Reef. Mean-annual modelled loads of photosystem II inhibiting herbicides, namely ametryn, atrazine, diuron, hexazinone, tebuthiuron and simazine, are estimated to range between 16,000 and 17,000 kilograms per year. The total pesticide load to the Great Barrier Reef lagoon is likely to be considerably larger, given that another 28 pesticides have been detected in the rivers.
- 4.2 The Fitzroy and Burdekin regions contribute at least 70 per cent to the modelled total suspended solids load to the Great Barrier Reef lagoon from human activity. Grazing lands contribute over three quarters of this load. The dominant sediment supply to many rivers is from a combination of gully and streambank erosion, and subsoil erosion from hillslope rilling, rather than broad-scale hillslope sheetwash erosion. Fine sediment (less than 16 micrometres) material is the fraction most likely to reach the Great Barrier Reef lagoon, and is present at high proportions in monitored total suspended solids in the Burdekin, Fitzroy, Plane, Burnett, and Normanby catchments.
- 4.3 The Fitzroy, Burdekin and Wet Tropics regions contribute over 75 per cent to the modelled total nitrogen load to the Great Barrier Reef lagoon from human activity. Particulate nitrogen comprises by far the largest proportion, followed by dissolved inorganic and dissolved organic nitrogen respectively. Sediment erosion processes, particularly in grazing lands, are sources of particulate nitrogen; sugarcane, other cropping and grazing are sources of dissolved inorganic nitrogen; and land use changes in filter and buffer capacity are the main sources of dissolved organic nitrogen.
- 4.4 The Fitzroy and Burdekin regions contribute approximately 55 per cent to the modelled total phosphorus load to the Great Barrier Reef lagoon from human activity. Particulate phosphorus comprises by far the largest proportion, followed by dissolved inorganic and dissolved organic phosphorus respectively. Sediment erosion processes, particularly in grazing lands, are sources of particulate phosphorus; sources of dissolved inorganic phosphorus and dissolved organic phosphorus are unclear.
- 4.5 Most particulate nitrogen and phosphorus is lost or mineralised from fine sediment following delivery to the Great Barrier Reef lagoon and could be readily available for uptake in marine ecosystems.
- 4.6 The Wet Tropics, Burdekin and Mackay Whitsunday regions contribute over 85 per cent of the modelled total photosystem II inhibiting herbicides load to the Great Barrier Reef lagoon from human activity. Sugarcane contributes 94 per cent of this load. Groundwater potentially may be an important source of photosystem II inhibiting herbicides (as well as dissolved nutrients) to critical near-shore ecosystems of the Great Barrier Reef lagoon; however, insufficient information is available to evaluate the risks.
- 4.7 The role of modified freshwater flow regimes in driving pollutant transport and affecting reef condition, through surface water diversion, dam construction and wetland drainage and deforestation, has not been fully analysed but is important.
- 4.8 Compared to diffuse sources, most contributions to suspended sediment, nutrient and pesticide loads from point sources such as intensive animal production, manufacturing and industrial processing, mining, rural and urban residences, waste treatment and disposal, ports and shipping are relatively small but could be locally, and over short-time periods, highly significant. Point sources are the major sources of pollutants such as metals, industrial chemicals and pharmaceuticals. Whilst point sources are generally regulated activities, monitoring may not include this broad range of chemicals, and monitoring and permit information is not always available. In contrast to nutrients, sediments and pesticides, there is a lack of knowledge of the risks posed by these chemicals to Great Barrier Reef ecosystems.



## 5. Improved land and agricultural management practices are proven to reduce the runoff of suspended sediment, nutrients and pesticides at the paddock scale.

Our knowledge of the effectiveness of specific management practices in terms of water quality benefits and economic outcomes has improved significantly since 2008 and improved the ability to prioritise management action. However, the costs and risks for landholders associated with changing management practices can prove significant barriers to adoption and are not well understood.

### Summary of evidence:

- 5.1 In grazing lands, sediment loads are reduced by: setting stocking rates that maintain ground vegetation cover and biomass (particularly during droughts and at the end of the dry season) and vegetation diversity (including maintaining some tree cover particularly in riparian areas); and managing stock access to, and increasing ground cover in, riparian or frontage country and wetlands, and rilled, scalded and gullied areas. Techniques for managing gully and streambank erosion, which are known to be a significant source of sediments in grazing lands, are important and require further investigation as to their economic viability and effectiveness.
- 5.2 Soil management practices that reduce runoff and sediment movement reduce loads of particulate and total nutrients in runoff.
- 5.3 In most cropping systems of the Great Barrier Reef, management systems that reduce or eliminate tillage and maximise soil cover (via crop residue retention) and the use of grassed headlands, and where appropriate grassed inter-rows, reduce soil loss. Controlled traffic and contour embankments also reduce runoff and soil loss. Targeting practice improvement to areas contributing most to soil loss, considering erosion rates, soil texture and location of sediment traps including reservoirs, can increase the effectiveness at the Great Barrier Reef scale.
- 5.4 Losses of nitrogen are related to nitrogen fertiliser applications and the nitrogen surplus (i.e. the difference between nitrogen inputs and nitrogen in crop off-take) at both the field and whole-Great Barrier Reef scales. Where surpluses are high, nutrient loads are most effectively reduced by reducing nutrient inputs and surpluses. The same principles should apply to phosphorus. When nitrogen applications closely match crop requirements (i.e. nitrogen surpluses are low), management 'tactics' such as splitting or altering the timing of fertiliser applications, altering fertiliser types and burying fertiliser, can help manage the risk of nitrogen supply limiting yield.
- 5.5 Nutrients from sources such as nitrogen from legumes and nitrogen and phosphorus from mill mud in sugarcane areas may substantially increase nutrient surpluses and thus have water quality impacts.
- 5.6 In furrow irrigated sugarcane, increasing irrigation efficiency (i.e. reducing over-application of irrigation) reduces nutrient losses. Efficiencies can be increased either by better managing irrigation within a given system, or moving from systems with lower (e.g. furrow) to higher (e.g. trickle) efficiency.
- 5.7 Soil management practices that reduce runoff and sediment movement (e.g. retention of crop residues, controlled traffic) reduce pesticide runoff. Managing pesticide application timing (i.e. increasing the time between application and runoff) as well as the amount, placement and application method (e.g. banded spraying) will reduce pesticide runoff greatly, especially for the highly soluble photosystem II inhibiting herbicides. Applying products with rapid degradation rates (e.g. 'knockdown' herbicides) will reduce concentrations and loads in runoff.
- 5.8 Constructed wetlands need to be maintained, with accumulated sediments, particulate nutrients and associated weed biomass removed off-site. If not maintained, these accumulated materials can be 'flushed out' of the wetlands and flow to the Great Barrier Reef during flood events, reducing the water quality improving capacity of wetlands.
- 5.9 Wetlands have much broader values in the landscape than just water quality improvement, so they should not be used as a substitute for poor land management practices. Poor quality water flowing into freshwater wetlands can impair wetland functions and be detrimental to wider landscape health and productivity.
- 5.10 The costs of changing management practices to improve water quality vary greatly (e.g. two orders of magnitude) between different agricultural enterprises on a per-hectare basis. Therefore, it is difficult to assume a single economic outcome of changed management.
- 5.11 Improving farm management to meet an industry-based Best Management Program generally gives positive economic benefits in the long-term, and so little or no external support may be needed to encourage this change. However, the economic benefits of Best Management Programs alone may not be large enough to drive adoption. The benefits from changing management practices also varies between farms, so the cost-effectiveness of changes can differ significantly across practices, farms and industries. This means that there is a challenge to find the most efficient solutions that will deliver improvements where they achieve the largest benefits.
- 5.12 The transaction costs associated with changing management and the largely risk-averse nature of agribusinesses are factors that can prove significant barriers to adopting improved practices. Increasing adoption rapidly and in cost-effective ways remain key challenges.



