Report Card | Methods Manual

Updated July 2021

Authors

Healthy Land and Water

About this document

The aim of this document is to outline the structure of the Ecosystem Health Monitoring Program (EHMP) and annual Report Card. It presents a rationale for the Report Card framework and each of the indicators and describes the approach used for calculating the *Environmental Condition Grade*, *Waterways Benefits Rating* and *Priority Actions.*

It is a 'live' document that will be updated as the program evolves.

About Healthy Land and Water

Healthy Land and Water is an independent organisation dedicated to improving and protecting South East Queensland's environment.

As experts in research, monitoring, evaluation and project management, we deliver innovative and science-based solutions to challenges affecting our landscapes, waterways and biodiversity.

Healthy Land and Water came to life after two of the region's most experienced natural resource management groups – Healthy Waterways and SEQ Catchments – merged to form one entity in June 2016. We are now best-placed to act as an enabler and facilitator of change, to provide solutions and connect others, and to drive and influence decisions, policy and actions.

At Healthy Land and Water, we believe that maintaining healthy landscapes and waterways is not just important for wildlife and ecosystems. A healthy environment also supports a vibrant economy, strong livelihoods, great lifestyles and the happiness and well-being of the community. Through our work, we encourage people to examine and change their behaviours for the benefit of the natural world and for the people and places we love.

Fundamentally, we help people understand the values and condition of South East Queensland's environment so we can ensure the sustainable use of our natural environment long into the future.

Acknowledgements

Traditional Owner Acknowledgement

We acknowledge that the place we now live in has been nurtured by Australia's First Peoples for tens of thousands of years. We believe the spiritual, cultural and physical consciousness gained through this custodianship is vital to maintaining the future of our region.

Contact details

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Contents

1 Introduction

The Ecosystem Health Monitoring Program (EHMP) is a comprehensive and scientifically robust waterway monitoring program managed by Healthy Land and Water that has monitored and assessed the health of South East Queensland's creeks, rivers, estuaries and Moreton Bay since 2000 (Figure 1). Annually the results are synthesised and communicated via the Healthy Land and Water Report Card, which is designed around three key elements:

1. **Environmental Condition Grade (A-F):** The spatial extent and intensity of pressures on waterways.
2. **Waterways Benefits Rating (1-5 stars):** The social and economic benefits that the wider community associate with their waterways.
3. **Actions (recommendations):** How and where management actions should be applied, and their impact on waterway health. The barriers and drivers for individuals and groups helping to protect and improve waterways.

The *Environmental Condition Grade* is comprised of multiple indicators, assessing key freshwater and estuarine aspects of the waterways (Figure 2). Indicators are assessed against established guidelines and benchmarks, resulting in a single grade for each catchment or bay zone. The data used to calculate the grade is an integration of modelling and field monitoring, and assesses progress towards the **program's objectives:**

- Restoring and maintaining key habitats (i.e. riparian vegetation) (introduced in 2015),
- Reducing pollutant loads (i.e. sediment and nutrients) entering waterways (introduced in 2015),
- Improving and maintaining water quality,
- Restoring and maintaining key ecosystem processes, and
- Restoring and maintaining resilient and healthy aquatic communities (i.e. fish populations).

The Waterway Benefits Rating (introduced in 2015) helps us to better understand how social and economic values will be affected by changing environmental conditions. The following components are measured:

- Community values and satisfaction with waterways,
- Appropriate access to local waterways,
- Economic benefits generated through recreation, and
- The contribution relevant catchments make to providing clean drinking water.

Actions undertaken by the community to protect and restore waterway health enhances the benefits that waterways provide. Healthy Land and Water is working with the community, local and state governments, water utilities, and the Council of Mayors (SEQ) to prioritise and recommend actions in each catchment. We are building regional decision support tools to assess the threats to environmental values within each catchment. These tools will help prioritise focus areas for action and support decision-makers in developing and implementing targeted, effective catchment management actions. We are also investigating indicators to better understand the barriers and drivers for individuals and groups helping to protect and improve waterways. These will be used to provide recommendations for motivating and enabling action.

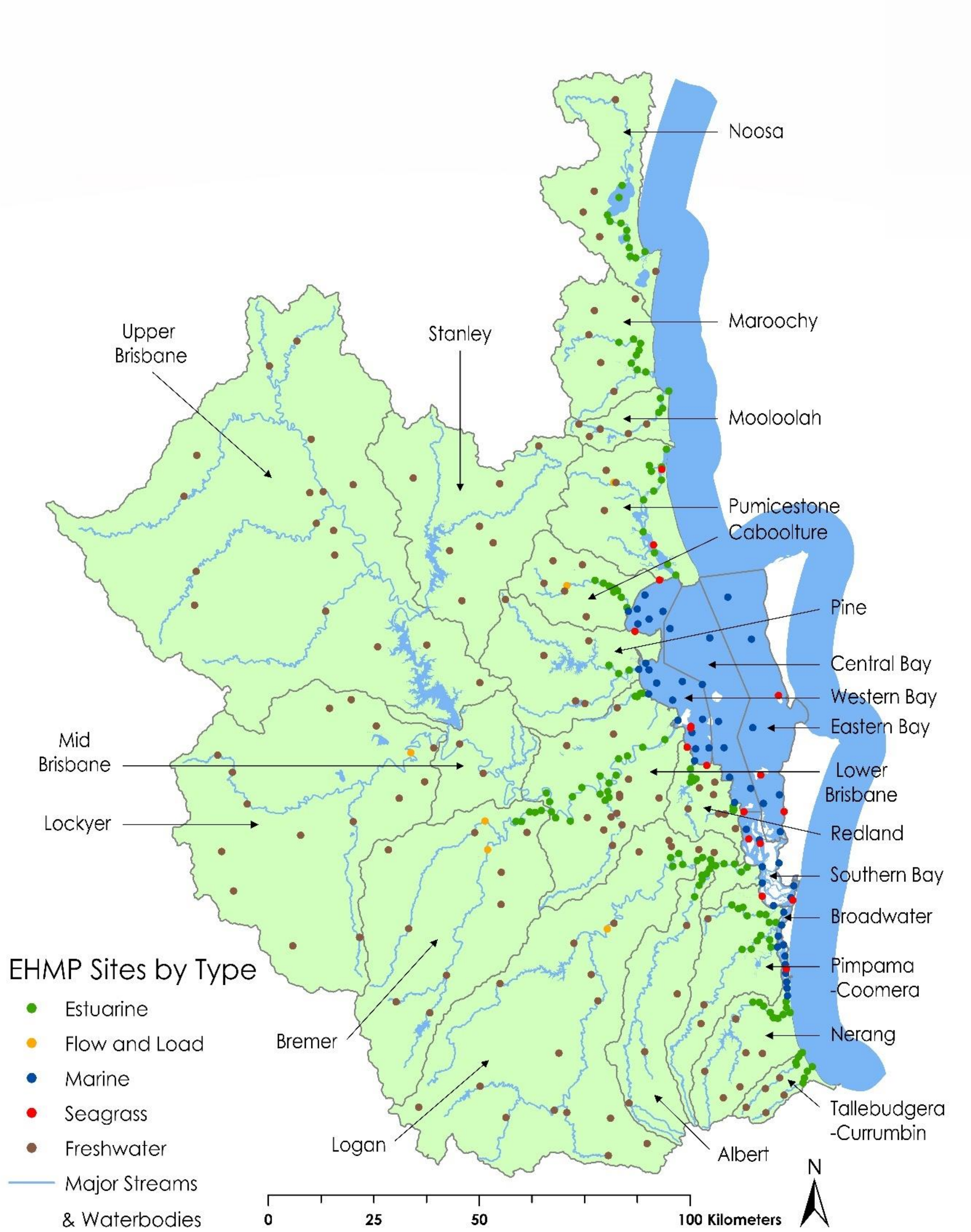

Figure 1: EHMP sites across South East Queensland (2015-2016) that supports the Report Card Environmental Condition Grade.

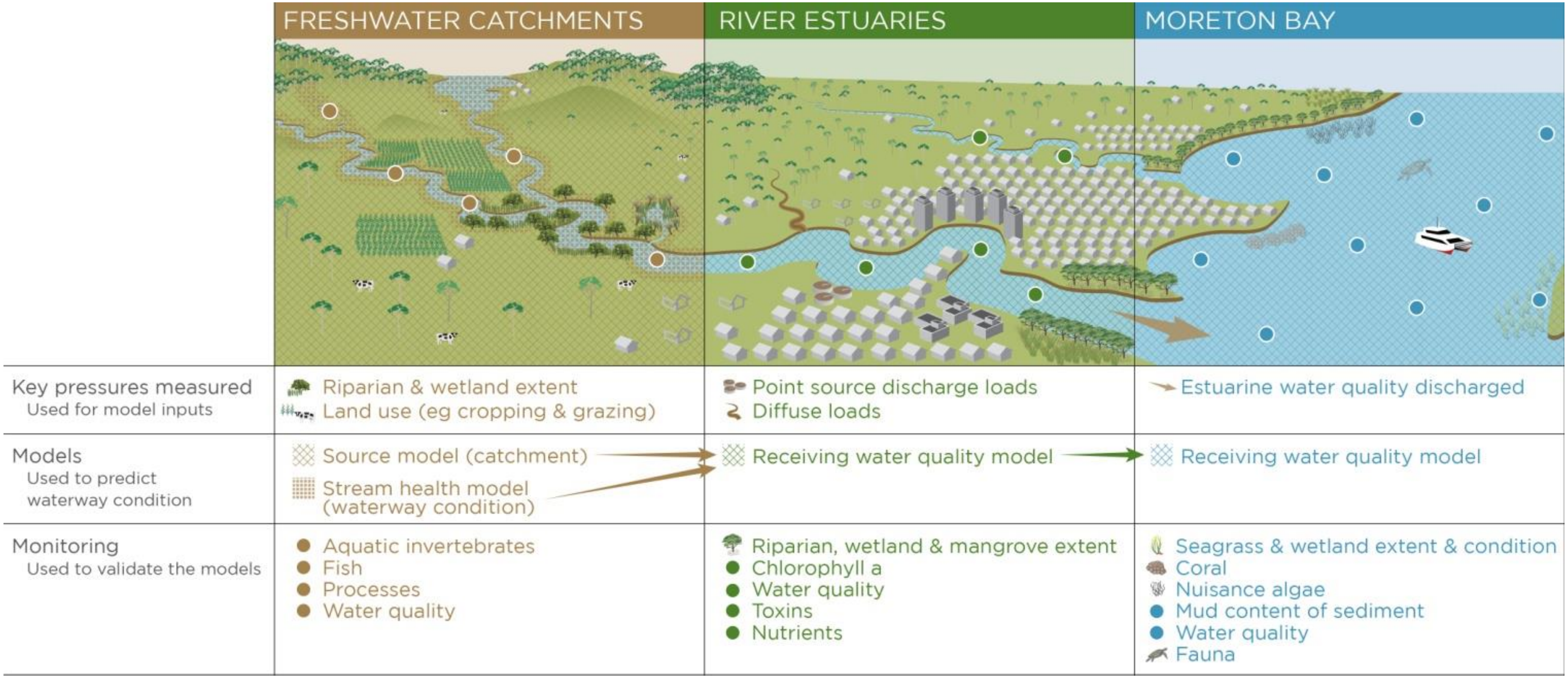

Figure 2: Conceptual diagram summarising the 'Environmental Condition' element of the EHMP.

2 Program background

Since 2000, the EHMP has assessed the ecological condition of waterways in South East Queensland and the results have been used to produce an annual Report Card. When first established, the EHMP was recognised as a world-class environmental monitoring and reporting program (Dennison and Abal, 1999; Bunn et al, 2010).

2.1 Program revised in 2015

In 2015 the monitoring program was revised to keep up with major advances in water quality automated monitoring and predictive modelling. This would help to create a program that reports on not only condition, but also on the drivers of ecosystem health, management responses to address issues and social and economic benefits (Smith, 2014). This new approach means the program now:

- Capitalises on the significant investment in predictive models made by the Healthy Land and Water partners over the past decade,
- Takes advantage of the substantial waterway health dataset amassed since the EHMP's inception by using these data to calibrate and validate the models,
- Utilises affordable automated water quality monitoring equipment to provide a superior understanding of water quality (minimising costs), and
- Provides stakeholders with information they need to effectively manage their catchments and waterways while recognising the need to ensure public funds are effectively allocated to address community priorities.

This optimised program has numerous advantages compared to the original program, as it delivers a holistic, triple-bottom-line approach to waterway management, including:

- Incorporating ambient and load-based monitoring to allow the impact of wet weather events to be monitored and better understood.
- Integrating monitoring and modelling giving capacity to:
  - Establish water quality and catchment load benchmarks for management.
  - Quantify changes in rural and urban land management practices.
  - Quantify the impact of such changes and other management actions.
  - Track progress towards agreed management targets.
  - Explore the efficacy of different management scenarios.
- Providing data on social and economic values of waterways and demonstrates how different activities effect these values.

2.2 How the revised program framework was developed

To ensure the monitoring program and Report Card had maximum impact with a broad audience (government, community groups, industry and general public), it was designed to closely align with the aims and objectives that Healthy Land and Water members have for South East Queensland waterways. This ensures the monitoring results being published in the Report Card, and the management activities that are subsequently applied, are fully linked to the aspects of waterways that member's value and are committed to protecting or restoring.

The steps to develop the revised monitoring program and Report Card framework are outlined in Figure 3. Four main steps were followed to design the program:

Step 1: Define the aims and objectives of the program based on the regional goal of Healthy Land and Water and its members and based on the DPSIR model[1].

Step 2: Select appropriate indicators that address each of the objectives and identify benchmarks to assess against indicator values.

Step 3: Calculate scores for each indicator, index and Report Card component.

Step 4: Define the grades and ratings to be used in the Report Card, set the cut-offs for each and assign grades and ratings to each catchment.

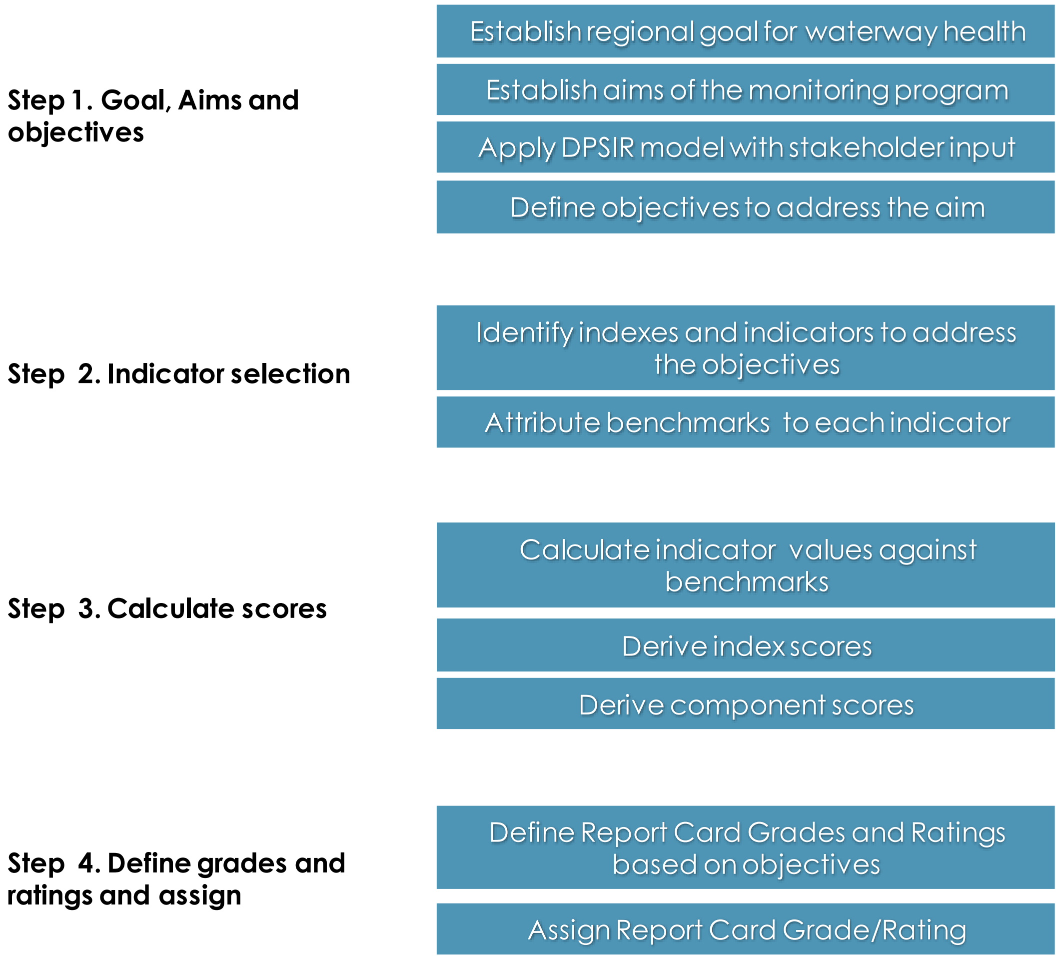

Figure 3: Approach to the development of the EHMP and Report Card.

The goals, aims and objectives of the program were developed (Step1) based on the outcomes of two independent reviews of the EHMP (Smith, 2014) and a series of workshops with stakeholders in 2012. The goals, aims and objectives are an adaptation of the DPSIR Framework (Driving forces, Pressures, State, Impacts and Responses), which is typically applied to assess and manage environmental problems. The ***socio-economic and socio-cultural forces*** are driving human activities

[1] DPSIR Framework (Driving forces, Pressures, State, Impacts and Responses) is used to assess and manage environmental problems. Driving forces are the socio-economic and socio-cultural forces driving human activities which increase or mitigate pressures on the environment. Pressures are the stresses that humans place on the environment. State, or state of the environment, is the condition of the environment. Impacts are the effects of environmental degradation. Response refers to the responses by society to the environmental state.

which increase or mitigate pressures on the environment. ***Pressures*** are the stresses that humans place on the environment. ***State, or state of the environment***, is the condition of the environment. ***Impacts*** are the effects of environmental degradation. ***Response*** refers to the responses by society to the environmental state.

The driver for many members in committing to improving waterway condition is the social and economic elements the community derive from waterways and the corresponding changes in lifestyles and livelihoods that result from improvements to waterway condition. The pressures on waterway condition in South East Queensland are the anthropogenic factors that result in changes to waterway condition. These have been identified by members and include elements like increase diffuse and point source pollutant loads, climatic changes and physical alterations to waterway habitats. The state is the environmental condition of the waterways. This is essentially what Healthy Land and Water has reported on previously through the EHMP. The impacts are the changes in the benefits that the community derives as a result of changes in waterway condition. The response to changing condition and benefits are the improvements in stewardship and the adoption of Best Management Actions in the six management themes identified by members. Increasing adoption of best management practice will lead to a reduction in the pollutant loads and other pressures on waterway condition.

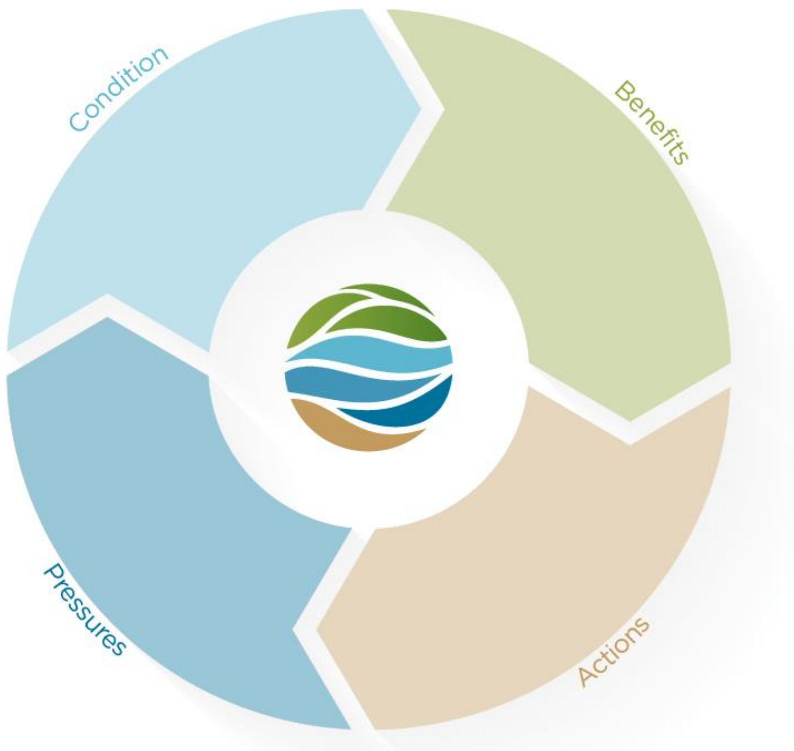

Figure 4: The EHMP and Report Card guiding framework.

With this structure, the monitoring program provides members with an understanding of the condition of South East Queensland waterways, as well as datasets to better assist members in making informed catchment management decisions. Understanding the changes to the key pressures on waterways will aid in the interpretation of changes in waterway condition. Understanding the link between waterway condition and the resultant socio-economic benefit will help to generate community engagement and inform the development of cost-effective and targeted management actions.

3 Monitoring program framework

3.1 Regional goal and objectives

The monitoring program has been designed to assess progress towards the regional goal for waterway management in South East Queensland:

"Enhance community quality of life by fostering stewardship to protect and restore waterway health."

The regional goal was developed in consultation with the Healthy Land and Water members and stakeholders and designed to account for the four goals of the Resilient Rivers Initiative (Council of Mayors (SEQ), July 2016).

The regional goal can be broken into three goals (each of which corresponds to the three elements of the Report Card) (Table 1). And each goal has a set of specific objectives (Table 1). Through the encouragement of members to achieve these objectives, Healthy Land and Water makes it clear that progress toward any objective should not be obtained via the detriment of any other (e.g. increasing recreational access to the detriment of key riparian habitat).

Table 1: Goals and objectives of the EHMP and Report Card.

Goal 1: Enhance community quality of life • Improve and optimise community access, interaction and satisfaction with their use of waterways. • Maintain and improve the economic benefit that waterways provide for commercial and recreational fishing. • Maintain and improve the contribution of waterways in providing low cost drinking water. • Maintain and improve the economic benefit generated by recreation.	⇨ WATERWAYS BENEFIT RATING
Goal 2: Foster stewardship • Maintain and improve the extent to which society is willing and able to behave in ways that protect and restore waterways (e.g. adoption of best management practice).	⇨ ACTIONS
Goal 3: Protect and restore waterway health • Maintain and restore key habitats (riparian, wetlands, seagrass, mangroves, and coral). • Minimise sediments and nutrient inputs to waterways. • Maintain and improve water quality. • Maintain and restore functionality of key processes. • Maintain and restore resilient and healthy aquatic communities.	⇨ ENVIRONMENTAL CONDITION GRADE

3.2 Aims and scope of the monitoring program

The aims of the monitoring program and Report Card are to:

- Inspire action.
- Identify priority areas for investment and support members to identify and implement actions.
- Provide an assessment of the effectiveness of management actions and progress towards targets.
- Provide data relevant for researchers, managers and the wider community that contributes to greater understanding of waterways.

The focus is on six main management themes:

1. Land.
2. Construction Site.
3. Riparian and In-Stream.
4. Community and Tourism.
5. Stormwater.
6. Point Source Management.

4 Report Card framework

This section summarises the Report Card framework, the indices that are measured and how they are scored. Additional detail on individual indicators (including definitions, rationale, data collection methods, benchmarks and score calculations) can be found in the following section (Section 5).

Healthy Land and Water synthesises data annually from our monitoring program to produce the Report Card (Figure 5), which provides an easy to understand assessment of the health of our catchments and waterways and highlights any issues that require intervention.

The Report Card is designed around three key elements:

Environmental Condition Grade (A-F): This grades 18 catchments and five regions of the bay, using 25 indicators that are combined into a single overarching index of environmental condition.

Waterways Benefits Rating (1-5 stars): This rates 18 catchments, using six indicators that are combined into a single overarching index of social and economic benefits that the wider community receive from their waterways.

Actions (recommendations): This describes the barriers and drivers for individuals and groups helping to protect and improve waterways, how and where management actions should be applied and their impact on waterway health.

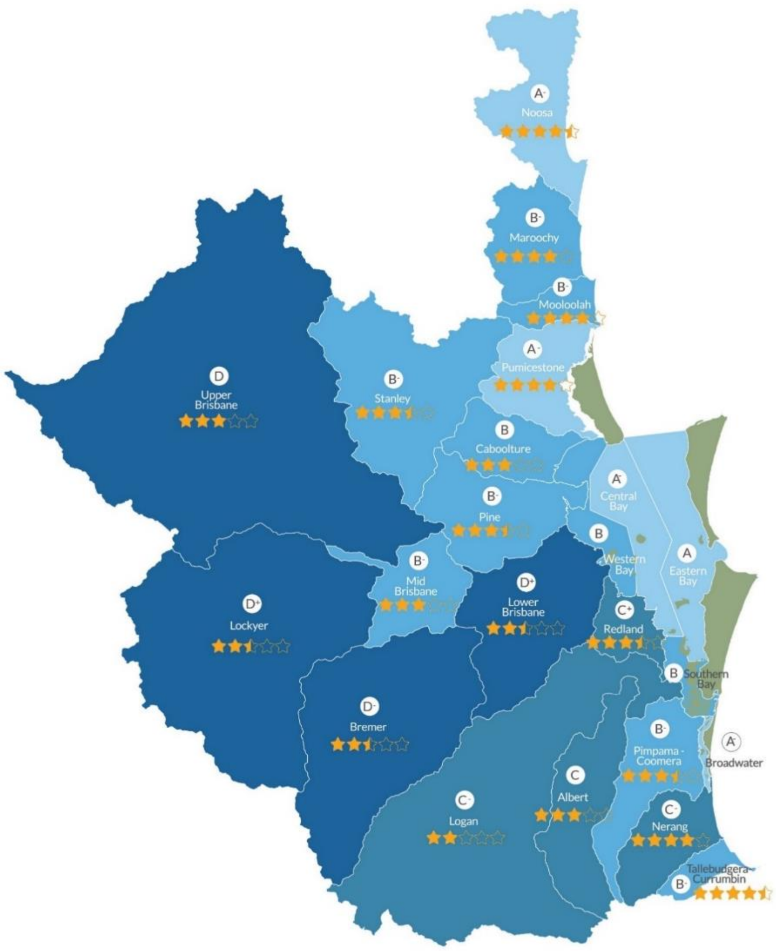

Figure 5: Report Card 2017.

4.1 Environmental Condition Grade (A-F)

The Environmental Condition Grade is calculated from 25 indicators, assessing key freshwater and estuarine aspects of the waterways. Indicators are assessed against established guidelines and benchmarks, resulting in a single grade for each catchment or bay zone.

It assesses progress towards the five key objectives that our members have for South East Queensland waterways:

- Restoring and maintaining key habitats (i.e. riparian vegetation) (*introduced in 2015)*.
- Reducing pollutant loads (sediment and nutrients) entering waterways (*introduced in 2015*).
- Improving and maintaining water quality.
- Restoring and maintaining key ecosystem processes.
- Restoring and maintaining resilient and healthy aquatic communities (i.e. fish populations).

The Grades

(A) Excellent: Conditions meet all guidelines. All key processes are functional and critical habitats are in near pristine condition.

(B) Good: Conditions meet guidelines for most of the reporting area. Most key processes are slightly impacted and most critical habitats are intact.

(C) Fair: Conditions are close to meeting guidelines in most of the reporting area. Key processes are impacted but still functional and critical habitats are impacted.

(D) Poor: Conditions meet few of the guidelines in most of the reporting area. Many key processes are not functional and most critical habitats are impacted.

(F) Fail: Conditions do not meet the set guidelines. Most key processes are not functional and most critical habitats are severely impacted.

The reporting zones (see the Report Card website or Figure 5 **for map)**

Catchment grades are calculated for:			Bay zone grades are calculated for:
Noosa	Albert		Western Bay
Maroochy	Pimpama-Coomera		Eastern Bay
Mooloolah	Nerang Tallebudgera- Currumbin		Central Bay
Pumicestone	Stanley		Southern Bay
Caboolture	Upper Brisbane		Broadwater
Pine Rivers	Mid Brisbane		
Lower Brisbane	Lockyer		
Redlands	Bremer		
Logan			

4.1.1 Calculating Grades for catchments

The overall Environmental Condition Grade for each of the 18 reporting catchments is calculated using 22 indicators (Figure 6). For coastal catchments, the overall score is made up of:

- 20% indicators of freshwater communities and process.
- 20% indicators of estuarine water quality.
- 40% indicators of habitat.
- 20% indicators of pollutant load.

For the western catchments, the overall score is made up of:

- 40% indicators of freshwater communities and processes.
- 40% indicators of habitat.
- 20% indicators of pollutant load.

A score for each indicator is calculated using data from a combination of sources, including environmental modelling, monitoring and remote sensing. The following section describes the four components that make up the catchment grades, and how scores for underlying indicators are calculated:

1. 20% freshwater communities and processes.
2. 20% estuarine water quality.
3. 40% habitat.
4. 20% pollutant load.

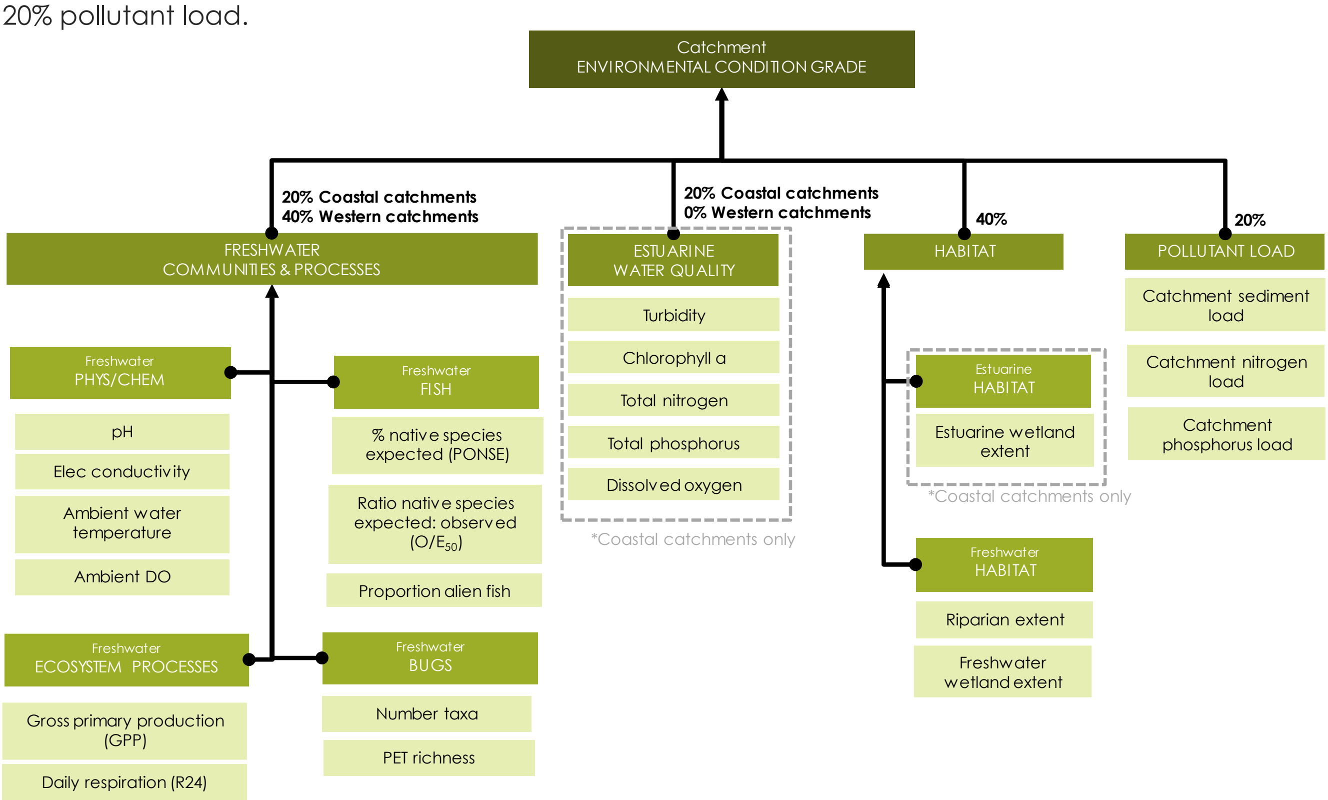

Figure 6: Diagram showing the 22 indicators (lightest green) that are combined into a single overarching environmental condition grade for the catchment reporting zones. Note that indicators for coastal catchments and western catchments are weighted differently.

1. Freshwater communities and processes (20%)

The condition of freshwater streams is reflected by the instream communities and ecosystem processes:

- Fish communities reflect a range of environmental disturbances and provide a measure of stream condition due to their mobility, long life and position near the top of the food chain.
- Aquatic bug communities (insects, crustaceans, snails, etc) are very sensitive to disturbance.
- Ecosystem process measures reflect the vigour or 'pulse' of a stream.
- Physical and chemical conditions reflect stream water quality.

Indices/Indicators

There are 11 indicators of freshwater communities and processes, that are condensed into four indices:

1. Fish
    - A. Percentage of native species expected (PONSE)
    - B. Ratio native species expected/observed (O/E50)
    - C. Proportion alien fish
2. Bugs
    - A. Number of taxa
    - B. PET richness
3. Ecosystem processes
    - A. Gross primary production (GPP)
    - B. Daily respiration (R24)
4. Physical and chemical
    - A. pH
    - B. Electrical conductivity
    - C. Ambient water temperature
    - D. Ambient dissolved oxygen

Data collection and scoring

A Stream Health Model (Appendix 8.5) is used to estimate the score for each index (i.e. fish, bugs, ecosystem processes and physical and chemical) at 129 representative sites across South East Queensland (**Figure 7**). The model is validated with field data collected once per year at 75 freshwater sites through the EHMP. The full 129 sites are sampled on a three-year rotation (i.e. 48 sites are sampled every year, while 81 sites are sampled every three years on rotation). Scores are standardised to guideline values (Table 2).

Table 2: Freshwater indicator guideline values used to standardise scores.

Index	Indicator	Upland		Lowland or coastal		Tannin-stained		Operand	Unit
		Guideline	**WCS**	**Guideline**	**WCS**	**Guideline**	**WCS**		
PhysChem									
	pH (min)	6.5	4.5	6.5	4.5	5	3	≥	$[H^+]$
	pH (max)	8.5	10.5	8.5	10.5	8.5	10.5	≤	$[H^+]$
	Conductivity	400	1041	400	1870	400	1870	≤	µS cm^{-1}
	Temp (max)	18	NA	22	NA	22	NA	≤	°C
	Temp (range)	4	NA	4	NA	4	NA	≤	°C
	DO (min)	30	NA	20	NA	20	NA	≥	% saturation
	DO (range)	30	NA	50	NA	50	NA	≤	% saturation
Ecosystem Processes									
	GPP	0.25	0.8	0.5	1.3	0.5	1.3	≤	g C m^{-2} day^{-1}
	R24	0.15	0.7	0.35	1.2	0.35	1.2	≤	g C m^{-2} day^{-1}
Fish									
	PONSE	100	0	100	0	100	0	≥	%
	Ratio = O/E	1	0	1	0	1	0	≥	Ratio (number)
	Prop. Alien Fish	0	100	0	100	0	100	=	%
Bugs									
	Number Taxa	22	0	22	0	11	0	≥	Number
	PET Richness	5	0	4	0	3	0	≥	Number

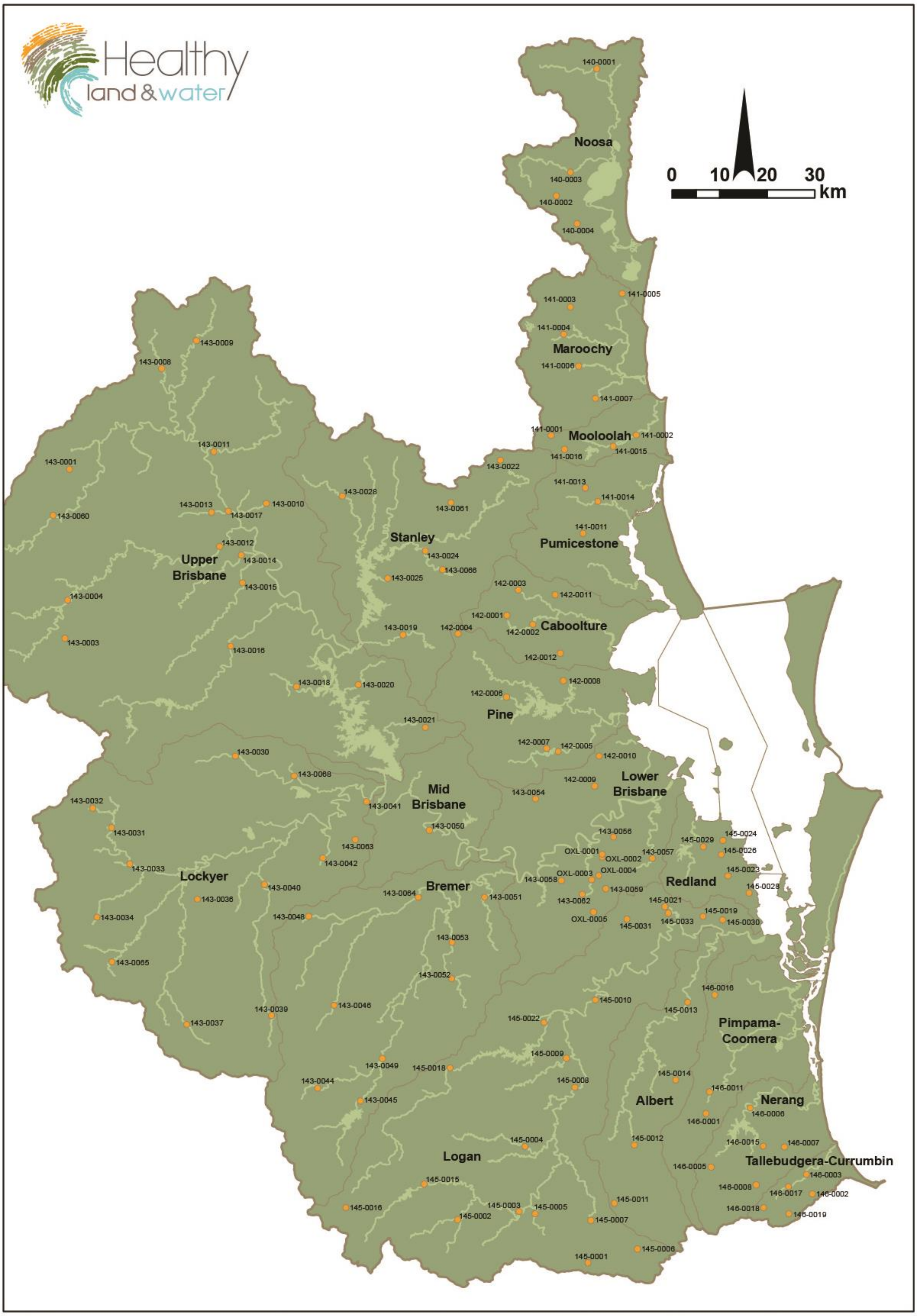

Figure 7: Freshwater monitoring sites.

2. Estuarine water quality (20%)

Water quality in estuaries refers to the physical and chemical properties of the water. Variation in water quality influences the types of organisms that will live and grow in an estuary.

Indices/Indicators

There are five estuarine water quality indicators:

1. Turbidity.
2. Chlorophyll a.
3. Total nitrogen.
4. Total phosphorus.
5. Dissolved oxygen.

Data collection and scoring

Estuarine and bay water quality models (using TUFLOW FV) are used to predict annual water quality medians throughout each of the estuarine and bay reporting zones. The models are validated using field data collected monthly at 143 estuarine sites (once per month for eight months per year - February, March, May, August, September, October, November and December) through the monitoring program (**Figure 8**). Then the models predict water quality medians for each indicator which are used to calculate a standardised score. This is done by applying an area weighted 'distance from guideline' approach using the Queensland Water Quality Guidelines (Table 3).

Table 3: Queensland Water Quality guideline and WCS (worst case scenario) for all water types in South-East Queensland for five parameters monitored in the program (turbidity (NTU), dissolved oxygen (%sat), total N (mg/L), total P (mg/L), chlorophyll a (ug/L)). Water type maps and additional information can be found on the Queensland Government website (https://www.ehp.qld.gov.au/water/policy/seq-moretonbay.html).

WATER TYPE		Guideline	WCS (0.9)	Guideline	WCS (0.9)	Guideline	WCS (0.9)	Guideline	WCS (0.9)	Guideline	WCS (0.9)
		Turbidity		Diss Ox		Total N		Total P		Chl-a	
SEQ estuaries (exc. Noosa)	Enclosed coastal	6	13	90	82.1	0.2	0.5	0.02	0.1	2	5.4
	Mid estuary	8	82	85	57.8	0.3	1.3	0.025	0.5	4	12.1
	Upper estuary	25	89	80	54.1	0.45	1.5	0.03	0.5	8	18.3
Noosa River estuary	Enclosed coastal	4	5	90	90.9	0.24	0.29	0.015	0.018	1.8	2
	Mid estuary	8	24	85	87.5	0.38	0.51	0.016	0.02	2.5	2.9
	Upper estuary	22	56	85	84.4	0.75	0.77	0.02	0.025	5	5.3
SEQ bays	Pum Pass Outer	6	13	90	88	0.22	0.35	0.025	0.03	2.6	4.8
	Pum Pass Central	10	20	95	82	0.33	0.48	0.023	0.03	4	6
	Western Bays	6	16	95	92	0.2	0.32	0.03	0.08	1.6	6.5
	Central Bay	5	7	95	94	0.16	0.21	0.02	0.033	1	3
	Eastern Bay	1	5	95	95	0.16	0.18	0.016	0.02	1	2
	Southern Moreton Bay	7	25	95	90.9	0.2	0.32	0.024	0.055	2	5
	Broadwater	6	12	90	90	0.19	0.28	0.022	0.03	2.5	3.5

Figure 8: Estuarine water quality monitoring sites.

3. Habitat (40%)

Estuarine and freshwater wetlands provide a variety of critical functions and services including the provision of habitat for aquatic organisms, coastal protection and bank stabilisation, carbon sequestration and nitrogen processing and removal. Riparian vegetation also provides a variety of critical functions and services including the provision of habitat and bank stabilisation.

Indices/indicators

There are three catchment habitat indicators:

1. Freshwater wetland extent (km^2).
2. Estuarine wetland extent (km^2).
3. Riparian extent (woody veg area (ha)/total stream riparian area (ha)).

Data collection and scoring

Freshwater and estuarine wetland extent is calculated every four years, with data derived from the Department of Environment and Heritage Wetland Info program (https://wetlandinfo.ehp.qld.gov.au/wetlands/. The extent of riparian vegetation is calculated approximately every three-four years by the Department of Environment and Science, using Landsat and Sentinel-2 satellite imagery. Extent values are standardised to calculate a catchment score.

4. Pollutant loads (20%)

Three major pollutants of concern in waterways are sediments, nitrogen and phosphorus.

Excess sediments in waterways reduces light penetration which restricts growth of aquatic plants, smothers benthic organisms and transports nutrients and contaminants.

Excess nutrients (nitrogen and phosphorus) in our waterways stimulates growth of macrophytes and algae (including cyanobacteria) to nuisance proportions, which can displace endemic species, diminish light availability to benthic species, and cause excessive fluctuations in pH and dissolved oxygen which can stress and eliminate sensitive species.

Indices/indicators

There are three pollutant load indicators:

1. Sediment load (kg/year).
2. Nitrogen load (kg/year).
3. Phosphorus load (kg/year).

Data collection and scoring

The source catchment model (Appendix 8.3) is run annually to estimate total annual sediment, nitrogen and phosphorus loads. The model simulates how catchment and climate variables such as rainfall, land use and vegetation, affect water runoff and subsequent pollutant loads (**Figure 9**). The model estimates of total annual loads are used to calculate a catchment score. The scores are standardised by scaling to the range of possible values across the region.

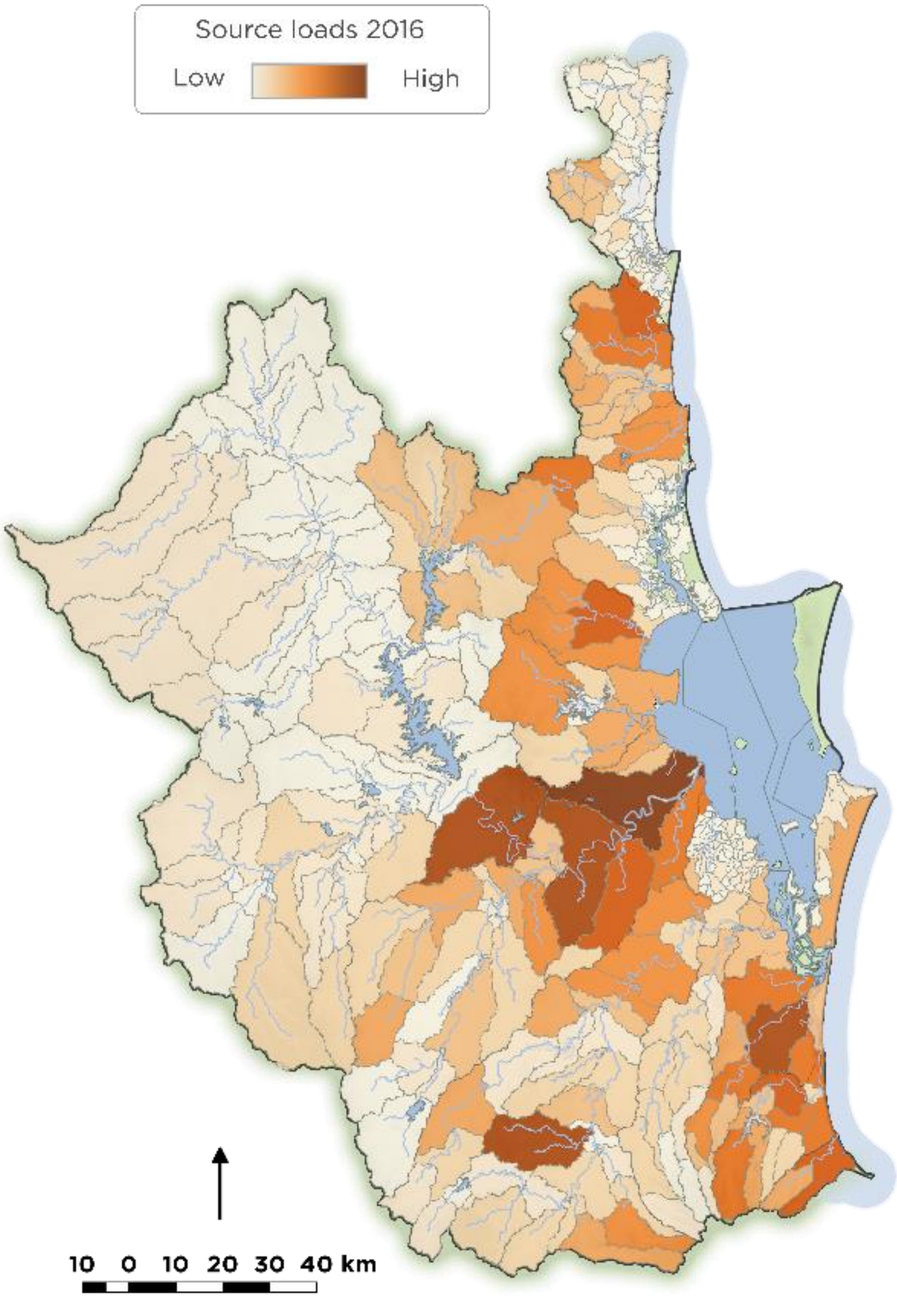

Figure 9: Example of pollutant loads modelled for Report Card 2016.

4.1.2 Calculating Grades for Bay zones

The overall Environmental Condition Grade for each of the five bay reporting zones (Western Bay, Eastern Bay, Central Bay, Southern Bay and Broadwater) is calculated using eight indicators (**Figure 10**). Water quality indicators make up 50% of the overall score, and habitat indicators make up the other 50% of the overall score. A score for each indicator is calculated using data from a combination of sources, including environmental modelling, monitoring and remote sensing. The following section describes the two components that make up the catchment grades, and how scores for the underlying indicators are calculated:

1. Bay water quality (50%).
2. Bay habitat (50%).

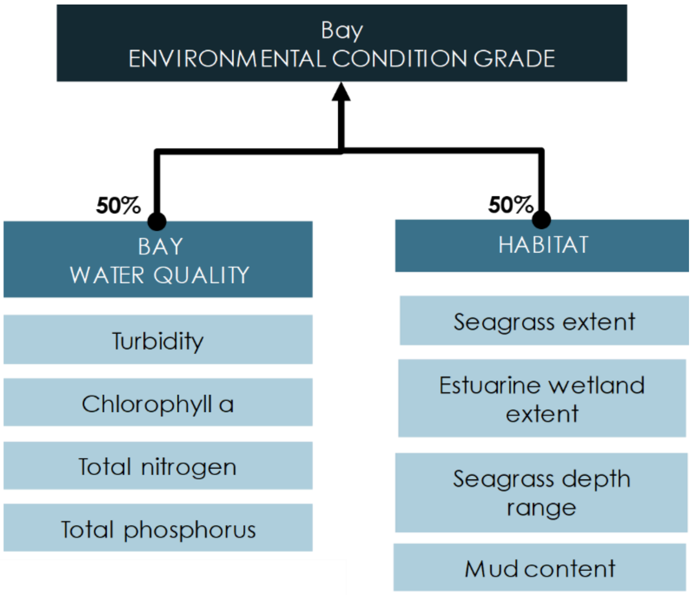

Figure 10: Diagram showing the eight indicators (lightest blue) that are combined into single overarching environmental condition grade for each of the bay reporting zones.

Bay water quality (50%)

Water quality refers to the physical and chemical properties of the water. The variation and range of water quality influence the types of organisms that can live and grow in the waterbody.

Indicators

There are four bay water quality indicators:

1. Turbidity.
2. Chlorophyll a.
3. Total nitrogen.
4. Total phosphorus.

Data collection and scoring

Estuarine and bay water quality models (using TUFLOW FV) are used to predict annual water quality medians throughout each of the estuarine and bay reporting zones. The models are validated using field data collected monthly at 41 bay sites (once per month for eight months per year – February, March, May, August, September, October, November and December) through the monitoring program (**Figure 11**). The model predicted water quality medians for each indicator are used to calculate a standardised score. This is done by applying an area weighted 'distance from guideline' approach using the Queensland Water Quality Guidelines (**Table 3**).

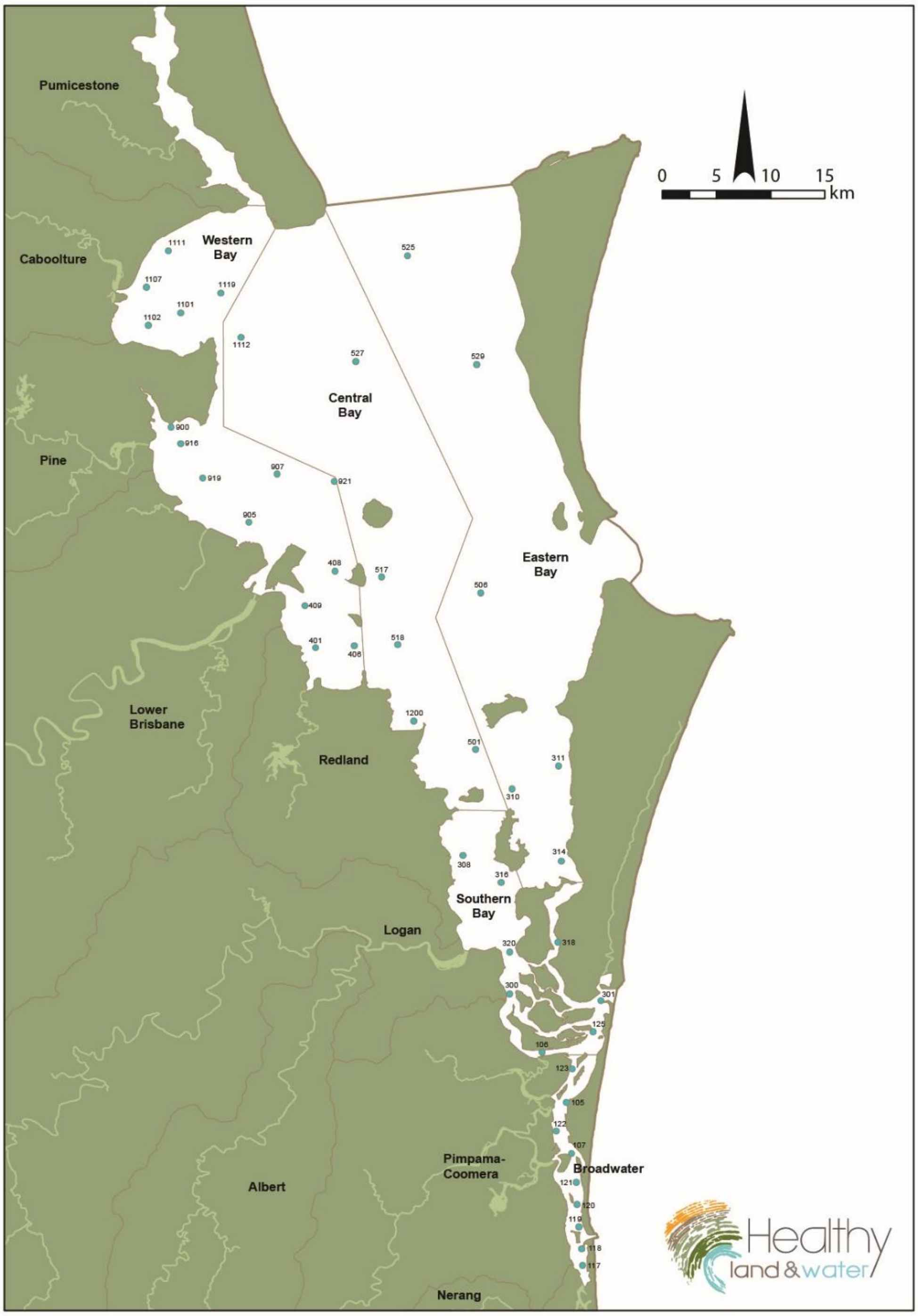

Figure 11: Bay water quality monitoring sites.

Bay habitat (50%)

Estuarine wetlands provide a variety of critical functions and services including provision of habitat for aquatic organisms, foreshore protection carbon sequestration and nitrogen processing and removal.

Sediment mud content reflects the level of pressure on bay habitats from catchment sediment loads.

Seagrass depth range reflects the degree to which seagrass is under pressure from sediment loads and associated changes in water clarity.

Indices

There are four bay habitat indicators:

1. Estuarine wetland extent (km^2).
2. Seagrass extent.
3. Seagrass depth range (m).
4. Mud content.

Data collection and scoring

Wetland extent is calculated every four years, with data derived from the Department of Environment and Heritage Wetland Info program (https://wetlandinfo.ehp.qld.gov.au/wetlands/). Wetland extent values are then standardised to calculate a final bay zone score.

Seagrass extent is measured approximately every three years using a combination of field sampling and remote sensing. Field data is collected through the monitoring program and by citizen science groups. Seagrass extent is expressed as the percentage of seagrass present compared to the 2004 map of seagrass extent in Moreton Bay.

Seagrass depth range is measured at 17 sites bi-annually, by the EHMP. *Zostera muelleri* is used as the indicator species. The depth range and general profile of the seagrass bed is determined along a main transect recording the upper and lower distributional limits (Figure 12).

Mud content is measured approximately every four years by the University of Queensland and citizen science volunteers.

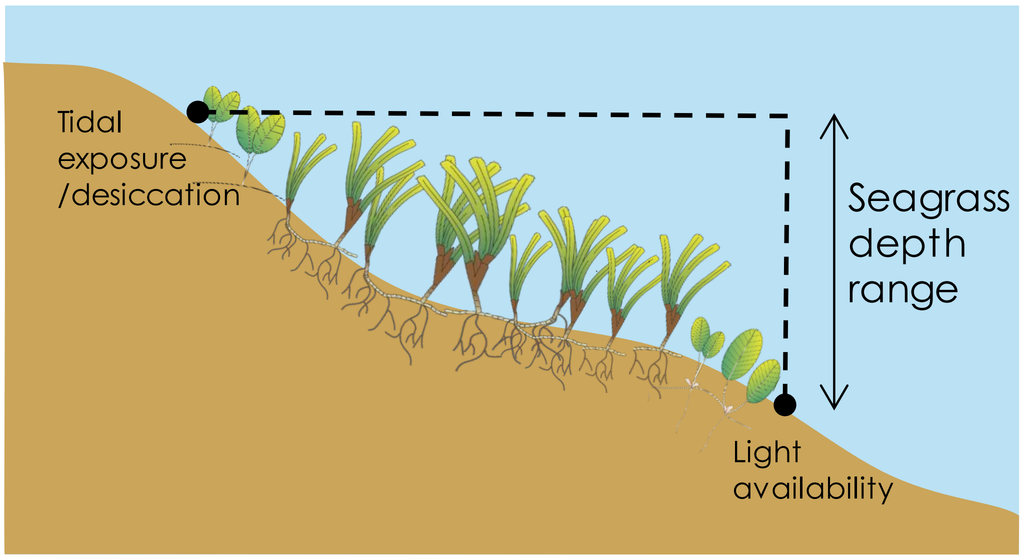

Figure 12: Schematic diagram illustrating how seagrass depth range is measured.

4.2 Waterways Benefits Rating (1-5 stars)

Our waterways provide important benefits such as clean and safe drinking water, nursery habitats for recreational and commercial fishing and a reliable water source for agricultural productivity. Recreation activities in and around waterways help to improve physical health and wellbeing and contribute approximately $3.22 billion to the region's economy annually.

The Waterway Benefits Rating (introduced in 2015) helps us to better understand how the social and economic benefits our waterways provide will be affected by changing environmental conditions.

The following components are measured:

- Community satisfaction with local waterways.
- Appropriate access to local waterways.
- Personal benefits residents derive from using local waterways.
- Community motivation to use and protect waterways.
- Economic benefits generated through recreation.
- Contribution relevant catchments make to providing clean low-cost drinking water.

__The 5-Star Rating__

__***** (5-stars) Maximum benefits:__ Local community fully satisfied with local waterways, including their accessibility and usability. Maximum financial benefit from recreational use and low-cost drinking water.

__**** (4-stars) Very high benefits:__ Local community highly satisfied with local waterways, including their accessibility and usability. Very high financial benefit from recreational use and low-cost drinking water.

__*** (3-stars) High benefits:__ Local community generally satisfied with local waterways, including their accessibility and usability. High financial benefit from recreational use and low-cost drinking water.

__** (2-stars) Moderate benefits:__ Moderate accessibility and usability of waterways limits community use and satisfaction. Moderate financial benefit due to moderate recreational use and higher cost drinking water.

__* (1-star) Minimum benefits__: Minimal accessibility and usability of waterway result in little to no social or recreational benefits for the community. Minimum financial benefit due to low recreational use and highest cost drinking water.

The reporting zones (visit the Report Card website hlw.org.au/reportcard **or** Figure 5 **for map)**

Waterway benefit ratings are calculated for the following catchments. There are no benefits ratings calculated for bay zones.

Reporting Zones		
Noosa	Lower Brisbane	Stanley
Maroochy	Redlands	Upper Brisbane
Mooloolah	Logan	Mid Brisbane
Pumicestone Passage	Albert	Lockyer
Caboolture	Pimpama-Coomera	Bremer
Pine Rivers	Nerang Tallebudgera- Currumbin	

4.2.1 Calculating Waterways Benefit Ratings for catchments

The overall Waterway Benefits Rating for each of the 18 catchment reporting zones is calculated by combining the score for five indicators (Figure 13). In drinking water catchments, social indicators make up 60% of the overall score, and economic indicators make up 40% of the score. In non-drinking water catchments, the social indicators make up 75% of the overall score, and economic indicators make up 25% of the overall score. The score for each indicator is calculated using data collected through a range of methods including community surveys and economic assessments. The following section describes the two components that make up the Waterways Benefits Rating, and how scores for underlying indicators are calculated.

1. Social (60%).
2. Economic (40%).

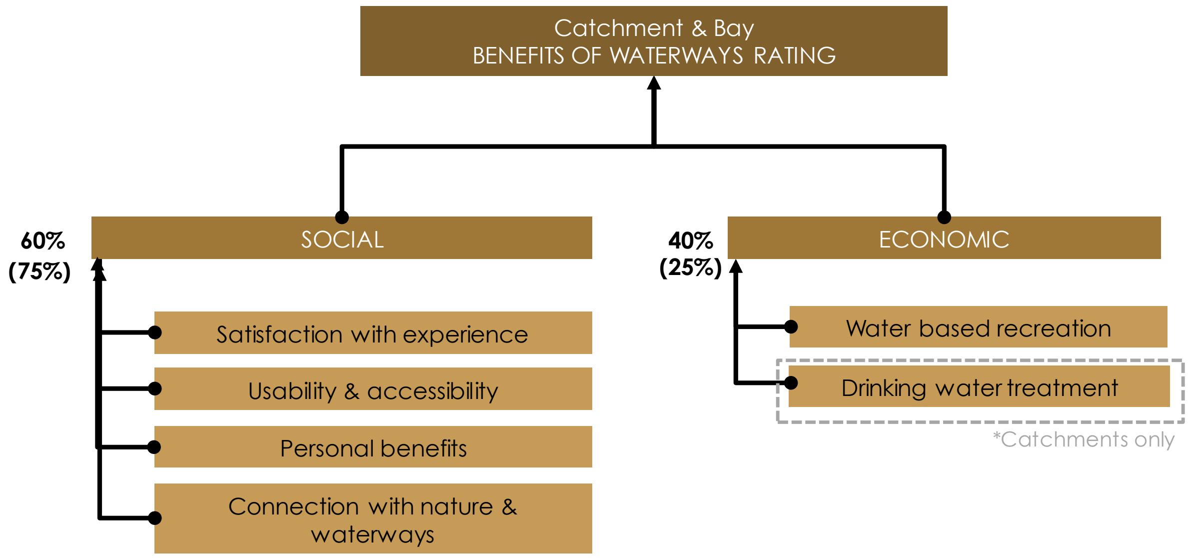

Figure 13: Diagram showing the five indicators (lightest brown) that are combined into a single overarching Waterways Benefit Rating for each of the catchment reporting zones.

Social (60%)

The level of social benefit a waterway provides the local community reflects two things:

- The community's willingness and ability to continue using local waterways and experience the associated mental health, physical health and cultural benefits.
- The community's willingness and ability to support and participate in activities that improve the condition of local waterways.

Indices

The purpose of including the social indicators in the Report Card is to help encourage individuals, industry, communities of practice and governments to act in ways that improve or sustain the condition of catchments and the services they provide.

We measure four indicators of social benefit which have been included to help managers identify the elements of communities in each catchment that facilitate action (Figure 14).

These include:

1. Satisfaction with experience of local waterways.
2. Usability and accessibility.
3. Personal benefits.
4. Connection with nature and waterways.

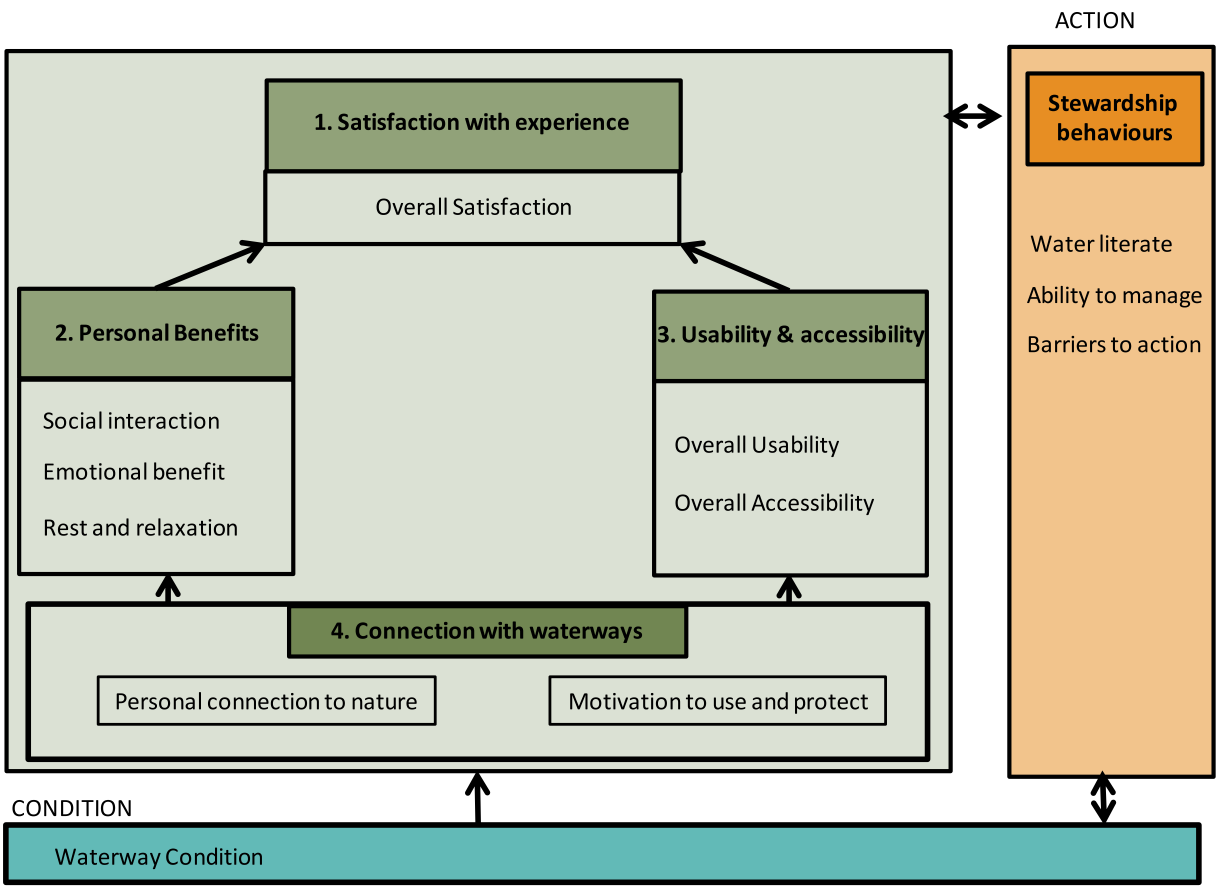

Figure 14: Framework for the four social benefit indices used in the Report Card.

Data collection and scoring

A community survey of South East Queensland residents is carried out annually. This provides a representative subsample of the population within each reporting zone. The survey is administered through a 20-minute online survey hosted by Queensland University of Technology. Survey respondents are recruited using panel data (more than 3000 people per year) and are adults (18+) living in South East Queensland. Indicator scores are calculated as the percentage of survey respondents within a catchment who positively report satisfaction/usability/importance of local waterways.

Economic (40%)

Waterways have the capacity to provide significant economic benefits to the local community. For example, the frequency of visits and type of recreation carried out on and beside waterways has an economic value to the community.

In addition, the amount of sludge treated in the production of drinking water reflects the quality of water entering a drinking water treatment plant, and therefore the economic value of a drinking water catchment to the community.

Future Report Cards will include an index that reflects the value of waterways to agriculture.

Indices

- Drinking water value (N/A for non-drinking water catchments.
- Water-based recreation value.

Data collection and scoring

Drinking water value is calculated annually using Seqwater sludge data based on kg/ML removed for each Water Treatment Plant (WTP).

The amount of water-based recreation carried out over the year is estimated using data from an annual community survey of South East Queensland residents (described above). The dollar value is then calculated by multiplying the frequency of each recreational activity by an estimate of its value which has been derived from the literature.

4.3 Actions

Healthy Land and Water is working with the community, local and state governments, water utilities, SEQ Catchments Members Association (SEQMA) and the Council of Mayors (SEQ) to prioritise action in each catchment.

We are developing regional decision support tools to assess the threats to environmental values within each catchment. Specifically, the environmental values and objectives are (as defined by our members):

- Restore and maintain key habitats (i.e. riparian vegetation).
- Reduce pollutant loads (sediment and nutrients) entering waterways.
- Improve and maintain water quality.
- Restore and maintain key ecosystem processes.
- Restore and maintain resilient and healthy aquatic communities (i.e. fish populations).

These tools help prioritise focus areas for action and support decision-makers in developing and implementing targeted, effective catchment management actions.

5 Indicators and benchmark for each index

A summary list of all Report Card indicators and data sources is provided in Appendix 8.1.

This section provides a definition and rationale for each indicator used to calculate the Environmental Condition Grade and Benefit Rating. It also describes the methodology for regional data collection and score calculation for each indicator.

In most cases an index is made up of more than one indicator (see summary table in Appendix 8.1). If an index has multiple indicators, the score is generally calculated by averaging across all indicators within the index.

5.1 Environmental Condition Grade indicators – Catchments

5.1.1 Habitat index

Riparian vegetation and wetlands are key habitats providing are vital link between land and water.

This index is an average of three indicators:

1. Riparian extent.
2. Freshwater wetland extent.
3. Estuarine wetland extent *(coastal catchments only)*.

5.1.1.1 Riparian Extent indicator

Rationale

Riparian vegetation is a critical component of a waterway. It provides habitat for a wide variety of organisms, prevents erosion of riverbanks and act as a filter to minimise sediments and nutrients entering the waterway. Riparian zones are also important wildlife corridors that provide refuges for many land-based organisms as well as providing essential habitat for aquatic species. Removal of riparian habitat reduces biodiversity and productivity of the system and can lead to a reduction in water quality through increase input of sediments and nutrients.

The presence of riparian vegetation also contributes to the social and economic benefits the community derives from waterways. Bushwalkers and wildlife observers all cite the naturalness of waterways as key components of their willingness to travel and pay for their recreational pursuits. Key freshwater habitats are under increasing threat from the physical removal associated with population increases and the increase in pollutant loads from changing catchment land uses.

Method

Data collection

The EHMP measures the extent of riparian woody vegetation in each of the reporting catchments in South East Queensland, and how that extent changes over time. Riparian woody vegetation includes riparian forest (trees > 5m height with dense foliage cover, riparian woodlands (trees >5m in height with sparse foliage cover and shrublands (shrubs < 8m in height).

Riparian woody vegetation extent for catchments is estimated by the Queensland Government Department of Environment and Science (DES) using data from Landsat and Sentinel-2 Multispectral Instrument satellite imagery, as well as data from the *State-wide Landcover and Trees Study* (SLATS) (DES, 2018).

Estimating riparian woody vegetation extent is made up of two key components:

1. Defining and mapping riparian areas.

   The riparian area is defined as land within 50m of a (mapped) stream (order one or higher) and riverine or lacustrine wetland. Estuarine reaches are excluded. The stream network was derived from the Queensland Governments (25m x 25m) Digital Elevation Model for the region with a stream initiation threshold of 0.1kms (BMT WBM, 2003).

2. Mapping riparian woody vegetation extent.

   Currently, the Landsat Satellite (30m resolution) data is used to derive an index of woody vegetation (Foliage Projective Cover (FPC)) and map current riparian woody vegetation extent across South East Queensland. Methods using higher resolution Sentinel-2 Satellite data are under development and due to be adopted for the 2022 Report Card.

   Riparian extent for each of the reporting catchments is expressed as a percentage of the maximum possible extent (in area) of riparian vegetation for each catchment. Maximum possible extent is assumed to be total stream riparian area (defined above). The current area of riparian vegetation for each catchment is converted to a ratio of pre-cleared riparian area (estimated as total stream riparian area) using the following formula:

$$Catchment\ riparian\ ratio = \frac{Current\ riparian\ area\ (ha)\ with\ woody\ vegetation}{Total\ stream\ riparian\ area\ (ha)}$$

Score calculation

The ratio will then be scaled to the range of possible data across the region using the following formula.

$$Riparian\ extent\ indicator\ = 1 - \left|\frac{(Catchment\ riparian\ ratio -\ BCS)}{(BCS - WCS)}\right|$$

BCS (Best Case Scenario) is 100% of the riparian area within the reporting zone is mapped as riparian woody vegetation. WCS (Worst Case Scenario) is 50% of the riparian area within the reporting zones mapped as riparian woody vegetation.

5.1.1.2 Freshwater Wetland Extent indicator

Rationale

Wetlands are critical components of a waterway. They provide of habitat for a wide variety of organisms, prevent erosion of riverbanks and act as a filter to minimise sediments and nutrients entering the waterway. They are important wildlife corridors that provide refuges for many land-based organisms as well as providing essential habitat for aquatic species.

The presence of wetlands also contributes to the social and economic benefits the community derives from waterways. Bushwalkers and wildlife observers all cite the naturalness of waterways as key components of their willingness to travel and pay for their recreational pursuits. Key freshwater habitats are under increasing threat from the physical removal associated with population increases and the increase in pollutant loads from changing catchment land uses.

Method

Data collection

The Queensland Wetlands Program, established in 2003 by The Australian and Queensland governments supports projects and programs that enhance the wise use and sustainable management of Queensland's wetlands. The Program routinely maps wetland extent and type, with datasets available for 200*1, 2005, 2009, 2013 and 2017*. Details of methods are provided in the Department of Environment and Science's Wetland Mapping and Classification Methodology.

The freshwater wetland extent indicator used in the Report Card is a summary of data from Queensland Wetlands Program for two wetland systems:

- Vegetated freshwater swamp (palustrine) systems are wetlands with more than 30% emergent vegetation cover, or waterbodies less than eight hectares and less than two metres deep,
- Lake (lacustrine) systems are wetlands with less than 30% emergent vegetation cover (but excluding riverine channels and associated fringing vegetation). Areas of open water less than eight hectares are classified as vegetated freshwater swamp systems unless the water is more than two metres deep.

The results do not include artificial wetlands or wetlands that have been highly modified, such as those converted to cane paddocks or lacustrine wetlands formed by dams across stream channels. However, the mapping of existing wetlands does include less modified wetlands, such as the vegetated freshwater swamps that have had levees or been dammed.

The current area of freshwater wetlands for each catchment is converted to a ratio of pre-cleared wetland area using the following formula:

$$Freshwater\ wetland\ ratio = \frac{Current\ wetland\ area}{Pre - cleared\ wetland\ area}$$

Score calculation

The ratio will then be scaled to the range of possible data across the region using the following formula.

$$Freshwater\ habitat\ extent\ indicator\ = 1 - \left|\frac{(Freshwater\ wetland\ ratio -\ BCS)}{(BCS - WCS)}\right|$$

BCS (Best Case Scenario) is the catchment with the highest catchment wetland ratio. WCS (Worst Case Scenario) is the catchment with the lowest catchment wetland ratio.

5.1.1.3 Estuarine Wetland Extent indicator

Rationale

Key estuarine habitats like coastal mangroves and saltmarsh provide a variety of functions and services including provision of habitat for aquatic organisms, bank stabilisation and foreshore protection, carbon sequestration and nitrogen removal. Removal of these habitats can lead to a deterioration in coastal water quality and reduce overall biodiversity and productivity of coastal ecosystems.

The presence of key habitats in estuaries also contributes to the social and economic benefits the community derives from waterways. Kayakers, recreational fisherman and wildlife observers all cite the naturalness of waterways as key components of their willingness to travel and pay for their recreational pursuits. Key estuarine habitats are under increasing threat from the physical removal associated with population increases and the increase in pollutant loads from changing catchment land uses.

Method

Data collection

The Queensland Wetlands Program, established in 2003 by The Australian and Queensland governments, supports projects and programs that enhance the wise use and sustainable management of Queensland's wetlands. The program routinely maps wetland extent and type, with datasets available for 200*1, 2005, 2009, 2013 and 2017*. Details of methods are provided in the Department of Environment and Science's Wetland Mapping and Classification Methodology (Environmental Protection Agency, 2005).

The EHMP reports the extent of estuarine wetland vegetation in each of the coastal catchments in South East Queensland, and how that extent changes over time. Estuarine wetlands are defined as areas that are periodically inundated by sea water, dominated by salt tolerant vegetation including mangroves, salt flat or salt marsh communities. Coastal waters that are also components of the estuarine wetland system were not included in the analysis. The results do not include artificial wetlands or wetlands that have been highly modified.

The current area of coastal mangrove and saltmarsh vegetation for each catchment is converted to a ratio of the pre-cleared area using the following formula:

$$Mangrove\ \&\ saltmarsh\ wetland\ extent\ ratio\ = \frac{Current\ wetland\ area}{Pre-clearing\ area}$$

This ratio is also available in the Queensland Department of Environment and Science's WetlandInfo website.

Score calculation

The ratio is then scaled to the range of possible data across the region using the following formula.

$$Mangrove\ \&\ saltmarsh\ extent\ indicator\ = 1 - \left|\frac{(Mangrove\ \&\ saltmarsh\ wetland\ extent\ ratio -\ BCS)}{(BCS - WCS)}\right|$$

BCS (Best Case Scenario) is the catchment with the highest catchment wetland ratio. WCS (Worst Case Scenario) is the catchment with the lowest catchment wetland ratio.

5.1.1 Pollutant Load index

Three major pollutants of concern in waterways are sediments, nitrogen and phosphorus. This index is the average of three indicators:

1. Sediment load in run-off.
2. Nitrogen load in run-off.
3. Phosphorus load in run-off.

5.1.1.1 Catchment Sediment Load indicator

Rationale

Sediment loads are eroded remnants of inorganic material like mud or sand that is transported through the environment by water or wind. The sediment found in South East Queensland waterways most commonly comes from exposed soils in poorly managed catchment areas, construction sites and eroded creek and river banks.

Exposed soils are easily eroded during rainfall events and the runoff enters waterways. Excess sediments in waterways cause a variety of environmental impacts including reduced light penetration in the water column which restricts the productivity of aquatic plants, smothering of benthic organisms and transport of contaminants like nutrients and heavy metals. Sediment enters our waterways in the runoff following rainfall events. A process that is accelerated by poor catchment management. Once in the waterways, sediments are readily resuspended by water flow.

Methods

Data collection

The EHMP calculates the amount of sediment entering South East Queensland waterways using the South East Queensland Source Catchment model. The Source Catchment Model is used to simulate how catchment and climate variables such as rainfall, land use and vegetation affect water runoff and subsequent sediment loads. The model is built upon a network of nodes throughout the South East Queensland catchments. Nodes are typically located at the confluence of streams and represent the sediment loads for that sub-catchment. The Source model outputs are validated with all available event load data including the South East Queensland load-based monitoring program.

Sediment load in runoff for the node at the end of each Report Card catchments is reported in kg/year, and is standardised to the associated catchment area:

$$Sediment\ laod\ in\ runoff\ (kg/yr/ha) = \frac{Total\ sediment\ load\ (kg/yr)}{catchment\ area\ (ha)}$$

Score calculation

Sediment loads for each catchment is standardised as a proportion of the total annual load per catchment area (kg/ha). Then the resulting values are assessed against the (Worst Case Scenario (WSC). The following formula is used:

$$Catchment\ Sediment\ Load\ Indicator = \frac{(Sediment\ load\ in\ runoff) -\ BCS}{(WCS - BCS)}$$

Best Case Scenario **(BCS)** is the node in South East Queensland with the lowest sediment load per area. Worst Case Scenario is the node in South East Queensland with the highest sediment load per area.

5.1.1.2 Catchment nitrogen load indicator

Rationale

Nitrogen is derived from natural ecological events such as organic litter fall, weathering and from human sources (e.g. sewage outfalls, adsorbed to sediment runoff from cleared land, fertiliser runoff and industrial and agricultural effluents). Excess nitrogen in our waterways can stimulate the growth of macrophytes and algae (including cyanobacteria) to nuisance proportions. Blooms of these can displace endemic species, diminish light availability to benthic species, and cause excessive fluctuations in pH and DO which can stress and eliminate sensitive species. Biologically available nutrients are precursors to algal blooms, especially when those nutrients are normally limiting.

Methods

Data collection

The EHMP calculates the amount of nitrogen entering South East Queensland waterways via the South East Queensland Source Catchment model. The Source Catchment Model is used to simulate how catchment and climate variables such as rainfall, land use and vegetation, affect water runoff and subsequent nutrient loads. The model is built upon a network of nodes throughout South East Queensland catchments. Nodes are typically located at the confluence of streams and represent the nutrient loads for that sub-catchment. The Source model outputs are validated with all available event load data including the South East Queensland load-based monitoring program.

Nitrogen load in runoff for the node at the end of each Report Card catchments is reported in kg/year, and is standardised to the associated catchment area:

$$Nitrogen\ laod\ in\ runoff\ (kg/yr/ha) = \frac{Total\ nitrogen\ load\ (kg/yr)}{catchment\ area\ (ha)}$$

Score calculation

Nitrogen loads for each catchment is standardised as a proportion of the total annual nitrogen load per catchment area (kg/ha). Then the resulting values are assessed against the Worst Case Scenario (WCS). The following formula is used:

$$Catchment\ Nitrogen\ Load\ Indicator = \frac{(Nitrogen\ load\ in\ runoff) - \ BCS}{(WCS - BCS)}$$

Best Case Scenario (BCS) is the node in South East Queensland with the lowest nitrogen load per area. Worst Case Scenario (WCS) is the node in South East Queensland with the highest nitrogen load per area.

5.1.1.3 Catchment phosphorus load indicator

Rationale

Phosphorus is derived from natural ecological events such as organic litter fall, weathering, and from human sources (e.g. sewage outfalls, adsorbed to sediment run off from cleared land, fertiliser runoff, and industrial and agricultural effluents). Excess phosphorus in our waterways can stimulate the growth of macrophytes and algae (including cyanobacteria) to nuisance proportions. Blooms of these can displace endemic species, diminish light availability to benthic species, and cause excessive fluctuations in pH and DO which can stress and eliminate sensitive species. Biologically available nutrients are precursors to algal blooms, especially when those nutrients are normally limiting.

Method

Data collection

The EHMP calculates the amount of phosphorus entering South East Queensland waterways via the South East Queensland Source Catchment model. The Source Catchment Model is used to simulate how catchment and climate variables such as rainfall, land use and vegetation, affect water runoff and subsequent nutrient loads. The model is built upon a network of nodes throughout the South East Queensland catchments. Nodes are typically located at the confluence of streams and represent the nutrient loads for that sub-catchment. The Source model outputs are validated with all available event load data including the South East Queensland load-based monitoring program.

Phosphorus load in runoff for the node at the end of each Report Card catchment is reported in kg/year, and is standardised to the associated catchment area:

$$Phosphorus\ laod\ in\ runoff\ (kg/yr/ha) = \frac{Total\ phosphorus\ load\ (kg/yr)}{catchment\ area\ (ha)}$$

Score calculation

Phosphorus loads for each catchment is standardised as a proportion of the total annual load per catchment area (e.g. tonnes/catchment area). Then the resulting values are assessed against the Worst Case Scenario (WCS). The following formula is used:

$$Catchment\ Phosphorus\ Load\ Indicator = \frac{(Phosphorus\ load\ in\ runoff) -\ BCS}{(WCS - BCS)}$$

Best Case Scenario (BCS) is the node in South East Queensland with the lowest phosphorus load per area. Worst Case Scenario (WCS) is the node in South East Queensland with the highest phosphorus load per area.

5.1.2 Estuarine Water Quality index

Water quality in estuaries refers to the physical and chemical properties of the water column. The variation and range of water quality in a waterway influences the types of organisms present in a system.

Estuarine Water Quality Index is the average of five indicators:

1. Turbidity.
2. Chlorophyll a.
3. Total nitrogen.
4. Total phosphorus.
5. Dissolved oxygen.

Note – these indicators are scored for coastal catchments only.

Receiving water quality models (TUFLOW) used to predict indicators

The TUFLOW Receiving Water Quality Model is used to predict annual medians throughout each estuarine system (see Appendix 8.2). Field data collected at 143 estuarine sites is used to validate the model outputs (Figure 8).

To calculate water quality indicator scores, the model predicted annual medians are benchmarked against Queensland Water Quality Guideline values. This is done using an area weighted 'distance from guideline' approach (see Appendix (4) – Calculating distance from guideline values).

5.1.2.1 Turbidity indicator

Turbidity is the measure of light scattering by suspended particles in the water column, providing an indirect indication of light penetration.

Rationale

Excess amounts of suspended particles can contribute to environmental damage, including reduced light penetration through the water column, smothering of benthic organisms like corals and seagrass, irritation of fish gills and transportation of contaminants. Changes to the availability of light within the water column influence the ability of aquatic plants to photosynthesise. Sediment enters our waterways through erosion and runoff accelerated by catchment alterations. Once in the waterways, fine sediments are readily resuspended by wave and tidal energy.

Method

Data collection

Annual medians are predicted using the TUFLOW Receiving Water Quality Model (Appendix 8.2) and validated using turbidity data collected monthly at 143 estuarine sites (eight months per year only – February, March, May, August, September, October, November and December).

In the field, turbidity is measured with a YSI turbidity sensor which forms part of a handheld, portable multi-parameter sonde connected to a data recorder. The turbidity sensor consists of an LED, near infrared light source for illuminating the sample and a photodiode to detect the intensity of light scattered by suspended particles in the water column. The wavelength of light used is between 830 and 890nm as specified by the International Standards Organization (ISO). The photodiode detects scattered light at 900nm from the light source in accordance with ISO standards. The output from the sonde's turbidity sensor is processed by the sonde's software and is recorded in Nephelometric Turbidity Units (NTUs).

Score calculation

Predicted annual medians are converted to a 'distance from guideline' value using the following equation:

$$Distance\ \% \quad = \frac{(Annual\ median\ at\ site) - Guideline}{(WCS - Guideline)}$$

Refer to Appendix 8.4 for guideline and Worst Case Scenario (WCS) values. If annual medians fall below guideline levels (i.e. they are compliant) then they are assigned a distance value of '0'. If they fall above WCS levels, they are assigned a distance value of '1'.

Turbidity scores are then calculated by area weighting the distance values and summing the values for each reporting zone using the following equation:

$$Turbidity\ indicator\ = \Sigma\left|\frac{Distance\ \%}{Area}\right|$$

5.1.2.2 Chlorophyll a indicator

Chlorophyll a (chl-a) is a pigment found in photosynthetic organisms. It is an essential molecule for the process of photosynthesis (the conversion of light energy to chemical energy resulting in the consumption of carbon dioxide and the production of oxygen). In surface waters, chl-a is present in phytoplankton such as cyanobacteria, diatoms and dinoflagellates. Because chl-a occurs in all phytoplankton it is commonly used as a measure of phytoplankton biomass.

Rationale

Chlorophyll a is measured as an indicator of phytoplankton biomass. Phytoplankton biomass is largely influenced by the availability of nutrients, light and optimal water temperature. By measuring phytoplankton biomass we are provided with an indication of the nutrient and light conditions present at the time of sampling and their resulting biological effect. Under certain environmental conditions, in particular elevated light and high nutrients, phytoplankton blooms can result. When phytoplankton blooms decay, the resulting bacterial activity can reduce DO concentrations in the water column, possibly leading to fish kills.

Method

Data collection

Annual medians are predicted using the TUFLOW Receiving Water Quality Model (Appendix 8.2) and validated using turbidity data collected monthly at 143 estuarine sites (eight months per year only – February, March, May, August, September, October, November and December). One sample is collected each time a site is surveyed.

Phytoplankton is collected in the field by filtering a known volume of water through a Whatman 1µm GFC glass microfibre filter paper. The sample is filtered through the filter paper under suction, with care taken to ensure that the pressure does not exceed half atmospheric pressure. Too much suction can disrupt the chloroplasts within the phytoplankton cells, potentially degrading the chlorophyll.

The amount of water filtered is subject to the level of turbidity at the sampling site. The greater the particulate matter in the water column, the less water can be filtered. Water is filtered until the flow through the filter paper at half atmospheric pressure is reduced to a trickle. The filter paper is then removed and blotted dry to remove excess moisture. The filter paper is placed into a 15ml graduated screw cap polypropylene tube. Each tube contains 0.01g magnesium carbonate which acts as a buffer during the extraction process.

During collection and storage, exposure of the samples to light is avoided. Samples are immediately wrapped in aluminium foil after filtering and placed on ice in a dark, insulated container to lower the sample temperature and prevent chlorophyll degradation. In the laboratory the samples are placed into a freezer for storage before analysis.

Chlorophyll a is then extracted from each sample using the following procedure (developed in accordance with the Standard Methods for the Examination of Water and Wastewater) (APHA, 1998). All tubes are inspected for weaknesses that may allow liquid to leak. 6ml of 90% acetone is added to each sample. Samples are placed in a freezer for 10 to 15 minutes to lower the temperature of the acetone. Samples are removed and macerated using a mechanical tissue grinder at approximately 2000rpm for 20 seconds. Grinding the sample disrupts the cells containing chlorophyll and allows the complete extraction of the pigment. The sample is kept cold during maceration by a chilled water bath below 50C. 90% acetone is then added to the sample tube to reach a volume of 10ml. Samples are placed back into a freezer for 12 to 24 hours before analysis to allow for full extraction of chlorophyll.

The chlorophyll a concentration of each sample is then measured, using the following procedure. Each sample is centrifuged for five minutes at 3900rpm, this ensures that all sediment is concentrated at the base of the tube and allows the supernatant to be decanted from the tube with a relatively low risk of sediment transfer. After centrifugation, the supernatant is transferred into a thoroughly clean glass cuvette. The absorbance of the extract is measured at a wavelength of 663nm, followed by the absorbance at 750nm. This accounts for any absorbance at 663nm that is due to turbidity. Chlorophyll a concentration is then calculated according to the equation stated in the Standard Methods for the Examination of Water and Wastewater (APHA, 1998) and reported in µg/L.

Score calculation

Predicted annual medians are converted to a ‘distance from guideline’ value using the following equation:

$$Distance\ \% = \frac{(Annual\ median\ at\ site) - Guideline}{(WCS - Guideline)}$$

Refer to Appendix 8.4 for guideline and Worst Case Scenario (WCS) values. If annual medians fall below guideline levels (i.e. they are compliant) then they are assigned a distance value of ‘0’. If they fall above WCS levels, they are assigned a distance value of ‘1’.

Chlorophyll a scores are then calculated by area, weighting the distance values and summing the values for each reporting zone using the following equation:

$$Chlorophyll\ a\ indicator = \Sigma \left|\frac{Distance\ \%}{Area}\right|$$

5.1.2.3 Total nitrogen indicator

Nitrogen and phosphorus are nutrients essential to biota in waterways. Specifically, nitrogen is present in animal and plant tissue chiefly as proteins.

Nitrogen is present in waters in both particulate and dissolved forms. Particulate forms include those bound up in living organisms, organic compounds like proteins and those bound to suspended particulate matter like clay and detritus. Dissolved nitrogen may either be inorganic nitrate (NO_3^-), nitrite (NO_2^-), ammonia (NH_4^+) or organic (e.g. urea; dissolved proteins). The EHMP measures dissolved inorganic nitrogen (DIN = NO_3^- + NO_2^- + NH_4^+) and total nitrogen (TN) concentrations (dissolved + particulate forms).

Rationale

Nitrogen is derived from natural ecological events such as oceanic upwelling, litter fall, weathering and from human sources (e.g. sewage outfalls, leaching from cleared land, fertiliser runoff and industrial and agricultural effluents). In a highly populated area like the Moreton Bay catchments, nutrients largely result from wastewater discharges and diffuse urban runoff.

Excess nutrients in our waterways can stimulate the growth of macrophytes and algae (including cyanobacteria) to nuisance proportions. Blooms of these can displace endemic species, diminish light availability to benthic species (e.g. seagrass and coral communities) and cause excessive fluctuations in pH and DO which can stress and eliminate sensitive species.

Healthy Land and Water monitors surface water nutrient concentrations in Moreton Bay to assess the spatial and temporal extent of nutrient loads in the Bay and, determine if biological processes are able to sequester nutrients at the same rate they are being delivered. Biologically available nutrients are precursors to algal blooms, especially when those nutrients are normally limiting. They can be compared with biological indicators like phytoplankton growth, seagrass maximum depth limit and seagrass distribution.

Method

Data collection

Annual medians are predicted using the TUFLOW Receiving Water Quality Model (Appendix 8.2) and validated using turbidity data collected monthly at 143 estuarine sites (eight months per year only – February, March, May, August, September, October, November and December). One sample is collected each time a site is surveyed.

Water samples taken from a site are separated into total nutrient samples and soluble nutrient samples. A clean plastic bucket is used to collect the sample. The bucket is cleaned thoroughly before sampling and is rinsed rigorously in sample water at least three times at each site. The sample is taken from just below the surface. Care is taken to keep the bucket free of contaminants from skin and motor exhaust with a lid that is placed on top. Total nutrient samples are poured directly from the bucket into a 250ml plastic bottle. The bottle, including the lid, is rinsed with at least 60ml of sample water at each site before sampling. Soluble nutrient samples are filtered for the determination of FRP and dissolved nitrogen. Water samples are filtered under pressure from a 60ml syringe through a 0.45μm membrane filter. The syringe is rinsed prior to sample collection three times with sample water from the bucket. At sites with large amounts of suspended sediments, a glass fibre pre-filter is used to remove large particles. All samples are transported on ice in a dark insulated container and are placed in a freezer immediately upon return to laboratories.

Total nutrient samples analysed for TN (total nitrogen) and TP (total phosphorus) are oxidised/digested using a simultaneous persulfate procedure at 1210C with an initial pH of 13 and a final pH of about two. If this digestion method does not fully digest all sediment bound nutrients, a Kjeldahl Procedure is used to digest the sample. This method uses a much higher temperature (3600C) with a pH ten times more acidic than that obtained by the persulfate method. Note this technique is particularly used for waters high in particulate matter or refractory compounds that occur from flood conditions. After digestion, analyses for TN and TP are performed using the FIA and photochemical methods (APHA, 1998). TN and TP concentration of each sample is reported in mg/L.

Soluble nutrient samples are analysed for NO3-, NO2–, NH3 and FRP simultaneously using an automated LACHAT 8000QC flow injection analyser (FIA) using photochemical methods and reported in mg/L.

Score calculation

Predicted annual medians are converted to a ‘distance from guideline’ value using the following equation:

$$Distance\ \% \quad = \frac{(Annual\ median\ at\ site) - Guideline}{(WCS - Guideline)}$$

Refer to Appendix (4) – Calculating distance from guideline values for guideline and Worst Case Scenarios (WCS) values. If annual medians fall below guideline levels (i.e. they are compliant) then they are assigned a distance value of ‘0’. If they fall above WCS levels, they are assigned a distance value of ‘1’.

Total nitrogen and phosphorus scores are then calculated by area weighting the distance values and summing the values for each reporting zone using the following equation:

$$Total\ nitrogen\ indicator\ = \Sigma \left|\frac{Distance\ \%}{Area}\right|$$

5.1.2.4 Total phosphorus indicator

Nitrogen and phosphorus are nutrients essential to biota in waterways. Specifically, phosphorus is contained in cell walls and energy transporting molecules.

Phosphorus is present in water in both particulate and dissolved forms. Particulate forms include those incorporated into plant and animal matter, and those bound to suspended particulate matter like clay and detritus. Dissolved phosphorus includes inorganic orthophosphates, polyphosphates, organic colloids and low molecular weight phosphate ethers. The EHMP measures the concentration of total phosphorus (TP) and filterable reactive phosphorus (FRP), which is similar to dissolved phosphorus.

Rationale

See rational for total nitrogen indicator above.

Method

See methods for total nitrogen indicator above.

Score calculation

Predicted annual medians are converted to a ‘distance from guideline’ value using the following equation:

$$Distance\ \% \quad = \frac{(Annual\ median\ at\ site) - Guideline}{(WCS - Guideline)}$$

Refer to Appendix (4) – Calculating distance from guideline values for guideline and Worst Case Scenarios (WCS) values.

Total phosphorus scores are then calculated by area weighting the distance values and summing the values for each reporting zone using the following equation:

$$Total\ Phosphorus\ indicator\ = \Sigma \left|\frac{Distance\ \%}{Area}\right|$$

5.1.2.5 Dissolved oxygen indicator

Dissolved oxygen (DO) concentration is a measure of the oxygen in a water body.

Rationale

Many estuarine and marine processes are dependent on the concentration of DO in the water. DO concentration in a water body is affected primarily by the rate of transfer from the atmosphere but also by oxygen-consuming (e.g. respiration) and oxygen-releasing (e.g. photosynthesis) processes. Organic matter, such as sewage effluent or dead plant material that is readily available to microorganisms has the greatest impact on DO concentrations. Microorganisms use water column DO during decomposition of the organic matter. DO concentration in the water column is highly dependent on temperature, salinity and biological activity. Consequently, DO concentrations under natural conditions may change substantially over a 24 hour period.

Variations in DO concentrations may affect many organisms such as fish, invertebrates and microorganisms, which depend upon oxygen for surviving. The oxygen requirements of aquatic organisms vary widely depending on which species, their life stage and different metabolic requirements.

Methods

Data collection

Annual medians are predicted using the TUFLOW Receiving Water Quality Model (Appendix 8.2) and validated using DO data collected monthly at 143 estuarine sites (eight months per year only – February, March, May, August, September, October, November and December).

In the field, DO is measured with a YSI DO sensor which forms part of a handheld multi probe sonde attached to a data recorder. The sensor comprises of a membrane covered Clark-type probe. The probe measures the current associated with the reduction of oxygen as it diffuses across a Teflon membrane that is proportional to the partial pressure of oxygen in the sample. DO is measured as a concentration in mg/L and recalculated using temperature to return percentage saturation (%).

Score calculation

Predicted annual medians are converted to a 'distance from guideline' value using the following equation:

$$Distance\ \% \quad = \frac{(Annual\ median\ at\ site) - Guideline}{(WCS - Guideline)}$$

Refer to Appendix (4) – Calculating distance from guideline values for guideline and Worst Case Scenario (WCS) values. If annual medians fall above guideline levels and below 105% sat (i.e. they are compliant) then they are assigned a distance value of '0'.

Dissolved oxygen scores are then calculated by area weighting the distance values and summing the values for each reporting zone using the following equation:

$$Dissolved\ oxygen\ indicator\ = \Sigma \left|\frac{Distance\ \%}{Area}\right|$$

5.1.3 Freshwater communities and processes index

The condition of freshwater stream communities and ecological process reflects overall stream condition and health. Specifically:

- Fish communities reflect a range of environmental disturbances and provide a measure of stream condition due to their mobility, long life and position near the top of the food chain.
- Aquatic bug communities (insects, crustaceans, snails, etc) are very sensitive to disturbance.
- Ecosystem process measures reflect the vigour or 'pulse' of a stream.
- Physical and chemical conditions reflect stream water quality.

As such, this component includes four indices:

1. Freshwater fish.
2. Freshwater bugs.
3. Freshwater ecosystem processes.
4. Freshwater PhysChem.

Stream Health model used to predict index scores

A Stream Health Model (Appendix (5) – Stream Health Model) is used to estimate each index score at 129 representative sites across South East Queensland:

4 indices x 129 sites

↓

Scores are then averaged across sites within each reporting area:

4 indices x 18 reporting areas

↓

Scores are then averaged across indices to provide a single score for each of the reporting areas:

1 score x 18 reporting areas

The Stream Health Model is validated with field data collected once per year at 75 freshwater sites through the EHMP. The full 129 sites are sampled on a three-year rotation (i.e. 48 sites are sampled every year, while 81 sites are sampled every three years on rotation)

Stream Health Model predictions checked against traditional EHMP method

The four predicted index scores are compared with traditional EHMP calculated index scores to determine which will be used. If one of a site's predicted index scores deviates more than 0.1 from the traditional EHMP calculated score, then the traditional EHMP calculated score is used. If not, the predicted score is used.

5.1.3.1 Freshwater PhysChem index

Water quality refers to the physical and chemical properties of the water column. The variation and range of water quality in a waterway influences the types of organisms present in a system.

This index includes four physical and chemical indicators:

1. pH.
2. Electrical conductivity.
3. Ambient water temperature.
4. Ambient dissolved oxygen.

5.1.3.1.1 pH indicator

The term pH is an abbreviation for "potential hydrogen". It is a measure of the concentration of free hydrogen ions [H+] or the acidity of the water. The pH scale is based on the logarithm of the reciprocal of [H+] and ranges from 1.0 (highly acidic) through 7.0 (neutral) to 14.0 (highly alkaline). As such, water with a pH of 5.0 has ten times the concentration of free hydrogen ions as water with a pH of 6.0.

Rationale

The pH of streams usually varies naturally between catchments due primarily to differences in catchment geology and vegetation. The pH of streams in South East Queensland generally ranges from about 4.5 in the tannin-stained streams associated with coastal 'wallum' heath, to near 9.0 in streams at the headwaters of some catchments.

Rapid changes in pH associated with the disturbance of acid-sulphate soils, or with the discharge of acidic drainage from coal mines. These are known to have adverse effects on the ionic balance and respiratory efficiency of fish and aquatic invertebrates. Agricultural runoff has also been shown to cause reductions in stream pH, which can lead to increases in the toxicity of ammonia and heavy metals within stream sediments and a reduction in the survival rates of aquatic organisms, particularly juvenile stages. Some species, such as the endangered Oxleyan Pigmy Perch, *Nannoperca oxleyana,* have specific pH requirements for survival.

Method

Data collection

Field data is collected once per year at 75 EHMP freshwater sites.

Field measures of pH are taken at a depth of approximately 10cm, using a handheld TPS WP-81 Conductivity-pH-Temperature meter fitted with a (K=1.0) pH sensor. The pH calibration of the meter is checked daily against 4.0 and 6.87 pH standards and the meter is re-calibrated if readings vary more than ±0.1 pH units from the true value.

Score calculation

Scores are calculated using the Stream Health Model (Appendix (5) – Stream Health Model) which predicts the overall Freshwater PhysChem index score.

The traditional EHMP method is used to calculate the pH indicator score and validate the predicted scores (See Appendix 8.6).

5.1.3.1.2 Electrical conductivity indicator

Conductivity is a measure of the ability of water to conduct an electrical charge, which is primarily dependent upon the concentration of ions in the water. Those ions are commonly associated with mineral salts, so electrical conductivity is usually closely related to salinity.

Rationale

Conductivity can affect both the community structure and function of freshwater ecosystems. Elevated conductivity levels are known to influence nutrient cycling, rates of primary production and respiration and the survival of riparian vegetation, aquatic macroinvertebrates and fish. Increased conductivity may also reflect the presence of pollutants from sources such as wastewater treatment plants (WWTPs), urban road runoff and agricultural runoff.

Method

Data collection

Field data is collected once per year at 75 EHMP freshwater sites.

Field measures of conductivity are taken at a depth of approximately 10cm, using a handheld TPS WP-81 Conductivity-pH-Temperature meter fitted with a (K=1.0) conductivity sensor. The conductivity calibration of the meter is checked daily and the meter is re-calibrated using a two point (0 and 1,413µS) calibration procedure.

Score calculation

Scores are calculated using the Stream Health (Appendix 8.5) which predicts the overall Freshwater PhysChem index score.

The traditional EHMP method is used to calculate the electrical conductivity indicator score and validate the predicted scores. See Appendix 8.6

5.1.3.1.3 Ambient water temperature indicator

This indicator is a combination of two temperature measures:

- Diel maximum ambient water temperature: the highest (95th percentile) water temperature over a 24-hour period.
- Range of ambient water temperature: the change in temperature of the typical stream water over a 24-hour period.

Rationale

Like conductivity, water temperature regulates aspects of both the community structure and function of aquatic ecosystems. For example, chemical attributes such as oxygen solubility and pH are sensitive to changes in water temperature. High temperatures cause a decrease in the level of dissolved oxygen (DO) available for aquatic organisms. As such, changes have a strong influence on ecosystem functions such as primary production and respiration. Fish and aquatic invertebrates are also sensitive to temperature changes with large temperature variations having deleterious effects on reproduction and survival.

Water temperature varies naturally as part of normal daily and seasonal cycles. However, more dramatic changes in temperature often occur as a result of human activities. Such changes are particularly noticeable in small streams where the loss of overhanging riparian streamside vegetation can lead to a marked increase in both water temperature and temperature range. High maximum temperatures and large temperature ranges can have adverse effects on an organism's growth, metabolism, reproduction, mobility and migration, which may lead to a decline in species richness and diversity.

Method

Data collection

Field data is collected once per year at 75 EHMP freshwater sites.

Field measure of ambient water temperature are taken from mid-stream, using TPS WP-82Y Dissolved Oxygen-Temperature meters fitted with an YSI 5739 DO probe with inbuilt thermistor. The water temperature feature of these meters is checked weekly and calibrated against a laboratory-grade mercury thermometer.

Ambient water temperature is recorded at each site every 10 minutes for a 24-hour period. The sensor is placed in a PVC housing fitted with a small water pump that expels water from the housing. Inlet ports, fitted with a foam filter to prevent the passage of debris into the housing, provide for the flow of water through the housing. This assembly is attached to a stake to hold it above the substrate when deployed in the field.

Minimum and maximum water temperatures are calculated as the 5^{th} and 95^{th} percentiles respectively.

The diel (24 hour) range of water temperature is calculated as the difference between the maximum and minimum values.

Score calculation

Scores are calculated using the Stream Health (Appendix 8.5) which predicts the overall Freshwater PhysChem index score.

The traditional EHMP method is used to calculate the ambient water temperature indicator score and validate the predicted scores. See Appendix 8.6.

5.1.3.1.4 Ambient DO indicator

This indicator is a combination of two dissolved oxygen (DO) measures:

- Diel minimum ambient DO: the lowest (5^{th} percentile) DO over a 24 hour period.
- Range of ambient DO: the change in DO of typical stream water over a 24 hour period.

Rationale

DO concentration is a measure of the availability of oxygen to aquatic organisms. Oxygen is a fundamental requirement for aquatic organisms that respire aerobically; and the concentration of DO affects the distribution, physiological activity and behaviour of aquatic animals. The DO concentration of less than 2mg/L is likely to have deleterious effects on aquatic invertebrates and fish.

The concentration of DO limits, and is limited by, the ecological processes of primary production and respiration that produce and consume oxygen, respectively. DO concentration is highly dependent on temperature and fluctuates over a 24 hour period under natural conditions. Under some conditions (e.g. low flow, high temperatures), high biological oxygen demand associated with plant respiration and microbial decomposition can lead to very low DO concentrations and a large diel DO range. Large daily fluctuations in DO place pressure on ecological function.

Method

Data collection

Field data is collected once per year at 75 EHMP freshwater sites and used to validate the Stream Health Model.

Field measures of ambient DO concentration are taken mid stream, using TPS WP- 82Y Dissolved Oxygen-Temperature meters fitted with an YSI 5739 DO probe. The DO feature of these meters is re-calibrated weekly using a two-point (0 and 100% oxygen saturation) calibration procedure, and then tested against several other newly calibrated WP-82Y meters. The calibration of each meter is then tested again before and after use in the field. All calibration data is recorded for quality assurance purposes.

DO concentration is recorded at each site every 10 minutes for a 24 hour period. As for ambient water temperature readings described above, to ensure a constant flow of the DO sensor, it is placed in a PVC housing fitted with a small water pump that expels water from the housing. Inlet ports, fitted with a foam filter to prevent the passage of debris into the housing, provide for the flow of water through the housing. This assembly is attached to a stake to hold it above the substrate when deployed in the field.

Minimum and maximum DO concentrations are calculated as the 5^{th} and 95^{th} percentiles respectively. The diel (24 hour) range of DO concentration is calculated as the difference between the maximum and minimum values.

Score calculation

Scores are calculated using the Stream Health (Appendix 8.5) which predicts the overall Freshwater PhysChem index score.

The traditional EHMP method is used to calculate the ambient DO indicator score and validate the predicted scores (See Appendix 8.6).

5.1.3.2 Freshwater ecosystem processes index

This index comprises two indicators that are measures of benthic metabolism:

1. Gross primary production (GPP).
2. Daily respiration (R24).

Benthic metabolism refers to the rates of respiration and primary production (i.e. photosynthesis) occurring at, and just below, the sediment-water interface of water bodies. The primary organisms responsible for these processes in this microhabitat are algae and bacteria.

5.1.3.2.1 Gross Primary Production (GPP) indicator

Rationale

Rates of instream production and respiration increase with anthropogenic disturbance such as riparian vegetation removal and agricultural runoff. The removal of stream-side vegetation, for example, results in less shading, increases in instream light intensity, and consequent increases in algal production. Increased amounts of algae are then available for decomposition, resulting in an increased rate of respiration.

Method

Data collection

Both gross primary production (GPP) and daily respiration rate (R24) are quantified from the net change in DO within two transparent plastic, dome-shaped chambers each isolating a portion of the stream bed and its associated benthos. Depending on the dominant substrate at a site, either one or more cobbles are sealed within the chambers using a plastic 'lid', or the chambers are pushed into the sediment to a measured depth to create a water-tight seal. A TPS WP-82Y Dissolved Oxygen-Temperature meter fitted with a YSI 5739 DO probe records DO and temperature within each chambers every ten minutes for 24 hours. A Whale 12V in-line pump recirculates water through the chambers and past the DO sensor to account for minor consumption of O2 by the sensor. Prior to, and during, fieldwork, sensors are calibrated weekly and serviced fortnightly. Calibration of the sensors involves both a temperature and two - point (0% and 100%) DO calibration, followed by a cross-check of their calibration against other sensors.

Rates of change in DO concentration over time (g O2 L-1 hr-1) are multiplied by chamber volume and divided by substrate surface area to obtain rates of oxygen consumption and production (g O2 m-2 hr-1) associated with the processes of respiration and production, respectively. Respiration rates are calculated by converting the rate of consumption of DO during the night to a rate of carbon release (g C m-2 day-1), assuming that one mole of carbon is equivalent to one mole of oxygen (i.e. 1 g O2 = 0.375 g C). Net primary production is calculated similarly and, assuming respiration to be constant during the 24 hour period of data recording, gross primary production (GPP, g C m-2 day-1) is calculated by adding the amount of carbon fixed during the day to the amount released during the night by respiration.

Score calculation

Scores are calculated using the Stream Health (Appendix 8.5) which predicts the overall freshwater ecosystem processes index score.

The traditional EHMP method is used to calculate the indicator score and validate the predicted scores (Appendix 8.6).

5.1.3.2.2 Daily respiration (R24) indicator

See description for Gross Primary Production (GPP) indicator above.

5.1.3.3 Freshwater fish index

Fish are a common and familiar component of freshwater environments, and fish communities reflect a range of natural and human-induced disturbances through changes in abundance and species composition.

This index comprises three indicators:

1. Percentage of native species expected (PONSE).
2. Ratio native species expected: observed (O/E50).
3. Proportion alien fish.

Rationale

Ecological assessments based on fish community structure have the advantage over more traditional physical and chemical indices (e.g. conductivity, turbidity and nutrients) in that fish provide an integrated measure of stream condition due to the mobility, relatively long-life and high trophic level of the animals involved. Data on fish communities is also valuable as it is of direct public interest, especially to recreational fishers and aquarium fish hobbyists, and required for the conservation of biodiversity.

5.1.3.3.1 Percentage Native Species Expected (PONSE) indicator

Percentage of Native Species Expected (PONSE) refers to the number of native fish species observed to occur at a site expressed as a percentage of the number of native fish species expected to occur at a physically similar site under minimally-disturbed conditions.

Method

Data collection

A combination of backpack electrofishing, followed (where practical) by seine-netting, is used to determine the relative abundance of individual fish species at each site. Electrofishing is conducted using a Smith-Root model 12, or LR-24, backpack electrofisher fitted with a 28cm anode ring supporting a dip net of 10mm (stretched) mesh. Pulse width and frequency are kept fixed at 2µs and 100Hz respectively, and output voltage is varied according to the conductivity of water at each site. A table of conductivity-voltage settings is used as a starting point for setting output voltage on each sampling occasion. Seine-netting is conducted using a 10m long (1.5m drop) pocket seine of 10mm (stretched) mesh. All fishing is undertaken in accordance with Animal Ethics approval to ensure, as far as practical, that fish are not injured in any way.

The extent of fishing at each site is based on dividing the habitat at each site into different units based primarily on flow conditions (e.g. riffle, run, pool), and ensuring that at least one full habitat unit of each type is fished intensively. If only one habitat unit is present at a site, two examples of that habitat unit are fished in an attempt to maintain an average length of fished stream of 75m (about 20 stream widths) and an electrofishing 'power-on' time of 900secs. As the majority of streams within the study area only flow intermittently, two sections of pool habitat are most commonly fished. Seine-netting can generally only be used infrequently due to a high abundance of woody debris and other obstacles hindering effective hauling of the net.

As backpack electrofishing involves field staff wading through water whilst surrounded by a dangerous (400 W continuous) electric field, this activity is led only by highly trained and experienced staff. All electrofishing is conducted in strict accordance with the *Australian Code of Electrofishing Practice* as a minimum standard.

Counts of the number of each fish species caught are recorded as fish are captured. Captured fish are retained in temporary storage until the completion of fishing within each habitat unit to prevent the occurrence of recaptures. When fishing has been completed, or recaptures are deemed to be improbable, fish are released alive back into the stream near where they were caught. A small number of specimens of any fish unable to be confidently identified at the time of capture are euthanized and retained for laboratory identification. Specimens of several difficult to identify genera are routinely retained for this reason; notably *Ambassis, Hypseleotris, Mugil and Philypnodon*.

A single set of relative abundance data is obtained for each site on each sampling occasion by pooling the results obtained for each habitat unit and mode of fishing (electrofishing, seine netting). This is the 'observed' data.

The 'expected' data for number of native fish species is predicted by a static numeric model, which uses details of each site in terms of elevation, distance from river mouth, distance from source and stream width as input. This underlying model was developed using regression tree analysis and, as it uses several abiotic parameters as input, results inherently account for the primary source of natural spatial variation.

Score calculation

Scores are calculated using the Stream Health (Appendix (5) – Stream Health Model 8.5) which predicts the overall Freshwater Fish index score.

The traditional EHMP method is used to calculate the indicator score and validate the predicted scores. See Appendix 8.6.

5.1.3.3.2 Ratio Native Species Expected: Observed (O/E_{50}) indicator

Ratio of observed to expected native species refers to the native fish species observed to occur at a site in relation to the native fish species expected to occur at a physically similar site under minimally disturbed conditions.

The O/E_{50} index differs from the preceding index, PONSE, in that observed and expected species are compared on a species-by-species basis rather than simple counts of species. This greater resolution allows better interpretation of what changes in fish communities may have occurred.

Method

Data collection

As per percentage native species expected (PONSE) indicator above.

Score calculation

Scores are calculated using the Stream Health (Appendix (5) – Stream Health Model 8.5) which predicts the overall Freshwater Fish index score.

The traditional EHMP method is used to calculate the indicator score and validate the predicted scores. See Appendix 8.6.

5.1.3.3.3 Proportion alien fish indicator

Proportion alien fish refers to the number of individual fish of species originating from outside of Australia expressed as a percentage of total fish catch at each site. Individuals of species translocated to South East Queensland streams from elsewhere in Australia (e.g. golden perch *Macquaria ambigua)* are not included as alien fish.

Method

Data collection

As per percentage native species expected (PONSE) indicator above.

Score calculation

Scores are calculated using the Stream Health (Appendix 8.5) which predicts the overall Freshwater Fish index score.

The traditional EHMP method is used to calculate the indicator score and validate the predicted scores. See Appendix 8.6.

5.1.3.4 Freshwater bugs index

Aquatic bugs (or macroinvertebrates) are animals without back- bones that live in the water and are large enough to see with the naked eye (e.g., beetles, bugs, shrimp, snails).

This index comprises three indicators:

1. Number of taxa.
2. PET richness.
3. SIGNAL score.

Rationale

Macroinvertebrates are one of the most commonly used biological indicators of stream ecological condition, because they are very sensitive to disturbances. These animals are ideally suited to biological monitoring because they are common, widespread, and easily sampled.

5.1.3.4.1 Number taxa indicator

Rationale

Number of taxa is a direct measure of taxa richness, which generally increases with ecological condition. A high number of taxa within a site indicate that the various water quality, habitat, and food requirements of those taxa have been met locally in recent times. This index is calculated simply as the number of macroinvertebrate taxa collected, excluding cladocerans, ostracods, copepods and spiders.

Method

Data collection

A representative sample of the aquatic macroinvertebrate fauna is collected from 'edge' habitat at each site and the presence/absence of (primarily family-level) taxa is determined. Edge habitat is defined as habitat along the water's edge, including backwaters and undercuts, where there is little or no flow, and few or no submerged/emergent macrophytes. Each sample is collected from a 10m length of 'edge' habitat. The length need not be continuous as all forms of edge habitat are required to be sampled in proportion to spatial occurrence over a 100m length of stream within which the sample is collected.

Samples are collected with a 250µm mesh dip net fitted to a 250mm x 250mm x 250mm triangular frame attached to a 2m handle. Three short, upward sweeps of the net are made perpendicular to the bank for every metre of stream bank sampled. Once collected, the sample is rinsed, emptied into a bucket and then evenly divided into two sorting trays. Two people pick macroinvertebrates from separate trays for 30 minutes with the objective of collecting the greatest diversity of taxa, and about ten individuals of each taxon. No formal identifications are undertaken in the field, so 'taxa' at this stage essentially refers to 'visually similar animals'. The animals picked by each person are placed into separate labelled vials containing 70% methylated spirits and transported back to the laboratory for further processing. The residues from 10% of field processed samples are retained for assessment of the representativeness of each field workers picking.

In the laboratory, all animals picked from samples by each person in the field are identified and counted using a stereo dissecting microscope. The only aquatic macroinvertebrates not identified to family level are:

- Porifera, Nemertea and Nematoda (identified to phylum).
- Oligochaeta, Polychaeta, Ostracoda, Copepoda and Branchiura (identified to class).
- Cladocera, Collembola and Acarina (identified to order).
- Chironomidae (identified to sub-family).

The laboratory identifications and counts of all staff are tested via independent identification and enumeration of taxa within a random 10% subsample of preserved samples.

A single set of taxa presence/absence data is obtained for each site by pooling the results obtained from each of the two worker's samples. Three different indices are calculated based on this data:

1. Number of Taxa.
2. PET richness.
3. SIGNAL score.

Score calculation

Scores are calculated using the Stream Health (Appendix (5) – Stream Health Model) which predicts the overall Freshwater Bugs index score.

The traditional EHMP method is used to calculate the indicator score and validate the predicted scores (Appendix 8.6).

5.1.3.4.2 PET richness indicator

Rationale

PET richness refers to the number of families in a sample belonging to one of the three particularly sensitive orders of aquatic insects: Plecoptera (stoneflies), Ephemeroptera (mayflies) and Trichoptera (caddisflies). It should be noted that Plecoptera are naturally rare in South East Queensland, so in this area PET richness essentially refers only to families of Ephemeroptera and Trichoptera. The abundance of individuals within PET taxa shows a marked decline with anthropogenic disturbance and is thus useful as an early warning indicator of a decline in stream health. This index is calculated simply as the number of taxa belonging to the Plecoptera, Ephemeroptera and Trichoptera orders.

Method

As per number taxa indicator above.

5.1.3.4.3 SIGNAL score indicator

Rationale

SIGNAL stands for 'Stream Invertebrate Grade Number – Average Level. The grade gives an indication of water quality based on the sensitivity of different macroinvertebrate families. This is a simple means of assessing waterway health using a biotic indicator. The SIGNAL score for a macroinvertebrate sample is calculated by averaging pollution sensitivity grades for invertebrate families present. Waterway sites with high SIGNAL scores are likely to have high dissolved oxygen, low turbidity, and low levels of nutrients.

Method

As per number taxa indicator above.

5.2 Environmental Condition Grade indicators – BAY

5.2.1.1 Bay Water Quality index

Water quality in bay zones refers to the physical and chemical properties of the water column. The variation and range of water quality in a waterway influences the types of organisms present in a system.

The Bay Water Quality Index is the average of five indicators:

1. Turbidity.
2. Chlorophyll a.
3. Total nitrogen.
4. Total phosphorus.
5. Dissolved oxygen.

Receiving water quality models (TUFLOW) used to predict indicators

The TUFLOW Receiving Water Quality Model is used to predict annual medians throughout each bay zone (Appendix 8.2). Field data collected at 41 bay sites is used to validate the model outputs (Figure 11).

To calculate water quality indicator scores the model predicted annual medians are benchmarked against Queensland Water Quality Guideline values using an area weighted 'distance from guideline' approach (Appendix 8.4)

Turbidity indicator

See description for *5.1.2.1* turbidity indicator above.

5.2.1.1.1 Chlorophyll a indicator

See description for *5.1.2.2* chlorophyll a indicator above.

5.2.1.1.2 Total nitrogen indicator

See description for *5.1.2.3* total nitrogen indicator above.

5.2.1.1.3 Total phosphorus indicator

See description for *5.1.2.4* total phosphorus indicator above.

5.2.1.1.4 Dissolved oxygen indicator

See description for *5.1.2.4*5 dissolved oxygen indicator above.

5.2.1.2 Bay habitat index

Rationale

Key bay habitats like seagrass beds provide a variety of functions and services including provision of habitat for aquatic organisms, stabilising the seafloor and sequestration of nutrients like carbon and nitrogen from the environment. Removal of these habitats reduces both biodiversity and productivity of the system and leads to a deterioration of water quality.

5.2.1.2.1 Seagrass extent indicator

*This is the proposed methodology for future Reports Cards (beyond 2016), another temporary methodology is currently being used based on a categorisation approach.

Method

Data collection

The extent of seagrass is measured in Moreton Bay using a combination of field sampling and remote sensing. Field sampling is used to calibrate images taken from the Landsat 7 satellite. It is also used as the primary sampling technique in the more turbid areas of the bay where satellite imagery doesn't penetrate the water column. Field sampling is conducted by the Queensland Government Department of Environment and Science (DES) and Healthy Land and Water with Earth Watch volunteers. The remote sensing component is conducted by the University of Queensland (UQ) Biophysical Remote Sensing Group. Both field sampling and the remote sensing methods follow the techniques outlined in Roelfsema et al (2009). Seagrass extent is proposed to be assessed every three years.

The seagrass extent for a sampling year for each relevant reporting area is expressed as the percentage of seagrass present compared to the 2004 map of seagrass extent in Moreton Bay, using the following formula:

$$Seagrass\ ratio = \frac{Current\ seagrass\ area}{2004\ seagrass\ area}$$

Score calculation

The ratio for each zone will then be scaled to the range of possible data across the region using the following formula.

$$\boldsymbol{Seagrass\ habitat\ indicator = 1 - \left|\frac{(Seagrass\ ratio - \ BCS)}{(BCS - WCS)}\right|}$$

5.2.1.2.2 Estuarine Wetland Extent indicator

As per 5.1.1.3 for the Estuarine Habitat index.

5.2.1.2.3 Bay Seagrass Depth Range indicator

Rationale

The seagrass depth range (SDR) is the difference in elevation (m) between the upper and lower depth record of the seagrass *Zostera muelleri* at a site. The use of SDR as an indicator of ecosystem health is based on the assumption that the shallow distributional limit of seagrass is determined by the tolerance of the seagrass to desiccation at low tide and that the deeper the distributional limit is determined by light availability.

Seagrass is a critical component of coastal ecosystems. It increases primary productivity, supports complex food webs, provides habitat for numerous species including fish, prawns and other invertebrates and provides sea floor stability.

The most common factor leading to seagrass loss is an increase in suspended sediments from terrestrial inputs and sediment resuspension leading to a long-term reduction in light.

The SDR provides an indication of water clarity at a site, as the depth to which seagrass can grow is directly dependent on the penetration of light through the water. By regularly measuring the depth range, the effect of temporal changes in water quality on seagrass meadows can be inferred. This provides the EHMP with link between change in water quality through Moreton Bay and the effects it has on biological systems.

Method

Data collection

Seagrass depth range is measured at 17 sites bi-annually by the monitoring program. *Zostera muelleri* is used as the indicator species as it is the most abundant seagrass in Moreton Bay. It has minimal seasonal variation in distribution and responds to changes in light availability. Contingency monitoring can also occur in response to a major environmental event (e.g. flood or algal bloom). The presence of other seagrass species, macroalgae (e.g. Caulerpa taxifolia) and the toxia cyanobacterium Lyngbya majuscule is noted along the transect, as well as geomorphological features such as sandbars, deep holes and evidence of disturbance (bait worming holes, propeller scars).

Measuring the depth range:

- An autoset level (dumpy level) and graduated staff are used to calculate elevations and distances.
- The depth range and general profile of the seagrass bed is determined along a main transect using basic surveying techniques. Ten replicate transects, approximately 10m apart, 5 on either side of the main transect, are surveyed to record the upper and lower distributional limits (i.e. no profile information is recorded).
- Where possible, all transects at a site are related back to a Permanent Survey Mark (PSM) to give absolute elevations relative to Australian Height Datum (AHD). To ensure that changes in the upper and lower distributional limits can be recorded, each successive survey at a site starts at the same position and elevation (e.g. a stake in the ground, paint on a rock wall, marked tree etc.).
- If the horizontal distance between the upper and lower distributional limits is too great and/or the water depth prevents the autoset level from being set up, the depth range is approximated within 10-20cm by using a combination of measurements. To do this, the water depth at the deepest seagrass limit is measured at the same time as the elevation of the water level on the intertidal zone.

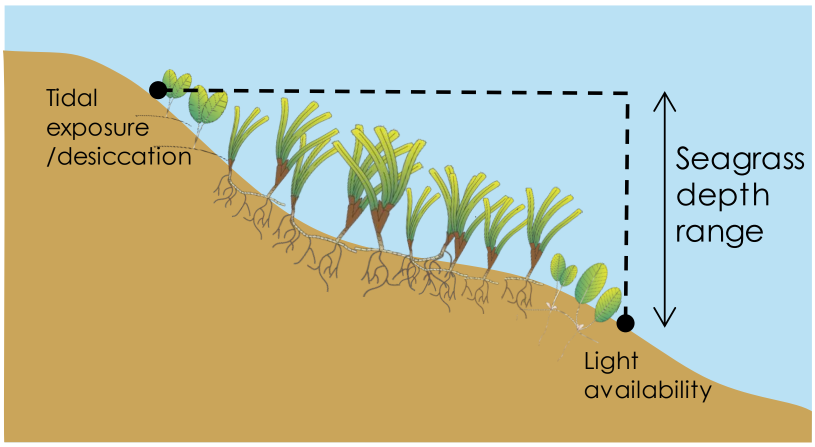

Figure 15: Schematic diagram illustrating how seagrass depth range is measured.

Score calculation

The seagrass depth range indicator for each Bay region is calculated using guideline and worst-case scenario values for each Bay region (see below). The minimum value for each region between 1999 and 2014 is considered the Worst Case Scenario (WSC). The guideline value is derived from water-quality guidelines.

$$\boldsymbol{Seagrass\ depth\ range\ indicator} = \mathbf{1} - \left| \frac{(\boldsymbol{Seagrass\ depth\ range} - \ \boldsymbol{Guideline})}{(\boldsymbol{WCS} - \boldsymbol{Guideline})} \right|$$

5.2.1.2.4 Mud content indicator

Rationale

The characteristics of sediments within bay and estuarine environments have a strong influence on the distribution and abundance of aquatic organisms and overall ecosystem function. Sediments in Moreton Bay are comprised of terrestrial sediments including mud and sand delivered via rivers, biogenic sediments produced by marine organisms such as oysters and coral and marine quartzose sands transported via the tidal deltas.

Fine sediment or 'mud' is transported to the Bay episodically during flood events. Mud can smother sandy habitats and bring pollutants to the Bay such as metals, hydrocarbons, pesticides and nutrients. The resuspension of mud by tidal currents and wave action can also increase water column turbidity, decreasing light availability on the seafloor. This affects the distribution and condition of seagrass and other photosynthetic organisms in the Bay.

Since the 1970s the area of mud within the bay has increased substantially. The expansion corresponds to an increase in the rate of supply of fine sediments to the Bay as a consequence of historical and ongoing land-use changes in the catchment. This has resulted in the historical loss of seagrass and oyster reefs in some areas of the Bay. Routine monitoring of sediment types within the Bay supports our understanding of trends in the distribution and remobilisation of sediments, including the impacts and recovery from floods.

Method

Data collection

Bottom sediments have been routinely collected (every four years) in Moreton Bay, the Gold Coast Broad Water and Pumicestone Passage since 2011. In 2015 sampling increased to include 223 sites (Figure 16). Sediments are collected using an Ekman Grab sampler. Grain size is measured using a laser diffraction particle size analyser. Since 2019 a penetrometer has also been used to estimate the distribution and volume of unconsolidated sediments in the Bay. Key outputs of this monitoring campaign include particle size distribution by site, mud content by site (%), mud extent (km^2), mud penetration depth (m) and deposit characterisation (consolidated, layered, unconsolidated).

The spatial extent (km^2) of sediment types (clean sand, sand, muddy sand, sandy mud, mud) is estimated using interpolation in ARC GIS. The extent of each sediment type is determined by inverse distance weighted interpolation to the power of four of the percent mud at each site. Areas with mud fractions of 50% or higher are then summed to determine total surface area of mud, which includes sandy mud and mud. This allows for estimates of the trends in the extent (expansion/contraction) of mud to be derived.

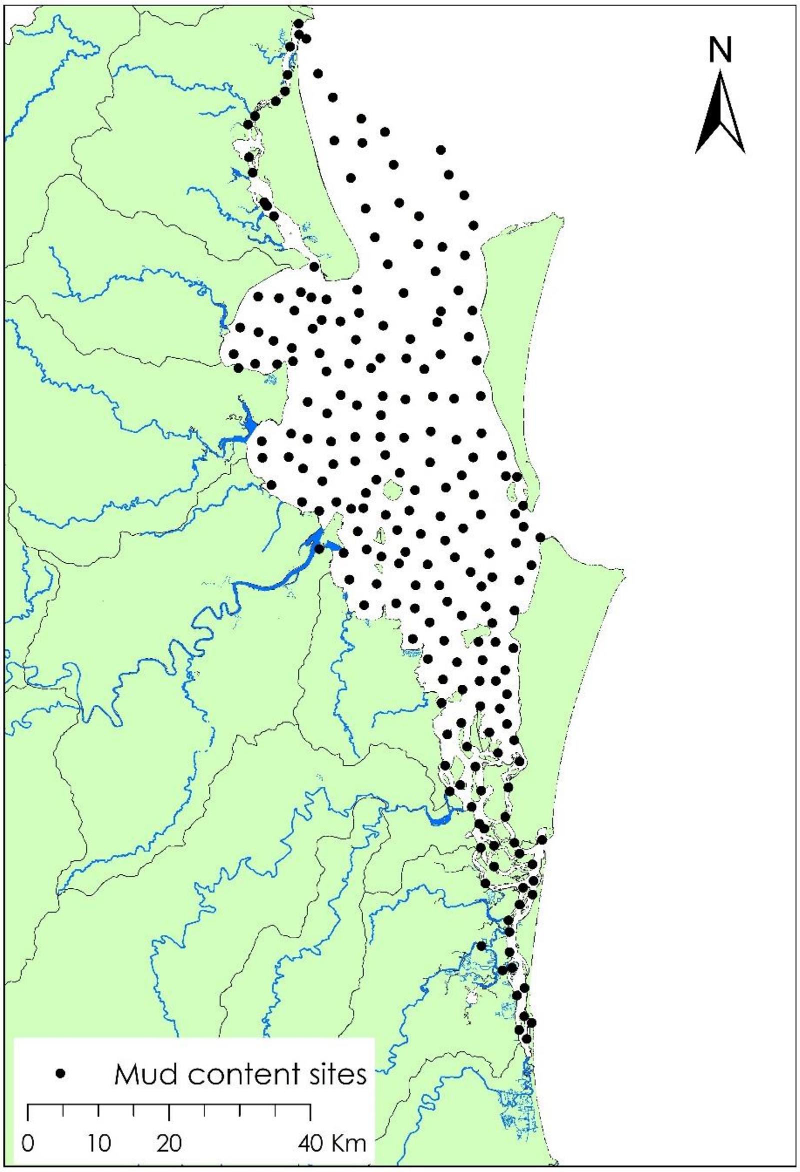

Figure 16: Mud content indicator site locations following expanded field sampling campaign (2015-present).

Score calculation

The annual mud score for individual Bay regions is calculated based on the percentage of change of average sediment mud content from the Worst Case Scenario (WCS).

$$\boldsymbol{Mud\ content\ indicator} = \mathbf{1} - \left|\frac{(\boldsymbol{Average\ \%\ change\ in\ mud\ content\ from\ WCS\ by\ reporting\ zone})}{(\mathbf{100})}\right|$$

2015 is considered the Worst Case Scenario. In 2011 and 2013 major floods delivered large quantities of mud to Moreton Bay. The distribution of mud in Moreton Bay surveyed in 2015 reflects the high fine sediment loads of in 2011 and 2013 and subsequent accumulation in the Bay.

5.3 Waterways Benefits Ratings indicators

This section provides a definition and rationale for each indicator used to calculate the Waterways benefit rating. It also describes the methodology for regional data collection and score calculation for each indicator.

Note that in some cases an index is made up of more than one indicator (see summary table in Appendix 8.1) If an index has multiple indicators, the score is generally calculated by averaging across all indicators within the index.

5.3.1 Social benefit to community

5.3.1.1 Satisfaction with experience index

The community's satisfaction with their experiences of the local waterways. Satisfaction indicates the extent to which local waterways are delivering benefits that the community want and expect.

Definition

The satisfaction a person derives from waterways is the positive emotional state they gain directly from the use of waterways. Individual satisfaction with our waterways is a measure of the extent to which our actual use of waterways meets our desired use of a waterway. People are more satisfied with waterways when they can use waterways in ways to ensure they receive the expected benefits from that use.

For example, a commercial fisher will likely be satisfied only if an adequate amount of their target species is caught. A recreational fisher, however, may be satisfied even if no fish are caught, if the experience allowed them to relax or spend time with family or friends. Alternatively, dissatisfaction occurs when an expectation is not met.

Rationale

Satisfaction can be gained from a visit to or particular use of a waterway. The collective experiences of people using particular waterways can provide a measure of the overall community satisfaction with that waterway.

Managers can use a measure of satisfaction to identify priority areas to increase community understanding regarding the expected use of waterways while improving the attributes of the waterway that facilitate that use (ability to use).

People that are satisfied with waterway experiences will continue to use waterways for that purpose, maximising the multiple benefits they can derive. Satisfaction also indicates the likelihood that a particular use will be maintained or increased, or whether it may be a one-off activity.

Other benefits associated with increased satisfaction include return visits to particular waterways. This may improve personal mental and physical health, or a closer attachment to a place or cultural experience It may also be a community impact such as improved social cohesion. Increased satisfaction may also drive increased willingness or ability to undertake stewardship behaviours.

Method

Data collection

In the Healthy Land and Water Community Benefits Survey, facilitated by the Queensland University of Technology (see section 6.4), people are asked to indicate their overall satisfaction with local waterways on a seven-point Likert scale, ranging from "Strongly disagree" (=1) to "Strongly agree" (=7). The construct 'Overall satisfaction' is used, and this is made up of four survey statements/questions:

Overall Satisfaction:

1. *Overall, I am satisfied with my local waterways.*
2. *My local waterways are close to my ideal.*
3. *I am delighted with my experiences with my local waterways.*
4. *I am very satisfied with my decisions to use/visit my local waterways.*

Score calculation

The steps are:

1. For each respondent, calculate their construct means = (Question1+Question2+Question3+Question4)/4.
2. For each catchment, calculate the % of respondent construct means that were equal to or above 4.5.

This calculation results in a ratio, which becomes the score (between 0 and 1). No standardisation is performed on this indicator.

5.3.1.2 Usability and accessibility index

Definition

The community's perception of how usable and accessible their local waterways are. Using waterways provides mental health, physical health and cultural benefits.

Rationale

The degree to which waterways are useable will influence the amount of social and economic benefits we derive from them. Recreating in and around waterways can improve our physical and mental health and our social cohesion by providing places for people to come together (e.g., at riverside parks). Measuring useability can also help to identify the catchments where waterway condition, perceptions of safety or other enabling factors reduce useability of waterways.

Useability of waterways will ultimately affect the rate of use of waterways within the catchment. Waterway useability is affected by available infrastructure (e.g. boat ramps, bike paths), as well as being strongly related to waterway condition. As a proxy, monitoring 'ability to use' captures the physical attributes of waterways that inhibit or enable use of waterways and their associated benefits.

Interaction with nature can affect health and wellbeing, through the pathways of air quality, physical activity, social contacts and stress. The outcomes of this effect will be dependent upon the type of recreational use as well as the type of waterway where the recreational use occurs.

Method

Data collection

In the Healthy Land and Water 2016 Community Survey (section 6.4) people were asked to indicate their satisfaction with the usability and accessibility of local waterways on a seven-point Likert scale, ranging from “Strongly disagree” (=1) to “Strongly agree” (=7). Two constructs made up of four questions is used:

Overall Use:

1. I get a lot out of using my local waterways.
2. I find my local waterways easy to use.
3. It doesn’t take much effort to use my local waterways.
4. I would like to use my local waterways more often.

Overall Accessibility:

1. I find it easy to access my local waterways.
2. Accessing my local waterways is simple.
3. It is fairly straightforward to get to my local waterways.
4. My local waterways are easy to access.

Score calculation

The steps are:

1. For each respondent, calculate their construct means = (Question1+Question2+Question3+Question4)/4.
2. For each catchment, calculate the % of respondent construct means that were equal to or above 4.5.
3. For each catchment, calculate the Indicator scores = (Construct1+Construct2)/2.

This calculation results in a ratio, which becomes the score (between 0 and 1). No standardisation is performed on this indicator.

5.3.1.3 Connection with waterways index

Definition

The level of personal connection the local community has with nature. Communities with high levels connection are motivated to use and protect waterways and gain psychological benefit from doing so.

Rationale

Connection to waterways and natural environments is an important component of physical and mental health. Health and wellbeing is increased with exposure to local waterways through enhanced opportunities for exercise and increased sense of place and strengthened cultural ties and social fabric. In addition, communities are more likely to act to manage and revitalise waterways when there is a high degree of connectedness with, and value of waterways.

Method

Data collection

In the Healthy Land and Water 2016 Community Survey (section 6.4) people were asked to indicate their level of connection with their local waterways on a seven-point Likert scale, ranging from “Strongly disagree” (=1) to “Strongly agree” (=7). Two constructs made up of three - four questions is used:

Motivation to use and protect waterways (previous called "Integrated regulation"):

1. Using local waterways is part of the way I have chosen to live my life.
2. Using local waterways is a fundamental part of who I am.
3. Using local waterways is an integral part of my life.

Personal Connection to Nature (previously called "Nature relatedness"):

1. I always think about how my actions affect the environment.
2. I take notice of wildlife wherever I am.
3. My relationship to nature is an important part of who I am.
4. I feel very connected to all living things and the earth.

Score calculation

The steps are:

1. For each respondent, calculate their construct means = (Question1+Question2+Question3+Question4)/4.
2. For each catchment, calculate the % of respondent construct means that were equal to or above 4.5.
3. For each catchment, calculate the indicator scores = (Construct1+Construct2)/2.

This calculation results in a ratio, which becomes the score (between 0 and 1). No standardisation is performed on this indicator.

5.3.1.4 Personal Benefits index

Definition

The level of personal benefits local residents gain from using their waterways. Personal benefits arise when waterways act as a place of rest and relaxation or a place to socialise with friends and family.

Rationale

Having a local place in nature to socialise with friends and family, or for rest and relaxation is a key component of physical and mental health. It contributes to having an increased sense of place and strengthened cultural ties and social fabric. Communities are more likely to act to manage and revitalise waterways when there is a high degree of value and personal benefits associated with their waterways.

Method

Data collection

In the Healthy Land and Water 2016 Community Survey (section 6.4) people were asked to indicate the level of personal benefits they get from their local waterways on a seven-point Likert scale, ranging from "Strongly disagree" (=1) to "Strongly agree" (=7). Three constructs made up of four questions are used:

Social interaction and connection (previously called "Social value"):

1. I am happy when I visit or use local waterways with my friends.
2. I find using my local waterways more interesting when my friends are with me.
3. It is more interesting to use my local waterway as part of a group.
4. Social outings at my local waterways make them more interesting.

Emotional benefit (previously called "Fascination"):

1. My local waterways have fascinating features.
2. There is a lot to explore and discover at my local waterways.
3. My local waterways are exciting.
4. My local waterways are fascinating.

Rest and relaxation (previously called "Being-away"):

1. Spending time using my local waterways gives me a break from my day-to-day routine.
2. My local waterways are a place to get away from it all.
3. Using my local waterways helps me to relax.
4. Using my local waterways helps me to get relief from everyday stress.
5.

Score calculation

The steps are:

1. For each respondent, calculate their construct means = (Question1+Question2+Question3+Question4)/4.
2. For each catchment, calculate the % of respondent construct means that were equal to or above 4.5.
3. For each catchment, calculate the indicator scores = (Construct1+Construct2+Construct3)/2.

This calculation results in a ratio, which becomes the score (between 0 and 1). No standardisation is performed on this indicator.

5.3.2 Economic Benefit to Community

5.3.2.1 Drinking Water Treatment index

Definition

Clean drinking water is essential for supporting the health and quality of life of the South East Queensland community. Drinking water is collected from many of the catchments in the region and chemically treated to remove pathogens, sediments, unusual tastes and odours in water treatment plants. The quality of the water that enters the treatment plants is a function of the ability of the catchment to reduce the pollutant loads. This function lowers the quantity of chemicals required to treat the water and the alum sludge bi-product produced, which is costly to manage.

Rationale

Minimising the cost of drinking water in the face of increasing supply and demand and, increasing pressures on catchment areas is a priority to ensure the ongoing health of the community.

The Australian Drinking Water Guidelines (2011) states that, "The most effective means of assuring drinking water quality and the protection of public health is through adoption of a preventive management approach that encompasses all steps in water production from catchment to consumer." The guidelines recognise that the first barrier to clean drinking water is the condition of the catchment. This indicator measures the contribution that each catchment has to minimising the costs of managing and disposing alum sludge, a bioproduct of delivering safe drinking water. Healthy Land and Water will work closely with Seqwater to ensure that it is in alignment with the considerable work they have completed in recent years in this field.

Method

Data collection

Seqwater is legislatively required to report the quantity of alum sludge generated to the National Pollution Inventory and Queensland Waste Data System for each Water Treatment Plant (WTP). This varies as the volume of water supplied varies, as distinct from capital costs which remain fixed even though water supply volume changes. For the purpose of this indicator, the quantity of alum sludge produced per quantity of treated drinking water produced for each WTP has been used.

Data from Seqwater indicates that the amount of sludge produced from catchments in poor condition is generally higher than those in good condition. The quantity of alum sludge bi-product per megalitre of drinking water produced (kg/ML) can therefore serve as a proxy for the water quality entering the plant. The 90th percentile of the worst performing year in terms of alum sludge production per megalitre of water, based on four years of data (2012 to 2016/7), was used to establish a worst-case scenario. The best-case scenario assumes no alum treatment is required and hence no alum sludge biproduct generated to produce drinking water and is therefore 0.

The quantity of sludge produce per WTP is calculated using the following equation:

$$Sludge\ Produced\ (kg/ML) = \frac{Wet\ Sludge\ (T)}{Water\ Produced\ (ML)} x\ 1000$$

WTPs which produce less sludge per megalitre of water indicates that less chemical treatment is required per ML to supply drinking water, and shows that water quality in that catchment is delivering a higher benefit to society. In theory, residents should pay less for drinking water which is sourced from catchments in good condition as the cost of treatment and alum sludge disposal is lower. This delivers a financial benefit to the community.

Score calculation

The Best Case Scenario (BCS) assumes no alum treatment is required to produce drinking water at a WTP and therefore generates little to no sludge. This indicates that raw water delivered from the catchment is of suitable quality for drinking with no treatment. This is expressed as a score which is calculated using the following equation:

$$Drinking\ Water\ Index \quad = 1 - \frac{(Sludge\ Produced\ (kg/ML) - BCS)}{(WCS - BCS)}$$

The closer the score is to 1, the greater the benefit received from catchment water quality.

5.3.2.2 Water based recreation index

Definition

Waterways are used for multiple recreational activities:

- Boating and sailing.
- Walking, cycling or running.
- Picnics and BBQs.
- Recreational fishing.
- Rowing, kayaking and canoeing.
- Scuba diving and snorkelling.
- Surfing, kite-surfing and sail boarding.
- Swimming.
- Enjoying nature e.g. birdwatching, conservation, photography and camping.
- Recreational fishing.

Rationale

Recreation in an around waterways is very popular in South East Queensland, providing an economic benefit to the community generated through expenditure. Moreton Bay, freshwater reservoirs, creeks and estuaries in South East Queensland provide a substantial diversity in recreational opportunities which generates significant revenue to the local economy.

Methods

The ability of a catchment/waterway to contribute an economic benefit relies on two aspects:

1. The number of people visiting/using a waterway,
2. The costs associated with accessing the waterway to undertake a specific activity.

In the Healthy Land and Water 2016 Community Survey (see section 6.4) people were asked to select their preferred type and frequency of recreational pursuits in and around waterways. Specifically, the survey question was:

How often do you use South East Queensland's waterways for the following purposes? Almost every day/ every week/ every month/ once or twice a year/every few years/never.

- Boating, sailing.
- Walking, cycling or running.
- Picnics, BBQs.
- Recreational fishing.
- Rowing, kayaking, canoeing.
- Scuba diving, snorkelling.
- Surfing, kite-surfing, sail boarding.
- Swimming.
- Enjoying nature e.g. birdwatching, conservation, photography, camping.
- Recreational fishing.

Response to this question was used to estimate to following measure:
Total number of (#) visits per annum.

The costs associated with each of the specific recreational activities included in the community survey were then multiplied to calculate the expenditure per visit using the formula:

$$Expenditure\ associated\ with\ each\ activity\ per\ person = \frac{\#\ visits\ per\ anuum\ \times estimated\ cost\ per\ visit}{\#\ number\ of\ respondants}$$

Where the respondents' answers were allocated the following frequencies:

Survey answer category	Frequency per year allocated	
Almost every day	260	(i.e. weekdays only)
Every week	52	
Every fortnight	26	
Every month	12	
One or twice a year	1.5	
Every few years	0.333	

And the estimated expenditure per visit for each activity was as per the following table:

Recreation type	Estimated cost per visit	Source
Boating and sailing	$173	Marsden and Jacobs (2013)
Walking and running	$1.90	Qld Health (2011)
Picnics and BBQ's	$62	Ag Economics (2010)
Recreational fishing	$85	Pascoe et al (2014)
Rowing, kayaking and canoeing	$30.21	Ag Economics (2010)
Surfing, kite surfing andsail boarding	$30.21	Griffith University (2012)
Swimming	$16.90	Ag Economics (2010)
Cycling	$2.52	
Jetskiing and water-skiing	$60	

Total annual expenditure per catchment is calculated by summing the expenditure for each of the recreational pursuits. The total expenditure per catchment is then standardised by population. The Waterway Recreational Index is then calculated using the following formula:

$$Waterway\ Recreational\ Indicator = 1 - \left|\frac{(Catchment\ expenditure\ ratio - BCS)}{(WCS - BCS)}\right|$$

BCS (Best Case Scenario) is the catchment with the highest catchment expenditure ratio. WCS (Worst Case Scenario) is the catchment with the lowest catchment expenditure ratio.

5.4 Action indicators (used for narration only)

This element of the Report Card is under development. Currently it is presented as a narrative of recommendations around:

1. The barriers and drivers to stewardship.
2. Willingness and ability to act and.
3. Priority actions required to address threats to environmental values.

For one and two above, the responses to the Healthy Land and Water Community Survey (see section 6.4) are currently used.

For three above, Healthy Land and Water is working with the community, local and state governments, water utilities SEQ Catchments Members Association (SEQMA) and the Council of Mayors (SEQ) to prioritise action in each catchment. We are developing regional decision support tools to assess the threats to environmental values within each catchment. Specifically, the environmental values/objectives are (as defined by our members):

- Restore and maintain key habitats (i.e. riparian vegetation).
- Reduce pollutant loads (sediment and nutrients) entering waterways.
- Improve and maintain water quality.
- Restore and maintain key ecosystem processes.
- Restore and maintain resilient and healthy aquatic communities (i.e. fish populations).

These tools will help prioritise focus areas for action and support decision-makers in developing and implementing targeted, effective catchment management actions.

6 Report Card data sources

6.1 Freshwater Monitoring Program

The freshwater program samples 75 freshwater sites once per year in autumn. Each year the sites consist of 48 'fixed' sites sampled each year and one of three sets of 27 rotating sites sampled once every three years. Using this protocol, 129 sites will be assessed every three years. Monitoring is currently carried out by Queensland Government DES scientists.

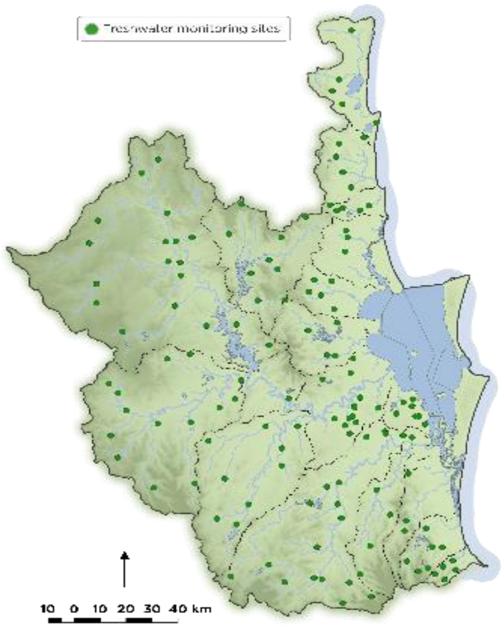

Figure 17: Location of the 129 freshwater monitoring sites.

Table 4: Geographic coordinates of the 48 'fixed' freshwater sites - sampled annually.

Site code	Waterway	Site name	Longitude	Latitude
140-0001	Noosa River	Cooloola Way, Coops Corner, Cooloola	153.00720	-26.05719
141-0001	Mooloolah River	Harris Road, Diamond Valley	152.92030	-26.75220
141-0002	Mooloolah River	Westaway Road, Meridan Plains	153.08170	-26.75180
141-0004	South Maroochy River	Colemans Road, Yandina	152.94390	-26.56080
141-0005	Doonan Creek	Doonan Bridge East Road, Peregian Springs	153.05450	-26.48360
141-0014	Coochin Creek	Bruce Highway, Beerwah	153.00880	-26.87750
142-0003	Wararba Creek	Campbells Pocket Road, Wamuran	152.85790	-27.04482
142-0004	North Pine River	Mount Brisbane Road, Mount Pleasant	152.74400	-27.12760
142-0005	South Pine River	Carter Court, Bunya	152.93410	-27.35090
142-0007	Cedar Creek	Edward Allison Park	152.91170	-27.34510
142-0008	Sideling Creek	Forbes Road, Kurwongbah	152.94340	-27.21631
142-0009	Kedron Brook	Grinstead Park, Royal Parade, Alderley	153.00260	-27.41626
142-0010	Cabbage Tree Creek	Phillip Vaughan Park, Carseldine	153.01140	-27.35964
143-0004	Emu Creek	'Rae Burn', Blackbutt Road, Pierces Creek	152.00460	-27.06410
143-0008	Brisbane River	Western Branch Road, Mount Stanley	152.18290	-26.62520
143-0009	Brisbane River	Eastern Branch Road, Mount Stanley	152.24880	-26.57197
143-0010	Kangaroo Creek	Kangaroo Creek Road, Moore	152.38090	-26.88060
143-0011	Monsildale Creek	Monsildale Creek Road, Linville	152.28140	-26.78268
143-0013	Wallaby Creek	Himstedts Road, Moore	152.27740	-26.89723
143-0014	Maronghi Creek	Turtle Creek Road, Harlin	152.33360	-26.97856
143-0015	Ivory Creek	Ivory Creek Road, Ivory Creek	152.33610	-27.03113
143-0017	Brisbane River	Arababy Creek Road, Moore	152.30940	-26.89513
143-0021	Northbrook Creek	Red Cedar Picnic Grounds, Dundas	152.68210	-27.30570
143-0025	Oaky Creek	Westvale Road, Westvale	152.61080	-27.02265
143-0028	Sheepstation Creek	Crossing No 2, Kilcoy - Murgon Road, Kilcoy	152.52460	-26.86690
143-0034	Stockyard Creek	Stockyard Creek Road, Stockyard	152.06060	-27.66460
143-0037	Blackfellow Creek	Glen Rock Regional Park, East Haldon	152.23010	-27.86752
143-0040	Laidley Creek	Railway Bridge, Gordon Street, Forest Hill	152.37700	-27.60235
143-0046	Bremer River	Adams Bridge, Rosevale	152.50950	-27.83204
143-0049	Warrill Creek	Kalbar Connection Road, Kalbar	152.60030	-27.93221
143-0050	Brisbane River	Summerville Road East, Borallon	152.68980	-27.49970
143-0054	Enoggera Creek	Mount Nebo Road, Enoggera Reservoir	152.89050	-27.44070
143-0056	Norman Creek	Ekibin Park South, Arnwood Place, Annerley	153.03880	-27.51293
143-0059	Oxley Creek	Brookbent Road, Pallara	153.02330	-27.61050
143-0060	Cooyar Creek	Kooralgin Gilla Road, Kooralgin	151.97710	-26.90320
143-0064	Bremer River	Haigslea-Amberley Road, Walloon	152.66880	-27.62689
145-0004	Canon Creek	Kooralbyn Road, Kooralbyn	152.87080	-28.09940
145-0006	Christmas Creek	Christmas Creek Road, Lamington	153.08390	-28.29325
145-0012	Cainbable Creek	Cainbable Creek Road, Kerry	153.07790	-28.09650
145-0015	Burnett Creek	Boonah Rathdowney Road, Maroon	152.68030	-28.17010
145-0028	Moogurrapum Creek	Syracuse Street, Redland Bay	153.29570	-27.61840
145-0033	Scrubby Creek	Queens Road, Kingston	153.14200	-27.65680
146-0001	Back Creek	Back Creek Road, Witheren	153.21370	-28.03612
146-0002	Currumbin Creek	Craigs Crossing, Currumbin Valley	153.41480	-28.18880
146-0006	Nerang River	Latimers Crossing, Gilston	153.29740	-28.02590
146-0008	Mudgeeraba Creek	Austinville Road, Austinville	153.30820	-28.17120
146-0016	Pimpama River	Upper Ormeau Road, Kingsholme	153.23010	-27.81150
OXL-0005	Oxley Creek	Johnson Road, Larapinta	153.00040	-27.65474

Table 5: Geographic coordinates of the rotating sites – sampled once every three years.

Rotation	Site code	Waterway	Site name	Longitude	Latitude
1	140-0002	Sandy Creek	Cootharaba Road, Cootharaba	152.93040	-26.29785
1	141-0007	Eudlo Creek	Bruce Highway service road, Forest Glen	153.00370	-26.68207
1	141-0013	Bluegum Creek	Roys Road, Beerwah	152.98520	-26.85120
1	142-0002	Caboolture River	Litherland Road, Upper Caboolture	152.88570	-27.10980
1	142-0006	Kobble Creek	Mount Samson Road, Dayboro	152.83570	-27.24776
1	143-0001	Yarraman Creek	Gibsons Road, Yarraman	152.00840	-26.81554
1	143-0016	Cressbrook Creek	Esk-Crow's Nest Road, Biarra	152.31380	-27.15133
1	143-0024	Neurum Creek	Neurum Road, Mount Archer	152.68250	-26.97070
1	143-0031	Murphys Creek	Mill Road, Upper Lockyer	152.08780	-27.49490
1	143-0033	Lockyer Creek	Back Flagstone Road, Iredale (Helidon)	152.12280	-27.56320
1	143-0041	Lockyer Creek	Pointings Bridge, Lowood	152.57130	-27.44530
1	143-0052	Purga Creek	Ipswich-Boonah Road, Peak Crossing	152.73190	-27.78081
1	143-0053	Purga Creek	Purga School Road, Purga	152.73280	-27.71210
1	143-0057	Bulimba Creek	Stackpole Street, Wishart	153.11210	-27.55300
1	143-0062	Blunder Creek	Carolina Parade, Forest Lake	152.97920	-27.62140
1	145-0001	Running Creek	Mount Gipps Road, Mount Gipps	152.99010	-28.31903
1	145-0002	Mount Barney Creek	Seidenspinner Road, Mount Barney	152.74270	-28.23727
1	145-0013	Albert River	Chardon Bridge Road, Cedar Creek	153.17870	-27.82590
1	145-0016	Teviot Brook	Head Road, Carneys Creek	152.53200	-28.21460
1	145-0022	Teviot Brook	Brooklands Bridge, Undullah Road, Kagaru	152.90750	-27.86400
1	145-0026	Hilliards Creek	Industry Court, Cleveland	153.24270	-27.54580
1	145-0030	Native Dog Creek	Stern Road, Carbrook	153.24460	-27.66950
1	146-0003	Tallebudgera Creek	Robinson Park, Tallebudgera Valley	153.40380	-28.15170
1	146-0005	Nerang River	Numinbah Community Hall, Numinbah Valley	153.22300	-28.13840
1	146-0011	Coomera River	Maybury Creek Road, Clagiraba	153.22060	-27.99600
1	146-0019	Currumbin Creek	Long Tan Road, Currumbin Valley	153.37090	-28.22660
1	OXL-0002	Stable Swamp Creek	Bale Street, Rocklea	153.01740	-27.55130
2	140-0003	Kin Kin Creek	Galloways Lane, Cootharaba	152.95690	-26.25320
2	141-0006	Petrie Creek	Coronation Avenue, Nambour	152.97220	-26.62043
2	141-0013	Bluegum Creek	Roys Road, Beerwah	152.98520	-26.85120
2	141-0015	Mooloolah River	Rustic Cabin, Steve Irwin Way, Glenview	153.03800	-26.77250
2	142-0001	Caboolture River	McNamara Road, Rocksberg	152.83630	-27.09290
2	142-0011	Lagoon Creek	Appaloosa Close, Caboolture	152.92810	-27.05360
2	143-0003	Pierces Creek	Blackbutt Road, Pierces Creek	152.00010	-27.13650
2	143-0018	Esk Creek	'Glen Rock', Falls Road, Esk	152.43790	-27.22820
2	143-0022	Stanley River	River Road, Booroobin	152.82410	-26.79887
2	143-0030	Buaraba Creek	Buaraba Creek Road, Buaraba	152.32190	-27.35930
2	143-0032	Murphys Creek	Odin Street, Murphys Creek	152.05280	-27.45810
2	143-0039	Laidley Creek	Peacocks Bridge, Mulgowie Road, Townson	152.39090	-27.85021
2	143-0045	Reynolds Creek	'Yarramolong' camp ground, Charlwood	152.55960	-28.01237
2	143-0051	Bundamba Creek	George Palmer Park, Sealy Street, Silkstone	152.79450	-27.62690
2	143-0061	Stony Creek	Stony Creek Day Use Area, Stony Creek	152.73090	-26.87940
2	143-0063	Plain Creek	Schulz Road, Coolana	152.54910	-27.51765
2	145-0007	Christmas Creek	Burgess Park, Lamington	152.99550	-28.23910
2	145-0008	Logan River	Il-Bogan Bridge, Beaudesert	152.96530	-27.98743
2	145-0010	Logan River	Cusack Lane, Jimboomba	153.00390	-27.82130
2	145-0011	Albert River	Kerry Road, Darlington	153.04030	-28.20650
2	145-0018	Teviot Brook	Old Beaudesert Road, Coulson	152.72900	-27.95026
2	145-0021	Slacks Creek	Meakin Park, Meakin Road, Slacks Creek	153.13600	-27.64421
2	145-0024	Hilliards Creek	Francis Street, Ormiston	153.24560	-27.51920
2	145-0029	Coolnwynpin Creek	Glover Drive, Alexandra Hills	153.20890	-27.53120
2	146-0015	Mudgeeraba Creek	Little Nerang Road, Mudgeeraba	153.32220	-28.09860
2	146-0018	Tallebudgera Creek	Tallebudgera Creek Road, Tallebudgera Valley	153.32310	-28.21520
2	OXL-0001	Rocky Waterholes	Cobden Street, Moorooka	153.01680	-27.54560
3	140-0004	Ringtail Creek	McKinnon Drive, Ringtail Creek	152.96970	-26.35080
3	141-0003	Maroochy River	Wegner Road, North Arm	152.95720	-26.50890
3	141-0011	Tibrogargan Creek	Rapkins Road, Beerburrum	152.98090	-26.93700
3	141-0016	Mooloolah River	King Road, Mooloolah Valley	152.94520	-26.77850
3	142-0012	Burpengary Creek	Koel Drive, Narangba	152.93750	-27.16460
3	143-0012	Emu Creek	Grieves Road, Colinton	152.29280	-26.96295
3	143-0019	Reedy Creek	Mount Byron Road, Mount Byron	152.63990	-27.12990
3	143-0020	Sandy Creek	Wivenhoe - Somerset Road, Crossdale	152.55540	-27.22460
3	143-0036	Deep Gully	Ropeley Rockside Road, Ropeley	152.25050	-27.63100
3	143-0042	Woolshed Creek	Warrego Highway, Hatton Vale	152.48810	-27.55270
3	143-0044	Warrill Creek	Villis Bridge, Niebling Road, Tarome	152.47840	-27.98860
3	143-0048	Western Creek	Rosewood-Laidley Road, Grandchester	152.46140	-27.66316
3	143-0058	Bullockhead Creek	Progress Road, Wacol	152.93960	-27.59496

3	143-0065	Heifer Creek	Gatton-Clifton Road, West Haldon	152.08850	-27.74910
3	143-0066	Delaney Creek	Dewhurst Road, Mount Delaney	152.71500	-27.00615
3	143-0068	Buaraba Creek	Rocky Gully Road, Coominya	152.43360	-27.39750
3	145-0003	Logan River	Ian Tilley Park, Rathdowney	152.85940	-28.22200
3	145-0005	Running Creek	'Dulbolla', Running Creek Road, Rathdowney	152.88990	-28.22680
3	145-0009	Allan Creek	Allan Creek Road, Gleneagle	152.94880	-27.93120
3	145-0014	Canungra Creek	Wonglepong Bridge, Wonglepong	153.15640	-27.97260
3	145-0019	California Creek	Gavin Way, Cornubia	153.20760	-27.66320
3	145-0023	Eprapah Creek	Springacre Road, Thornlands	153.25510	-27.58660
3	145-0031	Scrubby Creek	Campden Street, Browns Plains	153.06400	-27.66840
3	146-0007	Bonogin Creek	Gunsynd Drive, Mudgeeraba	153.36210	-28.09980
3	146-0017	Tallebudgera Creek	Smailes Park, Tallebudgera Valley	153.36960	-28.17510
3	OXL-0003	Blunder Creek	King Avenue, Willawong	152.99700	-27.59360
3	OXL-0004	Oxley Creek	Beatty Road, Acacia Ridge	153.01060	-27.58580

6.2 Estuarine-Marine Monitoring Program

Several characteristics of surface waters are monitored *in situ* and surface water samples are collected for analysis of chlorophyll-a and nutrient concentrations (**Table 6:** Parameters measured at all sites of the estuarine-marine monitoring program (**Table 6**) at each of 182 estuarine-marine sites (**Table 7** and Figure 18) during eight months of each year (February, March, May, August, September, October, November and December). Monitoring is carried out by Queensland Government DES scientists.

Water samples collected for quantifying chlorophyll-a concentrations are analysed by DES and water samples collected for quantifying nutrient concentrations are analysed at the Queensland Urban Utilities SAS Laboratory, Darra.

Table 6: Parameters measured at all sites of the estuarine-marine monitoring program.

Source	Parameter
In situ	Temperature
	Salinity
	pH
	Secchi depth
	Turbidity
	Dissolved oxygen
Water samples	Chlorophyll-a
	Total Nitrogen
	Organic Nitrogen
	Dissolved Inorganic Nitrogen
	Oxidised Nitrogen
	Ammonia
	Total Phosphorus
	Dissolved Reactive Phosphorus

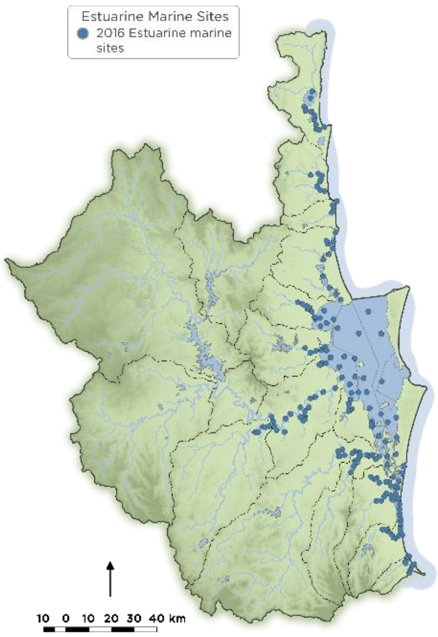

Figure 18: Location of the 182 estuarine-marine sites in the monitoring program.

Table 7: Geographic coordinates (WG84 datum) of the 182 estuarine-marine sites to visited eight times per year.

Report Card zone	Site code	Longitude	Latitude
Albert River	E01701	153.23940	-27.69527
	E01702	153.23354	-27.70501
	E01703	153.22656	-27.71531
	E01704	153.21554	-27.71833
	E01705	153.21613	-27.72705
	E01706	153.20879	-27.73959
	E01707	153.19783	-27.76437
Bramble Bay	E00900	153.07996	-27.26433
	E00905	153.14437	-27.34339
	E00907	153.16771	-27.30338
	E00916	153.08771	-27.27839
	E00919	153.10604	-27.30672
	E00921	153.21535	-27.30961
Bremer River	E00600	152.85370	-27.58234
	E00601	152.82930	-27.57976
	E00602	152.76792	-27.60332
	E00603	152.80118	-27.58300
	E00605	152.78120	-27.60324
	E00606	152.81424	-27.58374
Brisbane River	E00700	153.15711	-27.38647
	E00701	153.12607	-27.42777
	E00702	153.07266	-27.44452
	E00703	153.03612	-27.46298
	E00704	153.01481	-27.46894
	E00705	153.00928	-27.50427
	E00706	152.97069	-27.50581
	E00707	152.97059	-27.54459
	E00708	152.92681	-27.53063
	E00709	152.90411	-27.55034
	E00710	152.89888	-27.60250
	E00711	152.86352	-27.59555
	E00712	152.84900	-27.56096
	E00713	152.84143	-27.54208
	E00718	152.99202	-27.52108
Cabbage Tree Creek	E04101	153.06735	-27.32909
	E04102	153.05987	-27.33582
	E04104	153.07254	-27.32876
	E04105	153.08653	-27.32997
	E04106	153.05471	-27.33526
Caboolture River	E01000	153.03788	-27.15300
	E01001	153.02142	-27.12315
	E01002	153.01250	-27.10940
	E01003	153.00306	-27.11176
	E01004	153.00716	-27.10494
	E01005	152.99947	-27.10208
	E01006	152.99205	-27.09903
	E01007	152.97835	-27.09281
	E01008	152.95863	-27.08676
	E01011	153.03475	-27.14503
Central Bay	E00501	153.33229	-27.53197
	E00517	153.25435	-27.38872
	E00518	153.26787	-27.44508
	E00527	153.23310	-27.21000
	E01112	153.13778	-27.19004
	E01200	153.28110	-27.50830
Coomera River	E00100	153.39757	-27.87157
	E00101	153.38179	-27.87187
	E00103	153.34866	-27.85852
	E00104	153.31257	-27.87724
	E00126	153.37886	-27.85624
	E00127	153.35753	-27.84671
	E00129	153.33443	-27.87623
Currumbin Creek	E02901	153.48258	-28.12789
	E02902	153.47043	-28.13749
	E02903	153.46353	-28.15190
	E02904	153.46042	-28.16274

Report Card zone	Site code	Longitude	Latitude
Deception Bay	E01101	153.08780	-27.17000
	E01102	153.06110	-27.18000
	E01107	153.05947	-27.14838
	E01111	153.07782	-27.11839
	E01119	153.12105	-27.15341
Eastern Banks	E00506	153.33657	-27.40198
	E00310	153.36256	-27.56434
	E00311	153.40113	-27.54561
	E00314	153.40330	-27.62470
	E00525	153.27610	-27.12250
	E00529	153.33308	-27.21248
Eprapah Creek	E04500	153.29329	-27.56238
	E04501	153.29203	-27.57704
	E04502	153.29027	-27.58004
	E04503	153.28990	-27.57140
Logan River	E00200	153.32428	-27.70098
	E00201	153.30996	-27.71108
	E00202	153.24809	-27.69773
	E00203	153.23649	-27.68477
	E00204	153.21677	-27.68036
	E00205	153.20390	-27.68685
	E00206	153.16886	-27.69537
	E00207	153.15972	-27.67189
	E00208	153.14007	-27.68065
	E00211	153.26842	-27.69379
	E00212	153.29369	-27.69408
	E00213	153.14512	-27.69937
Maroochy River	E01501	153.07924	-26.64053
	E01502	153.05943	-26.63596
	E01503	153.04500	-26.62170
	E01504	153.05720	-26.60420
	E01505	153.06681	-26.57900
	E01506	153.01560	-26.57690
	E01508	153.06321	-26.59392
	E01509	153.05042	-26.57023
Mooloolah River	E01400	153.13427	-26.68119
	E01402	153.11472	-26.69680
	E01404	153.11958	-26.71827
	E01405	153.11069	-26.72714
Nerang River	E01901	153.42207	-27.97625
	E01903	153.42876	-28.01197
	E01904	153.41162	-28.01622
	E01905	153.39896	-28.02447
	E01906	153.38838	-28.02319
	E01907	153.38060	-28.01175
	E01908	153.36435	-27.99817
	E01909	153.35439	-27.99043
	E01910	153.33890	-27.98985
	E01912	153.41859	-27.98863
	E01916	153.42010	-28.00170
Noosa River	E01601	153.07731	-26.38294
	E01603	153.05557	-26.39602
	E01604	153.04241	-26.39276
	E01608	153.02003	-26.32148
	E01609	152.98857	-26.30410
	E01610	153.01593	-26.26670
	E01613	153.03425	-26.35340
	E01614	153.03391	-26.33691
	E01615	152.99414	-26.31788
	E01618	153.02310	-26.24060
	E01636	153.04014	-26.37400
Oxley Creek	E04201	152.98860	-27.53936
	E04202	152.99188	-27.55210
	E04203	152.98243	-27.55833
Pimpama River	E01801	153.39389	-27.81918
	E01802	153.37778	-27.81889
	E01803	153.36950	-27.80261
	E01804	153.35480	-27.80131
	E01805	153.32444	-27.80474

Report Card zone	Site code	Longitude	Latitude
	E01806	153.31431	-27.78690
	E01807	153.30333	-27.78994
	E01808	153.28760	-27.78176
Pine River	E00800	153.06323	-27.27751
	E00801	153.04031	-27.27938
	E00803	153.01488	-27.28638
	E00804	152.99186	-27.26885
Pumicestone Passage	E01301	153.13202	-27.05273
	E01302	153.10056	-27.02759
	E01304	153.07350	-26.98299
	E01308	153.07417	-26.91469
	E01309	153.09866	-26.89552
	E01310	153.11712	-26.87166
	E01311	153.11740	-26.84376
	E01312	153.12909	-26.80587
	E01313	153.15173	-27.07551
Southern Bay	E00106	153.38764	-27.78309
	E00125	153.42965	-27.76598
	E00300	153.36063	-27.73449
	E00301	153.43635	-27.74034
	E00308	153.32179	-27.61984
	E00316	153.35342	-27.64226
	E00318	153.40052	-27.69196
	E00320	153.36072	-27.69991
Tallebudgera Creek	E02800	153.45877	-28.09744
	E02801	153.44934	-28.10680
	E02802	153.44280	-28.11811
	E02803	153.44408	-28.12387
The Broadwater	E00105	153.40738	-27.82464
	E00107	153.41203	-27.86708
	E00117	153.42110	-27.95974
	E00118	153.42002	-27.94629
	E00119	153.41789	-27.92772
	E00120	153.41636	-27.90924
	E00121	153.41582	-27.89098
	E00122	153.39932	-27.84831
	E00123	153.41243	-27.79701
Tingalpa Creek	E04300	153.19726	-27.47320
	E04301	153.18749	-27.49083
	E04302	153.19021	-27.50840
	E04303	153.20088	-27.51191
	E04304	153.19463	-27.51568
	E04305	153.18698	-27.51939
Waterloo Bay	E00401	153.19975	-27.44762
	E00406	153.23174	-27.44584
	E00408	153.21602	-27.38408
	E00409	153.19093	-27.41285

6.3 Environmental modelling

A suite of environmental models helps our members determine sustainable pollutant loads and set achievable environmental targets for waterway management in our catchment, estuaries and Moreton Bay.

Estuarine and bay water quality modelling

The TUFLOW model simulates water levels, speed and direction, temperature, salinity and suspended sediment and water quality processes. The model has been built to respond to tidal movements, atmospheric pressure and benthic roughness as well as pollutant loads from the SOURCE catchment model. (See Appendix 8.2)

Catchment pollutant modelling

The SEQ Source Catchments Model enables Healthy Land and Water to quantify pollutant loads from catchments and understand the effect of management interventions in reducing those loads over time. This modelling platform was developed by a team of leading Australian hydrologists from research organisations and industry. The model allows predicted loads to be used as a measure of catchment pressure. (See Appendix 8.3)

6.4 Community Benefits Survey

A community benefits survey of South East Queensland residents is undertaken annually (commenced 2015) to collect data on the attitudes and behaviours that underpin the community's expectations and actions towards using and valuing local waterways. It is designed to provide a representative subsample of the population within each reporting zone for the Health Land and Water Report Card.

The focus of the survey is to collect data on the following:

1. To what extent do people (across the 18 catchment areas in SEQ) use local and SEQ waterways?
    a. Which waterways are used for recreation (location and type)?
    b. Which activities, and how frequently, do residents undertake on or next to waterways?
    c. Do residents use their local waterways or travel to adjacent/distant waterways to undertake activities?
2. To what extent do the conditions of South East Queensland waterways impact the use and enjoyment of these waterways?
    a. How important are waterways to the South East Queensland community?
    b. To what extent do the conditions of waterways contribute to the use of these waterways?
    c. Which waterway attributes encourage or discourage people from using waterways?

Questions feature seven-point Likert scale questions (1 = Strongly Disagree to 7 = Strongly Agree), open text boxes, and distance pins on maps. The survey is administered through a 20-minute online survey hosted by QUT (Key Survey). Survey respondents are recruited using panel data (more than 3000 people per year) and are adults (18+) living in South East Queensland. It is designed to provide a representative subsample of the population within each catchment.

For further detail refer to:

- Johnston, K. & Beatson, A. (2016) 2016 Social Science Survey Report *(report to Healthy Waterways* 11 October 2016), Queensland University of Technology, Brisbane, pp 211.
- Johnston, K. & Beatson, A. (2015) 2015 Social Science Survey Report *(report to Healthy Waterways*), Queensland University of Technology, Brisbane.

6.5 Seagrass Monitoring

Seagrass depth range at 17 sites is assessed twice per year. Measurements are undertaken by Queensland Government DES scientists.

In addition, citizen science programs collect seagrass cover data at more than 4000 sites throughout Moreton Bay. These programs engage 30 – 40 people each year (see Wildlife Queensland Coastal Citizen Science https://wpsqccs.wordpress.com/ and Science Under Sail http://www.susa-velella.com/). Frequency and locations vary year to year.

Table 8: Data collected for the seagrass monitoring.

Source	Parameter
DES	Seagrass depth range *(Zostera muelleri)* (m)
DES and citizen science programs	Seagrass species (% cover)
	Macroalgae (% cover)
	Toxic cyanobacteria *Lyngbya majuscule* (% cover)
	Geomorphological features (% cover)

6.6 Fish community and habitat monitoring

The estuarine fish communities are assessed every three years. Baited remote under water video (BRUV) technology is used to estimate species richness and abundance in each estuary of South East Queensland. Assessments and video analysis are carried out by scientists at the University of Sunshine Coast.

In addition, citizen science programs are used to undertake fish community BRUV assessments in seagrass habitats throughout Moreton Bay (see Science Under Sail). Frequency and locations vary year to year.

Table 9: Data collected for the fish and habitat monitoring.

Type	Parameter
Fish	Species richness
	Species abundance

6.7 Catchment loads monitoring

Catchment pollutant loads associated with rainfall events, are monitored at six sampler stations. Water quality sampling is conducted monthly during periods of base flow conditions and throughout major flow 'events.' Samplers are managed by Queensland Government DES technicians.

Table 10: Catchment load data collected by the monitoring program.

Type	Parameter
Flow	Stream height
	Rating curves
Water quality	Total Nitrogen
	Organic Nitrogen
	Dissolved Inorganic Nitrogen
	Oxidised Nitrogen
	Ammonia
	Total Phosphorus
	Dissolved Reactive Phosphorus
	Suspended sediments

6.8 Riparian vegetation mapping

The extent of freshwater riparian vegetation is mapped every three years (or when new data is available) using Landsat satellite imagery (SLATS https://www.qld.gov.au/environment/land/vegetation/mapping/slats/). It is defined as the Foliage Projection Cover (FPC) (essentially woody vegetation) present within a 50m buffer zone adjacent to the freshwater edge. Resolution is at $30m^2$ pixels. The stream network was derived from the Queensland Governments (25m x 25m) Digital Elevation Model for the region with a stream initiation threshold of 0.1kms (product of the Health Land and Water "Stream Order Mapping" study.

7 References

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8 Appendices

8.1 Appendix (1) - Summary of Measures for all Report Card Indicators

<table>
<tr><th rowspan="2">Report Card Element</th><th rowspan="2">Components</th><th colspan="3">% of score</th><th rowspan="2">Index</th><th rowspan="2">Indicator/s</th><th colspan="3">% of score</th><th rowspan="2">Unit</th><th rowspan="2">Data source</th><th rowspan="2">Start year</th><th rowspan="2">Frequency assessed</th><th rowspan="2">Standardisation method</th><th rowspan="2">Standardisation calculation</th><th rowspan="2">Benchmarks, BCS & WCS</th></tr>
<tr><th>Coastal catchments</th><th>Western catchments</th><th>Bay</th><th>Coastal catchments</th><th>Western catchments</th><th>Bays</th></tr>
<tr><td>Environmental Condition Grade - Catchments</td><td>Habitat</td><td>40%</td><td>40%</td><td></td><td>Freshwater Habitat</td><td>Freshwater wetland extent</td><td>13%</td><td>20%</td><td></td><td>% of pre-cleared</td><td>RE Mapping (Qld Gov Wetlands Program)</td><td>2015</td><td>Every 4 years</td><td>Distance from best case</td><td>1- | (Catchment value-BCS)/(BCS-WCS) |</td><td>Pre-cleared</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td>Riparian extent</td><td>13%</td><td>20%</td><td></td><td>% of steambank</td><td>DSITIA layer</td><td>2015</td><td>Every 4 years</td><td>Distance from best case</td><td>1- | (Catchment value-BCS)/(BCS-WCS) |</td><td>Pre-cleared</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td>Estuarine Habitat</td><td>Estuarine wetland extent</td><td>13%</td><td>0%</td><td></td><td>% of pre-cleared</td><td>RE Mapping (Qld Gov Wetlands Program)</td><td>2015</td><td>Every 4 years</td><td>Distance from best case</td><td>1- | (Catchment value-BCS)/(BCS-WCS) |</td><td>Pre-cleared</td></tr>
<tr><td></td><td>Pollutant load</td><td>20%</td><td>20%</td><td></td><td>Catchment Pollutant Load</td><td>Sediment load in runoff</td><td>7%</td><td>7%</td><td></td><td>Tonnes/year/ha</td><td>SOURCE model</td><td>2015</td><td>Annually</td><td>Distance from best case</td><td>1- | (Catchment value-BCS)/(BCS-WCS) |</td><td>90th perentile of all sub-catchments in SEQ over 8 years (including 2011)</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td>Nitrogen load in runoff</td><td>7%</td><td>7%</td><td></td><td>Tonnes/year/ha</td><td>SOURCE model</td><td>2015</td><td>Annually</td><td>Distance from best case</td><td>1- | (Catchment value-BCS)/(BCS-WCS) |</td><td>90th perentile of all sub-catchments in SEQ over 8 years (including 2011)</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td>Phosphorus load in runoff</td><td>7%</td><td>7%</td><td></td><td>Tonnes/year/ha</td><td>SOURCE model</td><td>2015</td><td>Annually</td><td>Distance from best case</td><td>1- | (Catchment value-BCS)/(BCS-WCS) |</td><td>90th perentile of all sub-catchments in SEQ over 8 years (including 2011)</td></tr>
<tr><td></td><td>Estuarine Water Quality</td><td>20%</td><td>0%</td><td></td><td>Estuarine Water Quality</td><td>Turbidity</td><td>4%</td><td>0%</td><td></td><td>NTU</td><td>Tuflow models (RWQM) & EHMP estuare/marine program</td><td>2000</td><td>Annually</td><td>Distance from WQO</td><td>Sum | ((annual median - guideline)/(WCS-guideline))/area |</td><td>Table 10 - Qld Water Quality Guidelines</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td>Dissolved Oxygen</td><td>4%</td><td>0%</td><td></td><td>% Sat</td><td>Tuflow models (RWQM) & EHMP estuare/marine program</td><td>2000</td><td>Annually</td><td>Distance from WQO</td><td>1-Sum | ((lower guideline - annual median)/(lower guidleline-lower WCS))/area |</td><td>Table 10 - Qld Water Quality Guidelines</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td>TN</td><td>4%</td><td>0%</td><td></td><td>mg/L</td><td>Tuflow models (RWQM) & EHMP estuare/marine program</td><td>2000</td><td>Annually</td><td>Distance from WQO</td><td>Sum | ((annual median - guideline)/(WCS-guideline))/area |</td><td>Table 10 - Qld Water Quality Guidelines</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td>TP</td><td>4%</td><td>0%</td><td></td><td>mg/L</td><td>Tuflow models (RWQM) & EHMP estuare/marine program</td><td>2000</td><td>Annually</td><td>Distance from WQO</td><td>Sum | ((annual median - guideline)/(WCS-guideline))/area |</td><td>Table 10 - Qld Water Quality Guidelines</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td>Chl-a</td><td>4%</td><td>0%</td><td></td><td>mg/L</td><td>Tuflow models (RWQM) & EHMP estuare/marine program</td><td>2000</td><td>Annually</td><td>Distance from WQO</td><td>Sum | ((annual median - guideline)/(WCS-guideline))/area |</td><td>Table 10 - Qld Water Quality Guidelines</td></tr>
<tr><td></td><td>Freshwater communities & processes</td><td>20%</td><td>40%</td><td></td><td>PhysChem</td><td>pH</td><td>1%</td><td>3%</td><td></td><td>[H+]</td><td>Stream Health model (QUT) & EHMP freshwater program</td><td>2002</td><td>Annually</td><td>Distance from benchmark</td><td>1- | (Index value at site-guideline)/(WCS - guideline) |</td><td>Table 12 - Benchmarks and WCS values used for Freshwater</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td>Elec Conductivity</td><td>1%</td><td>3%</td><td></td><td>µS cm-1</td><td>Stream Health model (QUT) & EHMP freshwater program</td><td>2002</td><td>Annually</td><td>Distance from benchmark</td><td>1- | (Index value at site-guideline)/(WCS - guideline) |</td><td>Table 12 - Benchmarks and WCS values used for Freshwater</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td>Ambient water temp</td><td>1%</td><td>3%</td><td></td><td>°C</td><td>Stream Health model (QUT) & EHMP freshwater program</td><td>2002</td><td>Annually</td><td>Distance from benchmark</td><td>1- | (Index value at site-guideline)/(WCS - guideline) |</td><td>Table 12 - Benchmarks and WCS values used for Freshwater</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td>Ambient DO</td><td>1%</td><td>3%</td><td></td><td>% saturation</td><td>Stream Health model (QUT) & EHMP freshwater program</td><td>2002</td><td>Annually</td><td>Distance from benchmark</td><td>1- | (Index value at site-guideline)/(WCS - guideline) |</td><td>Table 12 - Benchmarks and WCS values used for Freshwater</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td>Ecosystem Processes</td><td>GPP</td><td>3%</td><td>5%</td><td></td><td>g C m-2 day-1</td><td>Stream Health model (QUT) & EHMP freshwater program</td><td>2002</td><td>Annually</td><td>Distance from benchmark</td><td>1- | (Index value at site-guideline)/(WCS - guideline) |</td><td>Table 12 - Benchmarks and WCS values used for Freshwater</td></tr>
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<tr><td></td><td></td><td></td><td></td><td></td><td>Fish</td><td>PONSE</td><td>2%</td><td>3%</td><td></td><td>%</td><td>Stream Health model (QUT) & EHMP freshwater program</td><td>2002</td><td>Annually</td><td>Distance from benchmark</td><td>1- | (Index value at site-guideline)/(WCS - guideline) |</td><td>Table 12 - Benchmarks and WCS values used for Freshwater</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td>Ratio = 0/E</td><td>2%</td><td>3%</td><td></td><td>Ratio (number)</td><td>Stream Health model (QUT) & EHMP freshwater program</td><td>2002</td><td>Annually</td><td>Distance from benchmark</td><td>1- | (Index value at site-guideline)/(WCS - guideline) |</td><td>Table 12 - Benchmarks and WCS values used for Freshwater</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td>Prop. Alien Fish</td><td>2%</td><td>3%</td><td></td><td>%</td><td>Stream Health model (QUT) & EHMP freshwater program</td><td>2002</td><td>Annually</td><td>Distance from benchmark</td><td>1- | (Index value at site-guideline)/(WCS - guideline) |</td><td>Table 12 - Benchmarks and WCS values used for Freshwater</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td>Bugs</td><td>Number Taxa</td><td>3%</td><td>5%</td><td></td><td>Number</td><td>Stream Health model (QUT) & EHMP freshwater program</td><td>2002</td><td>Annually</td><td>Distance from benchmark</td><td>1- | (Index value at site-guideline)/(WCS - guideline) |</td><td>Table 12 - Benchmarks and WCS values used for Freshwater</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td>PET Richness</td><td>3%</td><td>5%</td><td></td><td>Number</td><td>Stream Health model (QUT) & EHMP freshwater program</td><td>2002</td><td>Annually</td><td>Distance from benchmark</td><td>1- | (Index value at site-guideline)/(WCS - guideline) |</td><td>Table 12 - Benchmarks and WCS values used for Freshwater</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td>SIGNAL</td><td>3%</td><td>5%</td><td></td><td>Number</td><td>Stream Health model (QUT) & EHMP freshwater program</td><td>2002</td><td>Annually</td><td>Distance from benchmark</td><td>1- | (Index value at site-guideline)/(WCS - guideline) |</td><td>Table 12 - Benchmarks and WCS values used for Freshwater</td></tr>
</table>

Report Card Element	Components	% of score: Coastal catchments	% of score: Western catchments	% of score: Bay	Index	Indicator/s	% of score: Coastal catchments	% of score: Western catchments	% of score: Bays	Unit	Data source	Start year	Frequency assessed	Standardisation method	Standardisation calculation	Benchmarks, BCS & WCS
Environmental Condition Grade - **Bays**	Habitat			50%	Bay Habitat	Seagrass extent			13%	Extent of SG/2004 SG extent	DES layer	2015	Every 4 years	Distance from benchmark	1-(seagrass ratio- BCS)/(BCS - WCS)	BCS = 2004 Extent
						Seagrass depth range			13%	m	EHMP	1993	Annually	Distance from benchmark	1-(value-guideline)(WCS-Guideline)	WCS = min value 1999-2014
						Estuarine wetland extent			13%	% of pre-cleared	RE Mapping (Qld Gov Wetlands Program)	2015	Every 4 years	Distance from best case	1-| (Catchment value-BCS)/(BCS-WCS) |	Pre-cleared
						Mud Content			13%	% mud	EHMP	2015	Every 4 years	Distance from worst case	1-(Average % change from WCS)/100	WCS = 2015 extent
	Water quality			50%	Bay Water Quality	Turbidity			13%	NTU	Tuflow models (RWQM) & EHMP estuare/marine program	2000	Annually	Distance from WQO	Sum | ((annual median - guideline)/(WCS-guideline))/area |	Table 10 - Qld Water Quality Guidelines
						TN			13%	mg/L	Tuflow models (RWQM) & EHMP estuare/marine program	2000	Annually	Distance from WQO	Sum | ((annual median - guideline)/(WCS-guideline))/area |	Table 10 - Qld Water Quality Guidelines
						TP			13%	mg/L	Tuflow models (RWQM) & EHMP estuare/marine program	2000	Annually	Distance from WQO	Sum | ((annual median - guideline)/(WCS-guideline))/area |	Table 10 - Qld Water Quality Guidelines
						Chl-a			13%	mg/L	Tuflow models (RWQM) & EHMP estuare/marine program	2000	Annually	Distance from WQO	Sum | ((annual median - guideline)/(WCS-guideline))/area |	Table 10 - Qld Water Quality Guidelines

Report Card Element	Component	% of score: Drinking water catchments	% of score: Non-drinking water catchments		Index	Indicator/s	% of score: Drinking water catchments	% of score: Non-drinking water catchments		Unit	Data source	Year commenced	Frequency assessed	Standardisation method	Standardisation calculation	Benchmarks, BCS & WCS
Waterways Benefits Rating	Social benefit to community	60%	75%		Satisfaction with experience of local waterways	Overall satisfaction	20%	19%		% of local residents satisfied overall	HLW Community Survey (EHMP - QUT)	2015	Annually	No standardisation	NA	NA
					Usability and accessibility	Overall usability	10%	9%		% of local residents satisfied with usability	HLW Community Survey (EHMP - QUT)	2015	Annually	No standardisation	NA	NA
						Overall accessibility	10%	9%		% of local residents satisfied with accessibility	HLW Community Survey (EHMP - QUT)	2015	Annually	No standardisation	NA	NA
					Personal benefits	Social interaction	7%	6%		% of local residents who gain social benefit	HLW Community Survey (EHMP - QUT)	2017	Annually	No standardisation	NA	NA
						Emotional benefit	7%	6%		% of local residents who gain emotional benefit	HLW Community Survey (EHMP - QUT)	2017	Annually	No standardisation	NA	NA
						Rest and relaxation	7%	6%		% of local residents who gain relaxation benefit	HLW Community Survey (EHMP - QUT)	2017	Annually	No standardisation	NA	NA
					Connection with waterways	Personal connection to nature	10%	9%		% of local residents who report connection	HLW Community Survey (EHMP - QUT)	2015	Annually	No standardisation	NA	NA
						Motivation to use and	10%	9%		% of local	HLW Community Survey	2015	Annually	No standardisation	NA	NA
	Economic benefit to community	40%	25%		Drinking water treatment	Sludge	20%	0%		kg/mL	Seqwater	2015	Annually	Distance from best case	1-| (Sludge Produced - BCS)/(WCS-BCS) |	BCS = 0 kg/ML ; WCS = 478 kg/ML
					Recreational value of local waterways	Recreational value	20%	25%		$/person	HLW Community Survey (EHMP - QUT)	2015	Annually	Distance from best case	1-| (Catchment value-BCS)/(BCS-WCS) |	BCS = $3000/person; WCS = $0

8.2 Appendix (2) – TuFlow model

Bay model

The Moreton Bay TUFLOW FV model is a finite volume model that responds to tidal, atmospheric and bed roughness forcing to simulate water levels, current speed and direction, temperature, salinity and suspended sediment in three spatial dimensions. It is a state-of-the-art model that is parallelised and runs on both workstation and supercomputing facilities. The model includes almost 9,000 mesh elements and outside Moreton Bay, covers the entire South East Queensland coastline from Noosa to the Gold Coast (Figure A1). It also includes representations of all major estuaries that drain to Moreton Bay.

The Moreton Bay model is linked to the Source catchment model of South East Queensland so that all surface runoff and wastewater treatment plant flows and loads are delivered to the Bay model. This linkage is achieved via a combination of direct connections to *Source* and flows and loads modelled from the detailed estuarine models (see below).

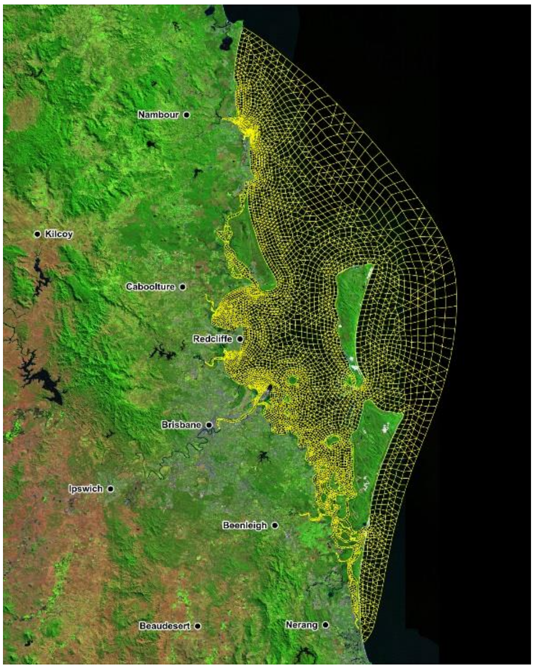

Figure A1: Model extent depicting mesh elements for South East Queensland.

The Moreton Bay model has been extensively calibrated to dedicated current and water level measurements, and an example of a current calibration is presented (Figure A2). Measurements are blue lines and model predictions are red.

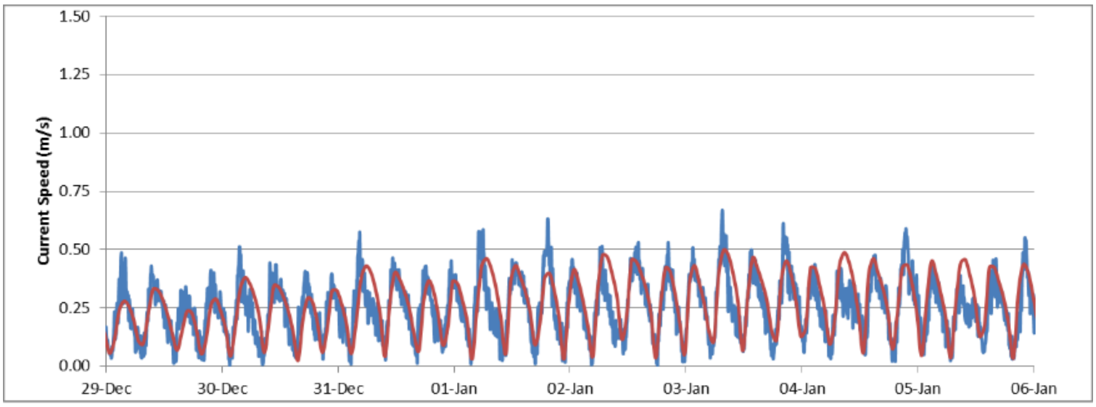

Figure A2: Modelled and measured current speeds at a location in Moreton Bay.

The Aquatic EcoDynamics (AED) water quality model was linked to TUFLOW FV and was set to simulate a range of environmental parameters, including dissolved oxygen, nutrients and algae. The processes captured included catchment delivery of pollutants, point source discharges, atmospheric exchange and sediment fluxes. Model predictions are also validated with measurements (primarily EHMP data) to ensure adequate model performance.

Estuary models

Intimately linked with the Moreton Bay TUFLOW FV – AED model, are the high resolution estuarine models. The models are fully three dimensional and simulate water levels, current speed and direction, temperature, salinity and suspended sediment (TUFLOW FV) and water quality processes including dissolved oxygen, nutrients and algae (AED). High resolution models of the Logan, Albert, Brisbane, Bremer, Pine, Caboolture, Mooloolah, Maroochy estuaries and Pumicestone Passage have been built and calibrated, and the Brisbane River model mesh is presented as an example (Figure A3) (note, Noosa Estuary model being developed in 2021).

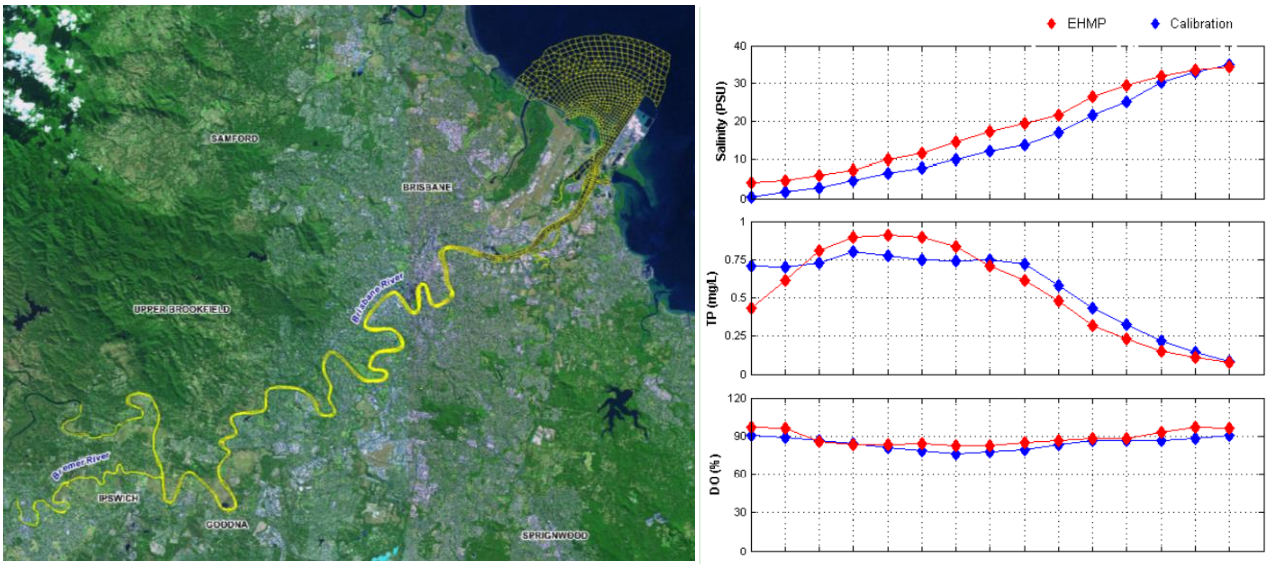

Figure A3: Mesh layout for the high resolution Brisbane River Estuary model and a comparison between model predictions and EHMP data for the Brisbane River Estuary.

All estuarine models included the influence of atmospheric exchange, tidal forcing, bed roughness, sediment fluxes, catchment inflows (as predicted by the Source model) and extractions (where appropriate), point source discharges (such as wastewater treatment plant discharges) and localised diffuse pollutant loads. The fate and transport of these loads was simulated by TUFLOW FV and AED, and model predictions were compared against EHMP data.

8.3 Appendix (3) – The South East Queensland Source Model

South East Queensland catchments have been modelled extensively in the past using the Environmental Management Support System (EMSS) modelling framework (Cuddy *et al*. 2004) which was a precursor to the Source modelling framework (Argent *et al.*, 2008; eWater CRC, 2009) and is now being widely used throughout Australia.

The Source modelling framework (Argent *et al* 2008) provides the ability to simulate current catchment characteristics and hydrological responses to rainfall, in addition to evaluating the impacts of land use change and the implementation of best management practices on pollutant loads. The Source framework is not a single model, but a framework in which groups of different models can be selected and linked such that the most suitable model to describe a particular aspect of the catchment can be used (Figure A4).

Model construction

The underlying data used to construct a catchment model within Source include:

- A digital elevation model (DEM) for sub-catchment delineation.
- A land use map.
- Climate data (daily rainfall and evaporation data).
- Hydrologic data for model calibration (if available).
- Observed flow data for calibration including any point source, storages and extractions.
- Observed water quality data and/or Event Mean Concentration (EMC) and Dry Weather Concentration (DWC) data for pollutant export model parameterisation and calibration.

Model specification

The development of the new South East Queensland Source model retained a similar sub catchment definition to previous modelling however the climate data, hydrologic calibration and model parameterisation have all been significantly updated to provide an up to date catchment model for the region. Key features of the model include:

- Daily runoff and pollutant load from 175 catchments in South East Queensland.
- 31 years of climate data extracted from the SILO database.
- Daily potential evapotranspiration data (PET) values from the SILO database,
- Land use based Queensland Land use Mapping Project (QLUMP) data,
- No point sources. Point sources were not included in the catchment model, but were incorporated in the linked Receiving Water Quality Model (RWQM),
- Four major water storages were modelled with calibrated outlet configurations to better represent the storage dynamics of the key storages at Wivenhoe, Somerset, North Pine and Hinze dams, plus water extractions at Mt Crosby weir, North Pine Dam and Hinze dam based on weekly water consumption figures published by the Queensland Water Commission,
- Pollutant concentrations were derived for event and dry weather parameters representing an analysis of the event-based monitoring program being run concurrently within South East Queensland by the state government, and
- Recalibration of the hydrologic parameters for the region using the Parameter Estimation Tool (PEST).

Following the model construction phase, calibration and verification is required to ensure the constructed numerical model adequately represents the study area.

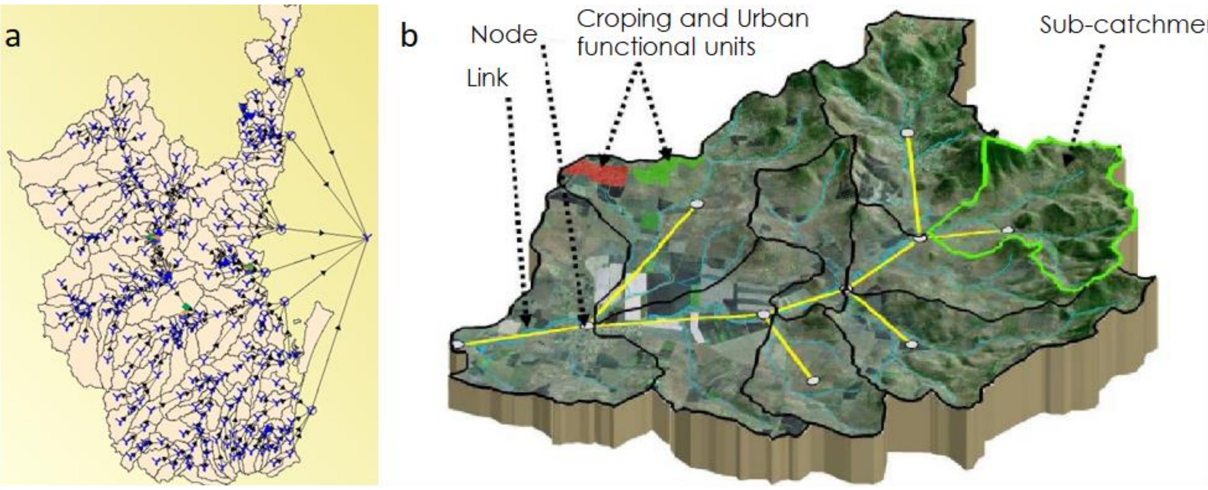

Figure A4: a Schematic of the South East Queensland Source catchment model showing, sub-catchments, nodes and links. b Conceptual diagram of the Source Catchment model (courtesy of eWater).

8.4 Appendix (4) – Calculating distance from guideline values

The estuarine and bay water quality indicators (see sections 5.1.3) are calculated based on an area-weighted 'distance from guideline' value. The 'distance from guideline' approach is used because it can most sensitively identify changes (improvements or declines) in water quality, regardless of compliance status. This enhances the indicators sensitivity to track changes in response to management intervention.

Guideline values

The Queensland Water Quality guideline values used are presented in

Table **11** (see South East Queensland Basins also https://www.ehp.qld.gov.au/water/policy/seq-moretonbay.html). The guidelines were developed and scheduled in 2010 by Queensland Government. They were derived from empirical data from minimally-disturbed reference sites and are typically defined as the 20th and/or 80th percentile. The guideline values are currently under review by the Queensland Government.

Table 11: Queensland Water Quality guideline and WCS (worst case scenario) for all water types in SEQ for five parameters monitored in the program (turbidity (NTU), dissolved oxygen (%sat), total N (mg/L), total P (mg/L), chlorophyll a (ug/L)).

WATER TYPE		Turbidity		Diss Ox		Total N		Total P		Chl-a	
		Guideline	WCS (0.9)	Guideline	WCS (0.9)	Guideline	WCS (0.9)	Guideline	WCS (0.9)	Guideline	WCS (0.9)
SEQ estuaries (exc. Noosa)	Enclosed coastal	6	13	90	82.1	0.2	0.5	0.02	0.1	2	5.4
	Mid estuary	8	82	85	57.8	0.3	1.3	0.025	0.5	4	12.1
	Upper estuary	25	89	80	54.1	0.45	1.5	0.03	0.5	8	18.3
Noosa River estuary	Enclosed coastal	4	5	90	90.9	0.24	0.29	0.015	0.018	1.8	2
	Mid estuary	8	24	85	87.5	0.38	0.51	0.016	0.02	2.5	2.9
	Upper estuary	22	56	85	84.4	0.75	0.77	0.02	0.025	5	5.3
SEQ bays	Pum Pass Outer	6	13	90	88	0.22	0.35	0.025	0.03	2.6	4.8
	Pum Pass Central	10	20	95	82	0.33	0.48	0.023	0.03	4	6
	Western Bays	6	16	95	92	0.2	0.32	0.03	0.08	1.6	6.5
	Central Bay	5	7	95	94	0.16	0.21	0.02	0.033	1	3
	Eastern Bay	1	5	95	95	0.16	0.18	0.016	0.02	1	2
	Southern Moreton Bay	7	25	95	90.9	0.2	0.32	0.024	0.055	2	5
	Broadwater	6	12	90	90	0.19	0.28	0.022	0.03	2.5	3.5

Worst Case Scenario (WSC) values

Worst case scenario values (**Table 11**) were derived using 15 years of EHMP water quality data from the estuarine and marine sites (2000-2015). They were defined as the 10th and/or 90th percentile of data for all of the sites for associated water types.

Water type boundaries

The spatial boundary of each water type is defined by the Queensland Government as part of the Environmental Values and Water Quality Objectives scheduling (latest 2010). Maps and associated documents can be found on their website: https://www.ehp.qld.gov.au/water/policy/seq-moretonbay.html. This framework was used to allocate different water types to the Report Card estuaries and bay zones.

Distance calculations

TUFLOW models (Appendix 8.2) are used to predict annual medians (for model cells) throughout each estuarine and bay reporting zone. Note: each estuary is divided into multiple cells (e.g. Brisbane estuary has approximately 10,000 cells) and predicted medians are resolved for each cell. To calculate water quality indicator scores the predicted annual medians for each cell are converted to a 'distance from guideline' value using the following equation:

$$Distance\ ratio = \frac{(Annual\ median\ at\ model\ cell) - Guideline}{(WCS - Guideline)}$$

If annual medians fall below guideline levels (i.e. they are compliant) then they are assigned a distance value of '0'. If they fall above WCS levels, they are assigned a distance value of '1'.

Except DO,

To calculate DO indicator scores the predicted annual medians for each cell are converted to a 'distance from guideline' value using the following equation:

$$Distance\ ratio = \frac{Lower\ guideline - \ (Annual\ median\ at\ model\ cell)}{(Lower\ guideline - lower\ WCS)}$$

Were if annual medians fall between the upper and lower guideline levels (i.e. they are frifcompliant) then they are assigned a distance value of '0'. If they fall above the upper WCS levels or below the lower WCS, they are assigned a distance value of '1'.

Score calculations

Water quality indicator scores are then calculated by area weighting the distance values and summing the values for each reporting zone using the following equation:

$$Indicator\ score\ = 1 - \ \Sigma \left|\frac{Distance\ ratio}{Area}\right|$$

8.5 Appendix (5) – Stream Health Model

The Stream Health Model is a suite of statistical models developed to predict annual freshwater communities and processes scores for each of the four freshwater indices at 129 sites across South East Queensland – the four indices are:

1. Physical and chemical.
2. Ecosystem processes.
3. Bugs.
4. Fish.

The four index models were developed based on an approach used by Sheldon et al. (2012) and the methodology is described in Peterson (2014). Conditional inference forest (CIF) models were fit using all existing freshwater EHMP data plus 49 additional predictor variables, derived from land use, vegetation cover and rainfall datasets (see Petersen (2014) for full list of predictor variables and their importance to each CIF model). Each reporting year predictor variables are updated with the latest available datasets.

In general, all four index model predictions captured the trend in measured indices (Table 13), with most score over-predicted by 0-10%. This version of the Stream Health Model (developed in 2014/2015) is viewed as an interim step to develop a predictive model that can be used to estimate ecosystem health throughout the SEQ freshwater stream network in future years.

Table 12: The squared Pearson's correlation (predictive r^2) and root mean-square-prediction error (RMSPE) for the observed and predicted scores from the four models.

Index Model	Predictive r^2	RMSPE
Fish	0.71	0.11
Bugs	0.65	0.12
Ecosystem processes	0.54	0.15
Physical/chemical	0.67	0.10

8.6 Appendix (6) – Calculating scores for the freshwater communities and processes indices using the traditional EHMP method

Calculation of standardised scores for all indicators (except temperature and DO)

The calculation of standardised scores for the freshwater bio-physical indices involves the use of a static table of ecosystem health guidelines and worst case scenario (WCS) values. Guideline values were derived from either the 20^{th} and/or 80^{th} percentile of empirical data for minimally-disturbed reference sites as part of the DIBM3 project or from theoretical limits. These values indicate the expected values of each index for streams in "healthy "condition. Worst case scenario values were derived from either the 10^{th} and/or 90^{th} percentile of data for all sites and assessment periods associated with the freshwater EHMP, or theoretical limits of the index. Worst Case Scenario (WCS) values indicate the expected value of each index for streams in the unhealthiest condition.

Both guideline and WCS values were derived independently for different groups of streams with similar physical conditions (i.e. stream classes) so that standardised scores account for the majority of natural spatial variation in the values of each index. Stream classes were identified using clustering analysis of assessment sites based on elevation, stream channel gradient, stream order and mean annual rainfall and were checked against the results of similar analyses based on fish catch data. Four different stream classes were identified (Upland, Lowland, Coastal, and Tannin-stained), and each Freshwater site is allocated to one of those classes. Index values for each site are only compared to guideline and WCS values for the same stream class.

Calculation of each standardised score involves an initial comparison of each index value against the corresponding guideline and WCS value (**Table 13**). Index values satisfying the criteria specified are awarded a score of 1.0 whilst and "worse" than/equal to the WCS are awarded a score of 0.0. The score for all other values is calculated using the equation:

$$Score = 1 - \left|\frac{(Index\ value\ at\ a\ site) - \ Guideline)}{(WCS - Guideline)}\right|$$

Two examples of the calculation of standardised scores follow:

Conductivity (lowland stream)

Indicator value = 1000 μS cm-1
Guideline value = 400 μS cm-1
WCS = 1870 μS cm^{-1}

$$1.0 - \left|\frac{(1000 - \ 400)}{(1870 - 400)}\right| \equiv \ 1.0 - \ \left|\frac{(600)}{(1470)}\right| \equiv \ 1.0 - |0.41| = 0.59$$

Number of taxa (upland stream)

Indicator value = 17 taxa
Guideline value = 22 taxa
WCS = 0 taxa

$$1.0 - \ \left|\frac{(17 - 22)}{(0 - 22)}\right| \equiv \ 1.0 - \ \left|\frac{(-5)}{(-22)}\right| \equiv \ 1.0 - |0.23| = 0.77$$

Table 13: The benchmarks and WCS values used for all indicators of the freshwater communities and processes component.

Index	Indicator	Upland		Lowland or coastal		Tannin-stained		Operand	Unit
		Guideline	**WCS**	**Guideline**	**WCS**	**Guideline**	**WCS**		
PhysChem									
	pH (min)	6.5	4.5	6.5	4.5	5	3	≥	$[H^+]$
	pH (max)	8.5	10.5	8.5	10.5	8.5	10.5	≤	$[H^+]$
	Conductivity	400	1041	400	1870	400	1870	≤	µS cm^{-1}
	Temp (max)	18	NA	22	NA	22	NA	≤	°C
	Temp (range)	4	NA	4	NA	4	NA	≤	°C
	DO (min)	30	NA	20	NA	20	NA	≥	% saturation
	DO (range)	30	NA	50	NA	50	NA	≤	% saturation
Ecosystem Processes									
	GPP	0.25	0.8	0.5	1.3	0.5	1.3	≤	g C m^{-2} day^{-1}
	R24	0.15	0.7	0.35	1.2	0.35	1.2	≤	g C m^{-2} day^{-1}
Fish									
	PONSE	100	0	100	0	100	0	≥	%
	Ratio = O/E	1	0	1	0	1	0	≥	Ratio (number)
	Prop. Alien Fish	0	100	0	100	0	100	=	%
Bugs									
	Number Taxa	22	0	22	0	11	0	≥	Number
	PET Richness	5	0	4	0	3	0	≥	Number

Calculation of scores for the indicators temperature and DO

The temperature and DO scores uses pass/fail thresholds (**Table 14**) in relation to guideline values (**Table 13**). This method places more emphasis on whether or not temperature range and minimal DO scores passes ecosystem health guideline criteria (rather than temperature maximum and DO range scores). Failure in either of these indices represents more deleterious condition than failure in terms of the other two indicators in the Freshwater PhysChem index (pH and conductivity). A standardised score is not calculated, instead one of the four indicator score options presented in **Table 14** are assigned (use guideline values presented in (**Table 13** and **Table 14**)). Note this score is not standardised as per the other indicators.

Two examples of calculating scores follows:

1. **Temperature (upland)**

   Indicator values = 17 to 19 °C
   Guideline Temperature MAX for upland = 18 °C
   Guideline Temperature Range for upland = 4 °C

   Temp Max value > guideline = 'Fail'
   Temp Range value < guideline = 'Pass'

   Therefore, the indicator score is **0.8**

2. **DO (tanin-stained)**

   Indicator values = 19 to 21 °C
   Guideline Temperature MAX for upland = 22 °C
   Guideline Temperature Range for upland = 4 °C

   Temp Max value > guideline = 'Pass'
   Temp Range value < guideline = 'Pass'

   Therefore, the indicator score is **1.0**

Table 14: Scores for water temperature and dissolved oxygen based on pass/fail criteria.

Water temperature				Dissolved oxygen			
		Temp. (maximum)				**DO (minimum)**	
		Pass	*Fail*			*Pass*	*Fail*
Temp (range)	*Pass*	1.0	0.8	**DO (range)**	*Pass*	1.0	0.3
	Fail	0.5	0.0		*Fail*	0.8	0.0

Calculating the index scores:

The scores for each indicator are averaged to calculate the four freshwater indices (as listed in **Table 13**).

1. Freshwater Fish index (average of three indicators).
2. Freshwater Bugs index (average of two indicators).
3. Freshwater Ecosystem Processes index (average of two indicators).
4. Freshwater PhysChem index (average of four indicators).

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