Department of Climate Change, Energy, the Environment and Water

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Estuary Report Card 2024-2025
Brisbane Water

July 2025

Acknowledgement of Country

The Department of Climate Change, Energy, the Environment and Water acknowledges that it stands on Aboriginal land. We acknowledge the Traditional Custodians of the land and we show our respect for Elders past and present through thoughtful and collaborative approaches to our work, seeking to demonstrate our ongoing commitment to providing places in which Aboriginal people are included socially, culturally and economically.

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Estuary Report Card 2024-2025 Brisbane Water

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Cover photo: View of Brisbane Water from Gosford Boat Ramp, Jezebel Sherborne (DCCEEW)

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Contents

1 Introduction

1.1 Background

The Central Coast Council (CCC) contracted the Estuaries and Catchments Team of the Department of Climate Change, Energy, the Environment and Water (DCCEEW) to monitor ecological health in Brisbane Water over the 2024-2025 financial year and provide Council with an estuary report card. The monitoring program and estuary report card for Brisbane Water commenced in 2018 as a 6-monthly program and was expanded to a year-round program in 2023-2024. CCC recognises that long-term monitoring programs are essential for tracking the ecological health of an estuary and to help identify potential areas of concern that may require additional management.

1.1.1 Location

Brisbane Water is a wave dominated barrier estuary located on the Central Coast of New South Wales. The waterway's origin is to the south-east of Gosford and is connected to the Tasman Sea 18 kilometres to the south at Broken Bay. Brisbane Water falls within CCC Local Government Area (LGA) and includes Woy Woy, meaning 'much water' or 'big lagoon' in the language of the Guringgai tribe, a likely reference to Brisbane Water.

1.1.2 Program outline and scope

CCC contracted the Estuaries and Catchments Team of DCCEEW to monitor ecological health in Brisbane Water over the 2024-2025 financial year and provide Council with an estuary report card. The Brisbane Water Water Quality Monitoring Program was designed by DCCEEW following standardised sampling, data analysis and reporting protocols outlined in the NSW Natural Resources Monitoring, Evaluation and Reporting (MER) Program for assessing estuary health (OEH, 2016). The project monitored water quality at nine zones from July 2024 – June 2025 and conducted an annual seagrass depth range survey at five sites in April 2025.

1.1.3 Aims and objectives of the program

The aim of the Brisbane Water Water Quality Monitoring Program is to assess the ecological health of Brisbane Water using methods that are scientifically valid and standardised. The objectives are to:

- Track change in condition through report card grading and continue to build a long-term dataset to support management decisions by CCC
- Provide CCC and the community with an annual report on estuary health

2 Methodology

2.1 Monitoring zones and frequency

The spatial scale of interest for the state-wide MER program is whole-of-estuary condition. As such, the state-wide program targets the assumed chlorophyll-a and turbidity maxima (OEH 2016), which is the central basin in lakes. To ensure representative spatial coverage, the estuary is divided into zones typically 500-700 m in diameter in lakes (OEH 2016). However, localised sampling programs such as Council MER programs, often need to consider condition at spatial scales that are smaller than the whole estuary. Localised issues may also require assessment of indicators in areas other than the assumed chlorophyll-a and turbidity maxima. In these instances, sampling zones may be smaller in size and additional zones may be added, in tributaries for example (OEH 2016).

Sampling zones were established in Brisbane Water and its tributaries (Figure 1) based on sampling protocols outlined for the MER estuary health assessments (OEH 2016), giving consideration to:

- estuary type, size and morphology,
- access and WHS issues,
- location of established or historical monitoring sites,
- location of tributaries or other major inputs,
- local knowledge of current water quality issues.

Over a 12-month period, monthly water quality sampling was carried out at nine zones throughout the study area; three zones in the main basin of Brisbane Water, three zones in tributary creeks (Erina, Narara and Woy Woy Creeks), one zone each at the mouth of Kincumber Creek, in Booker Bay and Cockle Bay (Figure 1). Sampling at this frequency allows both monthly and seasonal variability in water quality to be assessed. Seagrass depth range was surveyed at five sites SD1-SD5 in April 2025 (Figure 1). Two sites are monitored in the basins (SDR2, SDR3) and three other sites are in the receiving waters of Erina Creek (SDR1) , Woy Woy Creek (SDR4), and Kincumber Creek (SD5). Note that the location of the SDR2, SDR3, and SDR4 sites was changed in 2022. The revised sites are more suitable as they are less modified and are better aligned with existing Brisbane Water Seagrass Health sites monitored by Council.

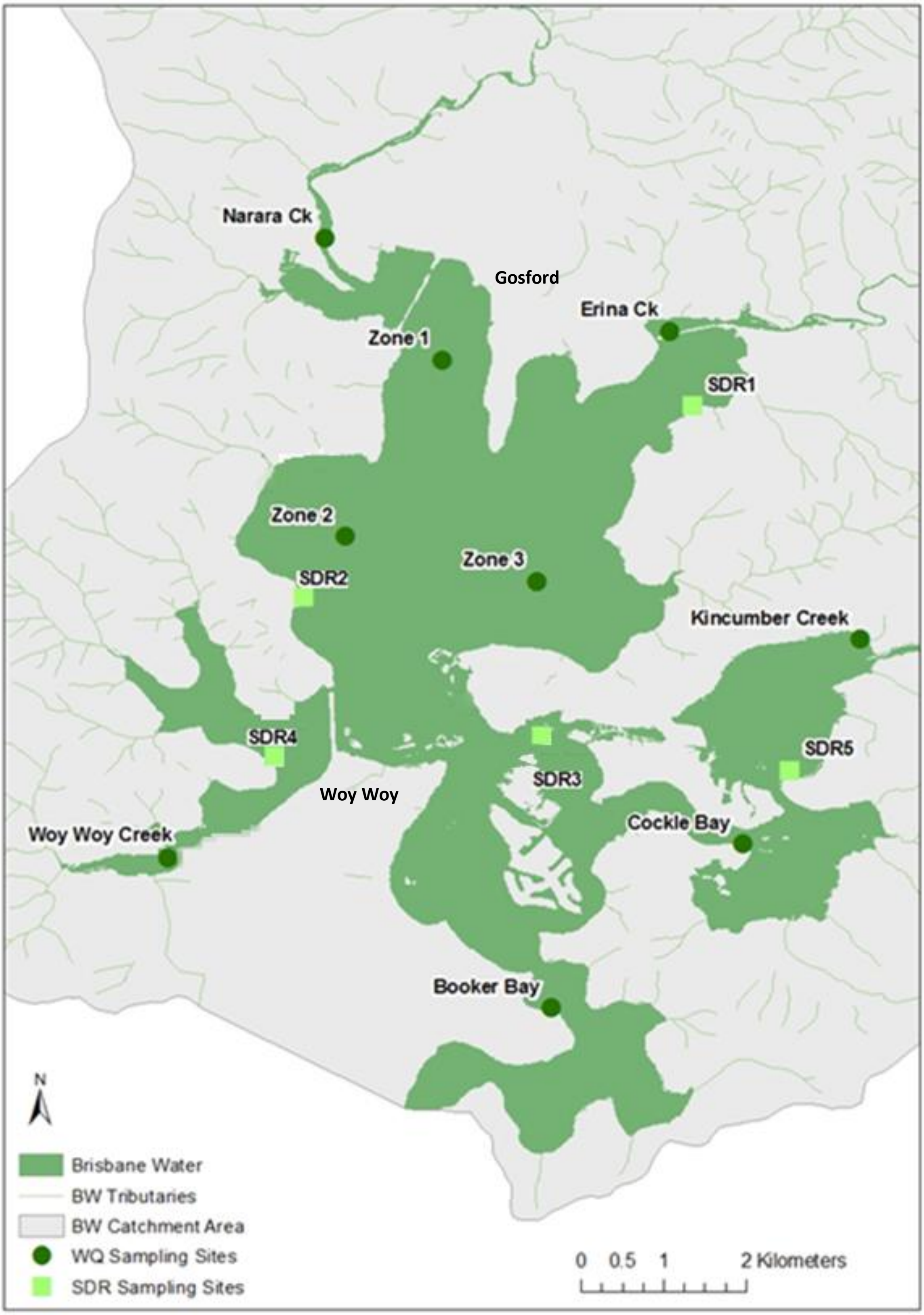

Figure 1 Sampling zones in Brisbane Water for the 2024-2025 program showing water quality (WQ) monitoring zones (circles) and seagrass depth range (SDR) sites (squares). The green circles indicate the centre of the monitoring zone which vary in size depending on the location (larger zones in the main basin, smaller zones in tributaries and nearshore areas).

2.1.1 Sampling methods

Water quality

All sampling was conducted from a 4.5 m research vessel. Using a Xylem EXO-2 multiparameter water quality sonde (WQ sonde) lowered to 0.3-0.5 m below surface, physicochemical water quality parameters were recorded, including:

- turbidity
- temperature
- salinity
- pH
- electrical conductivity and specific conductivity
- chlorophyll-a (by in-situ fluorometry)
- dissolved oxygen
- fluorescent Dissolved Organic Matter (fDOM)

Data was logged on the handheld device of the WQ sonde at a maximum depth of 0.5 m at one second intervals for a total of three minutes at each site. Meanwhile, the vessel used for sampling freely drifted, following the method outlined in MER sampling protocols (OEH 2016). Water quality data was downloaded from the device upon return to the office and laboratory.

A clean bucket was filled with approximately 10 litres of estuary water, collected from within 0.5 m of the surface using an integrated sampling pole, while drifting for 3 minutes in the sampling zone. The water in the bucket was used to collect samples for the analysis of chlorophyll-a, total suspended solids (TSS) and a suite of nutrients (total nitrogen, total dissolved nitrogen, ammonium, nitrate/nitrite, total phosphorous, total dissolved phosphorous and free reactive phosphorous). Total nutrient samples were directly transferred from the bucket to 30 ml vials using a clean 50 ml syringe barrel. All other nutrient samples were filtered immediately with 0.45 µm syringe-filters into two 30 ml vials. Nutrient samples were kept cool and frozen as soon as possible, in a portable freezer unit in the DCCEEW vehicle or, upon return to the laboratory.

Plastic bottles (111 ml) were filled with water from the bucket for chlorophyll-a analyses, taking care to exclude air bubbles. Chlorophyll-a samples were kept cool in an esky away from light until returning to the laboratory. One litre plastic bottles were filled with water from the bucket for TSS analysis, after mixing the water with the bottle to resuspend any solids. TSS samples were kept cool in an esky and stored in a cold room at 1-4 °C until analysis.

Seagrass depth range

Seagrass depth range (SDR) was calculated from the minimum and maximum water depth for seagrass cover at the site. Water depth was measured at the shallow limit and deep limit of seagrass *Zostera capricorni* cover across three transects at each monitoring site. One transect is a routine transect used in the survey each year. The remaining two transects are randomly located within 50 m each side of the routine transect. All depths were standardised to metres - AHD (Australian Height Datum) using standard height markers within the lake to remove potential errors from changing water levels.

2.2 Laboratory analysis

Nutrient samples (frozen) were sent to Yanco Soil Laboratory or Sydney Water for analysis. Chlorophyll-a samples, kept cool in an esky and away from light, were filtered upon return to the laboratory, through 0.45 µm glass fibre filter papers under vacuum. Filter papers were frozen in labelled 50 ml vials until analysis. TSS samples were kept at 1-4 °C until analysis. Chlorophyll and TSS analyses were done in-house using American Public Health Association (APHA) methods. Chlorophyll-a concentrations were determined by UV fluorometry following extraction with 95 % acetone solution using method APHA 10200H (APHA, 2012). TSS samples were analysed using APHA methods 2130B and 2540D (APHA 2012).

2.3 Indicators/parameters

Turbidity, chlorophyll-a and change in seagrass extent are considered appropriate measures of estuarine ecological health as they are short-term (turbidity, chlorophyll-a) and long-term (seagrasses) indicators of ecosystem performance in response to catchment pressure. There are extensive seagrass beds present in the main basin of Brisbane Water and annual change in seagrass depth range has been included as an additional indicator of ecological health since the monitoring program commenced. Monitoring seagrass depth range helps track their health and resilience.

Using turbidity, chlorophyll-a and change in seagrass extent as the primary indicators to assess whole-of-estuary condition is consistent with the state-wide MER program protocols (OEH 2016). Data for other standard physicochemical parameters are also collected in the monitoring program, to provide context for the primary indicators and more information about water quality.

- **Chlorophyll-a** concentration in the water column is used as a proxy for phytoplankton biomass and typically reflects the nutrient load into the system. Algae grow rapidly in response to inorganic nutrients; ammonia, nitrate and phosphate, which can lead to algal blooms if nutrients are present in excess.
- **Turbidity** measurements reflect water clarity and may reflect the sediment load to the estuary, including resuspension of catchment-derived fines from bed sediments. High turbidity can result in a reduction of light available for photosynthesis, limiting algal and seagrass growth. Thus, turbidity can be viewed as a surrogate for potential seagrass distribution.
- **Seagrasses** reflect changes in water quality as their high light requirements make them sensitive to turbidity, salinity, and other environmental conditions.
- **Dissolved oxygen** is important for survival of most animals in aquatic systems and shows considerable variation during the daily cycle due to plant photosynthesis and respiration. Very high or very low concentrations of dissolved oxygen can indicate poor estuary condition. Sampling and assessment of dissolved oxygen presents many challenges as instantaneous dissolved oxygen levels depend on a few

factors including salinity, temperature, time of day, cloud cover extent etc. when the sampling occurred. Surface water dissolved oxygen, as monitored in the MER program, is only useful for determining whether the entire water column is deoxygenated which occurs in severe situations. To gain a more wholistic understanding of oxygen demand and production in the area of interest, dissolved oxygen should be measured across the complete diurnal cycle by data loggers deployed near the estuary floor.

- **Salinity** is a measure of the dissolved salts in the water. **Salinity** and **temperature** are measured to provide context for the other indicators.
- **pH** reflects the amount of hydrogen ions in lake water and is reported in pH units. Estuarine waters are typically slightly alkaline pH 7.5-8.0
- **Electrical conductivity** measures the ability of water to conduct an electrical current which depends on the concentration of dissolved salts (i.e., the salinity). Electrical conductivity increases with increasing water temperature. **Specific conductivity** is calculated (by the WQ sonde software) from electrical conductivity corrected to a standardised temperature, usually 25°C.
- **Fluorescent Dissolved Organic Matter** (fDOM) refers to the fraction of coloured dissolved organic matter (CDOM) that fluoresces. fDOM is a surrogate for CDOM and a fast and easy means of tracking DOM in waterbodies. DOM is a heterogenous mixture derived primarily from the decomposition products of terrestrial plant material, bacteria and algae.

Turbidity and chlorophyll-a data collected from NSW estuaries by DCCEEW as part of the state-wide estuarine MER Program have been used to develop trigger values specific to NSW estuaries (OEH 2016). Trigger values are derived from the 80th percentile values for variables measured in estuaries at seaward end of low disturbance catchments, for each estuary type (e.g., lake, river, lagoon etc). Compliance against a guideline or trigger value is commonly used to assess the status of a condition indicator. Exceeding the trigger value frequently, or by a large extent, should prompt further investigation or management action. Table 1 shows updated trigger values established for NSW lakes and rivers that were generated from the state-wide estuarine water quality dataset (OEH 2018) and are used for grade calculations in this report.

Table 1 Trigger Values for water quality indicators in NSW Lakes and Rivers derived from the 80th percentile of data collected in all lakes and rivers in the NSW MER program (OEH 2018).

Indicators	Lakes	Rivers Lower (>25psu)	Rivers Mid (10-25psu)	Rivers Upper (<10psu)
Turbidity NTU	5.5	3	3.1	6
Chlorophyll-a µg/L	5.3	2.7	4.3	4.8
Ammonia µg/L	14	10	29	52
NOx µg/L	3	5	40	34
TDN µg/L	670	270	320	550
TN µg/L	750	270	420	670
Phosphate µg/L	1	2	2	5
TDP µg/L	9	6	6	6
TP µg/L	24	12	14	16

2.4 Data analysis

Estuary report card grades for Brisbane Water were calculated using salinity, turbidity, chlorophyll-a and seagrass depth range data collected during the water quality monitoring program. Since program inception, there has been no further analysis of any additional water quality data (outlined in Section 2.3), however, all data from the program is compiled and sent to CCC in Microsoft Excel format each year. The data compilation includes all water quality parameters, total suspended solids (TSS), chlorophyll-a and nutrient concentration data.

2.4.1 Water quality grades

Water quality grades were calculated using a subset of turbidity and chlorophyll-a data from the 2024-2025 sampling period, using only data collected over the warmer months from October 2024 to April 2025, consistent with MER sampling protocols (OEH 2016). Grades for water quality are calculated based on how often and to what extent the values for turbidity and chlorophyll-a exceed the state-wide 80th percentile trigger values. Data from lake basin/bay zones were compared to the NSW Trigger Values for Lakes while data collected in the tributaries were compared to NSW Trigger Values for Rivers (Table 1). Report card grades for turbidity and chlorophyll-a were calculated and turbidity and chlorophyll-a scores were averaged to get the overall water quality grade.

Grades assigned to turbidity, chlorophyll-a and overall water quality (**A** – very good, **B** – good, **C** – fair, **D** – poor and **F** – very poor) are determined by the zone score (0 - 1.0, Figure 2). The grade reflects the condition of a zone in comparison to the overall condition across all NSW estuaries with cut-off values for each grade defined by the percentage of estuaries in the state that received a score in that range (Figure 2). For example, a zone score of less than 0.07 is equivalent to the best 20% of scores in the state and receives an A (very good) grade (Figure 2, OEH 2016).

Figure 2 Relationship between distribution of NSW scores, grades and zone scores (OEH 2016)

An additional metric is provided in the sliding scale diagram of the turbidity and chlorophyll-a grades shown below each table of grades (Tables 2-8). A percentage value is shown for each indicator based on the score received in the grade calculation. The percentage grade reflects the number of exceedances and the extent of exceedance of the respective trigger values and is calculated using the equation below. If there were no exceedances of the trigger value, a percentage grade of 100 % is awarded. Lower percentages indicate that one or more samples exceeded the trigger value, with extent of exceedance further lowering the percentage grade.

$$Percentage\ grade\ [turbidity]\ (\%) = 100 - ([turbidity\ score]) * 100)$$

$$Percentage\ grade\ [chlorophyll]\ (\%) = 100 - ([chlorophyll\ score]) * 100)$$

Provision of the percentage grade allows for a finer scale assessment of change in chlorophyll-a and turbidity in the system, including occasions where the grade (A-F) remains the same.

A comprehensive description of how water quality grades are calculated is available in *Assessing Estuary Ecosystem Health: Sampling, data analysis and reporting protocols*, NSW Natural Resources Monitoring, Evaluation and Reporting Program (OEH 2016).

2.4.2 Seagrass depth range grade

Seagrass depth range (SDR) was calculated by measuring water depth at the shallow limit and deep limit of seagrass *Zostera capricorni* cover across three transects at each monitoring site. The mean shallow limit is subtracted from the mean deep limit to give the depth range for that site.

There are two components used to calculate the seagrass depth range (SDR) grade, a depth grade and a trend grade. The depth grade compares the measured depth range to an expected depth range based on the physical attributes of the site if conditions were optimal. The trend grade compares the recorded depth range that year with the depth range from the previous year. Therefore, the SDR grade reflects how seagrass has progressed, recovered, or regressed over time.

A percentage value is shown on the sliding scale for the SDR grade which is based on the points awarded for the depth grade and trend grade, with 100 % reflecting the maximum points assigned.

2.4.3 Overall ecological health grade

The overall ecological health grade was calculated by combining the average scores for turbidity and chlorophyll-a (70 % weighting) with the score for seagrass depth range (30 % weighting) for those zones where seagrass depth range is monitored. For those zones where only water quality is monitored, the overall grade is equivalent to the overall water quality grade.

2.5 QA/QC

The following QA/QC protocols were adhered to as part of this study:

- Standard operating procedures, best practice methods and peer-reviewed methods for completion of all field sampling, equipment operation and laboratory analyses
- Equipment was calibrated at an appropriate frequency and well maintained to ensure highest quality field data collection
- Maintain a high level of quality control of data management and file sharing and its interaction with end users and other external parties
- Adhere to the principles in the DCCEEW Scientific Rigour statement.

3 Results

3.1 Report Card Grades

3.1.1 Basin Zone (Zones 1-3)

Overall water quality and ecological health in the main basin of Brisbane Water scored A (very good) grades in 2024-2025. There was no exceedance of the trigger values for turbidity or chlorophyll-a, resulting in A (very good) grades, and 100 % for the percentage grades, for both indicators (Table 2, Figure 3). The seagrass depth range grade for the basin zone declined to a B (good) grade, and 80 % for the percentage grade (Table 2, Figure 3), due to a retraction in the depth range at SDR2 and SDR3 from an average of 3.04 m in 2024 to 2.42 m in 2025 (Table 9).

Table 2 Calculated grades for the basin zones during 2024-2025 and past monitoring periods for comparison.

Sampling Period	Turbidity	Chlorophyll-a	Overall Water Quality	Seagrass Depth Range	Overall Ecological Health
2017 – 2018	A	A	A	-	A
2018 – 2019	A	A	A	B	A
2019 – 2020	A	C	B	B	B
2020 – 2021	A	C	B	C	B
2021 – 2022	A	A	A	B	A
2022 – 2023	A	A	A	A	A
2023 – 2024	A	A	A	A	A
2024 – 2025	**A**	**A**	**A**	**B**	**A**

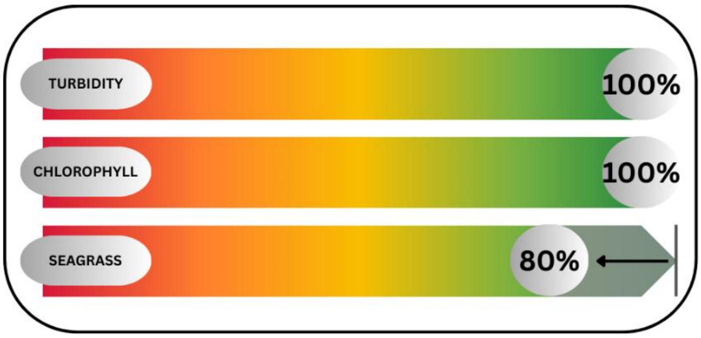

Figure 3 A sliding scale diagram of the percentage grades for turbidity, chlorophyll-a and seagrass in the basin zones. Arrows indicate change from last year’s percentage grades.

3.1.2 Narara Creek

Overall water quality in Narara Creek improved from a C (fair) grade in 2023-2024 to a B (good) grade in 2024-2025 due to an improved chlorophyll-a grade (Table 3). Chlorophyll-a scored a C (fair) grade in 2024-2025, and a percentage grade of 66 %, due to five exceedances of the trigger value (Table 3, Figure 4). The turbidity grade remained stable in 2024-2025, scoring a B (good) and a percentage grade of 92 %, based on three relatively minor exceedances of the trigger value (Table 3, Figure 4).

Table 3 Calculated grades for Narara Creek during 2024-2025 and past monitoring periods for comparison.

Sampling Period	Turbidity	Chlorophyll-a	Overall Water Quality	Seagrass Depth Range	Overall Grade
2017 - 2018	D	B	C	-	C
2018 - 2019	B	C	B	-	B
2019 - 2020	B	D	C	-	C
2020 - 2021	C	A	B	-	B
2021 - 2022	C	B	C	-	C
2022 - 2023	A	C	B	-	B
2023 – 2024	B	D	C	-	C
2024 – 2025	**B**	**C**	**B**	**-**	**B**

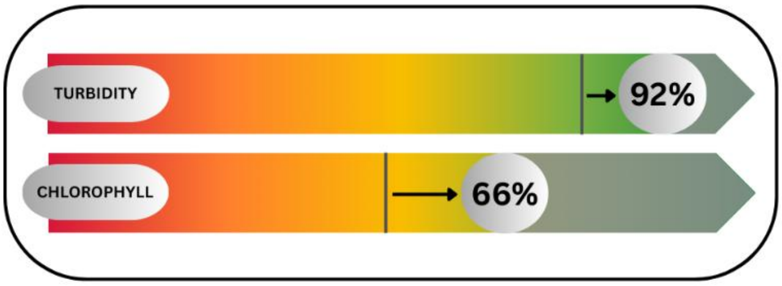

Figure 4 A sliding scale diagram of the percentage grades for turbidity and chlorophyll-a in Narara Creek. Arrows indicate change from last year's percentage grades.

3.1.3 Erina Creek

Overall water quality in Erina Creek improved from a C (fair) grade in 2023-2024 to a B (good) grade in 2024-2025, with the ecological health grade also improving to a B grade (Table 4). The improved grades were driven by a two-grade improvement for chlorophyll-a to B (good, Table 4). The trigger value for chlorophyll-a was exceeded on all occasions, however, exceedances were all relatively minor resulting in a percentage grade of 74 % (Figure 5). The turbidity grade remained stable, scoring a B (good) grade and 78 % for the percentage grade due to six minor exceedances of the trigger value (Table 4, Figure 5). The seagrass depth range grade for SDR1 remained stable at C (fair), with a slight reduction in depth range from 0.96 m to 0.88 m (Table 9), and a percentage grade of 60 % in 2024-2025 (Table 4, Figure 5).

Table 4 Calculated grades for Erina Creek during 2024-2025 and past monitoring periods for comparison.

Sampling Period	Turbidity	Chlorophyll-a	Overall Water Quality	Seagrass Depth Range	Overall Ecological Health
2017 - 2018	B	B	B	-	B
2018 - 2019	C	C	C	D	C
2019 - 2020	C	C	C	B	C
2020 – 2021	B	B	B	C	B
2021 – 2022	C	B	C	B	C
2022 – 2023	B	C	B	C	B
2023 – 2024	B	D	C	C	C
2024 – 2025	**B**	**B**	**B**	**C**	**B**

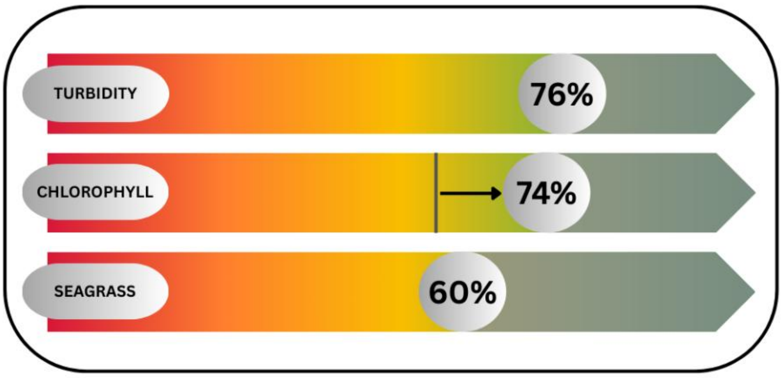

Figure 5 A sliding scale diagram of the percentage grades for turbidity, chlorophyll-a and seagrass in Erina Creek. Arrows indicate change from last year’s percentage grades.

3.1.4 Kincumber Creek

Overall water quality and ecological health in the receiving waters of Kincumber Creek remained good in 2024-2025, scoring a B grade for the fourth consecutive year. Both the chlorophyll-a and turbidity grades remained stable (Table 5). Turbidity scored a C (fair) grade in 2024-2025 with a percentage grade of 58 % due to exceedance of the trigger value on five occasions, some of which were considerable (Table 5, Figure 6). The chlorophyll-a grade scored a B (good) grade for the sixth consecutive year, with only one exceedance of the trigger value resulting in a percentage grade of 92 % (Table 5, Figure 6). Seagrass depth range retained a C (fair) grade in 2024-2025 and a percentage grade of 60 % (Table 5, Figure 6). There was a slight increase in the measured seagrass depth range at SDR5 from 1.11 m in 2024 to 1.18 m in 2025 (Table 9).

Table 5 Calculated grades for Kincumber Creek during 2024-2025 and past monitoring periods for comparison.

Sampling Period	Turbidity	Chlorophyll-a	Overall Water Quality	Seagrass Depth Range	Overall Ecological Health
2017 - 2018	F	B	D	-	D
2018 - 2019	F	C	D	B	D
2019 - 2020	C	B	C	B	C
2020 – 2021	D	B	C	C	C
2021 – 2022	B	B	B	B	B
2022 – 2023	B	B	B	C	B
2023 – 2024	C	B	B	C	B
2024 – 2025	**C**	**B**	**B**	**C**	**B**

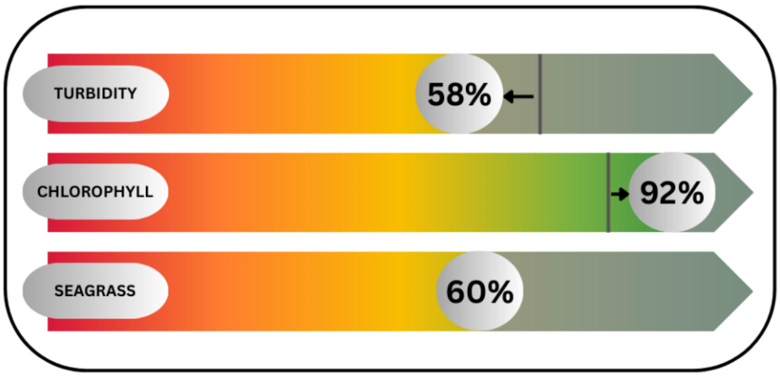

Figure 6 A sliding scale diagram of the percentage grades for turbidity, chlorophyll-a and seagrass in Kincumber Creek. Arrows indicate change from last year's percentage grades.

3.1.5 Cockle Bay

Overall water quality in Cockle Bay was very good, retaining an A grade in 2024-2025 for the fourth consecutive year (Table 6). There were no exceedances of the trigger value for either turbidity or chlorophyll-a, with both indicators scoring an A (very good) grade and a percentage grade of 100 % (Table 6, Figure 7).

Table 6 Calculated grades for Cockle Bay during 2024-2025 and past monitoring periods for comparison.

Sampling Period	Turbidity	Chlorophyll-a	Overall Water Quality	Seagrass Depth Range	Overall Grade
2017 - 2018	A	A	A	-	A
2018 - 2019	A	A	A	-	A
2019 - 2020	A	B	A	-	A
2020 - 2021	A	B	B	-	B
2021 - 2022	A	A	A	-	A
2022 - 2023	A	A	A	-	A
2023 - 2024	A	A	A	-	A
2024 - 2025	**A**	**A**	**A**	**-**	**A**

Figure 7 A sliding scale diagram of the percentage grades for turbidity and chlorophyll-a in Cockle Bay. Arrows indicate change from last year's percentage grades.

3.1.6 Booker Bay

Overall water quality in Booker Bay improved from a B (good) grade in 2023-2024 to an A (very good) grade in 2024-2025 due to an improved chlorophyll-a grade (Table 7). There were no exceedances of the trigger values for either turbidity or chlorophyll-a, with both indicators scoring an A (very good) grade and 100 % for the percentage grade (Table 9, Figure 10).

Table 7 Calculated grades for Booker Bay during 2024-2025 and past monitoring periods for comparison.

Sampling Period	Turbidity	Chlorophyll-a	Overall Water Quality	Seagrass Depth Range	Overall Grade
2017 - 2018	A	A	A	-	A
2018 - 2019	A	A	A	-	A
2019 - 2020	A	A	A	-	A
2020 - 2021	A	B	B	-	B
2021 - 2022	A	A	A	-	A
2022 - 2023	A	A	A	-	A
2023 - 2024	A	B	B	-	B
2024 - 2025	**A**	**A**	**A**	**-**	**A**

Figure 8 A sliding scale diagram of the percentage grades for turbidity and chlorophyll-a in Booker Bay. Arrows indicate change from last year's percentage grades.

3.1.7 Woy Woy Creek

Overall water quality in Woy Woy Creek remained very good (A) in 2024-2025. Turbidity, chlorophyll-a and ecological health all received A (very good) grades (Table 8). There was no exceedance of the trigger value for turbidity, resulting in a percentage grade of 100 % (Table 8, Figure 9). There was one minor exceedance of the chlorophyll-a trigger value resulting in a percentage grade of 96 % (Table 8, Figure 9). The seagrass depth range at Woy Woy increased from 1.74 m in 2024 to 1.83 m in 2025 (Table 9) resulting in a B (good) grade and a percentage grade of 70 % (Table 8, Figure 9).

Table 8 Calculated grades for Woy Woy Creek during 2024-2025 and past monitoring periods for comparison. A sliding scale diagram below the table shows the percentage grades for turbidity, chlorophyll-a and seagrass depth range for 2024-2025, with the arrow indicating change from last year's percentage grades.

Sampling Period	Turbidity	Chlorophyll-a	Overall Water Quality	Seagrass Depth Range	Overall Ecological Health
2017 - 2018	A	A	A	-	A
2018 - 2019	A	A	A	C	A
2019 - 2020	A	A	A	B	A
2020 - 2021	A	B	B	C	B
2021 - 2022	A	B	B	C	B
2022 - 2023	A	A	A	C	A
2023 - 2024	A	A	A	B	A
2024 - 2025	**A**	**A**	**A**	**B**	**A**

Figure 9 A sliding scale diagram of the percentage grades for turbidity, chlorophyll-a and seagrass in Woy Woy Creek. Arrows indicate change from last year's percentage grades.

3.2 Seagrass depth range

In 2025, seagrass depth range grades were retained at all sites except for the Basin Zone which dropped a grade to B (Table 2). The Basin Zone has two seagrass monitoring sites, and the decrease in grade was driven by a significant decline in the depth range at SDR2 (4.45 m decreasing to 2.90 m). Depth range increased from 1.60 m to 1.93 m at SDR3, the second monitoring site in the Basin, resulting in an average depth range of 2.42 m for the Basin Zone (Table 9). Despite the decline in seagrass depth range at SDR2, this site still has greatest measured seagrass depth range of all monitoring sites (2.9 m).

Measured seagrass depth range at the other monitoring sites were similar to that of the previous year, with a slight increase in the measured seagrass depth range observed as SDR4 and SDR5, and a slight decrease in measured seagrass depth range observed at SDR1 (Table 9).

Table 9 Observed seagrass depth range for the current monitoring period and past monitoring periods for comparison.

Year	Basin (SDR2, SDR3)	Erina (SDR1)	Woy Woy (SDR4)	Kincumber (SDR5)
2018	0.94	0.85	0.67	0.57
2019	1.33	0.44	0.66	0.68
2020	1.49	0.86	0.74	0.77
2021	1.27	0.86	0.76	0.84
2022	1.35 (**1.92***)	1.01	0.80 (**2.00***)	1.03
2023	1.97	0.94	1.67	1.07
2024	3.02	0.96	1.74	1.11
2025	**2.42**	**0.88**	**1.83**	**1.18**

* Seagrass depth range measured at new revised locations

4 Summary and discussion

In 2024-2025 the overall water quality and ecological health grades remained stable for the Basin, Kincumber Creek, Cockle Bay and Woy Woy Creek, with the grades for Narara Creek, Erina Creek and Booker Bay all improving a grade. The improvement in overall water quality and ecological health grades in Narara Creek, Erina Creek and Booker Bay was primarily driven by an improvement in the chlorophyll-a grades at these sites. Cockle Bay has always had very good water quality (except for 2020-2021, good water quality) as it is located close to the mouth at Broken Bay and is well flushed with oceanic water.

Total monthly rainfall at Gosford (AWS 61425) over the MER sampling period, October 2024 to April 2025, was 735 mm, well below the 8-year average for this period (916 mm, Table 11). In October 2024, December 2024 and February 2025, monthly rainfall was less than half the long-term average, whereas higher-than-average rainfall was recorded in January 2025 and April 2025 (Table 10). The improvement in chlorophyll-a grades (and the overall water quality grades) in 2024-2025 is likely to be linked to lower rainfall overall, as well as low level of rainfall in the days prior to most sampling dates (Table 10, Table 11). Chlorophyll-a concentrations in estuary waters can increase following rainfall as dissolved organic nutrients (ammonium, nitrate, phosphates) in catchment runoff fuel algal (phytoplankton) growth.

Only nutrient data from sampling dates in August 2024 through to February 2025 are available currently. Dissolved inorganic nitrogen (DIN; ammonium-NH_4^+, nitrate/nitrite-NO_x) and dissolved inorganic phosphate (DIP) concentrations were high in Narara Creek on all sampling occasions. Ammonium concentrations ranged from 8-59 µg/L, exceeding the NSW trigger value of 10 µg/L (Table 1, OEH 2018), 88 % of the time while NO_x concentrations ranged from 1-120 µg/L, exceeding the NSW trigger value of 5 µg/L (Table 1, OEH 2018), 88 % of the time. DIN concentrations in Erina Creek were in a similar range to Narara Creek. DIP concentrations in Narara Creek and Erina Creek ranged from 4-22 µg/L and 4-8 µg/L, respectively, exceeding the NSW trigger value of 2 µg/L (Table 1, OEH 2018), 100 % of the time.

The catchments of these creeks are heavily modified with light-industrial and urban land use with the catchment of Narara Creek also including a racecourse, golf course and several sporting fields. Thus, high concentrations of DIN and DIP are not surprising, nor is the C (fair) grade for chlorophyll for Narara creek in 2024-2025. In fact, DIN concentrations were highest in the first three sampling dates (Table 11) at which time chlorophyll-a concentrations were relatively low (<3.5 ug/L) as was turbidity (<3.5 NTU). There was little recent rainfall prior to the first two sampling dates (Table 11) but surface runoff from the maintenance of the golf course and sporting grounds near Narara Creek may occur even in the absence of rainfall. Cool water temperatures in August, September 2024 may have dampened algal growth rates along with other unknown factors.

DIN and DIP concentrations at the Kincumber Creek site were not as high, exceeding the NSW trigger values for NH_4^+, nitrate/nitrite-NO_x and phosphate, 50 %, 0% and 38% of the time, respectively. Note that this monitoring is near the outlet of Kincumber Creek, not in Kincumber Creek, but is located in an isolated embayment called Kincumber Broadwater. The catchment of Kincumber Creek is primarily urban land use and includes the Kincumber Sewage Treatment Plant, with runoff from the catchment ultimately draining to the Kincumber Broadwater.

The Redfield ratio of 16:1 is the consistent atomic proportions of nitrogen (N) to phosphorous (P) in marine phytoplankton. Molar ratios of DIN:DIP in the environment that deviate from 16:1 indicate nutrient limitation, with ratios less than 16 indicating the system is N-limited, and ratios above 16 indicating the system is P-limited. The concentrations of DIN and DIP in Narara Creek and Erina Creek result in an average Redfield ratio of 22 and 18, respectively, indicating that phytoplankton growth is P-limited. This is the result of DIN concentrations being particularly high in the creeks. Conversely, the average Redfield ratio for DIN:DIP at the Kincumber Creek site is 9, indicating N-limitation for phytoplankton growth. This likely reflects the fact that this monitoring site is in an isolated embayment of Brisbane Water (i.e., Kincumber Broadwater), rather than the creek.

DIN concentrations in the basin and bays of Brisbane Water were considerably lower than the tributaries, rarely exceeding the NSW trigger values. However, phosphate concentrations were generally between 3-8 µg/L and always exceeded the NSW trigger value of 1 µg/L (Table 1, OEH 2018). Redfield ratios (DIN:DIP) ranged from 3 to 6 indicating the phytoplankton growth in the main basin and bays of Brisbane Water is N-limited.

During the 2024 seagrass depth range survey, seagrass at SDR2 was found to extend out past the moorings, which had not been observed previously. At the time of the survey, it was unsure if this was the result of previous sampling underestimating depth range due to mooring scars creating false deep boundary. In the 2025 seagrass depth range survey, seagrass was not observed on the outside edge of moored boats despite thorough investigation. As a result, measured seagrass depth range at SDR2 was significantly reduced from 4.45 m in 2024 to 2.9 m in 2025, leading to a drop in the seagrass depth range grade to B for the Basin Zone. The very high rainfall in January 2025 (197 mm, Table 10) at the peak of the growing season for *Zostera capricorni* may have contributed to the significant decline in the seagrass depth range at the SDR2 site. Turbidity was very good in the Basin zones on the water quality sampling dates; however, high turbidity may have occurred in between sampling dates, impacting light available for seagrass growth in the basin of Brisbane water. Alternatively, the proximity of boat moorings may be preventing the seagrass bed from expanding at the deeper end. With only four years of data available at the new seagrass sites, further monitoring will be required to gain a better understanding of how seagrass depth range varies within the estuary over time.

Table 10 Monthly rainfall totals (mm) from October 2017 to June 2025 at Gosford Australian Weather Station (AWS, 61425, Bureau of Meteorology). Monthly totals in green font are from Ourimbah AWS (61093) as data were not available from Gosford AWS. Long-term monthly average rainfall at Gosford AWS from 2013-2025 are shown. Total annual rainfall from 2017 to 2024 at Gosford AWS is shown, with values in green font being a combination of data from Gosford AWS and Ourimbah AWS.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2017	35.6	152.4	399.2	113.4	36	*173.2*	7.8	10.6	2.4	79.2	78	61.8	**1150**
2018	26.6	163.2	102.8	73	17.8	213.6	12	17.6	58.2	258	*131.4*	*68.6*	**1143**
2019	57	109	256.4	40.2	17.6	161.2	46	212.6	112.6	49.8	*21.8*	3	**1087**
2020	125.6	*538.6*	180.4	39.8	50.2	56.4	171.6	51.2	50.2	253.2	36.2	197.6	**1751**
2021	119.6	91.4	467.6	41.4	81.4	67.6	44.8	72.2	46.2	55.6	190.2	150.6	**1429**
2022	116	*340.2*	579	225.2	129.8	14	448.8	30.2	149.4	160.6	25.2	49	**2267**
2023	88	173.4	74.6	133.2	46.8	21.2	*22.2*	*57.4*	16.8	58.8	135	66	**893**
2024	85.4	121.6	22.4	305.6	245.2	196	68.6	39.4	74.2	46.6	81	16.8	**1303**
2025	197.4	51.4	137.4	204.6	367.2	7.4							
Monthly and annual means (2013-2025)	**118.9**	**115.5**	**214.9**	**153**	**100.5**	**118.6**	**87.4**	**76.7**	**64**	**97.6**	**91.4**	**75.7**	**1314**

Table 11. A. Total rainfall (mm) recorded from October to April for each monitoring season (2017/18 to 2024/25) at Gosford/Ourimbah AWS are shown. Water quality data collected in this period are used to calculate the water quality grades. B. Rainfall recorded at Gosford AWS in the 3-days and 7-days prior to water quality sampling are shown as recent rainfall can affect water quality.

A.

Sampling period	Total rainfall (mm)
Oct 2017 - Apr 2018	585
Oct 2018 - Apr 2019	859
Oct 2019 - Apr 2020	677
Oct 2020 - Apr 2021	1207
Oct 2021 - Apr 2022	1763
Oct 2022 - Apr 2023	704
Oct 2023 - Apr 2024	795
Oct 2024 - Apr 2025	735
8-year average	916

B.

Sampling date	Rainfall mm 3-days prior	Rainfall mm 7-days prior
7/08/2024	0.6	3.0
26/08/2024	0.8	1.0
2/10/2024	9.4	49.4
22/10/2024	0.2	17.2*
20/11/2024	11.8	15.8
12/12/2024	0	1.6
31/01/2025	23.4	24.8
19/02/2025	0	5.8
18/03/2025	0	4.6
8/04/2025	6.2	6.2
12/05/2025	28.2	32.2
16/06/2025	0.6	1.4

*Rainfall mm 8-days prior

5 References

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OEH 2018, *NSW Estuary Water Quality Trigger Values*, *How new water quality Trigger Values for estuaries in NSW were derived*, Office of Environment and Heritage, Sydney.