Department of Climate Change, Energy, the Environment and Water

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Estuary Report Card 2023-2024 Mid-Upper Hawkesbury

August 2024

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.

Published by NSW Department of Climate Change, Energy, the Environment and Water

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Estuary Report Card 2023-2024 Mid-Upper Hawkesbury

First published: August 2024

Cover photo: Hawkesbury River downstream of Wisemans Ferry – Chris Baiada (DCCEEW)

Acknowledgements

This program was funded by the Hawkesbury City Council and Coastal and Estuaries grants.

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Contents

1 Introduction

1.1 Background

The Hawkesbury City Council (HCC) engaged the Estuaries and Catchments Team of the Department of Climate Change, Energy, the Environment and Water (DCCEEW) to assess water quality in the mid-upper Hawkesbury River over the 2023-2024 financial year and using the data collected, provide Council with an estuary report card. The Mid-Upper Hawkesbury Water Quality Monitoring Program commenced in 2018. HCC recognises that long term monitoring programs are essential for tracking the ecological health of an estuary and to identify potential areas of concern that may require management.

1.1.1 Location

The Hawkesbury River lies to the northwest of Sydney and is known as Dyarubbin to the Darkiňung and Dharug First Nations people. The majority of the mid-upper Hawkesbury River and its catchment falls within the Hawkesbury City Council (HCC) Local Government Area (LGA).

1.1.2 Program outline and scope

HCC engaged the Estuaries and Catchments Team of DCCEEW to assess water quality in the Mid-Upper Hawkesbury River over the 2023-2024 financial year through the delivery of a monthly water quality monitoring program and, using the data collected, develop and provide Council with an estuary report card.

The Mid-Upper Hawkesbury River 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 monthly in the main river stem between Windsor and Wisemans Ferry, as well as four tributary creeks feeding into the upper Hawkesbury River.

1.1.3 Aims and objectives of the program

The monitoring program aims to assess water quality in the main river stem and four tributary creeks of the mid-upper Hawkesbury River using methods that are scientifically valid and standardised. The objectives are to:

- Track change in condition and continue to build a long-term dataset to support management decisions by HCC.
- Collect data for potential use in future hydrodynamic and ecological response models
- Provide HCC with an annual Estuary Report Card report, for sharing with community as required

2 Methodology

2.1 Monitoring zones & frequency

Over 12-months, monthly water quality sampling was conducted at four zones in the mid-upper Hawkesbury River, located on the main river stem between Windsor and Wisemans Ferry (Windsor, Riverside Oaks, Lower Portland and Wisemans Ferry), and one zone in Macdonald River, a tributary of the mid Hawkesbury River (Figure 1). Sampling at this frequency allows both monthly and seasonal variability in water quality to be assessed.

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 mid to upper reaches of rivers/creeks. If feasible, rivers/creeks are sampled using a longitudinal transect from the mid-section to the upper section (OEH 2016). However, localised sampling 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 theoretical 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).

To better analyse localised issues, sampling zones were established in the main river stem and one tributary to the mid-upper Hawkesbury River (Figure 1) following the MER estuary health sampling protocols (OEH 2016), considering:

- 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.

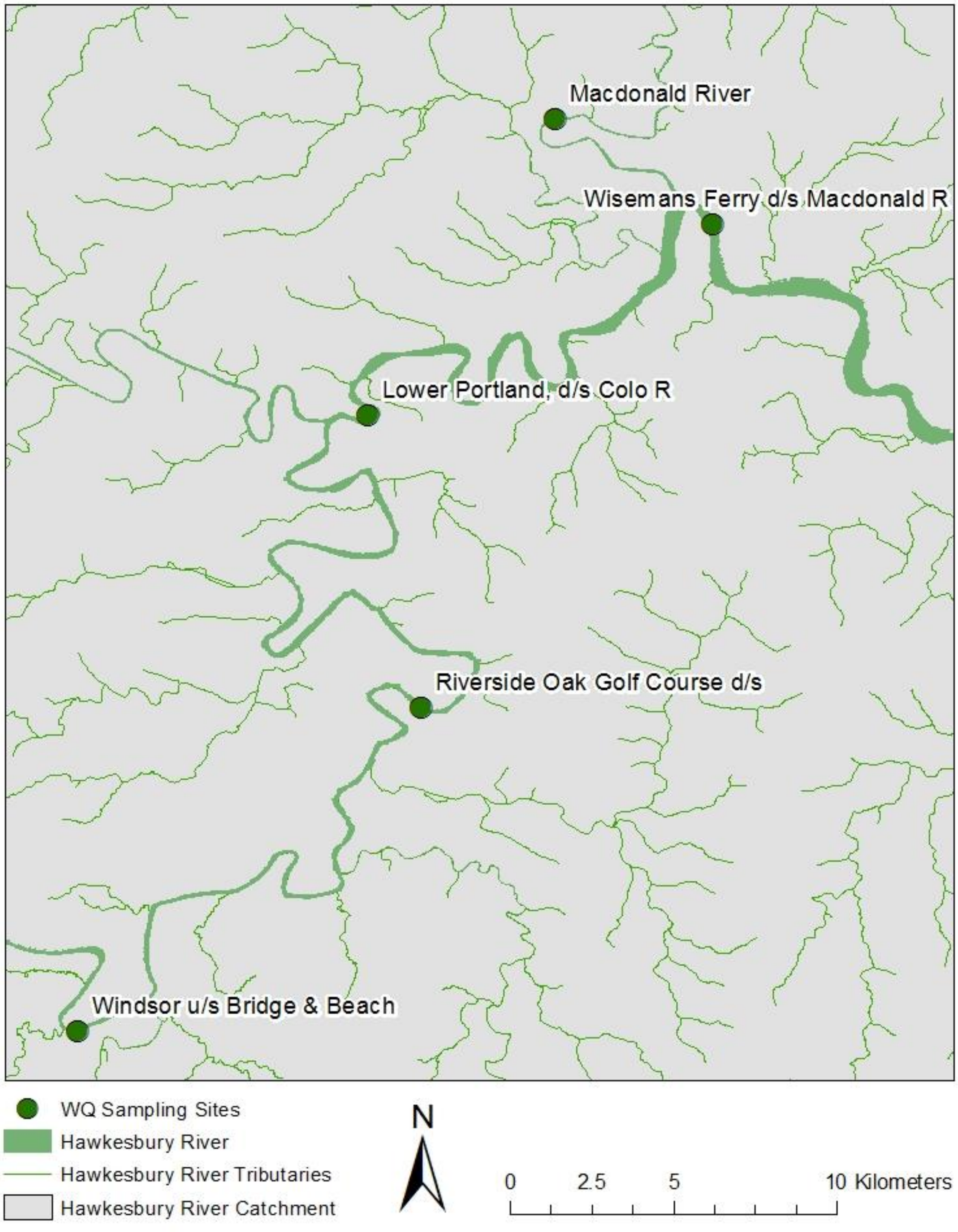


Figure 1 Sampling locations in the Mid-Upper Hawkesbury River water quality monitoring program 2023-2024. Note Windsor is upstream and Wisemans Ferry is downstream.

2.2 Sampling methods

2.2.1 Water quality

Continuous transects

All sampling was conducted from a 4.5m research vessel fitted with a water intake to allow continuous logging of water quality data along a longitudinal transect (OEH 2016). Water from 0.1-0.3m below surface is pumped continuously to the Xylem EXO-2 multiparameter water quality sonde (WQ sonde) fixed to the back of the vessel. The following physicochemical water quality parameters were continuously recorded along the longitudinal transect by the WQ sonde:

- turbidity,
- temperature,
- salinity,
- 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 which was downloaded from the device upon return to the laboratory.

In-situ sampling

At each zone samples were collected for chlorophyll-a, total suspended solids (TSS) and nutrients. A clean bucket was filled with approximately 10 litres of estuary water, collected from within 0.5m 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, 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 30ml vials using a clean 50-ml syringe barrel. All other nutrient samples were filtered immediately with 0.45 μm syringe-filters into two 30ml 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 (111ml) 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.

2.2.2 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 50ml vials until analysis. TSS samples were kept at 1-4° 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).

2.2.3 Indicators/parameters

Turbidity and chlorophyll-a are appropriate measures of estuarine ecological health as they are short-term indicators of ecosystem performance in response to catchment pressure and are 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 concentrations in the water column is used as a proxy for phytoplankton biomass and typically reflect 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.
- Dissolved oxygen is crucial for the survival of most aquatic animals and varies daily due to plant photosynthesis and respiration. Extremely high or low levels can indicate poor estuary conditions. Sampling dissolved oxygen is challenging because levels depend on factors like salinity, temperature, time of day, and cloud cover. Surface water measurements, as monitored in the MER program, only indicate severe deoxygenation. For a comprehensive understanding, dissolved oxygen should be measured throughout the diurnal cycle using data loggers 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.
- 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 Rivers that were generated from the state-wide estuarine water quality dataset (OEH 2018) and are used for grade calculations in this report.

It should be noted that a trigger value for chlorophyll-a of 7 µg/L has been adopted instead of the standard trigger value of 4.8 µg/L (OEH 2018) for upper reaches of rivers with a salinity of less than 10 psu (Table 1). The monitoring zones in the Mid-Upper Hawkesbury River Water Quality Monitoring Program are within the tidal freshwater pool of the Hawkesbury River. Due to limited data on tidal freshwater pools, a trigger value of 7 µg/L was deemed more appropriate. This decision is based on the 'Interim nutrient load cap assessment for the Hawkesbury Nepean River' report (Ferguson 2018), which identified a knowledge gap and found that 4.8 µg/L was not suitable for the tidal freshwater pool. It was also recommended that guideline values be reviewed and revised as more information becomes available (Ferguson 2018). DPE is working on developing revised trigger values for freshwater tidal pools as part of the Tidal Rivers Program.

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

Indicators	Rivers Lower (>25psu)	Rivers Mid (10-25psu)	Rivers Upper (<10psu)
Turbidity NTU	3	3.1	6
Chlorophyll-a µg/L	2.7	4.3	7*4.8
Ammonia µg/L	10	29	52
NOx µg/L	5	40	34
TDN µg/L	270	320	550
TN µg/L	270	420	670
Phosphate µg/L	2	2	5
TDP µg/L	6	6	6
TP µg/L	12	14	16

*A trigger value for Chlorophyll-a of 7 µg/L has been adopted instead of the standard OEH trigger value of 4.8 (see explanation above)

2.3 Data analysis

Estuary report card grades for the mid-upper Hawkesbury River were calculated using salinity, turbidity and chlorophyll-a data collected during the water quality monitoring program. Turbidity and chlorophyll-a data are plotted as a function of river flow to interpret the effect of river flow on water quality. All water quality data collected in the program, including total suspended solids (TSS), chlorophyll-a and nutrient concentration, is compiled and sent to HCC in Microsoft Excel format each year with no further analysis.

2.3.1 Water quality grade

Water quality grades were calculated using a subset of turbidity and chlorophyll-a data from the 2023-2024 sampling period, using only data collected over the warmer months from October 2023 to April 2024, consistent with MER sampling protocols (OEH 2016). Grades for water quality were calculated by looking at how often and to what extent the values for turbidity and chlorophyll-a exceed the state-wide 80th percentile trigger values. Data collected at all sites were compared to the NSW Trigger Values for Rivers (Table 1). Chlorophyll-a and turbidity scores determine the grades for these indicators, which were then averaged to get the overall water quality grade.

A comprehensive description of how the 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).

2.3.2 River flows and water quality

Flow conditions leading up to, and at the time of, sampling for water quality is important for determining primary drivers in the system (e.g., residence times, external versus internal nutrient supply and total suspended solids inputs from the catchment etc.), that in turn impact on the estuarine health indicators, turbidity and chlorophyll-a.

Discharge at Penrith Weir

Discharge rates (ML/day) at Penrith Weir, upstream of the confluence with the Hawkesbury River, for the 2023-2024 sampling season were obtained from gauges managed by Manly Hydraulics Laboratory (MHL, Table A 1). Flow rates and system state were interpreted from the flow exceedance curve for the Nepean River derived by MHL using historical discharge data at Penrith Weir (Figure A 1).

Water quality trends

Chlorophyll-a and turbidity data collected during the 2023-2024 water quality program are shown as a function of river flows in Figure 4 and Figure 6, respectively, which also include data from previous sampling years.

Salinity, turbidity and chlorophyll-a data collected at each zone during the water quality program are plotted as a time series in Figure 2 and Figure 5.

Spatial trends across the different zones and summary statistics (minima, maxima, median, quartiles) for turbidity, chlorophyll and salinity data collected during the 2023-2024 water quality program are shown in the box and whisker charts in Figure 3.

2.4 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 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

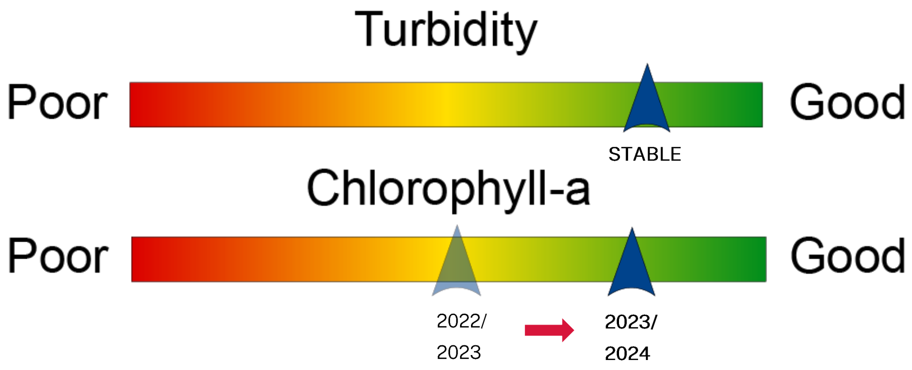
3.1.1 Wisemans Ferry (downstream of Macdonald River)

Overall water quality at Wisemans Ferry improved from a C (fair) grade in 2022-2023 to a B (good) grade in 2023-2024 due to an improvement in chlorophyll-a grade from a C (fair) to a B (good) grade (Table 2). The trigger value for chlorophyll-a was exceeded on four of the six sampling trips, however, exceedances were usually relatively minor. The turbidity grade remained stable at B (good) with only one exceedance of the trigger value.

The mean salinity recorded at Wisemans Ferry was 3.22 psu and the maximum recorded salinity was 9.87 psu in October 2023. This zone usually exhibits estuarine conditions and remained typically brackish until turning relatively fresh (<2.0 psu) from January 2024 through to June 2024 (Figure 2, Figure 3).

Table 2 Calculated grades at Wisemans Ferry during the 2023-2024 monitoring period and previous years for comparison. A sliding scale diagram of the turbidity and chlorophyll-a grades for 2023-2024 (relative to 2022-2023 grades) is shown below

Sampling Period	Turbidity	Chlorophyll-a	Overall Water Quality
2018 – 2019	C	F	D
2019 – 2020	C	B	B
2020 – 2021	B	B	B
2021 – 2022	C	B	B
2022 – 2023	B	C	C
2023 - 2024	**B**	**B**	**B**



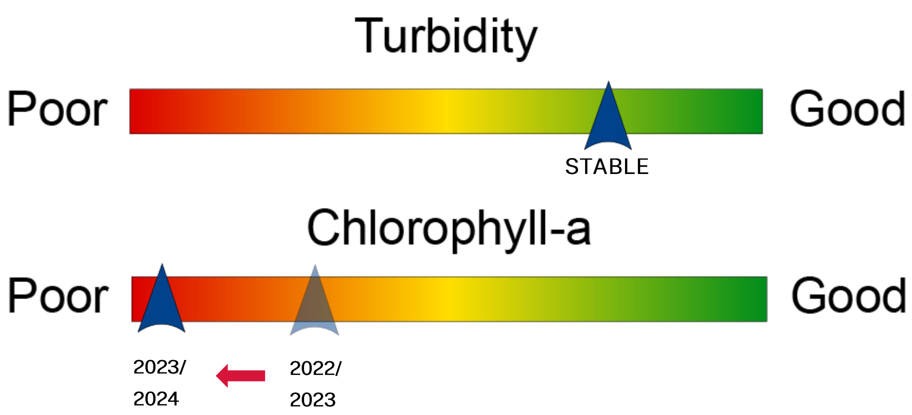
3.1.2 Lower Portland (downstream of Colo River)

Overall water quality at the Lower Portland zone remained stable scoring a C (fair) grade for 2023-2024 (Table 3). The trigger value for chlorophyll-a was exceeded on five sampling trips with chlorophyll levels more than three times the trigger value on three sampling trips. This resulted in a drop in grade from D (poor) in 2022-2023 to a F (very poor) in 2023-2024 (Table 3). The trigger value for turbidity was exceeded on two of the six sampling occasions in spring to autumn however a B (good) grade was retained as exceedances were very minor.

Salinity recorded at Lower Portland was always below 0.3 psu, with a mean salinity of 0.17 psu (Figure 2).

Table 3 Calculated grades at Lower Portland during the 2023-2024 monitoring period and previous years for comparison. A sliding scale diagram of the turbidity and chlorophyll-a grades for 2023-2024 (relative to 2022-2023 grades) is shown below

Sampling Period	Turbidity	Chlorophyll-a	Overall Water Quality
2018 – 2019	C	F	D
2019 – 2020	B	F	C
2020 – 2021	B	C	B
2021 – 2022	B	B	B
2022 – 2023	B	D	C
2023 - 2024	**B**	**F**	**C**



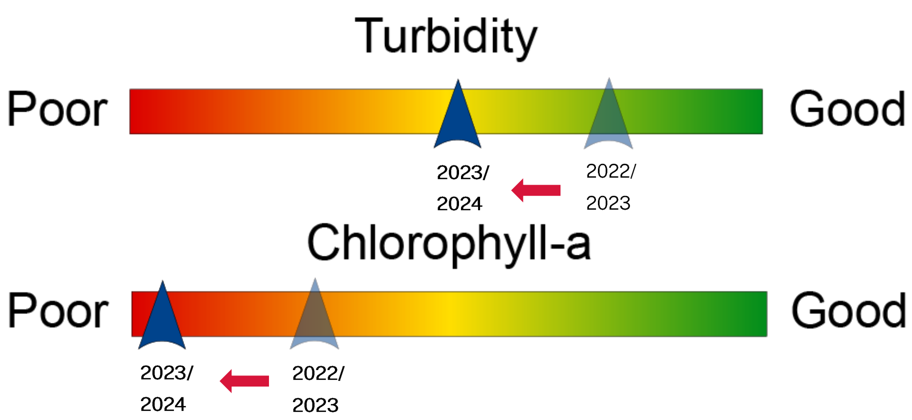
3.1.3 Riverside Oaks (downstream of golf course)

Overall water quality at Riverside Oaks deteriorated from a C (fair) grade in 2022-2023 to a D (poor) grade in the 2023-2024 sampling period (Table 4). This decline was driven by a drop in both the turbidity and chlorophyll-a grades due to exceedance of the respective trigger values on all six sampling occasions. The turbidity grade dropped from a B (good) in 2022-2023 to a C (fair) in 2023-2024. The chlorophyll-a grade dropped from a D (poor) in 2022-2023 to a F (very poor) in 2023-2024 due to major exceedances of the trigger value (Table 4).

Salinity recorded at Riverside Oaks was generally below 0.25 psu, with a mean salinity of 0.19 psu (Figure 2).

Table 4 Calculated grades at Riverside Oaks during the 2023-2024 monitoring period and previous years for comparison. A sliding scale diagram of the turbidity and chlorophyll-a grades for 2023-24 (relative to 2022-23 grades) is shown below

Sampling Period	Turbidity	Chlorophyll-a	Overall Water Quality
2018 - 2019	C	D	C
2019 - 2020	B	F	D
2020 - 2021	B	D	C
2021 - 2022	C	B	B
2022 - 2023	B	D	C
2023 - 2024	**C**	**F**	**D**



3.1.4 Windsor (upstream of Windsor Bridge)

Overall water quality at Windsor deteriorated from a C (fair) grade in 2022-2023 to a D (poor) grade in the 2023-2024 sampling period (

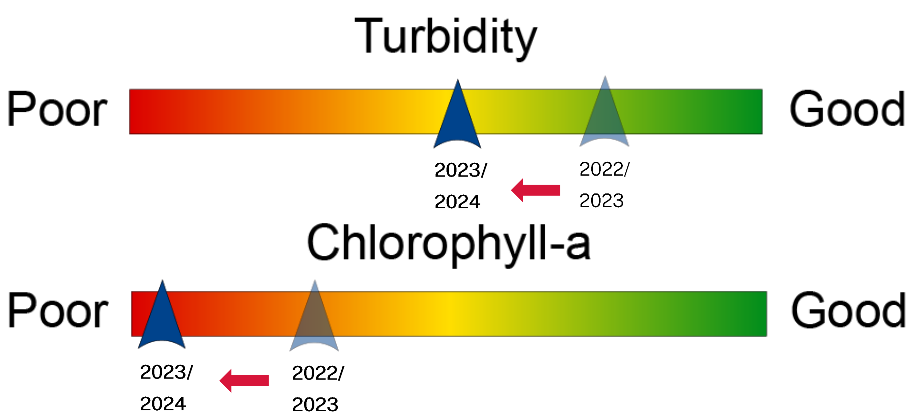
Table 5). This decline was driven by a drop in both the turbidity and chlorophyll-a grades due to exceedance of the respective trigger values on all six sampling occasions. The turbidity grade dropped from a B (good) in 2022-2023 to a C (fair) in 2023-2024. The chlorophyll-a grade dropped from a D (poor) in 2022-2023 to a F (very poor) in 2023-2024 due to major exceedances of the trigger value (

Table 5).

Salinity recorded at Windsor was generally below 0.2 psu, with a mean salinity of 0.16 psu (Figure 2).

Table 5 Calculated grades at Windsor during the 2023-2024 monitoring period and previous years for comparison. A sliding scale diagram of the turbidity and chlorophyll-a grades for 2023-24 (relative to 2022-23 grades) is shown below

Sampling Period	Turbidity	Chlorophyll-a	Overall Water Quality
2018 - 2019	C	D	D
2019 - 2020	C	D	D
2020 - 2021	B	D	C
2021 - 2022	B	C	C
2022 - 2023	B	D	C
2023 - 2024	**C**	**F**	**D**



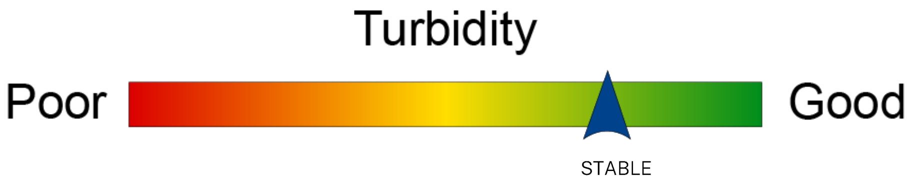
3.1.5 Macdonald River

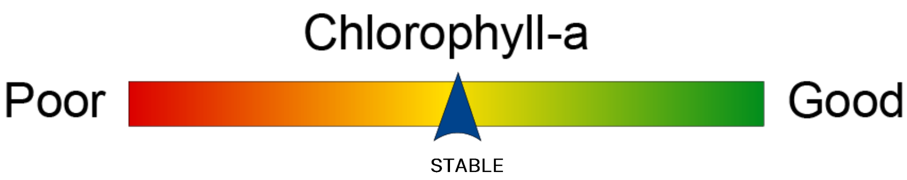
Overall water quality in the Macdonald River remained stable, scoring a C (fair) grade in 2023-2024 (Table 6). The turbidity grade remained stable at B (good), with only minor exceedances of the trigger value on three occasions. The chlorophyll-a grade also remained stable at C (fair) during 2023-2024 with four minor to moderate exceedances of the chlorophyll-a trigger value (Table 6).

The mean salinity recorded at the Macdonald River zone was 2.73 psu, with a minimum salinity of 0.15 psu. A maximum recorded salinity of 5.78 psu was recorded in October 2023 (Figure 2).

Table 6 Calculated grades in the Macdonald during the 2023-2024 monitoring period and previous years for comparison. A sliding scale diagram of the turbidity and chlorophyll-a grades for 2023-24 (relative to 2022-23 grades) is shown below

Sampling Period	Turbidity	Chlorophyll-a	Overall Water Quality
2018 - 2019	B	B	B
2019 - 2020	B	B	B
2020 - 2021	C	D	C
2021 - 2022	D	B	C
2022 - 2023	B	C	C
2023 - 2024	**B**	**C**	**C**





3.2 River flows and water quality

3.2.1 River flows

Discharge rates (ML/day) at Penrith Weir, upstream of the confluence with the Hawkesbury River, are shown in Table A 1 and the flow exceedance curve for the Nepean River is plotted in Figure A 1. River flows for the Nepean River at Penrith Weir were in the lowest 25% of the flow exceedance curve in July 2023 and during spring (September - October 2023, Figure A 1). Medium flows in the 50-80% range were observed in August 2023, January 2024, February 2024 with high flows in the 80-95% range in early December 2023 and the beginning of July 2024 (June 2024 sampling run was conducted on 2nd July 2024, Figure A 1). The river system had flows in the top 5% of the flow exceedance curve in April and May 2024, following very high rainfall catchment wide in April 2024 (>300 mm at Gosford, Table A 2).

3.2.2 Water quality trends

Salinity

Salinity at the upstream zones of the tidal pool (Windsor, Riverside Oaks, Lower Portland) was below 0.3 psu throughout the 2023-2024 sampling season (Figure 2, Figure 3). Wisemans Ferry and the lower Macdonald River at the downstream sampling zones were low-saline brackish conditions from July to December 2023 with maximum salinity of ~10 psu in October 2023 (Figure 2). Salinity at these zones reduced to ~1 psu in early 2024, before shifting to completely fresh in April 2024 following very high river flows in April 2024 (Figure 2).

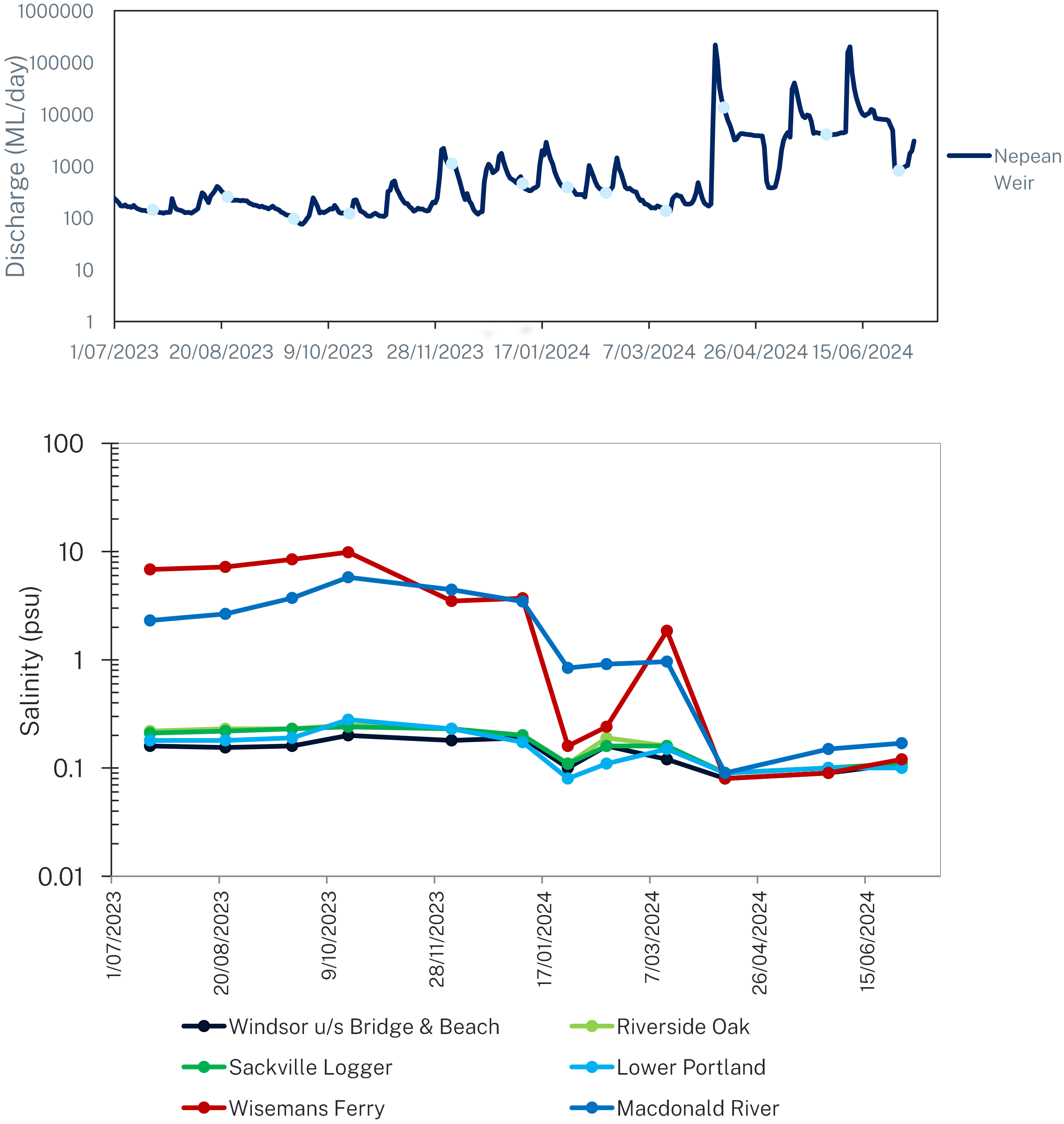


Figure 2 Temporal trends in salinity (psu) at the monitoring zones in the Hawkesbury River and Macdonald River during the 2023-2024 sampling period. Discharge (ML/day) at the Penrith Weir is shown in the top plot for context. Data points on the plots indicate sampling dates.

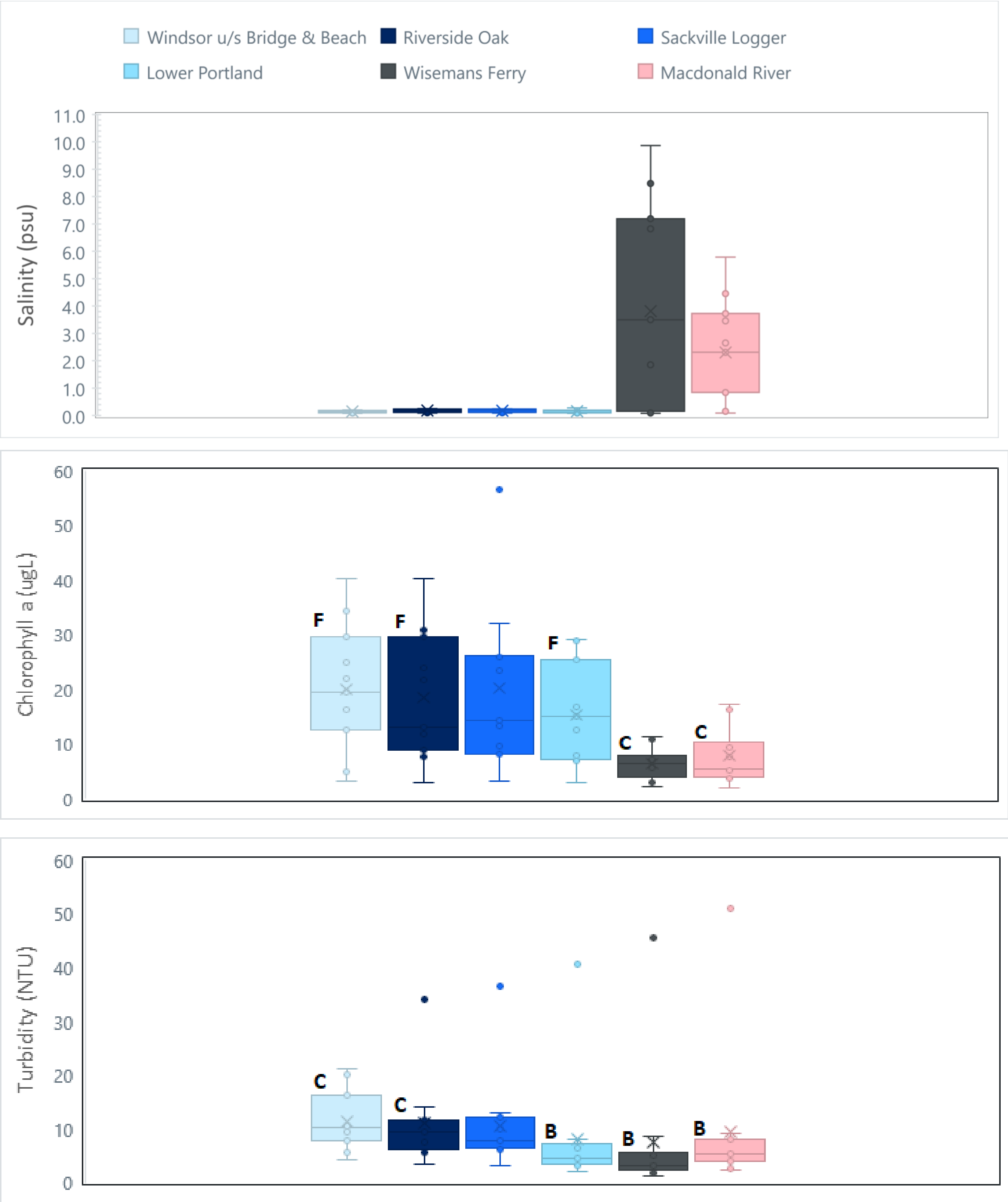


Figure 3 Spatial trends in salinity (psu), chlorophyll-a (ug/L) and turbidity (NTU) at monitoring zones from upstream (left) to downstream (right) during the 2023-2024 sampling period. Report card grades for chlorophyll-a and turbidity for each zone are shown in the chart. The whiskers indicate variability outside the upper and lower quartiles (the box) with mean (X), median (line) and outliers (circles) indicated in the box and whisker charts.

Chlorophyll

Chlorophyll-a concentrations in estuary waters is used as a proxy measure for phytoplankton (microalgae) biomass. Chlorophyll-a concentrations were higher and more variable in the tidal pool at the upstream reaches, than farther downstream (Figure 3). Chlorophyll-a concentrations ranged from 10 – 55 µg/L from July 2023 to December 2023, indicating phytoplankton biomass was increasing in the upper reaches during this period of low to medium river flows (Figure 4, Figure 5). Chlorophyll-a concentrations were below 10 µg/L at Wisemans Ferry and the lower Macdonald River from July to December 2023 (Figure 5). Chlorophyll-a concentrations at all zones were lower in 2024 and ranged ~2 – 12 µg/L indicating phytoplankton biomass was lower in the river from January to July 2024 when flows were in the medium and high flow ranges (Figure 4, Figure 5).

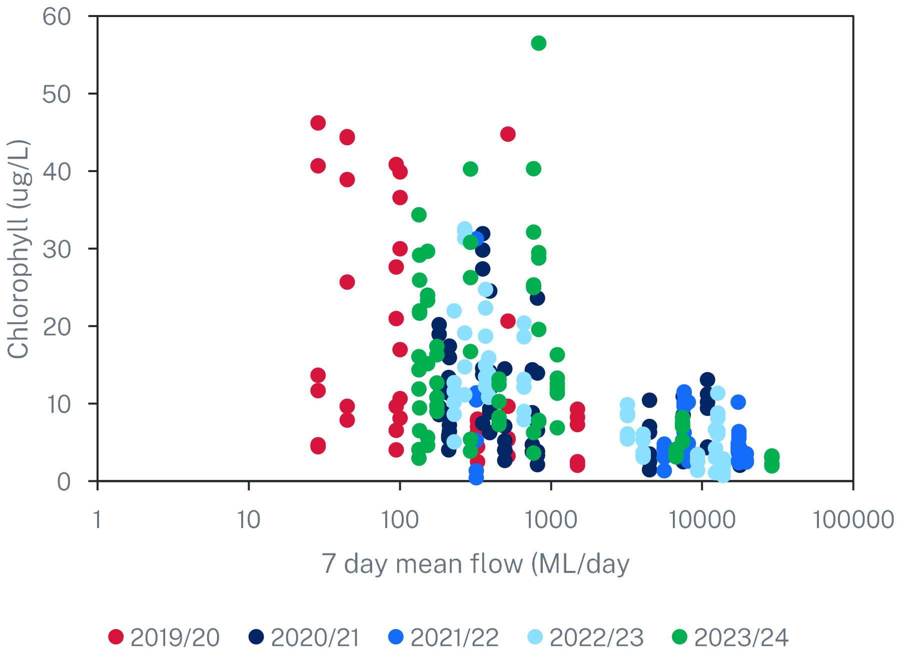


Figure 4 Flow vs chlorophyll-a for all zones sampled for the Mid-Upper Hawkesbury water quality monitoring program in 2023-2024 (green circles). Data from previous years is also shown (2019-2020 – red circles, 2020-2021 – dark blue circles, 2021-2022 - blue circles and 2022-2023 – light blue circles).

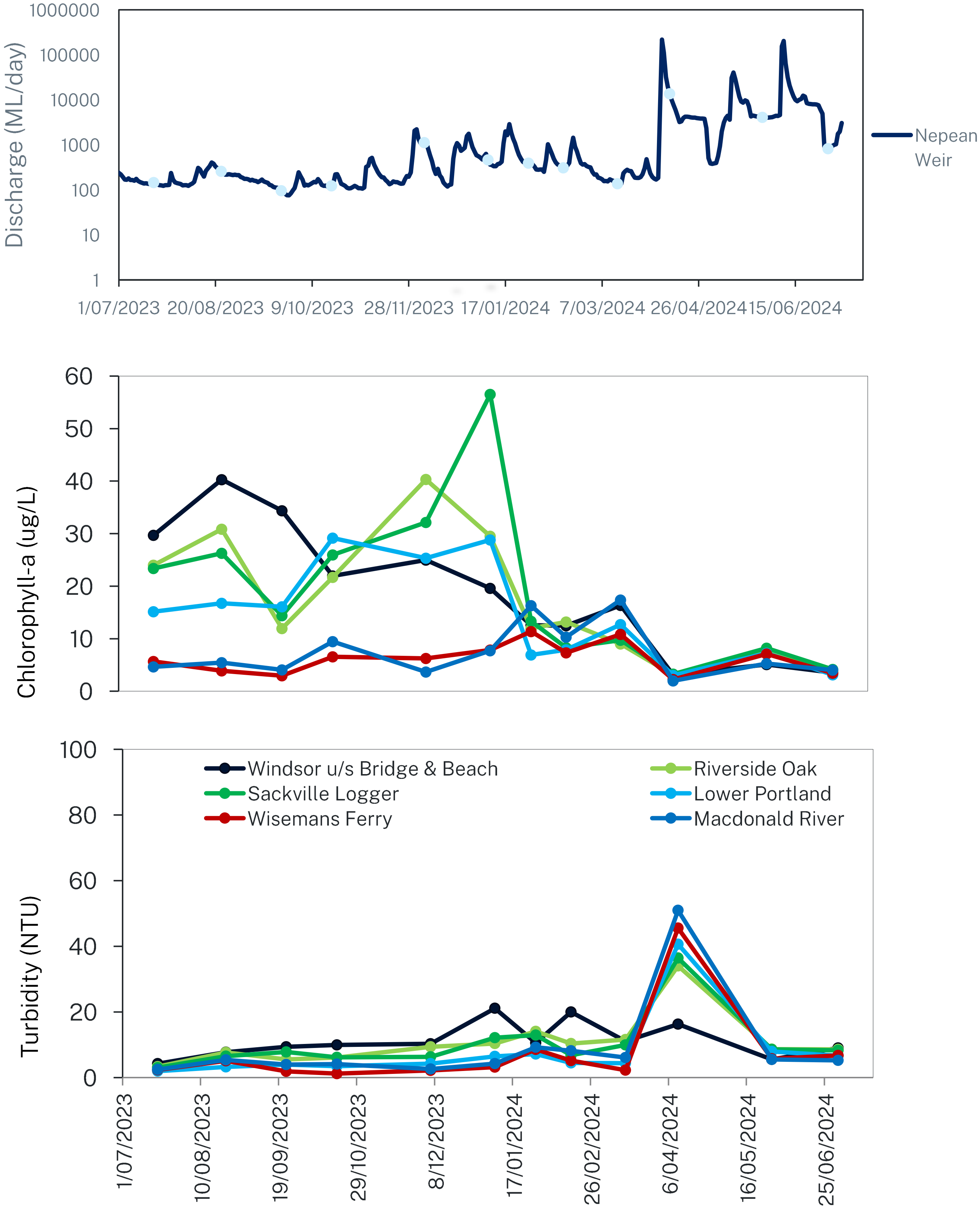


Figure 5 Temporal trends in chlorophyll-a (ug/L) and turbidity (NTU) at the monitoring zones in the Hawkesbury River and Macdonald River during the 2023-2024 sampling period. Discharge at the Penrith Weir is provided in the top plot for context of river flows at the time of sampling. Data points on the plots indicate sampling dates.

Turbidity

Turbidity throughout the system was variable in 2023-2024, with large spikes in turbidity observed when river flows exceeded 50,000ML/day (Figure 5, Figure 6). Turbidity in the Windsor reach of the Hawkesbury River was slightly elevated during low flows compared to zones farther downstream where turbidity was generally lower (Figure 5, Figure 6). Turbidity increased sharply up to as high as 50 NTU throughout the system during high flow periods in April 2024, with rapid recovery to <10 NTU by May 2024 (Figure 5, Figure 6). Turbidity maximum increased in the downstream reaches of the sampling area where turbidity was typically less variable than upstream zones (Figure 3).

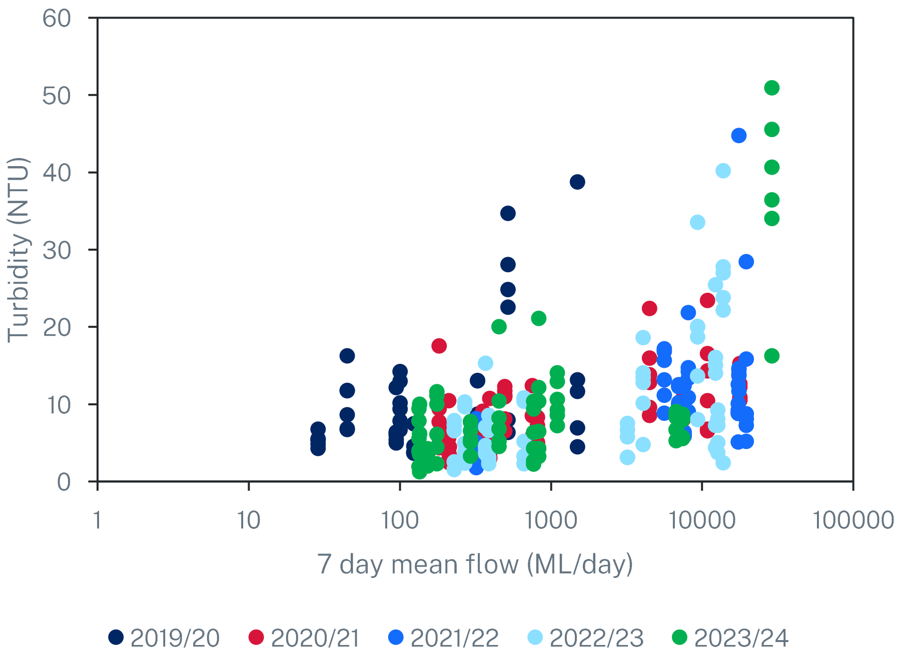


Figure 6 Flow vs turbidity for all zones sampled for the Mid-Upper Hawkesbury water quality monitoring program in 2023-2024 (green circles). Data from previous years is also shown (2019-2020 – dark blue circles, 2020-2021 - red circles, 2021-2022 – blue circles and 2022-2023 – light blue circles).

4 Summary and discussion

The overall water quality at Windsor and Riverside Oaks, the two most upstream zones, declined to a D (poor) grade in 2023-2024 due to both turbidity and chlorophyll-a dropping a grade. The overall water quality remained stable at Macdonald River (C-fair) with no change to turbidity (B-good) and chlorophyll-a (C-fair) grades. The overall water quality at Lower Portland retained its C grade despite the chlorophyll-a grade dropping from D (poor) to F (very poor). At the most downstream zone the Overall water quality at Wisemans Ferry, overall water quality improved to a B (good) grade in 2023-2024 due to an improved chlorophyll-a grade. The decline in water quality grades for the two upstream zones (Windsor and Riverside Oaks) was driven by a combination of an increase in chlorophyll-a concentrations during low flow periods in spring and an increase in turbidity during higher flows in summer and autumn.

Understanding the flow conditions leading up to and at the time of sampling for water quality is important for determining primary drivers that influence the health of the system (e.g., residence times, external versus internal nutrient supply and total suspended solids inputs from the catchment etc.). Flow condition in for most of 2023-2024 water quality sampling season were typical for the Hawkesbury River. However, there were very high flows in April and May 2024, following a significant rain event in early April which resulted in moderate to severe flooding in the catchment. It has been shown that chlorophyll-a concentrations within the Hawkesbury River are generally flow dependent and likely to be related to the residence times of the water bodies.

The general trends in chlorophyll-*a* observed at the upstream zones in 2023-2024 follow our conceptual understanding of tidal pool processes, that is, lower flows result in increased chlorophyll-a in the water column. Trends in turbidity are driven by spatial factors throughout the bulk of time, with episodic large spikes due to high-flow inputs of diffuse material. Chlorophyll-a and turbidity data from previous years of sampling have followed the same pattern, with high chlorophyll concentrations and lower turbidity observed during periods of low flow and lower chlorophyll-a concentrations and spikes in turbidity occurring during high flows.

The decline in the chlorophyll-a grade at Windsor, Riverside Oaks and Lower Portland was likely driven by low river flows during spring and longer residence times when rainfall was well below average from July-October 2023. Rainfall increased in early-to-mid 2024 resulting in high river flows, lower chlorophyll-a concentrations due to shorter residence time, and increased turbidity particularly in April 2024. The spike in turbidity in April 2024 throughout the system was likely due to high sediment load in catchment runoff affecting water quality in receiving waters and resulted in a drop in the turbidity grade (to fair - C) at Windsor and Riverside Oaks. Further downstream, river flows had less influence on phytoplankton biomass as shown by lower and less variable chlorophyll-a concentrations in the brackish zones at Wisemans Ferry and Macdonald River, where overall water quality remained stable. This year's results are in line with previous years for the Macdonald River zone, which usually receives better grades for water quality (except following major flood events) than the sampling zones in the main river stem due to the Macdonald River catchment being considerably less modified than the catchments of the main river stem and other tributaries.

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.

6 Appendix

Table A 1 Nepean River flows (ML d^{-1}) at Penrith Weir on the sample times (instantaneous) and for the preceding 7 and 14 days (means) – data sourced from MHL.

Sampling Trip no.	Sampling Date	Instantaneous	7-day mean	14-day mean
Trip 1	19/07/2023	145	140	152
Trip 2	23/08/2023	258	328	293
Trip 3	23/09/2023	96	114	134
Trip 4	19/10/2023	123	127	135
Trip 5	6/12/2023	1120	1361	768
Trip 6	8/01/2024	464	542	830
Trip 7	29/01/2024	390	497	1102
Trip 8	16/02/2024	307	415	452
Trip 9	15/03/2024	136	153	176
Trip 10	11/04/2024	13618	57506	28888
Trip 11	29/05/2024	4099	4268	7407
Trip 12	2/07/2024	818	4152	6708

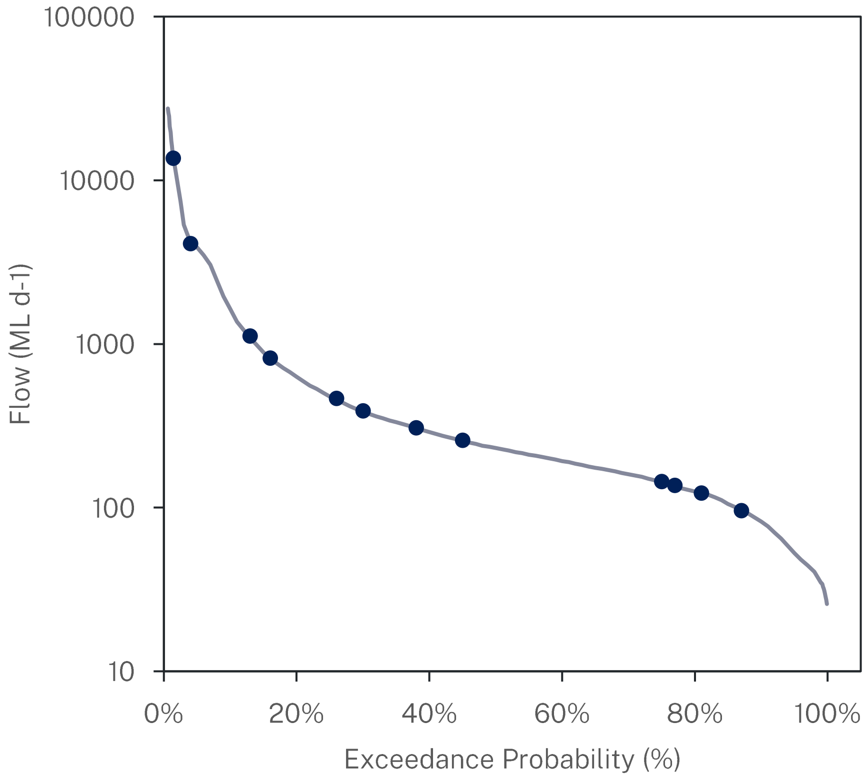

Figure A 1 Flow exceedance curve for Nepean River at Penrith Weir (grey line), showing flows during sample times (dark blue dots). Data source – MHL.

Table A 2 Rainfall totals (mm) from October 2017 to May 2024 at Australian Weather Station (AWS) 61425 at Gosford (Australian Bureau of Meteorology); monthly, annual totals and the sum of rainfall from October to April* each monitoring season.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	Sum Oct to Apr
2017	35.6	152.4	399.2	113.4	36.0	154.2	7.8	10.6	2.4	79.2	78.0	61.8	**1130.6**	
2018	26.6	163.2	102.8	73.0	17.8	213.6	12.0	17.6	58.2	258.0	77.0	61.0	**1080.8**	**584.6**
2019	57.0	109.0	256.4	40.2	17.6	161.2	46.0	212.6	112.6	49.8	*21.8*	3.0	**1087.2**	**858.6**
2020	125.6	256.4	180.4	39.8	50.2	56.4	*171.6*	51.2	*50.2*	253.2	*36.2*	*197.6*	**1468.8**	**676.8**
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	**1428.6**	**1207.0**
2022	116.0	*446.0*	579.0	225.2	129.8	14.0	448.8	30.2	149.4	160.6	25.2	49.0	**2373.2**	**1762.6**
2023	88.0	173.4	74.6	133.2	46.8	21.2	*22.2*	*57.4*	16.8	58.8	135.0	66.0	**893.4**	**704.0**
2024	85.4	*121.6*	22.4	305.6	245.2									**794.8**
Mean station all years (2013-2024)	**111.8**	**122.6**	**222.0**	**148.3**	**59.3**	**122.0**	**89.3**	**80.5**	**63.1**	**102.2**	**92.5**	**81.6**	**1312.5**	**881.0**

*Rainfall total is summed from October to April each sampling season as only water quality data from these months are used to calculate grades.

No data for Gosford AWS in February 2022, data from Wyong (AWS 61381) used instead

No data for Gosford AWS in July and August 2023, data from Ourimbah (AWS 61093) used instead