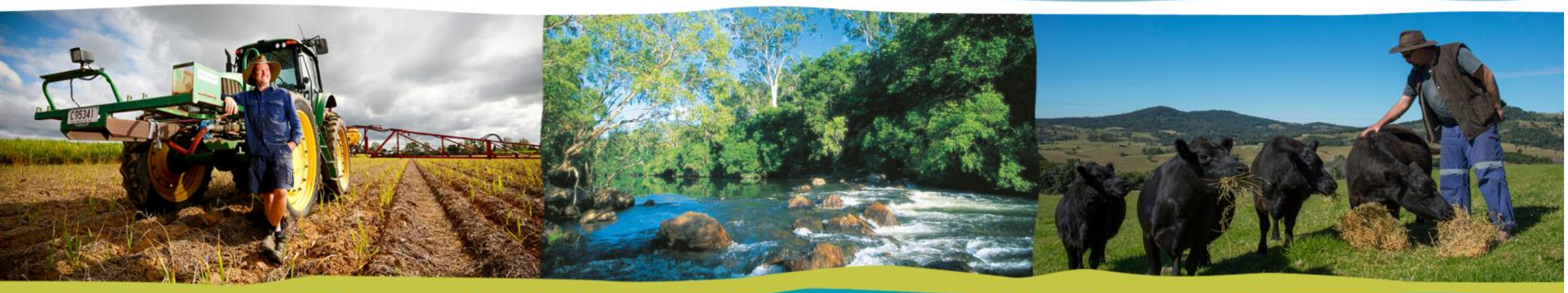
# Methods



## Great Barrier Reef
Report Card 2015

Australian Government

Queensland Government

**Great Barrier Reef Report Card 2015 Methods**

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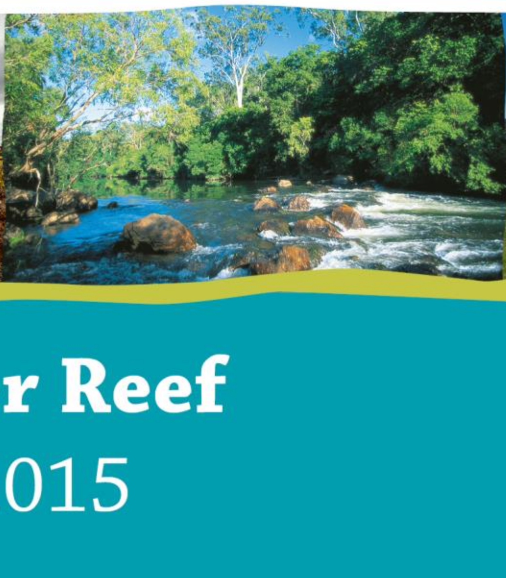
# Management practice methods

## Great Barrier Reef
Report Card 2015

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## Management practice methods

This report summarises the development of revised management practice baselines for the Reef Water Quality Protection Plan 2013 and the means of describing progress toward the plan's target for adoption of best practice:

- *90 per cent of sugarcane, horticulture, cropping and grazing lands are managed using best management practice systems (soil, nutrient and pesticides) in priority areas by 2018*.

### Paddock to Reef Program Water Quality Risk frameworks

The Paddock to Reef Integrated Monitoring, Modelling and Reporting Program (Paddock to Reef program) has developed water quality risk frameworks for each agricultural industry. These frameworks articulate best practice in relation to the Reef Water Quality Protection Plan adoption target. Features of the Paddock to Reef water quality risk frameworks are:

- The suites of practices relevant to each pollutant are described in the frameworks. This does not mean all of the practices in the production system, only those practices that pose the greatest potential water quality risk through movement of sediments, nutrients, or pesticides off-farm.
- Not all practices are equal. The frameworks allocate a percentage weighting to each practice depending upon its relative potential influence on off-farm water quality.
- The 'best practice' level is that targeted by Reef Water Quality Protection Plan investments.

These practices are described in terms of their relative water quality risk from Low to High.

For the purpose of describing industry status and progress in relation to the Reef Water Quality Protection Plan 2013 adoption target, best management practice (BMP) is defined as the area managed under Low and Moderate-Low risk levels.

**Table 1: Paddock to Reef program classification of management practices in the grazing industry based on relative risk to water quality**

| **Water Quality Risk** | **Low** | **Moderate-Low** | **Moderate-High** | **High** |
|---|---|---|---|---|
| **Resource condition objective** | Practices highly likely to maintain land in good (A) condition and/or improve land in lesser condition | Practices are likely to maintain land in good or fair condition (A/B) and/or improve land in lesser condition | Practices are likely to degrade some land to poor (C) condition or very poor (D) condition | Practices are highly likely to degrade land to poor (C) or very poor (D) condition |

For sugarcane, horticulture and grains, the water quality risk framework describes management practices relating to managing nutrients, pesticides and sediments. For grazing systems, the framework describes management practices relating to dominant sources of soil erosion; pasture (hillslope), streambank and gully erosion.

**Table 2: Paddock to Reef program classification of management practices in the cropping industries (sugarcane, bananas, grains and horticulture)**

| Water Quality Risk | Low | Moderate-Low | Moderate-High | High |
|---|---|---|---|---|
| **Description** | Lowest water quality risk, commercial feasibility not well understood | Best Management Practice | Minimum Standard | Superseded |

Water quality risk frameworks provide the basis for describing:

- Industry status in relation to achievement of best practice systems. The Paddock to Reef program has developed new management practice baselines to correspond with the revision of targets, actions and investments under Reef Water Quality Protection Plan 2013.
- Annual progress from these 2013 baselines toward the 90 per cent adoption target.

## Establishing farm management baselines for Reef Water Quality Protection Plan 2013

Paddock to Reef program management practice and management system benchmarks have been developed for each agricultural industry sector, and in each major river basin within each region. There are varying levels of uncertainty or confidence in these benchmarks for many reasons.

**Table 3: Summary of data sources and uncertainty around management system baselines developed for Reef Water Quality Protection Plan 2013**

| Industry | Primary data sources | Confidence in management system baselines | Sources of uncertainty |
|---|---|---|---|
| **Bananas** | • 1:1 growers survey<br>• Banana BMP Guide (anonymous, aggregated)<br>• Reef Programme grant applications (anonymous) | Good | • High level of heterogeneity within the industry, particularly with respect to farm size. There are a relatively small number of very large farms which can skew results. |
| **Grains** | • Grains BMP program (anonymous)<br>• Expert agronomist workshops | High | • Over 80 per cent of industry represented in baseline sample. However there are some Grains BMP questions which do not allow discrimination of practices at a fine level. |
| **Grazing** | • Grazier 1:1 survey | Good | • Survey has enabled an excellent appreciation of farm management. However there is an assumption that good management corresponds to good resource condition.<br>• Some river basins have insufficient sample size to develop a baseline that is specific to that basin. In these instances the broader regional baseline is employed. |

| | | | |
|---|---|---|---|
| **Horticulture** | Growcom Farm Management System (anonymous) | High | • Very large proportion of industry represented in baseline sample (depending on region). However there are some Horticulture farm management systems (FMS) questions which do not allow discrimination of practices at a fine level. |
| **Sugarcane** | • 1:1 grower surveys<br>• Smartcane BMP program (anonymous, aggregated)<br>• Reef Programme grant applications (anonymous) | High | • Uncertainty around management related to timing of fertiliser and herbicide applications. Mostly relates to variance in interpretation from field staff capturing data on-farm.<br>• Alternate lines of evidence validate baseline distributions for key practices. |

**Grazing**

The prevalence of different management practices utilised in grazing businesses was determined through surveying of commercial-scale graziers between late 2011 and early 2014. Surveys took the form of one on one, semi-structured interviews conducted on-farm by experienced professional grazing extension officers. Survey questions were designed to align with the practices articulated in the Grazing Water Quality Risk framework, i.e. the responses recorded align with varying degrees of water quality risk associated with that management. The framework further aligns these practices with the erosion process that is most directly influenced by those practices. While the key management categories remained consistent, the questions and practice descriptions used in wet coastal landscapes were different to those used in rangelands grazing systems.

For reporting and Paddock to Reef program modelling purposes, the specific management practice data was analysed to develop management system ratings (from Low to High risk) that reflect the water quality risk of the mix of individual practices on a farm. Survey responses to individual questions (practice descriptions) were weighted and aggregated to develop a water quality risk score for the practices associated with each erosion process (pasture (hillslope) erosion, streambank erosion, and gully erosion). Table 4 below provides an example for one question that relates to the objective determination of long-term carrying capacity.

**Table 4: Grazing land management survey question 11 - the categories of response and the water quality risk score allocated for each category of response**

| Survey Question: For long-term planning what do you base your average carrying capacity on? | Score | Risk level |
|---|---|---|
| Historical experience and/or anecdotal advice (not documented) | 0 | High |
| Long-term stock and stocking rate records (documented in diaries, paddock records etc.) | 4 | Moderate |
| Some objective measure of safe stocking rate calculations, including property map and based on historical data, subjective assessment of resource condition | 7 | Low-moderate |
| Documented records, including property map and safe stocking rate calculations based on land type, property infrastructure and objective assessments of land condition. | 10 | Low |

This survey question (table 4) accounts for 10% of the total water quality risk score for practices related to hillslope erosion risk. The ‘best practice’ response is allocated a score of 10, and the least sophisticated management is allocated a score of zero. A total water quality risk score for the practices related to hillslope erosion was derived through combining scores for all relevant questions.

Scores for each erosion process were then assigned a management risk rating (table 5), based on expert review of specific combinations of management practices.

**Table 5: Water quality risk scores used to categorise management risk ratings**

| Erosion Process | Water Quality Risk Rating | | | |
|---|---|---|---|---|
| | Low | Low-Moderate | Moderate | High |
| **Hillslope** | 81-100 | 59-80 | 33-58 | 0-32 |
| **Streambank** | 100 | 66-99 | 33-65 | 0 |
| **Gully** | 85-100 | 62-84 | 32-61 | 0-31 |

**Table 6: Key grazing management categories and their weightings in developing water quality risk scores and ratings**

| Erosion Process | Management category (each informed by a suite of practices) | P2R Weighting |
|---|---|---|
| **Hillslope erosion** | **1.** Average stocking rates imposed on paddocks are consistent with district long-term carrying capacity benchmarks for comparable land types, current land condition, and level of property development | 20% |
| | **2.** Retention of adequate pasture and ground cover at the end of the dry season, informed by (1) knowledge of ground cover needs and (2) by deliberate assessment of pasture availability in relation to stocking rates in each paddock during the latter half of the growing season or early dry season. | 40% |
| | **3.** Strategies implemented to recover any land in poor or very poor condition (C or D condition) | 25% |
| | **4.** The condition of selectively-grazed land types is effectively managed | 15% |
| | **Hillslope erosion assessment** | 100% |
| **Streambank erosion** | **5.** Timing and intensity of grazing is managed in frontages of rivers and major streams (including associated riparian areas) and wetland areas. | 100% |
| **Gully erosion** | **6.** Strategies implemented, where practical and affordable, to remediate gullied areas | 30% |
| | **7.** Linear features (roads, tracks, fences, firebreaks, and water points located and constructed to minimise their risk of initiating erosion | 40% |
| | **1 – 4** Hillslope erosion assessment | 30% |
| | **Gully erosion assessment** | 100% |

Grazing management system baselines for Reef Plan 2013 were based on management system ratings for individual businesses, aggregated to form baselines for representative river basins within natural resource management (NRM) regions. These individual ratings and baselines were reviewed by regional experts and compared with corresponding data where available, (such as aggregated, anonymous assessments conducted by graziers participating in the Grazing BMP program). Where insufficient samples were available to discriminate management at the level of river basins, the baseline for the entire NRM region is used.

**Table 7: Number of individual grazing businesses and area represented in grazing baseline estimates**

| Region | Rangelands | Wet Coastal | Area represented (% of region) | |
|---|---|---|---|---|
| Cape York (Normanby) | 11 +17* | - | 1,263,673 ha | (58%) |
| Wet Tropics | 8 | 117 | 123,129 ha | (18%) |
| Burdekin | 98 | - | 3,103,197 ha | (24%) |
| Mackay Whitsunday | - | 28 + 43* | 154,089 ha | (38%) |
| Fitzroy | 98 | - | 991,677 ha | (8%) |
| Burnett Mary | 55 | 30 | 368,130 ha | (10%) |

**additional detailed samples provided courtesy of Cape York Sustainable Futures and Reef Catchments Mackay Whitsunday Isaac NRM.*

### Sugarcane

Key management practices relevant to water quality risk of sugarcane farming systems were articulated in a water quality risk framework for sugarcane in 2013.

**Table 8: Key management categories articulated in the Paddock to Reef program water quality risk framework for sugarcane**

| Management category | Weighting |
|---|---|
| **Sediment (runoff and soil loss)** | |
| Crop residue cover (green cane trash blanketing) | 30% |
| Controlled Traffic Farming | 25% |
| Land management during cane fallow | 25% |
| Tillage in plant cane (land preparation) | 20% |
| **Nutrients (nitrogen)** | |
| Matching nitrogen supply to crop nitrogen requirements | 60% |
| Timing of fertiliser application with respect to rainfall or irrigation | 30% |
| Application method (surface or subsurface) | 10% |
| **Pesticides** | |
| Timing application of residual herbicides | 40% |
| Targeting application to reduce the volume of herbicide applied | 40% |
| Residual herbicide use in ratoons | 20% |
| **Water** | |
| Calculating the amount of water to apply | 70% |
| Managing surface runoff | 30% |

The prevalence of each of these key management practices in the sugarcane industry was estimated through a benchmarking process conducted throughout 2013-14.

- A suite of questions directly relating to the Paddock to Reef program water quality risk framework was the basis of a survey conducted by regional NRM organisations on behalf of the program. Sampling was targeted as much as possible to ensure that up to 50 per cent of the growers sampled had not previously had high levels of engagement with Reef Water Quality Protection Plan initiatives. In each region there was a target of a minimum of 100 randomly selected growers across catchments.
- Congruent datasets were obtained through the Smartcane BMP program and recent applications (2012-13 and 2013-14 where available) for the Australian Government's incentive programs.
- In each region small expert panels were convened to review the adoption levels indicated by the various source data and confirm adoption estimates for each practice level, for each management issue. The proportion of growers and area at each level were checked for sensibility and modified if sufficient supporting evidence was available. Supporting evidence was in the form of discrete data (mills, local productivity service organisations, specific project data, other Paddock to Reef program data on rates and volumes of nutrient and pesticide use) and weight of local opinion.

Best management practice systems for sediment, nutrient, or pesticide management are described through aggregating the adoption levels of each practice according to their framework weighting.

### Bananas

The Paddock to Reef program water quality risk framework for bananas is based on the Australian Banana Grower's Association (ABGC) *Banana BMP Guide* (http://bmp.abgc.org.au/ ). The specific practices that are most relevant to water quality risk of the banana farming system were collated into a focused framework that also aligns with the management practice monitoring system utilised by Terrain NRM (the regional NRM organisation in the Wet Tropics). Prioritising and weighting these practices for relative water quality risk occurred through consultation with Queensland Government scientists, officers from the ABGC, Terrain NRM and extension officers from the Queensland Department of Agriculture and Fisheries.

The pollutants of most concern with respect to the banana industry are sediments and nutrients. There is little to no use of the residual herbicides (with relatively high ecological toxicities) that are common in other cropping sectors. Herbicides that are commonly used in bananas have relatively low ecological toxicity and are not priorities for Reef Water Quality Protection Plan 2013. Offsite movement of these products - when it occurs - is largely a function of runoff and soil loss, which is a focus area in the framework.

**Table 9: Key management categories articulated in the Paddock to Reef program water quality risk framework for bananas**

| Management category | Weighting |
|---|---|
| **Sediment (runoff and soil loss)** | |
| Crop removal | 10% |
| Fallow management | 20% |
| Tillage – plant crop | 15% |
| Ground cover (inter-rows and headlands) | 35% |
| Controlling runoff (contouring) | 10% |
| Controlling runoff (drains) | 5% |
| Sediment traps | 5% |
| **Nutrients** | |
| Timing application of residual herbicides | 40% |
| Targeting application to reduce the volume of herbicide applied | 40% |
| Residual herbicide use in ratoons | 20% |
| **Water** | |
| Calculating the amount of water to apply | 70% |
| Managing surface runoff | 30% |

The prevalence of each of these key management practices in the Wet Tropics was estimated through a benchmarking process conducted during 2013-14. There was no data available to support baseline development in the banana production areas of southern Cape York, although this may change during 2015. Anonymous data sources for the Wet Tropics included:

- A grower survey conducted in 2012 by Terrain NRM and the ABGC, representing 125 growers and approximately 75 per cent of the cropped area of bananas.
- Management practice data collected by Terrain NRM as a component of 2012-13 applications for the Australian Government's Reef Rescue program.
- Aggregated anonymous data from the *Banana BMP Guide*, available for discussion while reviewing adoption benchmarks with experienced extension officers.

**Horticulture**

The Paddock to Reef program water quality risk framework for the horticulture industry is based on the Water Quality Management module of Growcom's *Hort360* best management practice program (see http://www.growcom.com.au/land-water/hort360/). The fifty management issues covered in the FMS module were reviewed in collaboration with Growcom to focus on a smaller subset of seventeen management issues with greatest influence on offsite water quality.

**Table 10: Key management categories articulated in the Paddock to Reef program water quality risk framework for horticulture**

| Management category | Weighting |
|---|---|
| **Sediment (runoff and soil loss)** | |
| Use of vegetated buffers | 5% |
| Fallow management | 35% |
| Managing in-field runoff | 20% |
| Managing inter-rows | 25% |
| Managing roads and headlands | 10% |
| Sediment trapping | 5% |
| **Nutrients** | |
| Soil testing to inform nutrient budgeting | 10% |
| Leaf testing to inform nutrient budgeting | 10% |
| Objective nutrient budgeting | 30% |
| Fertiliser application method | 25% |
| Determining crop nutrient requirements | 25% |
| **Pesticides** | |
| Determining pesticide requirements | 30% |
| Managing risk of runoff and drift | 30% |
| Integrated Pest Management (IPM) | 40% |
| **Water** | |
| Irrigation scheduling | 30% |
| Matching irrigation interval and volume with crop requirements | 50% |
| Water recapture and use | 20% |

Anonymous data from growers completing FMS modules during 2012-2014 was analysed according to the water quality risk framework weightings. This specific management practice data was analysed to develop management system ratings (from Low to High risk) that reflect the water quality risk of the mix of individual practices on a farm. Data was available for the Burnett Mary, Fitzroy, and Burdekin NRM regions. FMS data was not available for the Wet Tropics and the Mackay Whitsunday NRM regions (where there is no current Reef Water Quality Protection Plan investment focus in horticulture).

**Table 11: Number of individual horticulture businesses and area represented in horticulture baseline estimates**

| Region | Businesses | Area |
|---|---|---|
| Burnett Mary | 303 | 21,900 ha |
| Fitzroy | 45 | 2025 ha |
| Burdekin | 122 | 22,056 ha |

### Grains

The Paddock to Reef program water quality risk framework for the grain farming industry is based on a range of key management areas selected from four modules of the Grains BMP program (www.grainsbmp.com.au ). Eighteen management issues were assigned weightings according to their potential for influencing offsite water quality. These weightings were developed through a review process by Queensland Government scientists and experienced Central Queensland agronomists and agricultural consultants.

**Table 12: Grains BMP program modules and management questions used in developing the Reef Water Quality Protection Plan 2013 management baseline**

| BMP Module | Management category | Weighting |
|---|---|---|
| **Sediment (runoff and soil loss)** | | |
| Property design layout | Use of contour and diversion banks in sloping cropping areas | 15% |
| Property design layout | Sediment trapping devices | 5% |
| Property design layout | Waterways and drainage lines | 5% |
| Making best use of rainfall | Stubble volume and persistence | 15% |
| Making best use of rainfall | Retain stubble during the fallow | 20% |
| Making best use of rainfall | Cropping frequency | 10% |
| Making best use of rainfall | Need for tillage | 20% |
| Making best use of rainfall | Wheel traffic | 10% |
| **Pesticides** | | |
| Pesticide application | Pest identification | 5% |
| Pesticide application | Resistance management | 10% |
| Pesticide application | Product selection | 5% |
| Pesticide application | Risk of residual pesticide movement | 40% |
| Property design layout | Pesticide and sediment movement | 40% |
| **Nutrients** | | |
| Crop nutrition | Records of crop yield and quality | 10% |
| Crop nutrition | Frequency of soil testing for nitrogen | 30% |
| Crop nutrition | Influence of stored soil moisture on yield and fertiliser decisions | 30% |
| Crop nutrition | Impact of seasonal outlook on making fertiliser decisions | 20% |
| Crop nutrition | Application timing to minimise potential losses and maximise uptake | 10% |

Anonymous data from BMP program participants was analysed according to these weightings in order to develop management system ratings (from Low Risk to High Risk) that reflect the water quality risk of the mix of individual practices on a farm. Where insufficient samples were available to discriminate management at the level of river basins, the baseline for the entire NRM region was used for Paddock to Reef reporting.

The number of businesses represented in management system baselines for each category was:

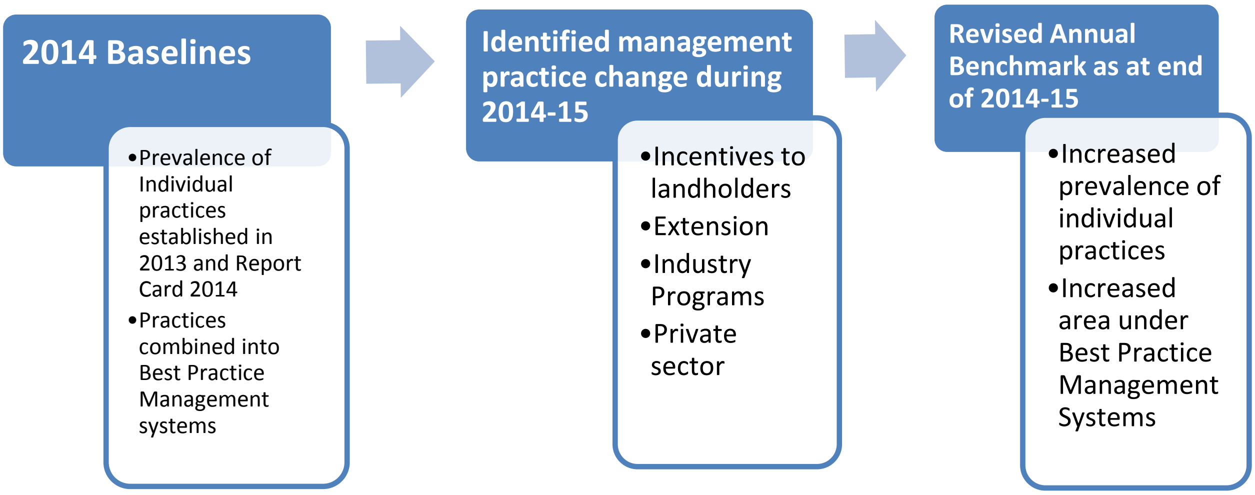
- Sediment (runoff and soil loss): 301
- Pesticides: 327
- Nutrients: 262

**Table 13: Area of grain farms represented in baselines by region and river basin**

| Region | River basin | Area |
|---|---|---|
| Burnett Mary | Barambah | 961 ha |
| | Burnett | 2275 ha |
| Burdekin | Suttor | 76,054 ha |
| Fitzroy | Boyne | 285 ha |
| | Comet | 74,869 ha |
| | Dawson | 62,463 ha |
| | Fitzroy | 12,140 ha |
| | Isaac | 16,076 ha |
| | Mackenzie | 31,022 ha |
| | Nogoa | 75,248 ha |

## Describing annual progress toward adoption the Reef Water Quality Protection Plan 2013 adoption target

Management practice baselines are available for each of the critical practices, for each agricultural industry, in each region (and river basin). At the farm scale, these management practices combine to form a management system. Progress in terms of the adoption over time of improved and/or best management practice is monitored. Where management change has occurred, the 2013 baseline is amended to reflect that change.




The limitations with this approach are:

- Management change is identified where and when it is reported to have occurred. This relies largely on organisations adequately reporting on their activities and what the impacts of those activities are. The Paddock to Reef program describes and reports on the impacts of change for which there is reasonable and sensible evidence.
- Any regression of practices (i.e. adopting practices with greater water quality risk) is difficult to detect as these are unlikely to be reported. However, the method can appropriately reflect regression if necessary.

**Evidence of management practice change**

Organisations receiving funding through Reef Water Quality Protection Plan 2013 for the purpose of improving adoption of best management practice are required to report the impacts of their work as per the relevant industry water quality risk framework.

This occurs through reporting on how individual sites or farm enterprises are managed – the practice descriptions in water quality risk frameworks – both before an intervention, and after (as a result of) that intervention. The 'intervention' may be in the form of a financial incentive, capacity building extension, industry training or self-driven change.

A critical element of this process put in place for the 2014 and 2015 Great Barrier Reef Report Cards is the provision of spatial data describing the exact location of reported impacts. The process is abbreviated as:

1. Delivery organisations provide annual evidence of impact to the Paddock to Reef program, in the form of GIS data (geographic information system data, or electronic mapping of locations) and detailed management practice data.
2. This data is reviewed by the Paddock to Reef program on a site by site basis to provide assurance that reporting towards adoption targets and modelled pollutant load reductions is sensible. This review includes:
   - identification of data handling errors
   - checking that the nature of the intervention aligns with the reported impact
   - checking that the degree of impact (farm management change) is sensible and realistic
   - checking that individual sites and impacts on those sites have not previously been reported to the Paddock to Reef program and included in estimates of progress towards Reef Water Quality Protection Plan targets
   - checking that the reported impacts correspond with other independent lines of evidence available to the Paddock to Reef program.
3. The best management practice adoption baseline is adjusted on an annual basis to reflect the areas validated through the above steps.
4. For every site (usually a paddock or farm), the degree of management change is aligned to modelling simulations which best represent the management in place on that site (for example, the tillage regime, the nutrient rates, the weed and irrigation management on a cane farm).
5. The GIS data and aligned modelling simulations are provided to the Paddock to Reef program catchment modelling team for the purposes of modelling estimated annual average pollutant load reductions expected as outcomes of the reported farm management change.

The degree of adoption of best management practice during 2014-15 is likely to be a conservative estimate. There were many investments aiming at facilitating the adoption of best management practice on farms during 2014-15 (reported investments are summarised in table 14). Most were able to describe the extent of their engagement (i.e. the people they interacted with) and evidence of impact in terms of improved knowledge and skills of participants. However, not all of these were able to provide evidence of the spatial extent and the degree of change which could be attributed to the program. In some instances this was due to no or inadequate impact evaluation, or because the impacts will not be apparent until later. There are several programs and projects that will report impacts for the first time in the 2015-16 year.

**Table 14: Program investments reviewed for Great Barrier Reef Report Card 2015**

| Region | Sector | Program | Total reported spatial extent of engagement reviewed for Report Card 2015 (hectares, or km of stream) | Spatial extent utilised in determining progress toward Reef Plan targets for adoption and pollutant load reduction |
|---|---|---|---|---|
| Burnett Mary | Sugarcane | Australian Government Reef Programme | 343 | 3243 |
| | | Smartcane BMP | 12,166 | - |
| | Grazing | Grazing BMP, QLD Government extension | 240,000 | - |
| | | Australian Government Reef Programme | 645 | 4645 |
| | | | 31km | 31km |
| | Dairy | Australian Government Reef Programme | 71 | |
| | | | | |
| Fitzroy | Grazing | Grazing BMP, QLD Government extension | 1,700,000 | - |
| | | Australian Government Reef Programme (collaboration with Grazing BMP) | 32,235 | 32,235 |
| | | | 399km | 399km |
| | Grains | Australian Government Reef Programme (collaboration with Grains BMP) | 22,033 | 22,033 |
| | Horticulture | Australian Government Reef Programme | 258 | 258 |
| | Cotton | Australian Government Reef Programme | 4237 | - |
| | | | | |
| Mackay Whitsunday | Sugarcane | Smartcane BMP | 44,294 | - |
| | | QLD Government extension | 2890 | - |
| | | Australian Government Reef Programme | 24,047 | 17,306 |
| | Grazing | Australian Government Reef Programme | 1376 | 1376 |
| | | | 18km | 18km |
| | | | | |
| Burdekin | Sugarcane | Smartcane BMP | 21,738 | - |
| | | QLD Government extension | | |
| | | Australian Government Reef Programme | 26,615.0 | 26,615.0 |
| Burdekin | Grains | Australian Government Reef Programme (collaboration with Grains BMP) | 24,447 | 7013 |

| Region | Sector | Program | Total reported spatial extent of engagement reviewed for Report Card 2015 (hectares, or km of stream) | Spatial extent utilised in determining progress toward Reef Plan targets for adoption and pollutant load reduction |
|---|---|---|---|---|
| | Grazing | Grazing BMP, QLD Government extension | 7,700,000 | |
| | | Australian Government Reef Programme (inc collaboration with Grazing BMP) | 451,024 | 313,052 |
| | | | 97km | 97km |
| | Horticulture | Australian Government Reef Programme | 4504 | 4504 |
| | | | | |
| Wet Tropics | Bananas | Australian Government Reef Programme | 1768 | 1768 |
| | Horticulture | Australian Government Reef Programme | 1885 | - |
| | Dairy | Australian Government Reef Programme | 242 | - |
| | Sugarcane | Australian Government Reef Programme | 19,307 | 19,307 |
| | | Smartcane BMP | 74,697 | - |
| | | QLD Government extension | 70,000 | - |
| | | | | |
| Cape York | Grazing | Australian Government Reef Programme | 52,880 | 36,484 |
| | | | 107km | 107km |

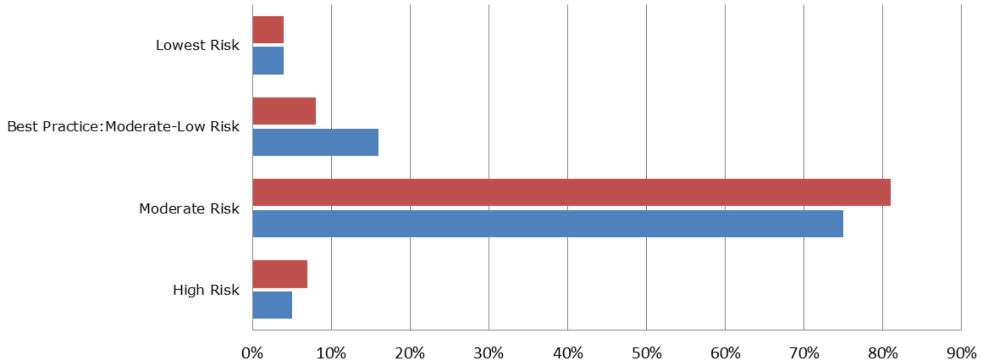
### Tracking the adoption of individual practices

The Paddock to Reef program monitors the adoption of the most important management practices over time, which is important for prioritising investments and for understanding the impacts of the broader management practice system. Practice change reporting, linked to spatial reporting, means that practice adoption can be tracked at fine or broad scale.

The example below describes the change in the level of adoption for practices related to targeting the application of herbicides in sugarcane, in this instance at the level of the entire NRM region.

For all sectors, best management practice systems for sediment, nutrient, or pesticide management are described through aggregating the adoption levels of each major component practice according to their framework weighting.

**Targeting application of herbcides in sugarcane - Wet Tropics NRM Region**




| | High Risk | Moderate Risk | Best Practice:Moderate-Low Risk | Lowest Risk |
|---|---|---|---|---|
| 2013 Baseline | 7% | 81% | 8% | 4% |
| 2014 Revised Baseline | 5% | 75% | 16% | 4% |

### Describing progress

Management practices that are at the Moderate-Low Risk and Lowest Risk levels are taken to be best management practices. These are summed in describing the proportion of area managed at best practice. In the example above (at the individual practice level), the area managed at best practice in the 2013 baseline was 12 per cent, increasing to 20 per cent by the end of the 2013-14 year.

Reporting the progress toward the adoption target of 90 per cent includes colour coding based on five categories.

**Table 15: The Paddock to Reef program scoring system for Report Card 2015**

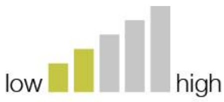
| Grade | Status | Criteria for June 2015 | Colour |
|---|---|---|---|
| A | Very good | 90-100% | Dark green |
| B | Good | 68-89% | Light green |
| C | Moderate | 46-67% | Yellow |
| D | Poor | 23-45% | Orange |
| E | Very poor | 0-22% | Red |

## Qualitative confidence rankings

**Sugarcane**


**Grazing**

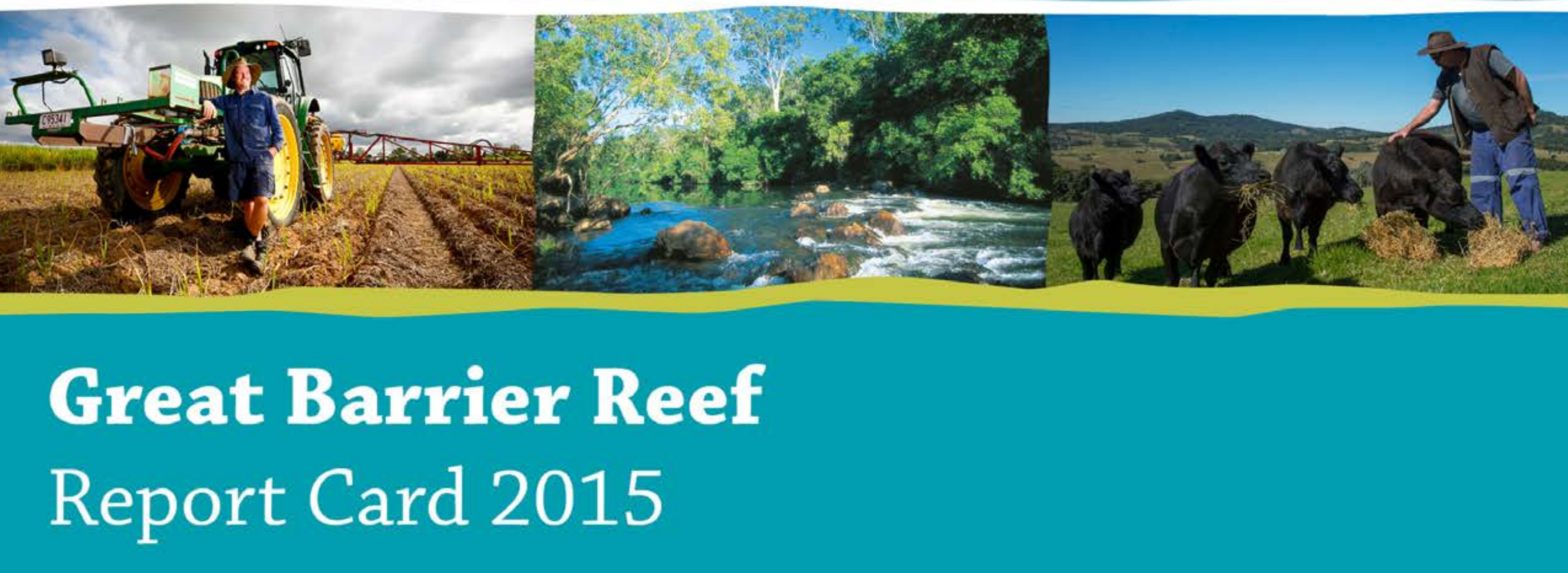

**Horticulture**




**Grains**


A multi-criteria analysis was used to qualitatively score the confidence in each indicator used in the Great Barrier Reef Report Card from low to high. The approach combined the use of expert opinion and direct measures of error for program components where available.

# Ground cover methods



## Great Barrier Reef

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## Ground cover methods

The following provides a brief overview of the data and methods used for reporting regional ground cover in the Great Barrier Reef Report Card 2015 (reef report card). Further detail about data processing and differences compared to previous report cards can be found in the ground cover technical report (DSITI 2016 in prep).

## Background

### Why measure ground cover?

Ground cover is defined as the vegetation (living and dead), biological crusts and stone that are in contact with the soil surface. Ground cover is a key component of many soil processes including infiltration, runoff and surface erosion. In the Great Barrier Reef regions, low ground cover can lead to soil erosion which contributes to increased sediment loads reaching the reef lagoon and loss of productivity for grazing enterprises.

It is particularly important to maintain ground cover during dry periods or periods of unreliable rainfall to minimise loss of water, soil and nutrients when rainfall eventually occurs. This will also maximise the pasture response to rainfall. Implementation of appropriate and sustainable land management practices, particularly careful management of grazing pressure, can help to maintain or improve ground cover, reducing erosion and improving the stability and resilience of the grazing system.

### Factors that influence ground cover

Ground cover levels are the result of complex interactions between landscape function (soil type, topography and vegetation dynamics), climate and land management. Some areas maintain naturally higher levels of ground cover due to factors such as high soil fertility and consistently high annual rainfall. The impacts of grazing land management practices on ground cover levels in these areas may be minimal due to the resilience of the land to respond to pressures. In areas where rainfall is less reliable and soils are less fertile, ground cover levels can vary greatly and the influence of grazing land management practices on ground cover levels and the species composition of the ground cover can be more pronounced.

A number of initiatives are in place or are planned in Great Barrier Reef regions aimed at improving grazing land management, including programs which are improving management of ground cover levels appropriate to the regional conditions. These include the industry-led Grazing Best Management Practice; a number of infrastructure projects such as fencing key areas and better distribution of watering points for stock; trialling different grazing strategies; and, a range of extension and education activities including development of online, interactive and reporting tools for accessing and viewing ground cover information.

### Reporting ground cover levels for Reef Water Quality Protection Plan 2013

Reporting for the ground cover target is provided by the Queensland Ground Cover Monitoring Program and is based on ground cover monitoring data derived from Landsat satellite imagery, calibrated by field data. While it is acknowledged that a range of factors influence ground cover levels, reporting is presently focused only on information which describes regional ground cover levels in the current and historical context. Rainfall data is provided in this report for context only as it is the primary driver of ground cover levels at a regional scale.

A range of products have been, or are being developed by the Queensland Ground Cover Monitoring Program which account for the influence of climate, land management and soil type. These are more appropriate for monitoring local scale variability and differences in ground cover levels, but are of limited use for the regional scale reporting required here. Products which prove useful for describing ground cover levels at the regional scale will help to revise future ecologically-relevant and regionally-focused targets, and will be incorporated into future reporting.

## Methods

The following provides a brief overview of the data and methods used for regional reporting in this report. For further detail about data processing refer to the ground cover technical report (DSITI 2016 in prep).

### Ground cover data

#### *Fractional ground cover*

Reporting is based on data derived using the fractional cover method described by Scarth *et al.* (2010) and Guerschmann *et al.* (2015). The method measures the proportion of green cover, non-green cover and bare ground using reflectance information from late dry season Landsat 5 Thematic Mapper (TM), Landsat 7 Enhanced Thematic Mapper (ETM+) and Landsat 8 Operational Land Imager (OLI) satellite imagery. The spatial resolution of Landsat imagery is approximately 30 metres. The return interval of a Landsat satellite is 16 days and the archive of Landsat data used here dates from 1987 to 2015.

The fractional cover data is calibrated using over 1500 field observations from a range of cover levels and environments. Using the field observations, a further adjustment is applied to the fractional cover data to account for the influence of trees, shrubs and ground cover fractions measured by the satellite. This results in a data product, named fractional ground cover, which aims to effectively remove the influence of trees and shrubs and provides estimates of the level of green ground cover, non-green ground cover and bare ground at ground level. Importantly, this data product enables reporting in areas of higher tree cover: up to 60 per cent persistent green (i.e. woody vegetation) cover. As a final step, the green and the non-green ground cover fractions are summed to produce a total ground cover estimate, as erosion and runoff are influenced by all ground cover. This estimate of total ground cover is what is used for reporting here and is hereafter referred to simply as '*ground cover*'.

***Late dry season ground cover***

Late dry season ground cover is estimated using a seasonal composite of fractional ground cover data. The seasonal composite is derived from each 16 day Landsat satellite image acquired throughout the season. It is produced by selecting the most representative per pixel estimate (i.e. 30 metre x 30 metre area) of fractional ground cover for the season; then, compositing these to generate a comprehensive regional data set. This approach has the advantage of removing errors and outliers in the data, providing the most spatially comprehensive coverage as there is generally very little missing data due to cloud, cloud shadow or satellite sensor issues. For reporting here, spring (September-November) seasonal composites (for the period 1987 to 2015) are used as this best approximates the late dry season.

## Reporting regions and grazing lands

Reporting is based on the six natural resource management regions which incorporate the Great Barrier Reef region:

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

Grazing lands in the reporting regions were spatially-defined based on the most recent version of land use data provided by the Queensland Land Use Mapping Program (QLUMP) (DSITI, 2012). The most recent version of the mapping is current to 2009 for all reported regions, except for Cape York and the Wet Tropics, which are current to 2013 and 2015, respectively.

A reporting region is therefore defined as that part of a natural resource management region which is grazing land and has less than 60 per cent persistent green cover.

## Reporting ground cover

This report provides a regional overview of late dry season ground cover levels in the Great Barrier Reef region based on analysis of seasonal (spring) total ground cover data. The statistics are calculated for each pixel (i.e. 30 metre x 30 metre area) and then summarised (i.e. averaged) for each of the regions.

Statistics reported include:

- 2015 mean late dry season ground cover
- 28 year mean late dry season ground cover (1987 to 2015)
- percentage of the region’s reporting area with late dry season ground cover less than 70 per cent in 2015
- percentage of the region’s reporting area with mean late dry season ground cover less than 70 per cent for the 28 year period, 1987 to 2015.

Graphs showing the distribution of ground cover for each region across the range of ground cover levels and a map of ground cover percentages have been provided for the Great Barrier Reef region, and each reporting region, as a visual representation of the statistics listed above. A map of ground cover decile rankings has also been produced to provide information on the ground cover levels for the reporting year (2015) compared to long-term mean ground cover levels.

It is important to note that averaging ground cover across whole regions can mask localised areas of lower cover, particularly in large catchments with a strong rainfall gradient (e.g. Burdekin or Fitzroy). The mean ground cover reported here is therefore indicative of general levels of ground cover within the reporting region.  Note that the reporting regions are further divided into catchments (and sub-catchments for larger catchments) for additional level of reporting in the ground cover technical report (DSITI 2016 in prep).

## Rainfall data

Rainfall data is provided for current and historical context as rainfall is the primary driver of ground cover levels at the regional scale. In general, high rainfall in the preceding seasons results in higher ground cover levels and low rainfall in preceding seasons results in lower ground cover levels. Rainfall data was obtained from Scientific Information for Land Owners (SILO) as a five kilometre grid (https://www.longpaddock.qld.gov.au/silo/).  The mean annual rainfall was then calculated from September to September for each year from 1986, to align the mean annual rainfall with the late dry season reporting period, for each reporting region.

## Scoring system

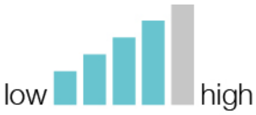
A standardised scoring system is used for each of the key indicators in the reef report card.  The scoring system is used to assess and communicate the status of the indicator against the Reef Water Quality Protection Plan target.

### Ground cover target

*Minimum 70 per cent late dry season ground cover on grazing lands by 2018.*

| Grade | Status | Criteria for June 2015 | Colour |
|---|---|---|---|
| A | Very good | Greater than 70% average groundcover | Dark green |
| B | Good | Between 50-69% average groundcover | Light green |
| C | Moderate | Between 40-49% average groundcover | Yellow |
| D | Poor | Between 30-39% average groundcover | Orange |
| E | Very poor | Less than 30% groundcover | Red |

**Qualitative confidence ranking**




A multi-criteria analysis was used to qualitatively score the confidence in each indicator used in the Great Barrier Report Card from low to high. The approach combined the use of expert opinion and direct measures of error for program components where available. Ground cover received a four bar confidence ranking.

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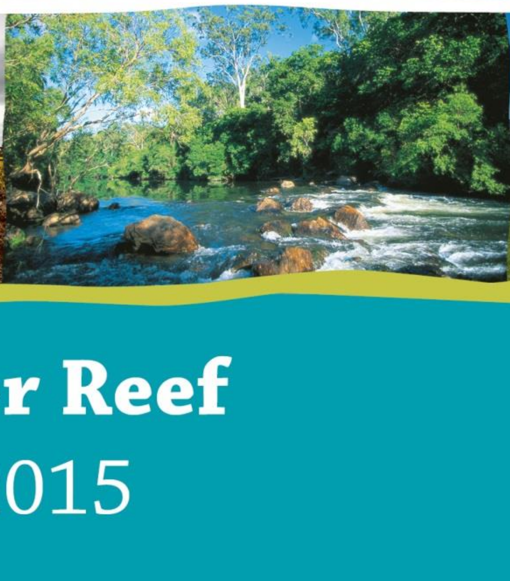
# Catchment pollutant loads modelling methods



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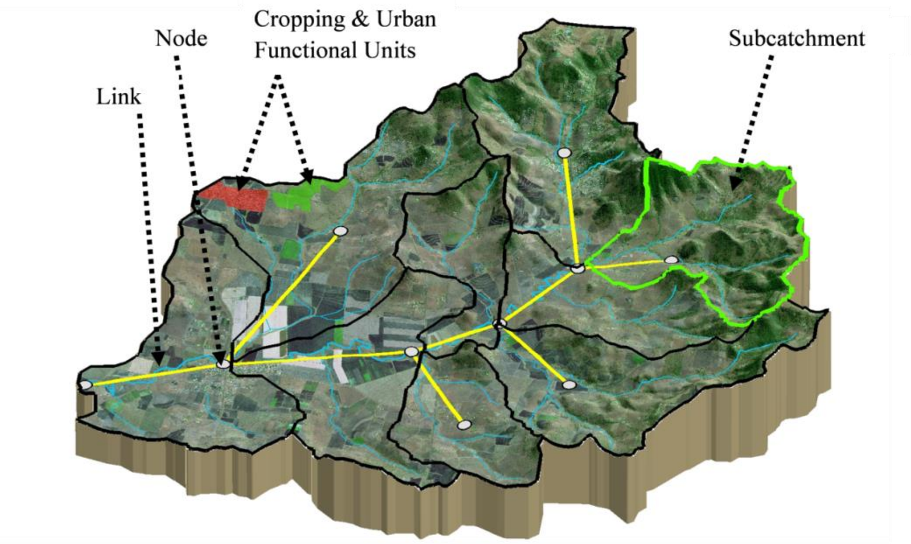
## Catchment pollutant loads methods

### Catchment modelling

**Why use modelling to measure pollutant load reductions?**
Monitored pollutant loads leaving catchments vary significantly year-to-year, mainly due to differences in annual rainfall and runoff. Therefore, catchment modelling is used to estimate the long-term annual pollutant load reductions due to the adoption of improved land management practices. This removes the impact of factors such as climate variability. Research suggests time lags to monitor the improvements from land management practice change could range from years for pesticides up to decades for nutrients and sediments, due to the high level of climate variability. The models use measured changes in on-ground management and well-documented and accepted methods and assumptions. Long-term water quality monitoring data is used to validate and improve the models, continuously improving confidence in the estimates of water quality over time.

**Catchment modelling framework**
The Source Catchments modelling framework (eWater 2010) is used to model pollutant loads for the 35 catchments in the Great Barrier Reef region. It is a catchment scale water quantity and quality model which uses a node link network to represent the stream. The model generates runoff and pollutant loads for each functional unit (landuse) within a sub-catchment, and runoff and pollutants are transported from a sub-catchment through the stream network via nodes and links to the end of the catchment.




*Example of a functional unit (FU) and node-link network generated in Source Catchments. These components represent the sub-catchment and stream network.*

Source Catchments runs at a daily time step which allows for the exploration of the interactions of climate and management at a range of time-steps. However, for the Great Barrier Reef Report Card, average annual catchment loads are reported.

The model was run for each scenario using a fixed climate period from 1986 to 2014 to remove the influence of climate on estimated load reductions. The latest land use mapping (Department of Science, Information Technology, Innovation and the Arts, 2012) was used to describe the spatial extent of each agricultural land use for the baseline year.

The Paddock to Reef Integrated Monitoring, Modelling and Reporting Program has developed water quality risk frameworks for each agricultural industry.  These frameworks articulate best practice in relation to the Reef Water Quality Protection Plan adoption targets.

These practices are described in terms of their relative water quality risk, from low to high. This is a departure from the ABCD management practice frameworks which were the basis for prioritising and reporting investments under the Reef Water Quality Protection Plan 2009.

See Management Practice methods for more information about the frameworks.

Three scenarios are run each year: predevelopment, the baseline (2013) then each subsequent year with the proportion of land managed using defined practices adjusted each year, to reflect the reported increase in adoption of improved management practices.

The proportion of land managed using defined management practices is the only variable that changes between modelled scenarios. This allows for the relative load reductions attributed to the areas of improved land management to be reported.

Fine and coarse sediment, dissolved and particulate nutrients and five photosystem II pesticides were modelled. Key land uses were modelled for the baseline scenario including grazing, cane, cropping, horticulture and forestry.

Modelled load estimates are validated against monitored data at 25 sites across the Great Barrier Reef catchments. For further information on the model validation processes, see Waters *et al*. (2014).

The catchment loads modelling program undergoes an external peer review every three years. The program was reviewed in 2012 and again in 2015. Prior to the release of each Great Barrier Reef Report Card, modelled load estimates are reviewed both internally and externally.

**Management practice change**

The management practice adoption frameworks describe and categorise farming practices according to recognised water quality improvements at a paddock scale. Improvements in water quality as a result of adopting improved management practices were determined by linking paddock model time series outputs to catchment models.

Management practice change has been modelled for the sugarcane, grains, horticulture, bananas and grazing areas of the Great Barrier Reef catchments. For details on how management practice changes are represented in the modelling, see the modelling technical reports volume 1-7 (references are listed in further reading below).

Investments in improved grazing management (in particular vegetation cover management) through riparian and streambank fencing was also modelled. Spatial data on the length of stream and gully fencing was provided by regional bodies.

**Modelling assumptions**

Loads reported for each Great Barrier Reef Report Card reflect the relative change in modelled average annual loads for the specified model run period (1986 to 2014).

- Land use areas in the model are static over the model run period and were based on the latest available Queensland Land use Mapping Program (QLUMP) data (Department of Science, Information Technology, Innovation and the Arts, 2012).
- Paddock model runs used to populate the catchment models represent 'typical' management practices for a given management class and do not reflect the actual array of management practices that occur year-to-year across the Great Barrier Reef catchments.
- Application rates of pesticides and fertilisers used to populate the paddock models were derived through consultation with relevant industry groups and regional bodies.
- Practice adoption areas represented in the model are applied at the spatial scale of the data supplied by regional Natural Resource Management bodies.
- The water quality benefits from adopting a management practice change are assigned in the year that investment occurs.
- It is important to note that these are modelled load reductions based on improved land management adoption data supplied by industry and regional Natural Resource Management groups. Therefore, results are indicative of the likely long-term water quality response due to adoption of improved land management practices for a given scenario rather than a measured reduction in load.

**Linking paddock and catchment models**

The public version of the eWater Source Catchments model was modified to incorporate hillslope constituent generation from the most appropriate paddock models for cropping and sugarcane areas, and the Revised Universal Soil Loss Equation (RUSLE) for grazing. In addition, gully and streambank erosion and floodplain deposition processes were added based on the SedNet/ANNEX approach (Wilkinson *et al*. 2014). A more detailed description can be found in Ellis and Searle (2013). These features were incorporated to better represent the erosion processes observed in the summer dominant rainfall areas of Northern Australian reef catchments.

Two approaches were used to represent improved land management practices in Source Catchments depending on the land use of interest. For sugarcane, bananas and cropping the constituent time-series (e.g. load per day per unit area) for the given land use was supplied from an output time-series from a paddock model. Unique combinations of climate, soil type and defined management practices within each land use were identified and represented spatially in the paddock model simulations used to inform catchment models. For cropping (grain cereal crops) and bananas, the HowLeaky model was used (Rattray *et al*. 2004). For sugarcane modelling, the Agricultural Production Systems sIMulator (APSIM) (Keating *et al* .2003) was used.

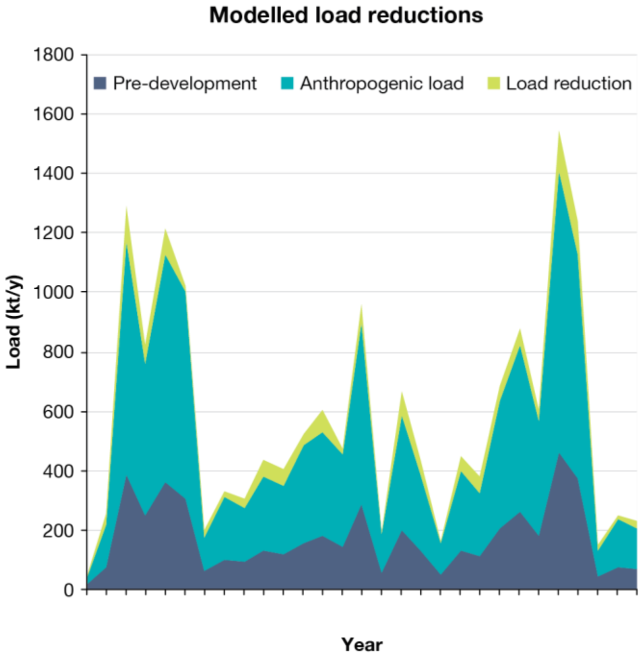
In the second approach, the RUSLE model has been written into Source Catchments to model hillslope soil erosion in grazing lands, where the cover term (C-factor) in the model is generated from remotely sensed ground cover satellite imagery seasonally (four scenes per year). The paddock scale model GRASP (McKeon *et al*. 1990) was used to provide scaling algorithms for each scenario to account for changes in management in each identified land type, e.g. shifting areas from moderate risk to moderate-low risk. These scaling algorithms were applied at the pixel scale to each ground cover satellite image for the modelling period. This is applied according to a spatial representation of areas of defined management practices as provided by regional Natural Resource Management groups annually. Calculations were performed pixel by pixel, with results accumulated to a single landuse representation in each sub-catchment. All loads generated for each landuse represented within a subcatchment were then aggregated at the sub-catchment scale and routed through the stream network.

**Total load**

The total baseline load was the load modelled within each Great Barrier Reef catchment as at 2012-13 land management. A pre-development land use map was also developed and modelled. The model was then run for a 28-year period to establish an average annual load for this period. Thus, the anthropogenic load was the total baseline load less the pre-development load.

**Load reductions**

The model was then re-run for the same climate period using updated proportions of lowest risk to high risk management practice areas to reflect investment in improved management practices since 2012-13. The relative change in pollutant loads from the anthropogenic baseline after investment reflects the load reduction due to changes in management practices.




*Example of modelled loads for natural (pre-development), human-caused (anthropogenic) and the load reduction following investment in improved practices.*

**Modelling improvements**

As part of the continuous program improvement, updated model input layers are incorporated when they become available. Paddock to Reef program phase 2 improvements already implemented include: seasonal ground cover, improved soils layer, extended modelling climate period and hydrology parameter updates, finer resolution topographic data and expanded water quality monitoring data sets. Improvements to the paddock modelling include more detailed modelling of bananas and grains, as well as representation of water recycling pits in the lower Burdekin region.

Gullies and stream bank erosion are modelled based on scientifically peer reviewed process understanding. Where updated gully maps are available these have been incorporated (areas included to date are the Normanby, Burdekin and Fitzroy catchments). A significant gully mapping program is continuing and further updates will be incorporated.

Pollutants losses via groundwater, such as nitrogen leaching through soils, are monitored at the Paddock to Reef farm trial sites and modelled through the paddock models. From Phase 2, the catchment modelling now represents this pollutant loss pathway as well.

**How the information is reported**
Progress towards Reef Water Quality Protection Plan targets is estimated by determining how much the modelled pollutant load has reduced from the average annual modelled anthropogenic baseline (total load less the pre-development load). This is calculated as a percentage reduction in average annual modelled load.

**The average annual percentage reduction in load is calculated from:**

$$\text{Reduction in load (\%)} = \frac{\text{(Anthropogenic baseline load less anthropogenic change)} \times 100}{\text{Anthropogenic baseline load}}$$

Where, anthropogenic baseline load = total load less pre-development load.

Modelled total suspended sediment, nitrogen, phosphorus and pesticide loads at the end of the catchment are reported for the total Great Barrier Reef and for the six regions that make up the Great Barrier Reef catchment.

The program now reports on overall toxic loads for pesticides. A pesticide toxic equivalent load is the calculated load of a pesticide multiplied by the relative toxicity of the pesticide compared to diuron.

## Qualitative confidence ranking

**Dissolved inorganic nitrogen**


**Sediment**


**Pesticides**


A multi-criteria analysis was used to qualitatively score the confidence in each indicator used in the report card from low to high. The approach combined the use of expert opinion and direct measures of error for program components where available.

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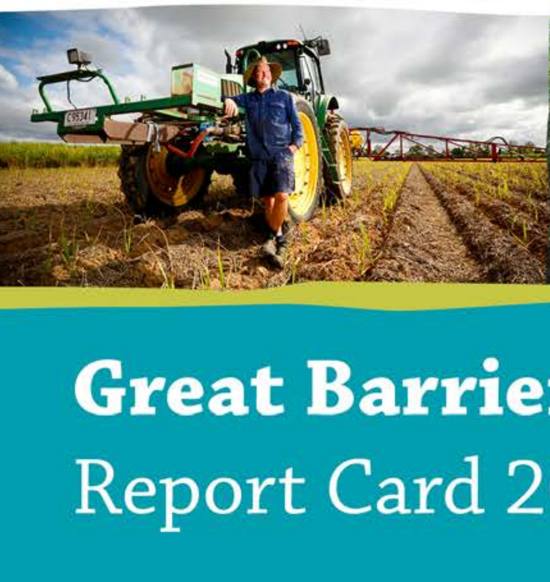
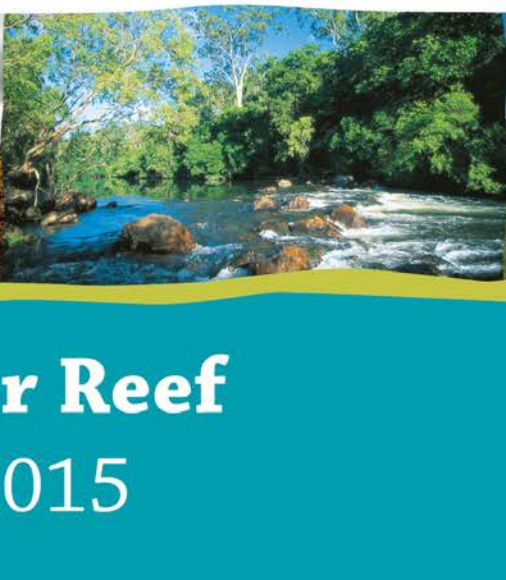
# Catchment pollutant loads monitoring methods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# Catchment pollutant loads monitoring methods

### Monitoring sites

The end-of-system monitoring sites are located at the lowest point in a river or creek, predominantly where gauging stations have been established and maintained by the Department of Natural Resources and Mines. These provide data on all of the catchment upstream of the site. Sub-catchment sites are located at the lowest point in a sub-catchment (tributary) predominantly at existing gauging stations. They provide data on all of the sub-catchment upstream of the site. Both provide data to calibrate and validate catchment models.

### Rainfall

Rainfall totals and rainfall decile data were obtained from the Bureau of Meteorology National Climate Centre. These data were synthesised using geographic information system tools to display total annual rainfall and annual rainfall deciles for Queensland during 1 July 2014 – 30 June 2015.

### River discharge

River discharge data (the volume of water moving past a point per unit time in $m^3 s^{-1}$) for monitoring sites were extracted from the Department of Natural Resources and Mines, Surface Water Database (Hydstra). River discharge data for some monitoring sites were adjusted using a timing and flow factors based on the nearest upstream gauging station; or a combination of modelled flow and flow measured by Horizontal Acoustic Doppler Current Profiler.

### Water quality sampling

Water samples were collected, stored, transported and quality assured and quality controlled in accordance with the Environmental Protection (Water) Policy Monitoring and Sampling Manual (https://www.ehp.qld.gov.au/water/pdf/monitoring-man-2009-v2.pdf). Water quality samples were collected using two different sampling methods: manual grab sampling and automatic grab sampling using refrigerated pump samplers. Intensive sampling (daily or every few hours) was conducted during high flow events and monthly sampling was conducted during low or base-flow (ambient) conditions.

### Water quality sample analysis

Total suspended solids and nutrient analyses were undertaken by the Science Division Chemistry Centre (Dutton Park, Queensland). Queensland Health Forensic and Scientific Services Organics Laboratory (Coopers Plains, Queensland) analysed water samples for pesticides. Both laboratories are accredited for the analyses conducted by the National Association of Testing Authorities (NATA).

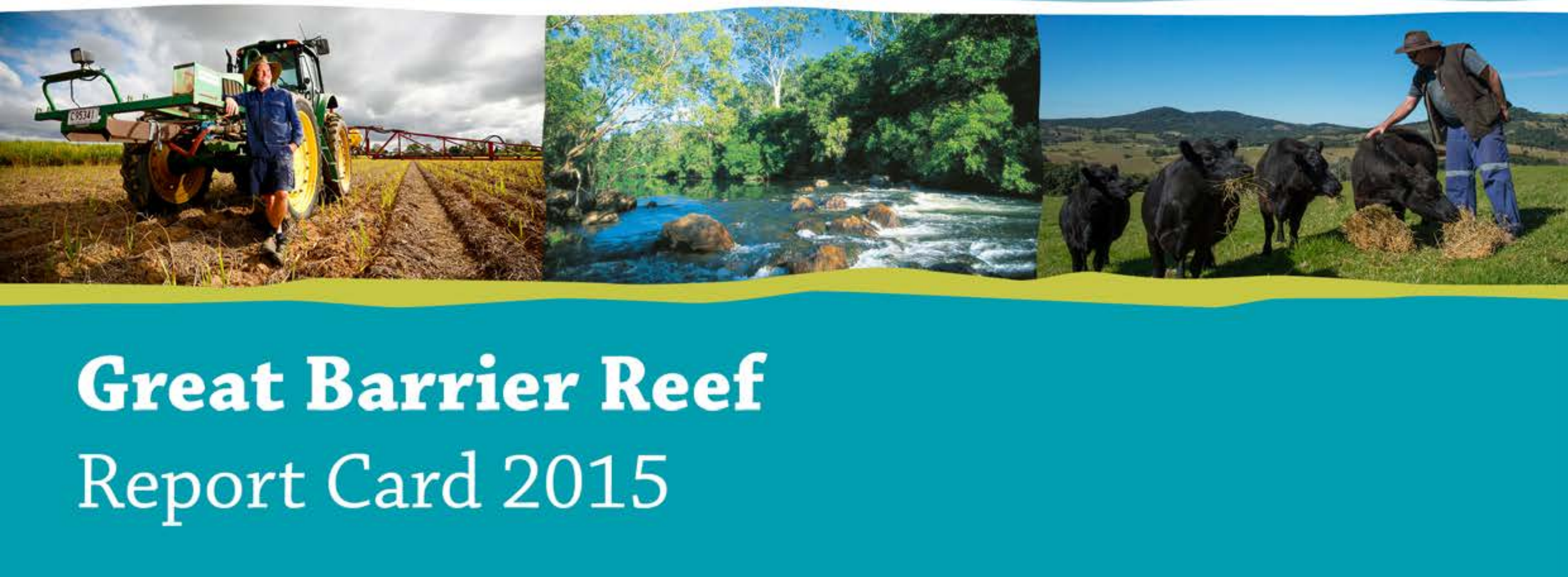
### Loads calculation

The suitability of the generated water quality monitoring data for load calculations was assessed using a sample representivity rating. The most appropriate load calculation method (i.e. either the average load (linear interpolation of concentration) or the Beale ratio) was determined by assessing sample coverage and the representivity rating. Annual loads were calculated for total suspended solids, nutrients (i.e., total nitrogen, particulate nitrogen, dissolved organic nitrogen, oxidised nitrogen, ammonium nitrogen, total phosphorus, particulate phosphorus, dissolved organic phosphorus, and dissolved inorganic phosphorus) and pesticides (i.e., ametryn, total atrazine, total diuron, hexazinone and tebuthiuron). Loads were calculated using the Loads Tool component of the software Water Quality Analyser versions 2.1.1.6.

**Toxic loads calculation**

A pesticide toxic-equivalent load (toxic load) is the calculated load of a pesticide multiplied by the relative toxicity of the pesticide compared to that of diuron (Smith et al., in review) and is expressed as an equivalent mass of diuron, i.e. diuron equivalent kg. The total toxic load is calculated by summing the toxic loads of all pesticides that have the same toxic mode of action.

# Marine methods



## Great Barrier Reef
Report Card 2015

Australian Government

Queensland Government

## Marine methods

### Marine Monitoring Program

The Australian Government's Marine Monitoring Program assesses water quality and the long-term health of key marine ecosystems (inshore coral reefs and seagrasses) in the inshore waters of the Great Barrier Reef. The three elements of the program are outlined below.

More information about the Marine Monitoring Program is available from the Great Barrier Reef Marine Park Authority website (http://www.gbrmpa.gov.au/about-the-reef/how-the-reefs-managed/reef-rescue-marine-monitoring-program).

#### Inshore water quality

Monitoring of year-round water quality includes the measurement of concentrations of organic carbon, inorganic and organic nutrients (nitrogen and phosphorus), chlorophyll *a*, suspended solids (water turbidity) and pesticides. Techniques used to monitor water quality include satellite remote sensing, automated data loggers and collection of water samples from research vessels for laboratory analysis. Passive samplers are used to measure the concentration of pesticides in the water column integrated over time (Booij et al., 2007; Shaw & Mueller, 2009).

Monitoring is also conducted in the wet season as the majority of the annual pollutant load to the reef is delivered by flood events in the monsoon (Devlin et al. 2001).

#### Seagrass condition

Monitoring temporal and spatial variation in the status of inshore seagrass meadows in relation to changes in local water quality is essential in evaluating long-term ecosystem health and resilience.

Monitoring includes an assessment of the seagrass abundance (per cent cover) and reproductive effort, which provides an indication of the health of seagrass meadows and their capacity to regenerate following disturbances. Tissue nutrient composition is assessed in the laboratory as an indicator of nutrient enrichment relative to light available for growth.

*Seagrass monitoring on the Great Barrier Reef (Image: L. McKenzie, Seagrass Watch HQ.)*

### Coral reef condition

Monitoring temporal and spatial variation in the status of inshore coral reef communities in relation to changes in local water quality is essential in evaluating long-term ecosystem health.

Monitoring covers a comprehensive set of community attributes including the assessment of hard and soft coral cover, the number of hard coral juvenile colonies (up to 5 centimetres in diameter), the proportion (per cent) of cover of algae that is macroalgae, the rate of change in coral cover (as an indication of the recovery potential of the reef following a disturbance) (Thompson and Dolman, 2010) and coral community composition (Thompson et al. 2016). Comprehensive water quality measurements are also collected at many of the coral reef sites.

*Coral reefs being monitored on the Great Barrier Reef (Image: Australian Institute of Marine Science).*

## Great Barrier Reef-wide and regional report card assessment scores

### Synthesis and integration of data and information

The Great Barrier Reef Report Card provides assessment scores for the condition of inshore water quality, seagrass and coral at Great Barrier Reef-wide and regional scales. There are six natural resource management regions: Cape York, Wet Tropics, Burdekin, Mackay Whitsunday, Fitzroy and Burnett Mary.

A sub-set of indicators are used to assess and report on water quality, seagrass and coral condition. These indicators are scored on a five-point scale (very good, good, moderate, poor, very poor) and aggregated into a score that describes the overall status of the Great Barrier Reef and each individual region.

An overview of the methods used to calculate the Great Barrier Reef-wide and regional scores is provided below. Great Barrier Reef-wide scores are standardised by the area of each region, while regional scores are unweighted averages. Detailed information is available from the technical reports on the Marine Monitoring Program website (http://www.gbrmpa.gov.au/managing-the-reef/how-the-reefs-managed/reef-2050-marine-monitoring-program/marine-monitoring-program-publications). Improvements have been implemented for coral metrics for the Great Barrier Reef Report Card 2015.

### Remotely sensed inshore water quality

Near-surface concentrations of chlorophyll *a* and total suspended solids from remotely sensed images are used to assess and report on inshore water quality. Chlorophyll *a* is a measure of phytoplankton biomass that is related to the amount of available nutrients in the water column and therefore the productivity of the ecosystem. Total suspended solids is a measure of all particulate matter in the water column including sediment. These two parameters are assessed against their relevant Great Barrier Reef Water Quality Guideline (GBRMPA, 2010) trigger values as the proportion of the inshore water body where the annual mean value does not exceed the Great Barrier Reef Water Quality Guidelines (the Guidelines) (GBRMPA, 2010). Inshore waters include enclosed and open coastal waters as defined in the Guidelines.

Chlorophyll *a* and total suspended solids have been chosen as the best information currently available to describe the water quality over a large spatial area with linkages to Reef Water Quality Protection Plan targets. Limitations of this approach are recognised, as there are areas with limited validation data, and temporal and spatial variability in the number of valid observations. Specifically, it is recognised that there is a high level of uncertainty associated with data for some parameters obtained from remote sensing in shallow and turbid coastal waters. This year additional technical work was undertaken by James Cook University and Australian Institute of Marine Science to improve confidence in this information, which involved:

- delineating and masking out (excluding) the shallow, turbid enclosed coastal water body
- reprocessing the relevant statistics for the year and the dry/wet seasons
- reprocessing data from previous years, to derive information on long-term trends.

However the results obtained did not improve the certainty associated with the information (Tracey et al. 2016) and for consistency, the water quality metric implemented the same method as for previous Great Barrier Reef Report Cards with the following exceptions: water quality was not evaluated at the regional level for the Cape York and Burnett Mary regions because of the limited amount of on-ground data available for validation. The uncertainty associated with water quality estimates from satellites is higher in these two regions and therefore they have been excluded from overall reef-wide assessment of water quality.

It should also be noted that the number of remotely sensed images available in the wet season is substantially lower than in the dry season due to high cloud cover, so there is greater uncertainty in the wet season. The full historical time-series was updated and presented in the Great Barrier Reef Report Card 2014. There were further updates to the archive data which affected the time-series for 2013-14 and updated the information used for this year's Great Barrier Reef Report Card. The time-series is available through the e-Reefs Marine Water Quality Dashboard (http://www.bom.gov.au/marinewaterquality/).

A project is being developed to improve the way that water quality is assessed and reported in future reports.

**Site-specific water quality**

Site-specific water quality data also described in the Report Card 2015, based on year-round and wet season monitoring (Lønborg et al. 2016). Trends in water quality parameters (turbidity/water clarity, chlorophyll *a* and concentrations of particulate nitrogen and phosphorus) relative to the Guidelines (GBRMPA 2010) are available in the annual report (Lønborg et al. 2016) on the Marine Monitoring Program website at http://www.gbrmpa.gov.au/managing-the-reef/how-the-reefs-managed/reef-2050-marine-monitoring-program. From 2014-15, site-specific water quality monitoring was expanded to comprehensively detect changes in water quality in four focus regions in the Wet Tropics (Tully and Russell Mulgrave) and Burdekin and Mackay Whitsunday (O'Connell).

Site-specific water quality data is not included in the water quality scores because while the overall trends are consistent with remote sensing data, the scores are not directly comparable. The method for assessing water quality will be refined for 2016 Great Barrier Reef Report Card.

**Pesticides**

Pesticides are monitored using two methods (Gallen et al. 2016): grab samples of pesticides collected in flood plumes during the wet season to give an indication of peak concentrations, and passive samplers provide an integrated assessment of pesticide concentrations over time in wet and dry seasons (Booij et al., 2007; Shaw & Mueller, 2009).

The most frequently detected pesticides in inshore waters include those herbicides that inhibit the photosynthetic pathway (PSII) of plants: diuron, atrazine, hexazinone, simazine and tebuthiuron (Haynes et al., 2000a; Mitchell et al. 2005; Kapernick et al. 2006; Lewis et al. 2009; Packett et al. 2009). These PSII herbicides may also have a negative impact on non-target organisms such as algae, corals and seagrass (Magnusson et al., 2008; Jones and Kerswell, 2003; Haynes et al., 2000(b)).

An index has been developed using PSII herbicide equivalent concentrations to assess the potential combined toxicity of these pesticides relative to the Guidelines. The PSII herbicide equivalent concentration incorporates the relative potency and abundance of individual PSII herbicides compared to a reference PSII herbicide, diuron. For reporting purposes, the index has five categories: concentrations detected at the lowest level (Category 5) are not expected to have an impact on seagrass or coral, while the highest level (Category 1) corresponds to the guideline for diuron set for the protection of 99 per cent of species (http://www.gbrmpa.gov.au/about-the-reef/how-the-reefs-managed/water-quality-in-the-great-barrier-reef/water-quality-guidelines-for-the-great-barrier-reef).

**Table 1. PSII Herbicide Equivalent (HEq) Index developed as an indicator for reporting of PSII herbicides across the reef**

| Category | Concentration (ng.L$^{-1}$) | Description |
|---|---|---|
| 5 | PSII-HEq ≤ 10 | No published scientific papers that demonstrate any effects on plants or animals based on toxicity or a reduction in photosynthesis. The upper limit of this category is also the detection limit for pesticide concentrations determined in field collected water samples. |
| 4 | 10 < PSII-HEq ≤ 50 | Published scientific observations of reduced photosynthesis for two diatoms. |
| 3 | 50 < PSII-HEq < 250 | Published scientific observations of reduced photosynthesis for two seagrass species and three diatoms. |
| 2 | 250 ≤ PSII-HEq ≤ 900 | Published scientific observations of reduced photosynthesis for three coral species. |
| 1 | PSII-HEq > 900 | Published scientific papers that demonstrate effects on the growth and death of aquatic plants and animals exposed to the pesticide. This concentration represents a level at which 99 per cent of tropical marine plants and animals are protected, using diuron as the reference chemical. For high ecological value water bodies like the Great Barrier Reef Marine Park and the World Heritage Area, a guideline concentration that is protective of 99 per cent of species is appropriate. |

Note that Category 1 is higher than Category 5 and that concentrations of pesticides at Categories 2 to 4 represent biologically relevant concentrations. However:

- The published scientific papers indicate that the reductions in photosynthesis at these concentrations are reversible when the organism is no longer exposed to the pesticide.
- Detecting a pesticide at these concentrations does not necessarily mean that there will be an ecological effect on the plants and animals present.
- These categories have been included as they indicate an additional level of stress that plants and animals may be exposed to in the Marine Park. In combination with a range of other stressors (e.g. sediment, temperature, salinity, pH, storm damage and elevated nutrient concentrations) the ability of these plant and animal species to recover from impacts may be reduced.

Classifying the data into index categories provides an indication of the extent and frequency of exposure to PSII herbicides at a given site (and the potential consequences for marine organisms). The PSII herbicide equivalent concentrations used in the index are calculated from the combined toxicity of diuron, hexazinone, atrazine and its breakdown products, tebuthiuron, ametryn, prometryn, simazine, metolachlor, terbutryn, flumeturon and imidacloprid, all of which are used to control weeds and other plant species in the Great Barrier Reef catchment and are regularly found in the Great Barrier Reef Marine Park. Note that reference to pesticides in the report includes all herbicides, insecticides and other chemicals used to treat pest or weed species.

Refinements are underway to evaluate pesticides using a new method termed the Multiple Substances-Potentially Affected Fraction (ms-PAF) (Traas et al., 2002). This method is also based on the additive model of mixture toxicity, but uses species sensitivity distributions (which are also used to derive water quality guidelines) to determine the equivalent pesticide concentrations. The transition from evaluation based on single species data to multiple species using species sensitivity distributions has commenced (Gallen et al. 2016), but requires additional validation prior to inclusion in the Great Barrier Reef Report Card scores. It is expected to be included in future reports.

**Seagrass**

Abundance, reproductive effort and tissue nutrient status are used to assess and report on inshore seagrass condition (McKenzie et al. 2016).

Seagrass abundance is an assessment of the average per cent cover of seagrass per monitoring site in relation to the Seagrass Abundance Guidelines (McKenzie 2009). The 80th, 50th and 20th percentiles were used to define the Seagrass Abundance Guidelines, as these are recommended for Queensland Water Quality Guidelines (Department of Environment and Resource Management 2009) and there is no evidence that this approach would not be appropriate for seagrass meadows in the Great Barrier Reef. Developing guidelines for individual sites requires three to 10 years of monitoring with a minimum of 18 or more observations with no identified impacts, depending on the variability for the site. The Seagrass Abundance Guidelines can then be applied to determine seagrass condition for each monitoring event. For example, if median abundance is at, or above, the 50$^{th}$ percentile for that site, the condition is considered 'good'.

Reproductive effort is the ratio of the average number of reproductive structures on an area basis relative to the long-term average, and provides an indication of the capacity for meadow recovery following disturbances.

The nutrient status of seagrass is based on the ratio of carbon to nitrogen in leaf tissue, and reflects the level of nutrients in the surrounding waters relative to the amount of light the plant is receiving to grow.

Seagrass monitoring takes place in four representative habitat types: estuarine, coastal intertidal, reef intertidal and reef subtidal meadows throughout the Reef in 2014-15. The additional Cape York sites (established in 2012), four subtidal sites in the Wet Tropics and Burdekin regions (established in 2008), and one intertidal site in the Burdekin region (established in 2012) were included in the overall assessments of Great Barrier Reef seagrass ecosystem condition. Additional sites in Cape York (Yum Yum Beach), Wet Tropics (Midge Point), Mackay Whitsundays (Hydeaway bay) and Burnet Mary (Burrum Heads) monitored by Seagrass Watch were also included in the Great Barrier Reef Report Card 2015.

Seagrass condition assessments, which now have a greater confidence ranking, were hindcast for the entire time-series in 2013-14 so that results from previous years are comparable.

**Corals**

Five indicators are now used to assess and report on inshore coral reef condition - coral cover, coral cover change, juvenile coral density, coral community composition and proportional macroalgae cover (Thompson et al. 2016). Coral community composition is a new indicator added for this year's Great Barrier Reef Report Card.

Coral cover is a measure of the abundance of hard and soft corals, and indicates the capacity of coral to persist under the current environmental conditions and to recover from disturbances by estimating the availability of adult broodstock (Thompson et al. 2016).

Coral change is a measure of the observed change in hard coral cover compared to modelled predictions derived from the preceding four years of information, and provides an indicator of the balance between disturbance and recovery. A healthy and resilient coral reef is expected to show an increase in coral cover during periods free from disturbances. There is now appropriate 'raw' observational data for the coral change indicator and as such the data provided are the means and standard errors of the reef level metric scores. This improvement was facilitated by the way in which this metric is now derived from a continuous rather than categorical scale (Thompson et al. 2016).

Juvenile density is a measure of the abundance of hard coral juvenile colonies (up to five centimetres in diameter) per area of available space, and indicates the potential of the community to recover from disturbances or stress (Thompson et al. 2016).

Macroalgal cover is a measure of the proportion (per cent) of cover of algae that is classified as large, fleshy algae. A low score for macroalgae (i.e. poor or very poor) means macroalgal cover is high, which is indicative of poor water quality. Conversely, a high score for macroalgae (i.e. good or very good) means cover is low. High macroalgal cover, once established, reduces the recovery of corals by denying space or producing chemical deterrents that limit coral recruitment and growth (Thompson et al. 2016).

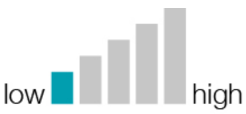
Coral community composition scores are the mean and standard error for locations of communities in multivariate space, constrained to lie along a gradient of water quality (combination of Chl and TSS). Smaller numbers represent communities typical of poorer water quality (Thompson et al. 2016).

The refinements to the assessment of these criteria implemented this year have been hindcast so that results from previous years are comparable (Thompson et al. 2016).

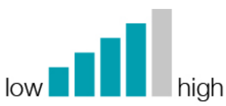
No coral monitoring occurs in the Cape York or Burnett Mary regions under the Marine Monitoring Program. Coral scores also incorporate monitoring of inshore reefs undertaken through the Australian Institute of Marine Science's Long-Term Monitoring Program (http://www.aims.gov.au/docs/research/monitoring/reef/reef-monitoring.html).

### Qualitative confidence rankings

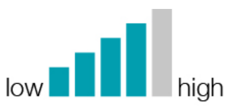
Remote sensed water quality




Seagrass




Coral




A multi-criteria analysis was used to qualitatively score the confidence in each indicator used in the Great Barrier Reef Report Card from low to high. The approach combined the use of expert opinion and direct measures of error for program components where available. Remote sensed water quality received a one bar confidence ranking, seagrass received a four bar confidence ranking and coral received a four bar confidence ranking.

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