Lake Illawarra Estuary Health and Water Quality Report 2023

Reporting on data May 2022 to April 2023

Prepared by Wollongong City Council

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wollongong
city of innovation

Shellharbour
CITY COUNCIL

NSW GOVERNMENT

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Summary

Wollongong City Council and Shellharbour City Council have been monitoring water quality and estuary health in Lake Illawarra since October 2013. This is a report for the monitoring period from May 2022 to April 2023, focussing on those measurements that are especially important for assessing the lake condition for its ecosystem health and recreational use.

Rainfall and hence freshwater discharge continues to be an influential factor on the water quality of the Lake. While the total rainfall for the sampling period was the second highest since 2009, the majority of the rain fell over the winter period. This is different to what has occurred in previous years, particularly so when compared to the last sampling period 2021-22, where large and sustained rainfall events occurred during summer and early autumn. The analysis of estuary health is undertaken with data from the summer period (1st November 2022- 30th April 2023) and nine of the eleven sites were rated as good or very good. For the first time an overall grade for the Lake Illawarra as a whole was calculated, and the lake received a Good rating or a B grade. Site 4 at Burroo Bay and Site 6 at Griffins Bay were the only sites rated as being in fair condition. Importantly though trend analysis tells us what is happening on a long-term scale at these sites. Even though Burroo Bay and Griffins Bay were rated fair it is significant that these sites plus Site 5 at Kanahooka have decreasing trends for 3 of the 4 parameters despite them being close to feeder creeks and catchment inputs. Site 3 (near Picnic Island) is the only site in the Lake that continues to show an increasing trend for total nitrogen and total phosphorous. The in-lake sites continue to show no trend for chlorophyll *a*, total phosphorus, total nitrogen and turbidity values over the long term. This is not surprising though as they have been graded as being in good or very good condition since 2017.

Assessing recreational water quality (primary and secondary recreation contact) has been utilised through sampling for enterococci at three sites in Lake Illawarra since 2018. Estuarine sites are particularity impacted by potential sources of faecal contamination, including stormwater and urban and rural run-off. All sites had higher percentage compliance than the previous year and reflects the lower rainfall over the 2022/23 summer period.

Monitoring the health of the lake should continue, as long-term datasets are essential to gain insights into how the lake is changing over time and is of greater value than focusing on specific individual sampling events. Given the large-scale developments occurring in the catchment of the lake and the potential impacts of a changing climate, it is important that the health of the lake is monitored. The implementation of the suite of management actions in the Lake Illawarra Coastal Management Program to control catchment inputs is strongly supported, and long-term monitoring of the lake will inform whether investment in the lake is making a difference.

Contents

1 Introduction

Lake Illawarra is a significant natural asset for the community, and it is highly valued for its ecological, social and economic attributes (BMT 2020a). Wollongong City and Shellharbour City Councils, in partnership with the State Government, have prepared a Coastal Management Program to address the main threats to the Lake values. Catchment development and its potential impact on water quality in the Lake is identified to be one of the most significant threats needing to be managed (BMT 2020 b). Several actions in the Coastal Management Program for the Lake relate to protecting water quality. Targeted monitoring, evaluation and reporting of water quality and other health indicators are recommended to track the outcome of implementing these actions (refer to Appendix 1 for the list of water quality improvement and management actions in the Lake Illawarra Coastal Management Program 2020-2030).

There is a long history of water quality monitoring in the Lake, with various agencies involved at differing times. Wollongong City and Shellharbour City Councils took on this responsibility in October 2013, often with funding and technical assistance from the NSW Government Department of Planning and Environment (DPE) coast and estuary management program, and since then regular reports on the results have been issued. These reports have considerable detailed analysis and show that there can be spatial and temporal variation in water quality, with season and weather patterns (particularly rainfall) having a major influence. This report covers the monitoring period from May 2022 to April 2023 and focusses on those measurements that are especially important for assessing the lake condition for its ecosystem health and recreational use.

This report has been developed to accompany the 2022-23 Lake Illawarra Estuary Health Report Card and provides the technical information on how the Report card scores are calculated as well as more detail on the results.

2 Water quality and estuary health

Good management of our estuaries requires an understanding of how estuaries function, an assessment of their condition and informed management decisions to maintain or improve the health of the estuary. The NSW Department of Planning and Environment (DPE) has undertaken extensive research of NSW estuary functioning, the impacts of catchment activities on estuary and the development of an estuary health monitoring and reporting framework (Roper et al 2011).

From this research the abundance of chlorophyll-*a* and turbidity are two measures recommended as indicators of estuary health. Wollongong and Shellharbour City Councils use these two indicators to measure the estuary health of Lake Illawarra, as well as a number of supporting water quality parameters such as nitrogen and phosphorous. Chlorophyll-*a* is an indicator of the microalgal abundance in a water body, and its measure is preferred for estuary health assessment as it is reported to be a good short-term indicator of response to a range of pressures and management, including nutrient (such as nitrogen and phosphorus) status. Water clarity and sediments inputs are assessed my measuring turbidity.

Ecological health does not refer to environmental health issues such as drinking water quality, safety for swimming, heavy metal contamination or our ability to harvest shellfish or fish.

2 Monitoring program

2.1 Water quality and estuary health monitoring

Eleven sites within Lake Illawarra are monitored monthly for water quality and estuary health (Table 1, Figure 2). The parameters sampled are:

Water Quality:

- Temperature
- pH
- Dissolved oxygen
- Salinity
- Phosphorus (total phosphorous, filtered total phosphorous and filterable reactive phosphorus)
- Nitrogen (total nitrogen, nitrite and nitrate, and ammonia)

Estuary Health:

- Turbidity
- Chlorophyll-*a*

Figure 1: Description of estuarine ecological indicators

Nitrogen is analysed as total nitrogen in unfiltered water (TN), the total after filtration (FTN), the amount present as nitrate and nitrite (often referred to as NOx's), and as ammonia, the reactive inorganic forms which are generally considered to be more bioavailable.

Phosphorus is analysed as total phosphorus in unfiltered water (TP), in filtered water (FTP), and as filterable reactive phosphorus (FRP). The filterable reactive phosphorus generally constitutes simple inorganic phosphorus (such as orthophosphate) and is considered more bioavailable than other forms of phosphorus.

The sampling procedure for turbidity and chlorophyll *a* are taken in accordance with the NSW Monitoring, Evaluation and Reporting sampling, data analysis and reporting protocols (State of NSW and Office of Environment and Heritage 2016).

2.2 Recreational water quality

Since the 2018/19 summer, three sites within Lake Illawarra were included for recreational water quality testing, following the NSW Beachwatch Program protocols, which test for the presence of enterococci – a group of bacteria indicating water quality condition for recreational use.

A site at the entrance (called Entrance lagoon beach) has been monitored for many years by the NSW Beachwatch Program and the data is analysed and reported within the NSW Beachwatch framework (State of NSW and DPE 2022). Currently the three sites added by Councils are not reported under the NSW Beachwatch program.

The sites added by Councils in 2018/19 to measure recreational water quality are located at Ski Way Park, Kanahooka and Purry Burry Point, which are popular launch sites for many recreational pursuits in the Lake (Table 1, Figure 2). These three sites were tested for the presence of enterococci on 20 occasions between October 2022 and April 2023.

Table 1: Description of the 11 sites monitored for water quality and estuary ecosystem health (in blue) and 3 sites monitored for recreational water quality (in orange)

Water Quality and Estuary Health sites		
Site ID	**Site location**	**Lake Zone**
Site 2	Boat ramp at Windang Peninsula	Lake entrance
Site 3	Bridge to Picnic Island	Lake entrance
Site 3A	Jetty at Boonerah Point Reserve	Foreshore
Site 4	Jetty at Sailing Club at Burroo Bay	Foreshore
Site 5	Boat ramp and jetty at Kanahooka	Foreshore
Site 6	Jetty at Griffins Bay Wharf	Foreshore
NS1	North along a north-south transect	In-lake
NS2	Middle along a north-south transect	In-lake
NS3	South along a north-south transect	In-lake
EW1	East along an east-west transect	In-lake
EW2	West along an east-west transect	In-lake
Recreational water quality sites		
Purry Burry Point	Primbee	Foreshore
Ski Way Park	Oak Flats	Foreshore
Kanahooka	Kanahooka/Koonawarra	Foreshore

Figure 2: Map showing location of the 11 sites monitored by Council for water quality and estuary ecosystem health (in blue) and the 3 sites for recreational use (in orange)

3 Data Analysis

3.1 Water quality analysis for estuary ecosystem health

As in previous years, all indicators including those not covered in this report have been plotted against sampling date, rainfall, and the corresponding guideline trigger value from October 2013 to April 2023 for the 11 sites monitored. The indicators discussed in depth in this this report are various forms of nitrogen and phosphorous, chlorophyll-*a* and turbidity, which are some of the more important indicators of estuary ecosystem health and the catchment influence on the Lake. The guideline trigger values utilised are given in Table 2.

Table 2: Guideline trigger values

Parameter	Guideline	Source
Total Nitrogen (TN)	0.3 mg/L	ANZECC (2000)
Filtered Total Nitrogen (FTN)	0.3 mg/L	Based on TN from ANZECC (2000)
Nitrate and Nitrite (NOx's)	0.015mg/L	ANZECC (2000)
Ammonia	0.015 mg/L	ANZECC (2000)
Total Phosphorous (TP)	0.03 mg/L	ANZECC (2000)
Filtered Total Phosphorus	0.03 mg/L	Based on TP from ANZECC (2000)
Filtered Reactive Phosphorus	0.005 mg/L	ANZECC (2000)
Chlorophyll-*a*	3.6 µg/L[a]	State of NSW and DPE
Turbidity	5.7 NTU[b]	State of NSW and DPE

[a] This value has been updated to 5 µg/L in State of NSW and Office of Environment and Heritage (2016)
[b] This value has been updated to 6 NTU in State of NSW and Office of Environment and Heritage (2016)

The guideline trigger values for chlorophyll-*a* and turbidity continue to be the values previously adopted for the NSW Monitoring, Evaluation and Reporting Program (State of NSW and Office of Environment and Heritage 2013) rather than the updated values (State of NSW and Office of Environment and Heritage 2016), in order to maintain consistency with the values ulitised in earlier reports. These are also the values utilised in developing a risk-based framework for protecting the health of Lake Illawarra (Office of Environment and Heritage and the Environment Protection Authority 2017). Therefore, retaining these values as the desired target condition for the rest of the lake is reasonable at this time.

The data for TN, TP, chlorophyll-*a* and turbidity have also been subjected to a trend analysis using the water quality software program eWater to determine whether statistically significant trends are apparent for these indicators at any of the sites over the eight years. The non-parametric Seasonal Kendall test has been used for this, a method that is widely used to detect trends where there is a significant seasonal influence on water quality. Rainfall effects can detract from the seasonality pattern, and to account for this, data points that were greater than two standard deviations from the mean were excluded from the analysis. The trend analysis was performed with the filtered data.

3.2 Estuary ecosystem health condition

The estuary ecosystem health condition of each site has been determined based on its chlorophyll *a* and turbidity status over the summer months. The summer period is taken to be from 1 November to 30 April, while the winter is from 1 May to 31 October.

The methodology used is consistent with that recommended by the NSW Monitoring, Evaluation and Reporting (MER) protocols for estuaries and coastal lakes, which assesses the degree of compliance of these parameters with their water quality trigger values and allocates a condition grade ranging from very poor to very good, as described in Table 3. The full methodology for calculation of the estuary condition grade is described in State of NSW and Office of Environment and Heritage (2016). As noted in Table 2, the trigger values utilised for chlorophyll-*a* and turbidity are 3.6 µg/L and 5.7 NTU respectively, rather than the updated values as reported in 2016 (State of NSW and Office of Environment and Heritage 2016).

Assigning the Estuary Condition Grade

The estuary condition grading system is based on detailed work by the NSW MER framework that looked at data for 130 estuaries in NSW. The grade definitions described in Table 3 are structured to allow easy comparison between different estuaries and for individual estuaries over time.

It is important that the cut-off values for each grade reflect the condition of each site in comparison to a broader scale of condition across all New South Wales estuaries (i.e., an 'Good' grade represents a good condition for a New South Wales estuary). To assist with the derivation of cut-offs, scores were calculated for 130 zones across a wide range of New South Wales estuaries using the same guidelines and worst expected values (State of NSW and Office of Environment and Heritage 2016). Cut-offs were then defined as representing a percentage of the scores for the state (Table 3). For example, a site score less than 0.07 defined the 20% of best site scores in the state and this became our 'Very Good' grade (see Figure 3 for other cut-offs).

Table 3: Descriptors for estuary ecosystem health condition grades

Grade	Result	Definition	Description
A	Very Good	The indicator meets the benchmark values for almost all of the time period.	Equivalent to the best 20% of scores in the state
B	Good	The indicator meets the benchmark values for most of the time period.	Equivalent to the next 30% of good scores
C	Fair	The indicator meets the benchmark value for some of the time period.	Equivalent to the middle 30% of scores
D	Poor	The indicator does not meet the benchmark value for most of the time period.	Equivalent to the next 15% of poorer scores
E	Very Poor	The indicator does not meet the benchmark value for almost all of the time period.	Equivalent to the worst 5% of scores in the state

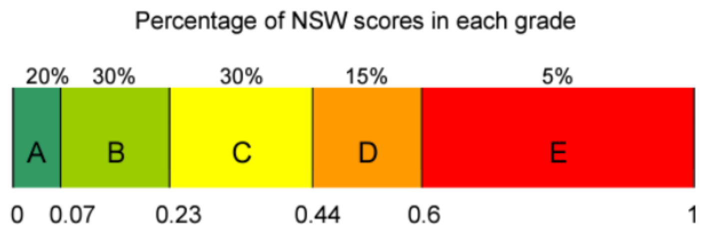


Figure 3: Relationship between distribution of NSW scores, grades and site scores

3.3 Water quality for recreational use

The analysis of the three sites within Lake Illawarra tested for the presence of enterococci calculates the percentage of the testing occasions when the sites complied with the guidelines for primary and secondary recreational use contact criteria (Table 4).

Table 4: Guideline trigger values for recreational use

Recreational Use	Guideline trigger value (enterococci)
Primary contact	35 cfu/100ml
Secondary contact	230 cfu/100ml

(source: ANZECC (2000))

4 Results

Several factors can influence water quality in a lake such as Lake Illawarra. These include weather, catchment runoff, assimilation and/or release of dissolved substances in the water by lake sediments, aquatic plants and animals, and the extent of flushing of the waterbody by tidal and catchment flows. These factors may not be uniform through the lake, suggesting variations in water quality can be expected in space and time. Rainfall has a significant influence on water quality and is considered one of the most important factors affecting water quality in the Lake in previous years. Table 5 presents the seasonal and yearly total rainfall records for the last twelve years and it shows that the 2022/23 was the second wettest year total since sampling began. Compared to the year before though and many other previous years, the largest amount of rainfall occurred during the winter period, rather than during the summer (Table 5).

Table 5: Seasonal rainfall (mm) at Darkes Road since 2009

Year	Winter (1 May to 31 Oct)	Summer (1 Nov-30 April)	Year total
2009/10	333.5	523	856.5
2010/11	520	800	1320
2011/12	476.5	616	1092.5
2012/13	215	515	730
2013/14	498.5	813	1311.5
2014/15	365	771.5	1136.5
2015/16	461	460	921
2016/17	602.5	748	1350.5
2017/18	108	458	566
2018/19	253	407	660
2019/20	286.5	598	884.5
2020/21	474.5	720	1194.5
2021/22	384.5	1425.5	1810
2022/23	1046.5	510	1556.5

4.1 Temporal analysis of parameters

4.1.1. Temperature, salinity and pH

Long term graphs of temperature, salinity and pH since 2014 have been presented in Appendix 2 for the 11 sites monitored for water quality and estuary health. In the past 12 months sites have continued to show a seasonal pattern in temperature as evident in previous years. The temperature variation between summer and winter can be as much as approximately 10-15^{0}C, and this can be expected to cause seasonal change in other water quality processes which are temperature dependent.

A pH range of 7 to 8.5 is considered to be satisfactory for estuarine ecosystems (ANZECC 2000). Values did not go below 7 for the May 2022- April 2023 period, with four exceedances above 8.5 at Site 6 only suggesting there are no concerns relating to pH at Lake Illawarra.

Salinity since 2014 has been graphed against the daily rainfall records (Appendix 2). The results show that a salinity of around 30-35ppt continues to be maintained, except close to rainfall events where it decreases temporarily (Appendix 2).

4.1.2 Nitrogen

When assessing the condition of an estuarine water body, chlorophyll *a* and turbidity are considered better indicators of estuary ecosystem health than the nitrogen and phosphorus concentrations. High nutrient concentrations do not always correlate with poor estuary health (Scanes et al. 2007), and there can often be a weak correlation between nitrogen loads and chlorophyll *a* concentrations (Roper et al. 2011). High nutrient inputs can, however, ultimately lead to poor water quality, and monitoring their concentrations in different parts of the lake can help identify inputs where nutrients may be significant and thus require management.

Over the May 2022 to April 2023 period the concentrations of nitrate, nitrite and ammonia were below or close to their respective detection limits (0.01mg/L) for all of the sampling period for the in-lake sites, indicating these more bio-available forms of nitrogen continue to be rapidly utilised by phytoplankton and other plant life in the Lake. The foreshore sites though showed greater variability, with high nitrate, nitrite and ammonia levels recorded at Site 3, 4, 5 and 6 in May 2022. A high rainfall event occurred a few weeks before in mid-April resulting in a significant increase of the nitrogen load of the lake. Site 3 displayed consistently high levels of nitrate and nitrite for 11 of the 12 sampling events, and Site 6 had 5 sampling events with high levels.

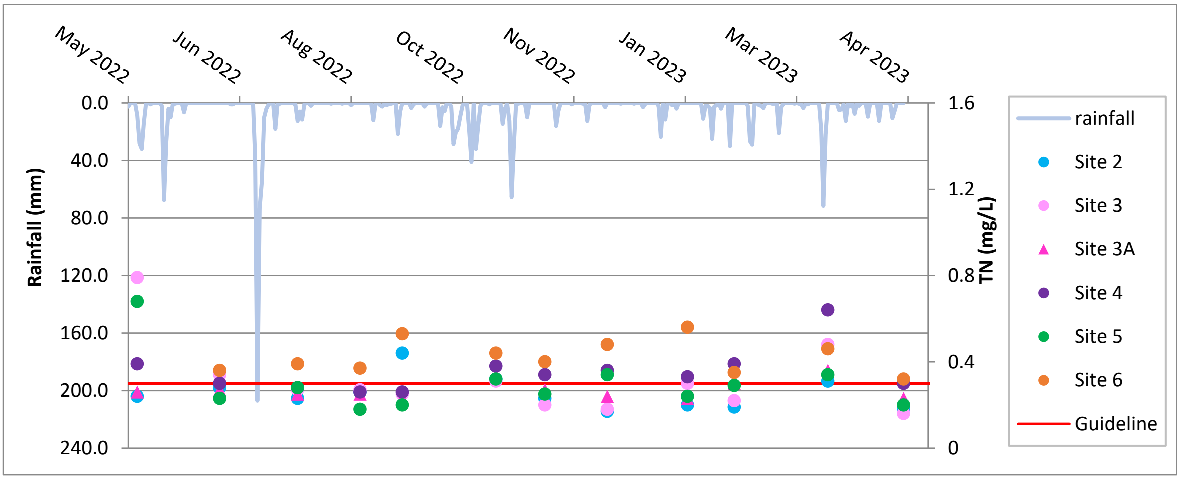
Figure 4 shows total nitrogen (TN) values and rainfall for May 2022-April 2023 for the foreshore and in-lake sites. In Appendix 2 graphs of the results from the last eight years are presented for all 11 sites. Griffins Bay (Site 6) had TN values higher than the recommended guideline 8 out the 12 sampling events (Figure 4a). Site 4 also had high TN values for 50% of the sampling events, and this pattern of these two sites having high TN values is reflective of patterns in other years.

In May 2022 Sites 4, 5 and 3 showed TN levels 2 to 3 times higher than the recommended Guideline (Figure 4a). Ammonia, nitrate and nitrate levels were also high at this time. A high rainfall event occurred in mid-April, thus indicating significant nitrogen loads to the estuary and that the high load of nitrogen was not able to be utilised by phytoplankton and plants. A high rainfall event in March 2023 saw all sites being recorded with values above the recommended guideline, but the highest values being recorded at Sites 3, 4 and 6; while the other sites were just slightly above the guideline.

All in-lake sites were below, or just above the recommended ANZECC guideline for TN for the entire sampling period (Figure 4b).

Interestingly an extremely high rainfall event occurred in early July with 207mm of rain. Sampling took place 17 days later and all sites were close or below the guideline value (Figure 4). This indicates the nitrogen were flushed out of the lake by the time of sampling and/or were able to be utilised by phytoplankton and other plant life in the lake.

A: Foreshore sites



B: In-lake sites

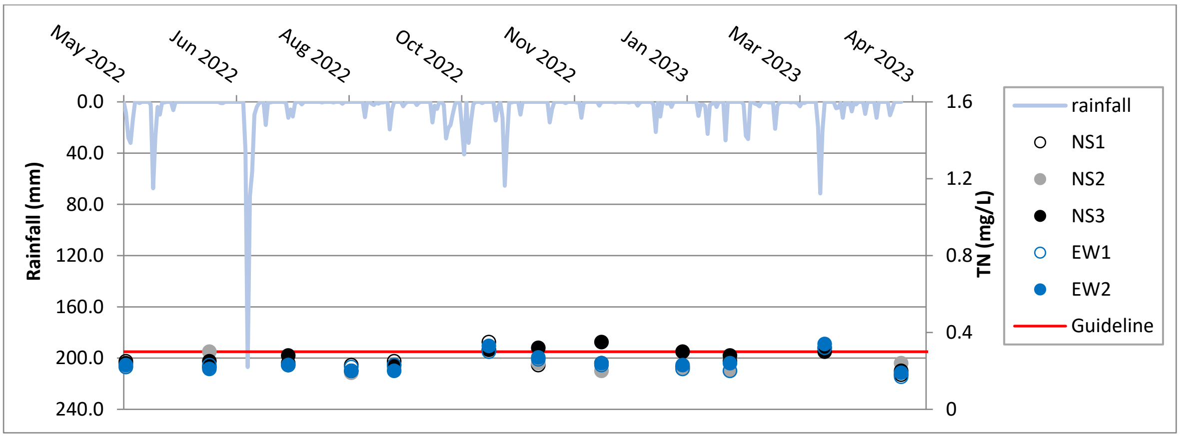
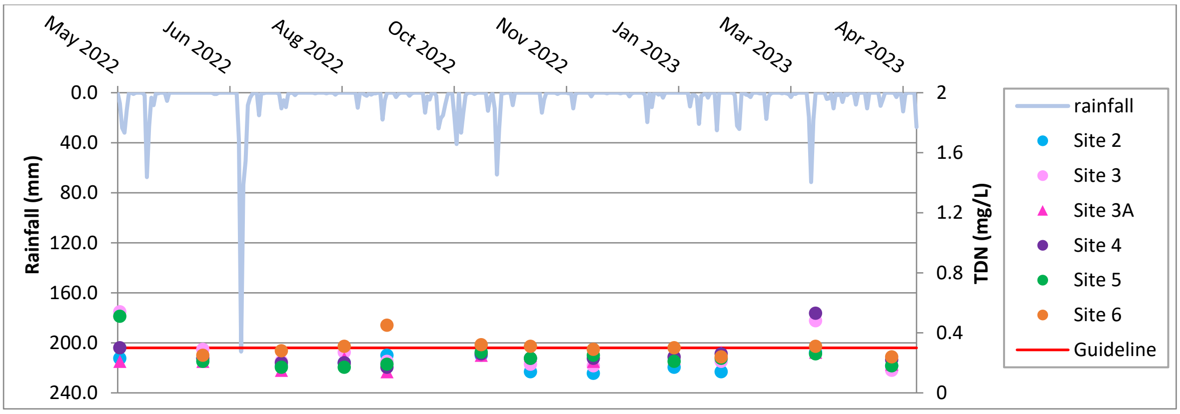


Figure 4: Plots of total nitrogen (TN) and rainfall from May 2022 to April 2023 for the (A) Foreshore (lake edge) sites and (B) In-lake sites

The TN value represents nitrogen that is present in water in both the dissolved and suspended forms, including microscopic algae and sediments, while the filtered total nitrogen (FTN) excludes the suspended component. The FTN for the May 2022-April 2023 period (Figure 5) continues to show better compliance with its guideline trigger value than TN. Similar to the pattern for TN, foreshore sites 3 and 5 had FTN values nearly two times greater than the ANZECC guideline in May 2022, and Sites 4 and 6 had high values in March 2023 related to rainfall (Figure 5a). All in-lake sites recorded values below the Guideline throughout the year (Figure 5b).

A: Foreshore sites



B: In-lake sites

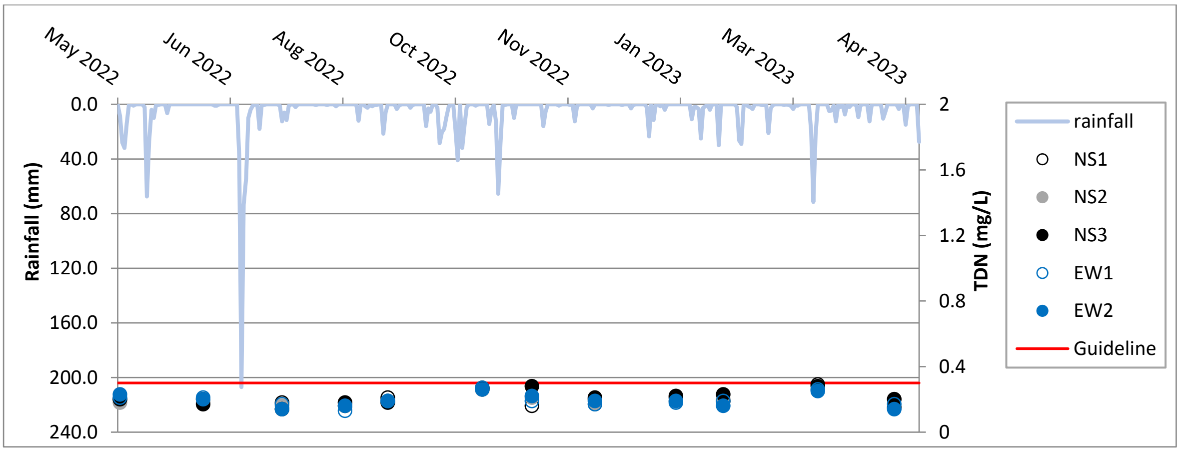
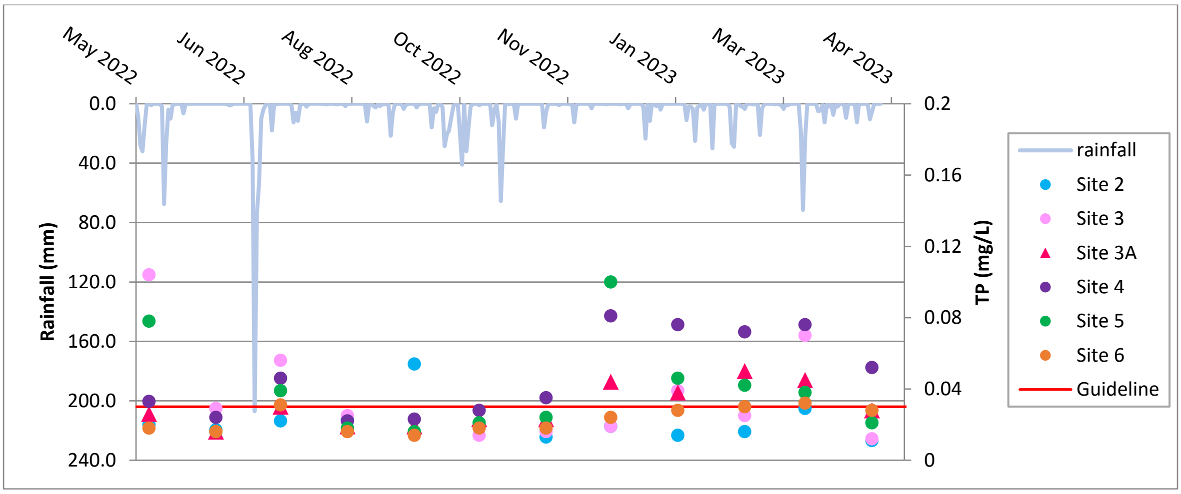


Figure 5: Plots of filtered total nitrogen (FTN) and rainfall from May 2022 to April 2023 for the (A) Foreshore (lake edge) sites and (B) In-lake sites

4.1.3 Phosphorus

Figure 6 shows total phosphorous (TP) values and rainfall for the period May 2022-April 2023 for the foreshore and in-lake sites. In Appendix 2 graphs of the results from the last nine years are presented. For the foreshore sites (Figure 6a) the recent observations are very similar to previous observations, with several sites routinely exceeding the guideline value, and with greater variation of total phosphorus values at the lake edge sites compared to in-lake sites. Along the lake edge Burroo Bay (Site 4) had high TP values for 7 of the 12 sampling events with very high values for all sampling events from December 2022 to April 2023 indicating a consistent source of phosphorus into this part of the lake. Sites 5 and 3A showed a similar pattern too (Figure 6a). Also, at this time the in-lake site NS2 in the central part of the Lake showed high TP values from December 2022 to March 2022 (Figure 6b). These high TP values did not correspond to a high rainfall event. The large rainfall event in early July 2022 did see high TP values when sampled 17 days later at Sites 5, 4, and 3 but all in-lake sites were below the recommended Guideline value (Figure 6).

A: Foreshore sites



B: In-lake sites

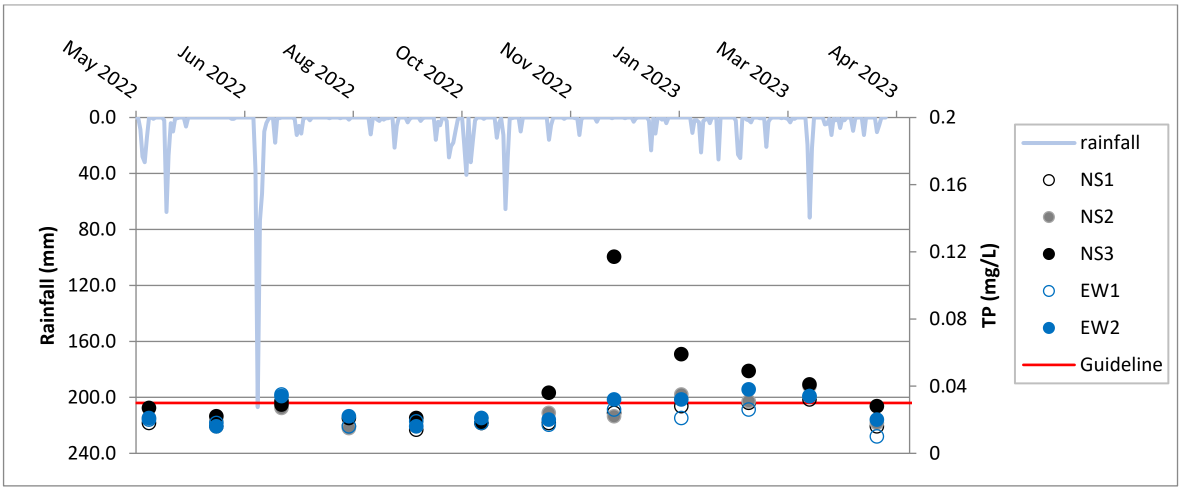
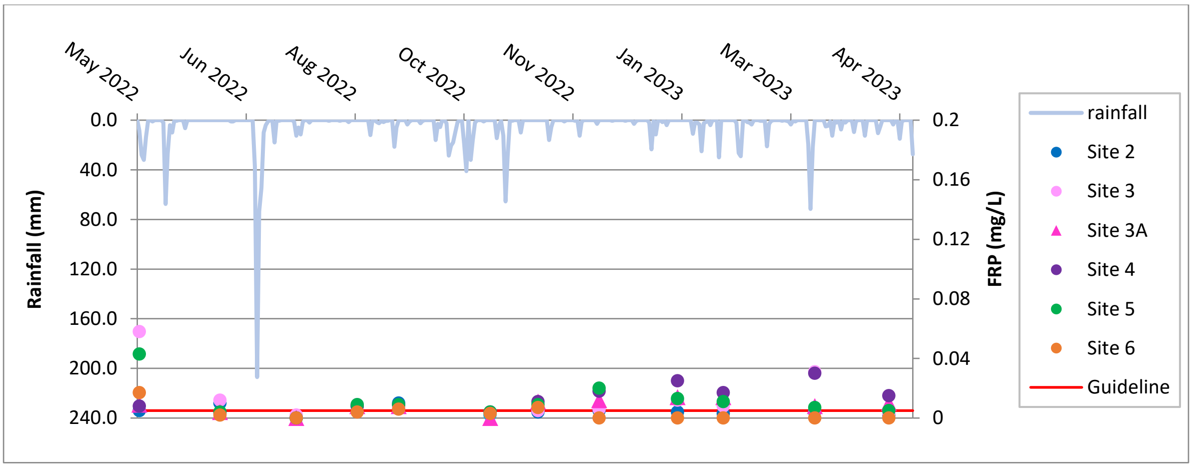


Figure 6: Plots of total phosphorous (TP) and rainfall from May 2022 to April 2023 for the (A) Foreshore (lake edge) sites and (B) In-lake sites

Lake Illawarra is known to be a phosphorus-rich environment due to the catchment soils having naturally high phosphate levels, which may explain the high values in the absence of very high rainfall events.

The filterable reactive phosphorus (FRP) results are presented in Figure 7. The guideline value for this form of phosphorus is very low at 0.005 mg/L, and in a phosphorus-rich environment such as Lake Illawarra most sites continue to be at the guideline level or exceed it slightly (Figure 7). At most sites, about 70 to 80% of the total phosphorus (TP) in the water is present in the dissolved form (FTP), and about half of this dissolved fraction is in the reactive form (FRP). The detection of this reactive form of phosphorus in the water suggests that phosphorus is not a limiting nutrient for primary production in the lake.

A: Foreshore sites



B: In-lake sites

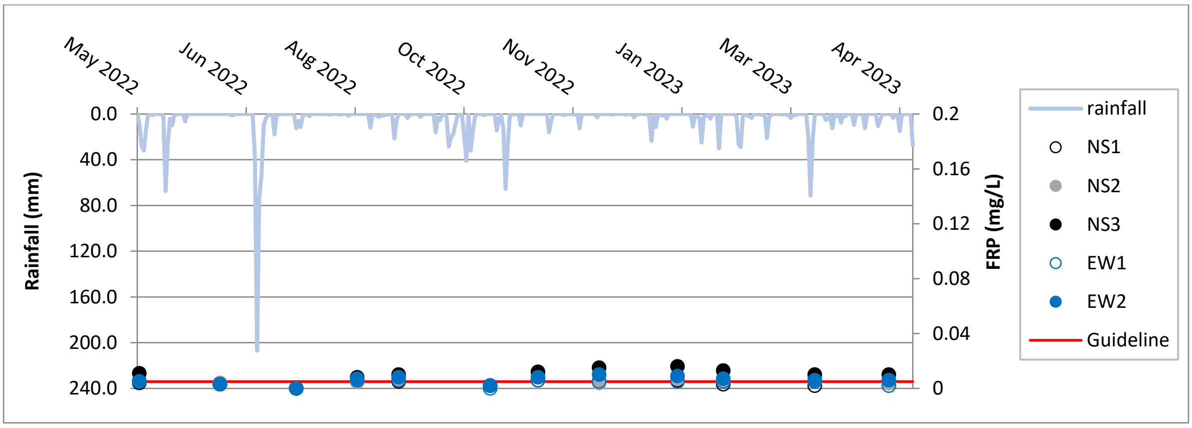


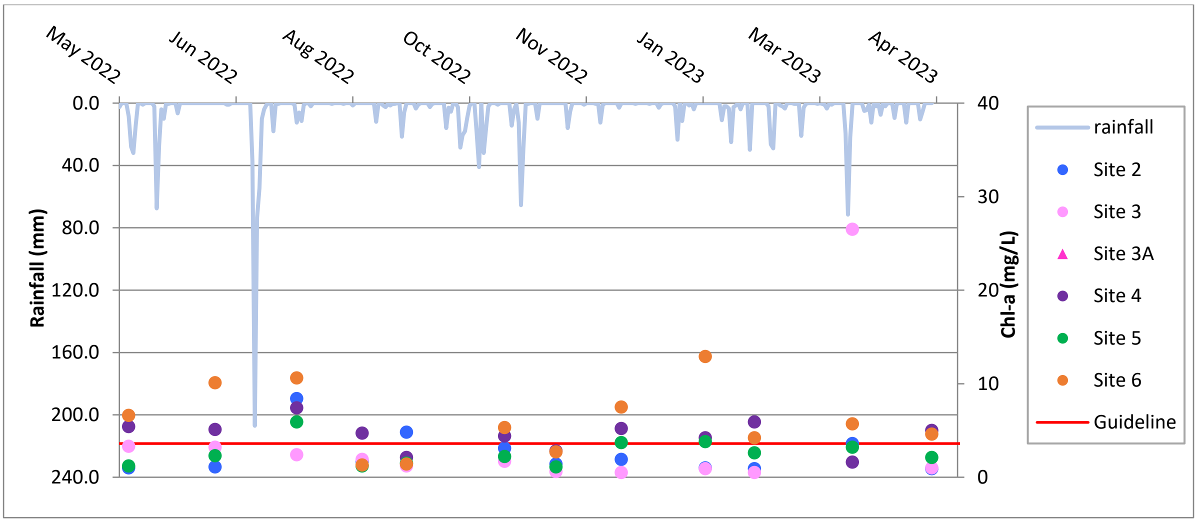
Figure 7: Plots of filterable reactive phosphorus (FRP) and rainfall from May 2022 to April 2023 for the (A) Foreshore (lake edge) sites and (B) In-lake sites

4.1.4 Chlorophyll-*a*

The results for chlorophyll-*a* are presented in Figure 8. Two foreshore sites consistently showed non-compliance with the MER recommended guideline with Sites 4 and 6 having chlorophyll-*a* values above the guideline for 9 of the 12 sampling events (Figure 8a). Site 3 though recorded a chlorophyll -*a* value seven times greater than the guideline value in March 2023 (Figure 8a). There was a rainfall event at this time, but such high values were not recorded at other sites. The very high rainfall event of 200mm in early July 2022 saw an increase above for the guideline for 4 foreshore sites – Sites 2, 4, 5 and 6. However all in-lake sites were well above the guideline value at this time too (Figure 8b).

Throughout the year the other foreshore generally show compliance with the NSW MER trigger value for the majority of the sampling events. A similar pattern occurred for the in-lake sites but NS3 had values above the guideline in November and December 2022 which could be related to seasonal effect over summer, where we would expect higher chlorophyll-*a* values (Figure 8b).

A: Foreshore sites



B: In-lake sites

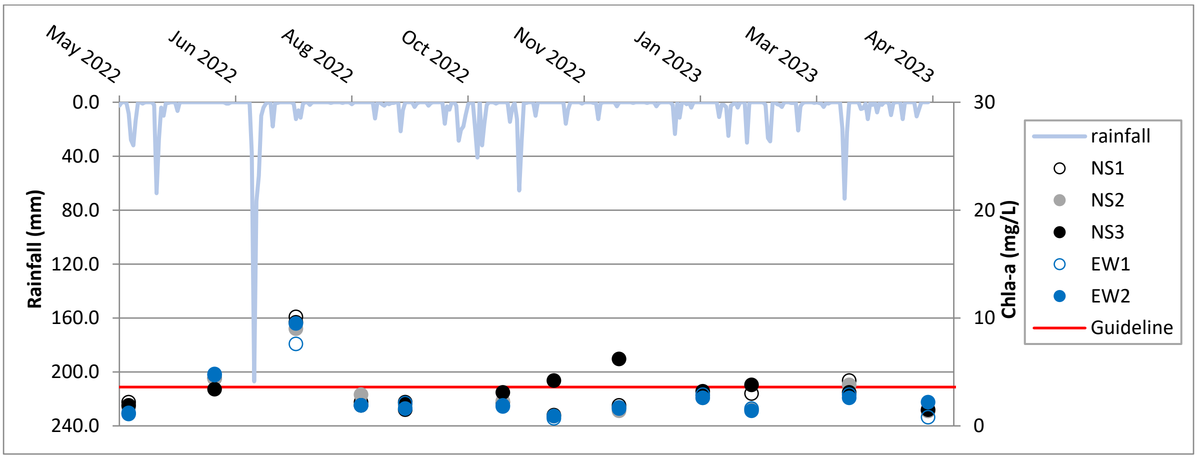


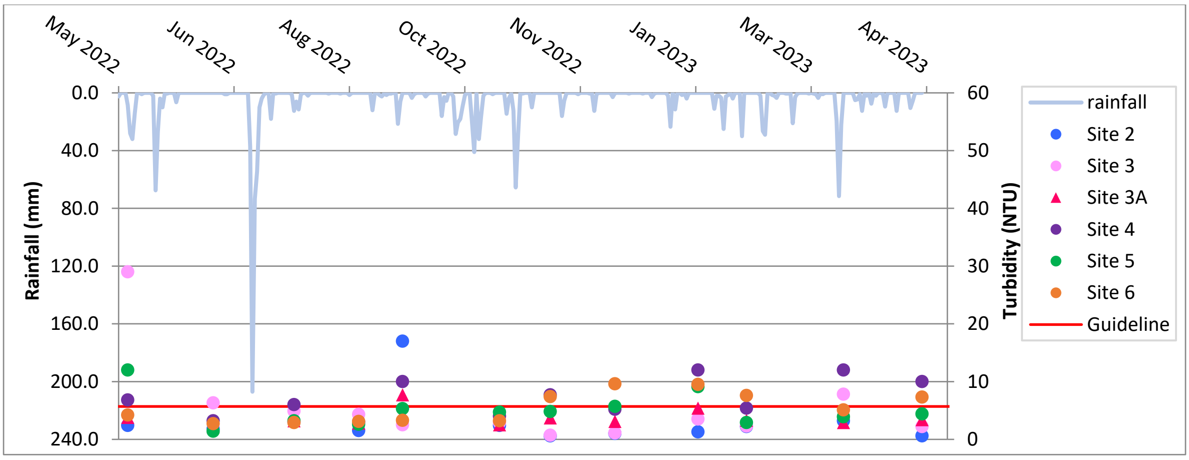
Figure 8: Plots of chlorophyll-*a* and rainfall from May 2022 to April 2023 for the (A) Foreshore (lake edge) sites and (B) In-lake sites

4.1.5 Turbidity

Turbidity gives an indication of light availability in the water and is influenced by the amount of suspended material present. In a relatively shallow lagoon such as Lake Illawarra, together with the amount of suspended microscopic algae and other organisms, the nature of the bottom sediments (whether muddy or sandy), the weather conditions (especially wind and rain), and boating or other traffic that can cause local turbulence in the water are all important factors that can affect the turbidity levels, as well as catchment run-off.

The results for the last 12 months show for the majority of the sampling period foreshore sites and - in-lake sites were below or just above the trigger value, with a number of exceptions. Site 6 at Griffins Bay showed consistent exceedances above the guideline from November 2022 to April 2023 except during March (Figure 9a). This is a higher number of turbidity exceedance compared to last year for this site. This was a similar story for Site 4 which showed high turbidity levels in late 2022 and early 2023, which was not exhibited the previous sampling period (Figure 9a). Values four times greater than to MER guideline and two times greater were recorded at Site 3 and Site 5 respectively and this was directly related to a rainfall event. (Figure 8a). The in-lake sites were generally just above or below the guideline value (Figure 9b). The foreshore sites are shallower than the in-lake zones, and are dominated by muddy bottom sediments, except around the eastern margin where sediments are sandier. These mud-dominated edge sites can generally be expected to be more turbid than the sites around the entrance and in the deeper in-lake zones, as any turbulence in the water caused by wind or boating activities can quickly mobilise the bottom sediments. Also, the foreshore sites are more impacted by catchment run-off. The results obtained agree with this expectation, where the in-lake sites remain largely stable, even during the high rainfall events (Figure 9b).

A: Foreshore sites



B: In-lake sites

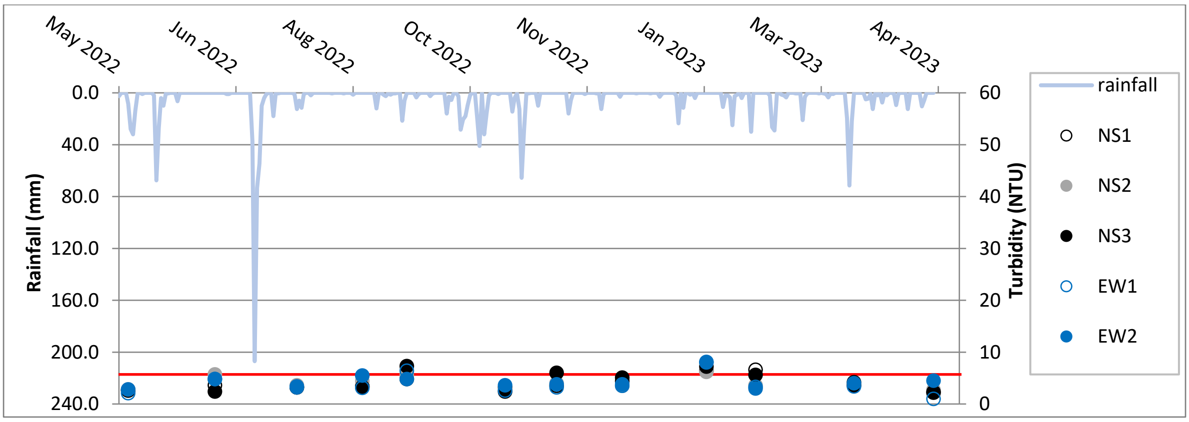


Figure 9: Plots of turbidity and rainfall from May 2022 to April 2023 for the (A) Foreshore (lake edge) sites and (B) In-lake sites

4.2 Water quality and estuary health trends

Water quality trends over time are important because they can inform whether management strategies put in place to protect the health of the lake are effective. Data over a reasonably long period is required for these trends to become apparent, as there can be significant short-term variation arising from seasonal and meteorological effects, and these can detract from the background trend. Whether these factors are significant must be considered in any trend analysis.

The trend analysis was performed with the filtered data for total nitrogen, total phosphorous, turbidity and chlorophyll-*a*. A decreasing trend means that the values are decreasing over time and hence an improvement in the condition of that site.

Foreshore sites are particularly vulnerable to catchment run-off, and it is significant that Sites 4, 5 and 6 have decreasing trends for 3 of the 4 parameters despite them being close to feeder creeks and catchment inputs (Table 6). Site 3 is the only site in the Lake that continues to show an increasing trend for total nitrogen and total phosphorous. The reason for this could be that increased sand deposition across the seaward end of this channel observed over time is restricting flushing of this area, plus the presence of a large stormwater drain in the vicinity. This site exhibited high nitrite and nitrate levels for 11 of the 12 sampling events, and thus there are significant nitrogen loads coming into his area.

The in-lake sites continue to show no trend for chlorophyll *a*, total phosphorus, total nitrogen and turbidity values over the long term (Table 6). This is not surprising though as they have been graded as being in good or very good condition since 2017 (refer to Figure 11).

Table 6: Results of trend analysis for chlorophyll-*a*, turbidity, total nitrogen and total phosphorous at all sites

Site	Chlorophyll-*a*	Turbidity	Total nitrogen	Total phosphorous
2	no trend	no trend	no trend	no trend
3	no trend	no trend	increasing trend	increasing trend
3A	no trend	decreasing trend	no trend	no trend
4	decreasing trend	decreasing trend	no trend	decreasing trend
5	decreasing trend	no trend	decreasing trend	decreasing trend
6	decreasing trend	decreasing trend	no trend	decreasing trend
NS1	no trend	no trend	no trend	no trend
NS2	no trend	no trend	no trend	no trend
NS3	no trend	no trend	no trend	no trend
EW1	no trend	no trend	no trend	no trend
EW2	no trend	no trend	no trend	no trend

4.3 Estuary ecosystem health condition

The estuary ecosystem health condition is based on the chlorophyll *a* and turbidity data for the summer period only (November to March), as recommended under the NSW MER framework for estuaries and coastal lakes (State of NSW and Office of Environment and Heritage 2016), using the guideline trigger values of 3.6 µg/L for chlorophyll-*a* and 5.7 NTU for turbidity. The results for the recent summer (2022/23) are presented in Figure 10. Results from the previous years from each summer period from 2015/16 are shown in Figure 11 so changes in condition over the years can be seen. There have been changes in the number and location of some sites over the years.

The results show that for the 2022/23 period, six of the eleven sites are in very good condition and three sites in good condition (Figure 10). Two foreshore sites – Site 6 in Griffins Bay and Site 4 at Burroo Bay were rated as being in fair condition.

Site 6 has continuously been rated as fair to very poor since 2013/14, indicating the high input of nutrients and sediment from the catchment in this area and the lack of flushing that occurs in this bay.

In the previous sampling period Site 4 (Burroo Bay) was graded as good, but this year it was fair (Figure 10). This was largely due to several high turbidity values that were double the recommended guideline value. These high values were not experienced during the 2021/22 summer when the site received a good rating. This site is situated near to two catchment inputs – Macquarie Rivulet and Horsley Inlet which could be the source of the high turbidity values. Also, it is located at the Oak Flats Sailing Club and turbulence from activities at the foreshore would be contributing to high turbidity values.

KEY
Very good Good Fair Poor Very Poor

Figure 10: Estuary health condition ratings (based on chlorophyll *a* and turbidity) over the summer period (November to April) for 2022/23 for 11 sites monitored across Lake Illawarra, and the overall estuary grade for Lake Illawarra.

Site 5 last year was rated as being in fair condition largely a result of several very high chlorophyll *a* and turbidity values over the summer period related to rainfall events. This year it was rated as very good condition. This can be contributed to less rainfall over the summer period on which estuary condition grades are based, and hence less catchment runoff from Brooks Creek that is located near this site.

In past years other foreshore sites have had poorer estuary health condition ratings compared to the in-lake sites and was related to these lake edge sites being more susceptible to catchment inputs (Figure 11). Turbidity at edge sites can also be easily influenced by prevailing wind conditions at the time of sampling, particularly as the lake is very shallow, and by other disturbances such as boating. However, in the last few years there has been an improvement in the health of foreshore sites, with the majority of the foreshore sites now being rated as being in good condition (Figure 11). Plots of the estuary health condition of the sites since 2016 show that over time the condition of the foreshore sites within Lake Illawarra has improved (Figure 11).

For the first time, an overall estuary health condition grade has been calculated for Lake Illawarra. The estuary was rated as being in good condition or a B grade (Figure 10).

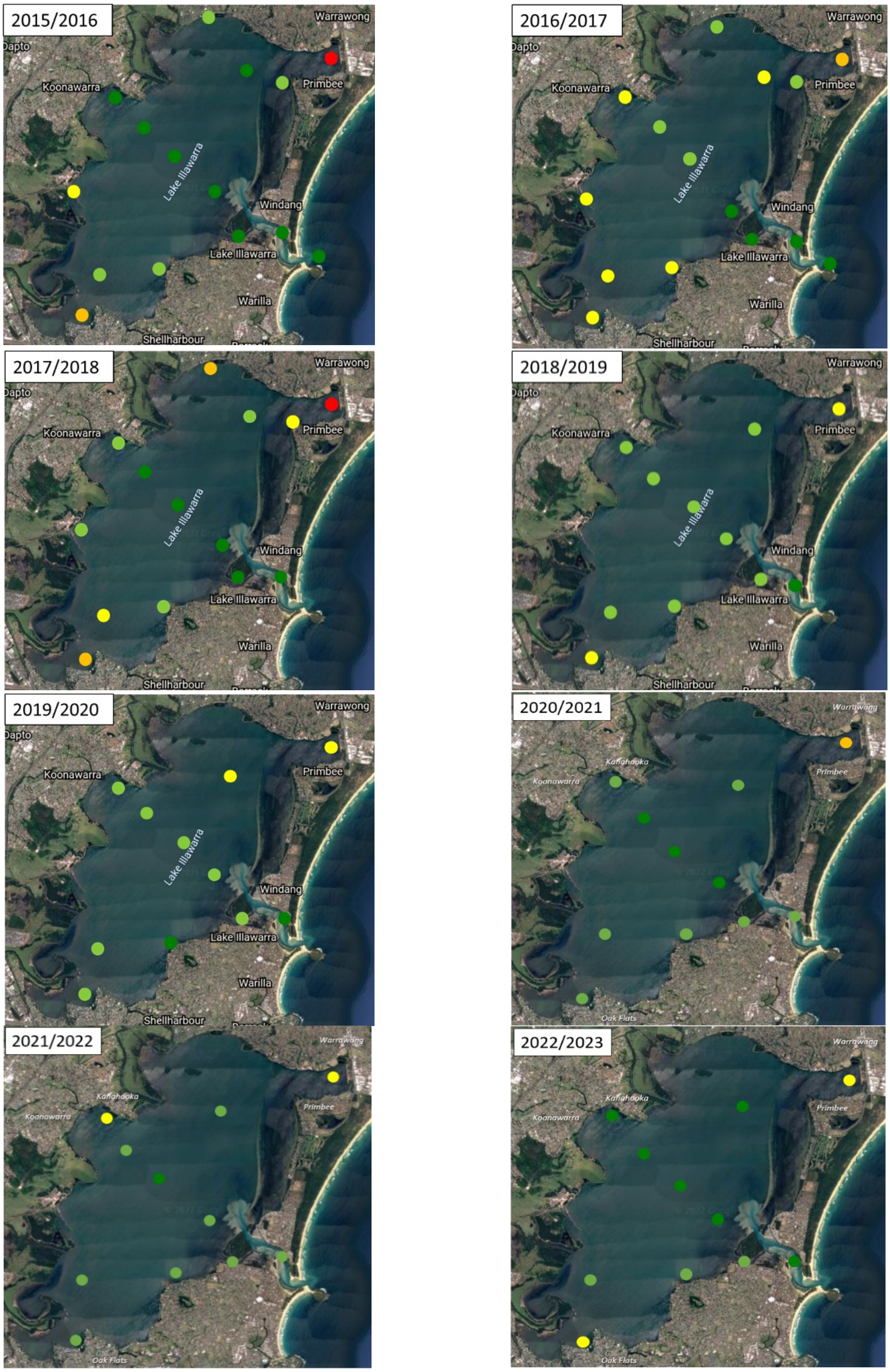
4.4 Recreational water quality

Figure 12 shows the percentage compliance of the 20 test occasions meeting the recreational water guideline for primary (35 cfu/100 ml) and secondary (230 cfu/100 ml) contact for three estuarine sites sampled for the presence of enterococci. Estuarine sites are particularity impacted by potential sources of faecal contamination, including stormwater and urban and rural run-off. All sites had a higher percentage compliance than the previous year and reflects the lower wet weather conditions over the summer period (Figure 12 and 13). This was particularly noticeable at Kanahooka and Purry Burry Point that had between 81-85% primary and secondary recreation contact compliance. Ski-Way Park had a lower compliance of 73-75% for primary and secondary recreation compliance (Figure 12), largely a result of high values recorded in January, March and April 2023 (Figure 13).

Rainfall is the major driver of pollution and enterococci levels to recreational water quality, and it is recommended that swimming should be avoided during and for up to one day following heavy rain at ocean beaches and up to three days at estuarine sites (NSW DPIE 2022). While a very high rainfall event occurred in March 2023, only Purry Burry showed high numbers while the other two sites had much lower numbers but were still above the recommended values for primary and secondary recreation contact (Figure 13).

The entrance site (called Entrance Lagoon Beach) that is sampled, analysed and reported under the NSW Beachwatch program was rated as good for the 2021-2022 period (State of NSW and DPE 2022). The beach suitability grade of good means that the location has generally good microbial water quality and water is considered suitable for swimming most of the time (State of NSW and DPE 2022).

No NSW Beachwatch summary report was available for the 2022-2023 summer period at the time of publication of this report.



KEY TO ESTUARY HEALTH GRADE

● Very good ● Good ● Fair ● Poor ● Very Poor

Figure 11: Estuary health condition ratings (based on chlorophyll *a* and turbidity) over the summer period (November to April) for each year from 2015-2023 for 11 sites monitored across Lake Illawarra.

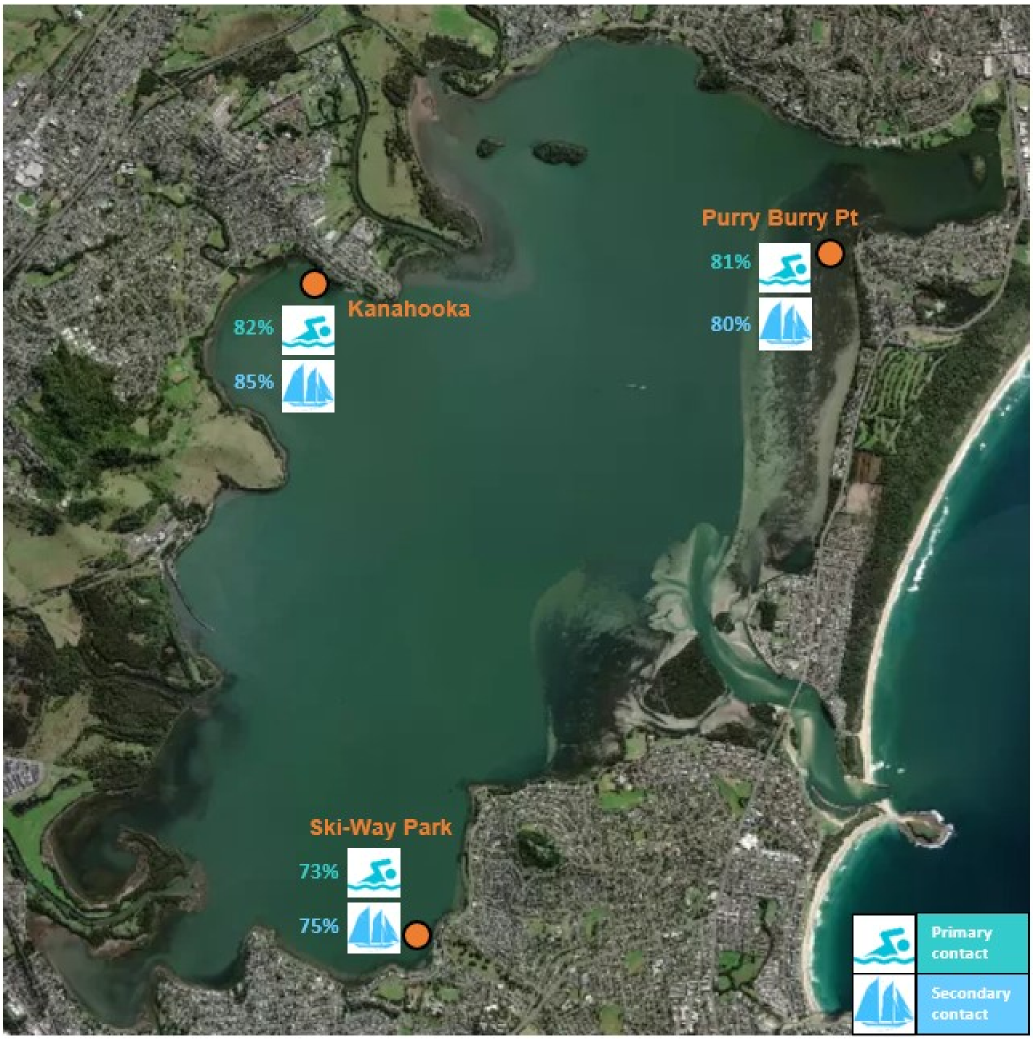


Figure 12: Percentage of the test occasions meeting primary (35 cfu/100 ml) and secondary (230 cfu/100ml) contact recreational water quality guidelines, at three locations within Lake Illawarra from October 2022-April 2023.

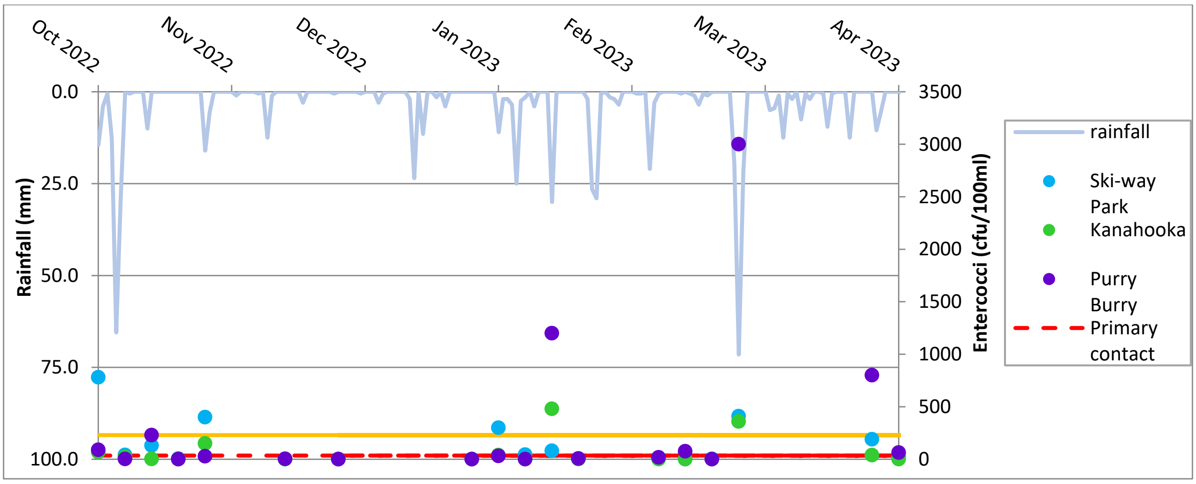


Figure 13: Plot of enterococci concentrations against rainfall from October 2022-April 2023

5 Conclusion

This report has reviewed selected parameters and indicators to describe the water quality and estuary health condition in Lake Illawarra for the period May 2022 to April 2023, and for trends in estuary health since 2013. Recreational water quality has also been monitored over the summer period. The indicators are nitrogen and phosphorus concentrations, turbidity and chlorophyll-*a* for estuary health, and the bacterial species enterococci for recreational water quality.

A diverse range of factors can influence water quality including residence times as set by mainly circulation patterns and freshwater inputs, sediment fluxes and geomorphological processes. Evidence for strong spatial variation in nutrient values and turbidity around the lake, as noted in previous reports, has been reinforced with recent data. Water quality at the foreshore edge sites show greater variation and more exceedances of the ANZECC guidelines or trigger values than the in-lake sites. This is to be expected given the lake edge sites are closer to the freshwater catchment inputs and are not as greatly flushed as the in-lake sites. Also, the foreshore sites are generally shallower than the in-lake zones, and are dominated by muddy bottom sediments, except around the eastern margin where sediments are sandier. These mud-dominated edge sites can generally be expected to be more turbid than the sites around the entrance and in the deeper in-lake zones, as any turbulence in the water caused by wind or boating activities can quickly mobilise the bottom sediments. The spatial differences also reinforce that the residence time for the more central portion of Lake Illawarra is shorter than that for the more enclosed areas of the lake (e.g., Griffins Bay). Longer residence times in the more enclosed areas north in the lake and some sections in the south, where water quality can be poor, mean that catchment inputs have more time to be incorporated into bottom sediments. These sediments are part of the internal nutrient reserves that feed the water column, contributing in part to the poor water quality observed in these areas, particularly at Site 6 Griffins Bay and Site 4 Burroo Bay.

Temporal variations in water quality can be evident over different timescales. For this year through seasonal differences were not as apparent, largely because there was high rainfall during the winter months. The results show seasonal differences were not overly apparent. Over the summer months (November to April) when temperatures and daylight hours are greater than in the winter months (May to November), higher nutrient and chlorophyll-*a* concentrations are known to be present in estuarine waters. This seasonal pattern is not uncommon and has been observed in other waterbodies, regardless of rainfall conditions. This was only noticeable for total phosphorous during this sampling period, where higher values of total phosphorus were evident over the spring and summer. This suggests that there must be internal sources within the lake, such as phosphorous rich bottom sediments which release nutrients into the water column over the summer months.

Rainfall and hence freshwater discharge continues to be an influential factor on the water quality of the Lake. While the total rainfall for the sampling period was the second highest since 2009, the majority of the rain fell over the winter period. This is different to what has occurred in previous years, particularly so when compared to the last sampling period 2021-22, where large and sustained rainfall events during summer and early autumn. La Nina was in effect during the 2021/22 summer which resulted in the highest summer rainfall recorded for the Lake Illawarra catchment since sampling began in 2009 (Wollongong City Council 2022). La Nina extended into autumn and early winter which resulted in wetter than normal conditions over the winter period in 2022 and resulting in higher rainfall during the winter than summer which is unusual for this region. As shown in Table 5 more rainfall tends to occur over the summer.

Large freshwater inflows into estuaries can change salinity regimes (including stratification and circulation patterns), water balances and water quality (i.e., changes to the transformations of nitrogen and phosphorus, which occur within areas of high turbidity from catchment-derived sediments), alter sedimentation, erosion rates and nutrient loads, and change flushing and residence times (Glamore et al. 2016). Increased nutrient loads were apparent in Lake Illawarra in May 2022 at the foreshore sites related to a rainfall event. A major rainfall event of 200mm occurred in July 2022. Sampling occurred 17 days after this rainfall event and high nutrient values were not captured. However, 10 of the 11 sites had high chlorophyll-*a* values indicating an increase in phytoplankton biomass due to high nutrients from the rainfall and catchment run-off a couple of weeks earlier.

Based on current analysis the condition of the estuary seems to be improving over the period 2013-2023, with nine of the eleven sites rated good to very good for 2022/23. For the first time a grade for Lake Illawarra as a whole has been calculated. The Lake was graded as being in Good condition or a B rating. Lake Illawarra appears resilient and maintaining good estuary health. It is important to note that this is based on only two indicators of estuary health and other ecological impacts may be occurring.

Two foreshore sites were rated as Fair– Site 6 in Griffins Bay and Site 4 at Burroo Bay. Site 6 has continuously been rated as fair to very poor since 2013/14, indicating the high input of nutrients and sediment from the catchment in this area and the lack of flushing that occurs in this bay. Site 4 was also rated fair largely due to several high turbidity values that were double the recommended guideline value. These high values were not experienced during the 2021/22 summer when the site received a good rating (Wollongong City Council 2022). This result could be due to a number of influences. It is situated near to two catchment inputs – Macquarie Rivulet and Horsley Inlet which could be the source of the high turbidity values. Also, it is located at the Oak Flats Sailing Club and turbulence from activities at the foreshore would be contributing to high turbidity values. Lastly it is in a slightly enclosed bay and hence would not receive much flushing and the residence time would be greater.

Importantly though the trend analysis tells us what is happening on a long-term scale at these sites. Trend analysis was performed for total nitrogen, total phosphorous, turbidity and chlorophyll-*a*. A decreasing trend means that the values are decreasing over time and hence an improvement in the condition of that site. Water quality trends over time are important because they can inform whether management strategies put in place to protect the health of the lake are effective. Data over a reasonably long period is required for these trends to become apparent, as there can be significant short-term variation arising from seasonal and meteorological effects, and these can detract from the background trend.

Even though Sites 4 and 6 were rated fair it is significant that these sites plus Site 5 have decreasing trends for 3 of the 4 parameters despite them being close to feeder creeks and catchment inputs. Site 3 is the only site in the Lake that continues to show an increasing trend for total nitrogen and total phosphorous. The reason for this could be that increased sand deposition across the seaward end of this channel observed over time is restricting flushing of this area, plus the presence of a large stormwater drain in the vicinity. This site exhibited high nitrite and nitrate levels for 11 of the 12 sampling events, and thus there are significant nitrogen loads coming into his area.

The in-lake sites continue to show no trend for chlorophyll-*a*, total phosphorus, total nitrogen and turbidity values over the long term. This is not surprising though as they have been graded as being in good or very good condition since 2017.

Recreational water quality was monitored over the summer period at three sites within the lake and the percentage compliance with primary and secondary recreation contact compliance was calculated. Estuarine sites are particularity impacted by potential sources of faecal contamination from animal faeces and sewerage overflows, including urban and rural stormwater run-off. All of the three sites had higher percentage compliance than the previous year (WCC 2021), and this result was directly related to less rainfall over the summer and early autumn compared to the following year. Rainfall is the major driver of pollution and high enterococci levels to recreational water quality, and it is recommended that swimming should be avoided up to three days at estuarine sites following heavy rain (State of NSW and DPE 2022).

Continuation of the monitoring program will help establish how the lake responds following extended wet weather periods and the impact of catchment run-off, as well as gaining insights to how the estuary is varying over time and responding to changing climate regimes. Climate change is expected to cause heavy rainfall events to become more extreme with an increase in east coast lows over the warmer months. This will lead to increased catchment run-off, periods of decreased salinity in estuarine waters, and increased sediment and nutrient loads in coastal and estuarine waters (Adapt NSW 2022).

As part of the implementation of the Lake Illawarra Coastal Management Program, Wollongong and Shellharbour City Councils have also begun a catchment water quality program. This program will capture baseline water quality monitoring data for the catchment, including from wet weather events for a number of environmentally and aesthetically important urban and rural creeks within the Lake Illawarra catchment. This data will inform us in understanding inputs into the lake and in current and future environmental management and monitoring programs.

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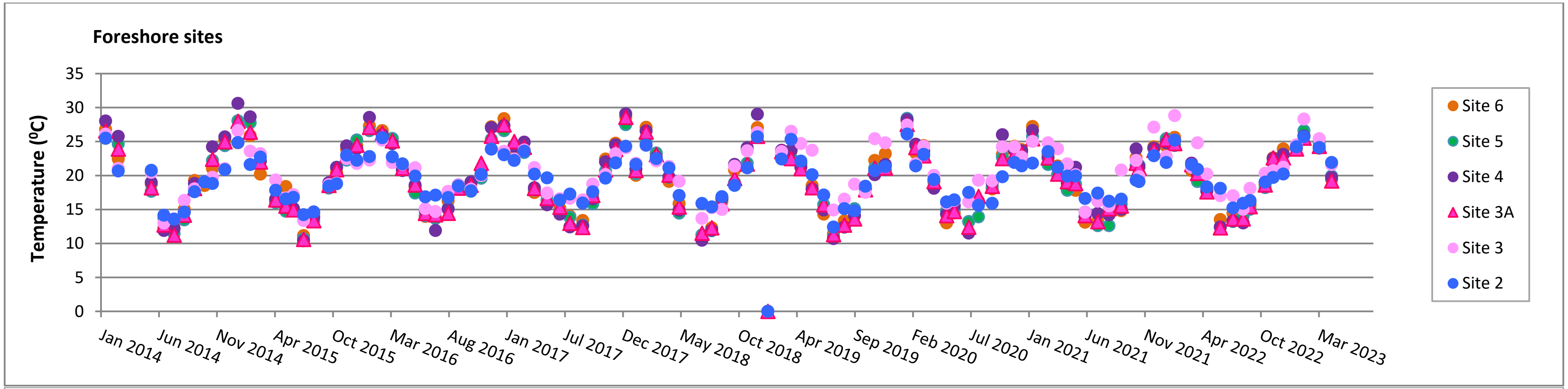
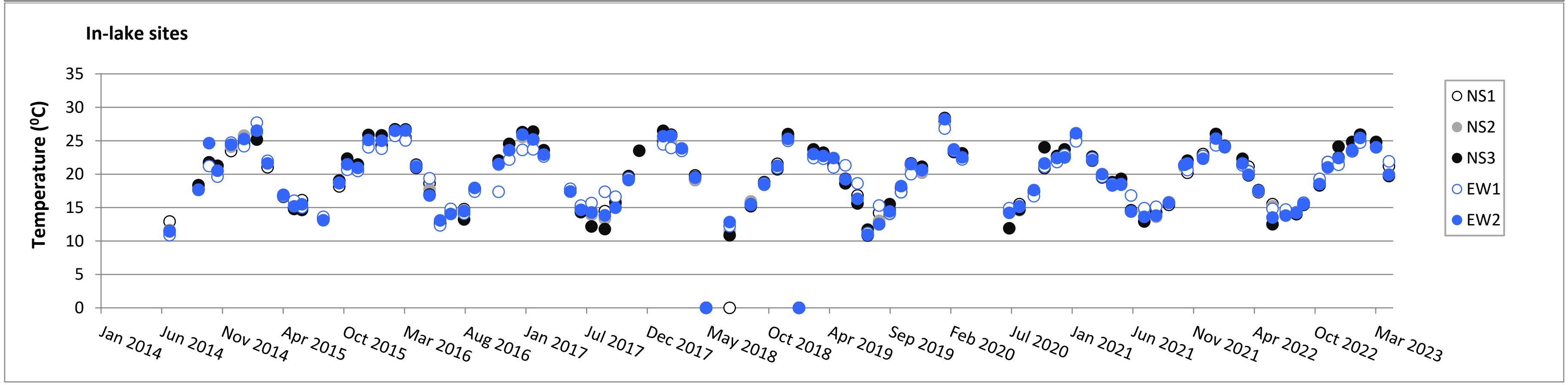
Appendix 1: List of management actions in the Lake Illawarra Coastal Management Program relating to improving water quality

Strategy 1: Improve Water Quality (WQ)	
WQ1	Implement a Risk Based Stormwater Management Framework for the Lake Illawarra catchment
WQ2	Upgrade existing stormwater quality management measures, or install new devices, which may include water sensitive urban design or other design that will improve water quality as well as entrance habitat and natural values
WQ3	Review and prioritise maintenance and cleaning regime for existing stormwater quality devices
WQ4	Design and implement targeted catchment input monitoring as required for developments resulting in a large-scale change or intensification of land use
WQ5	Reduce sediment load to the Lake by improving compliance with erosion & sediment controls for development sites
WQ6	Reduce the impact of sewer overflows
WQ7	Implement water quality monitoring programs for estuary health, recreational use and physico-chemical and bacteriological indicators in the Lake and its catchment
WQ8	Improve litter management
WQ9	Investigate and manage potential pollution sources including contaminated sites that contribute to poor water quality in the Lake.

Appendix 2: Long-term plots of parameters at all sites from 2013/14 to April 2023

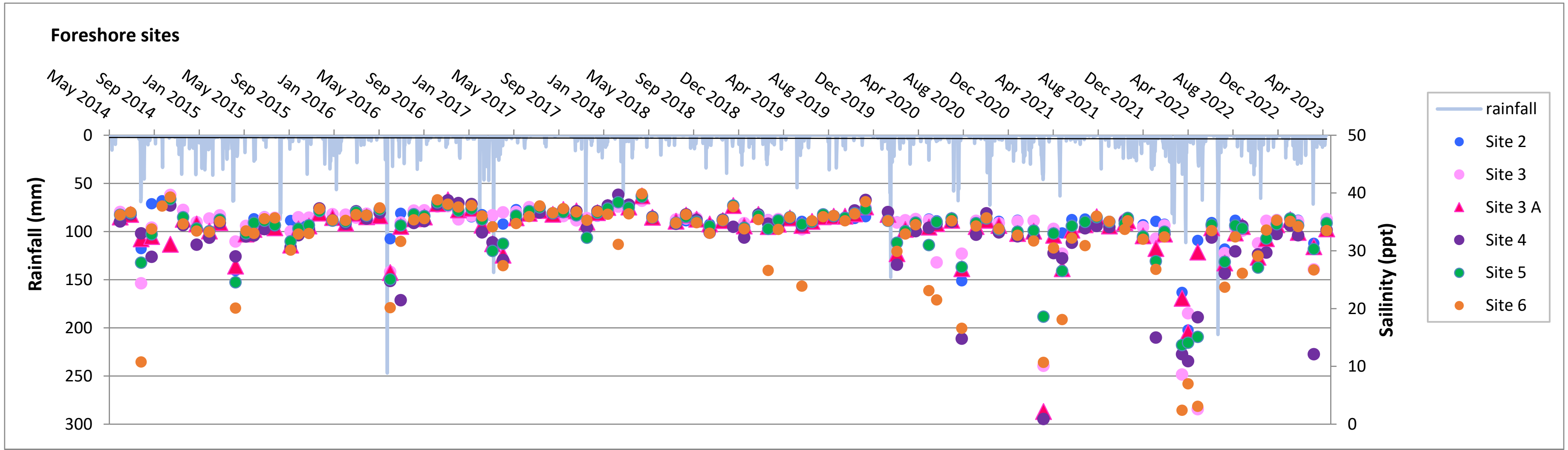
Plots of Temperature (^{0}C) from 2014 to April 2023

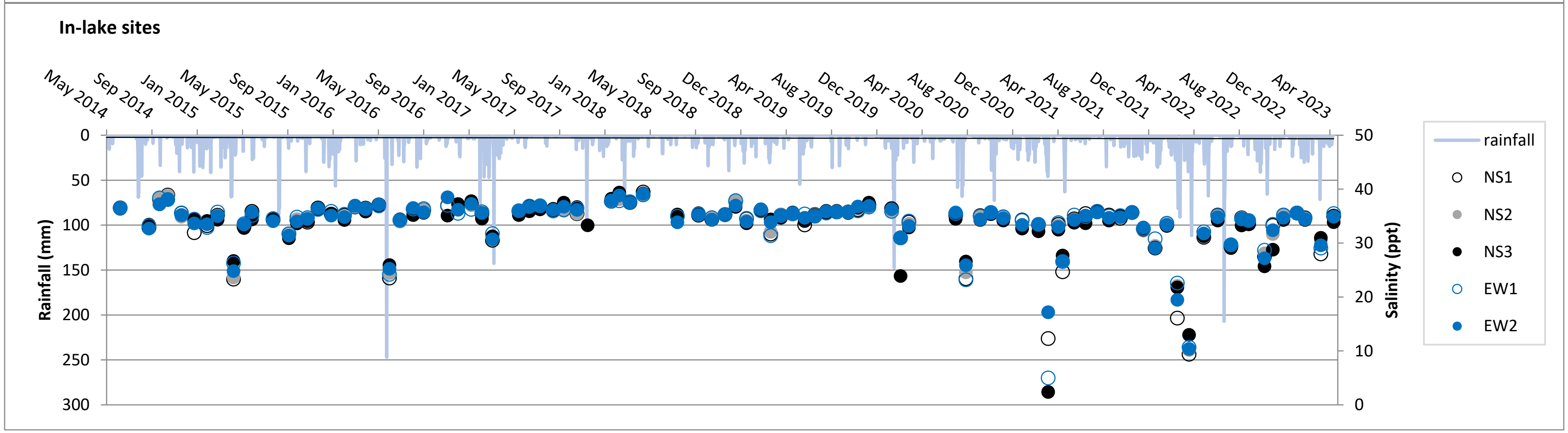




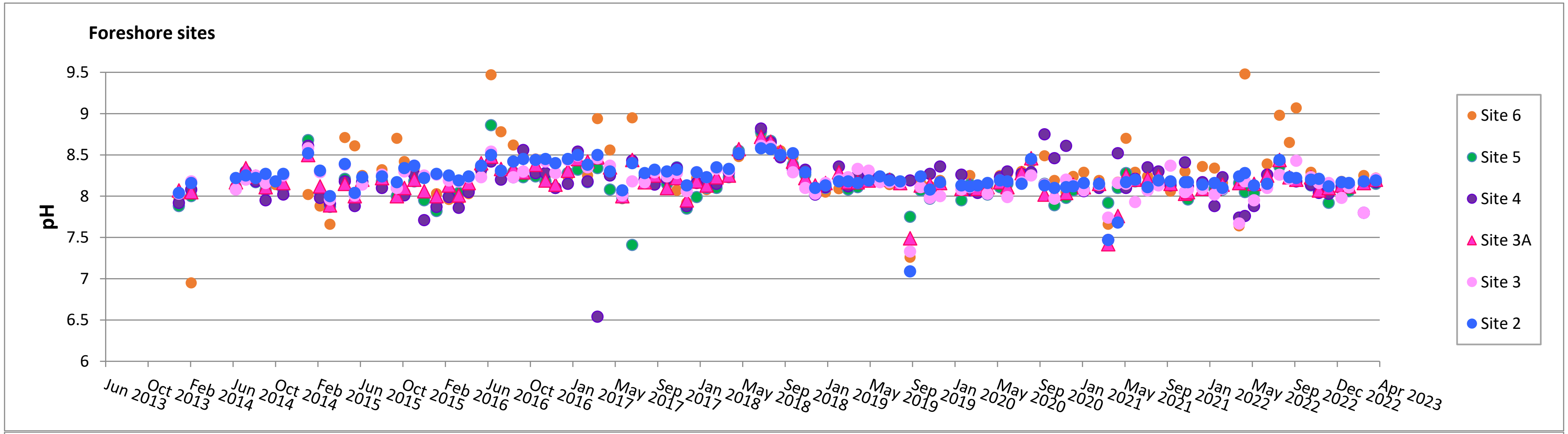
Note: zero readings due to equipment issues

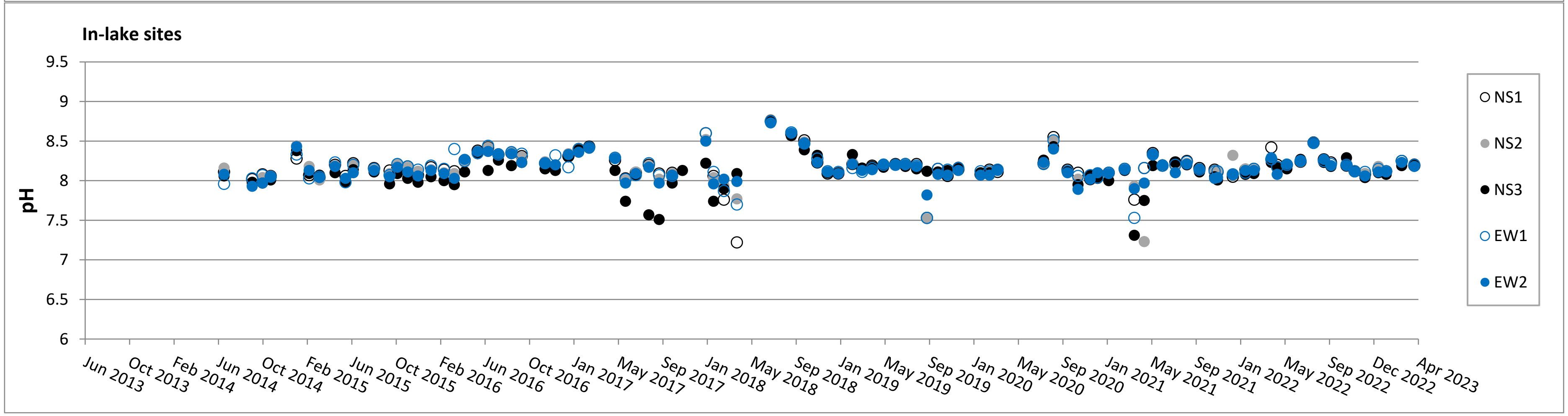
Plots of Salinity (ppt) from 2014 to April 2023



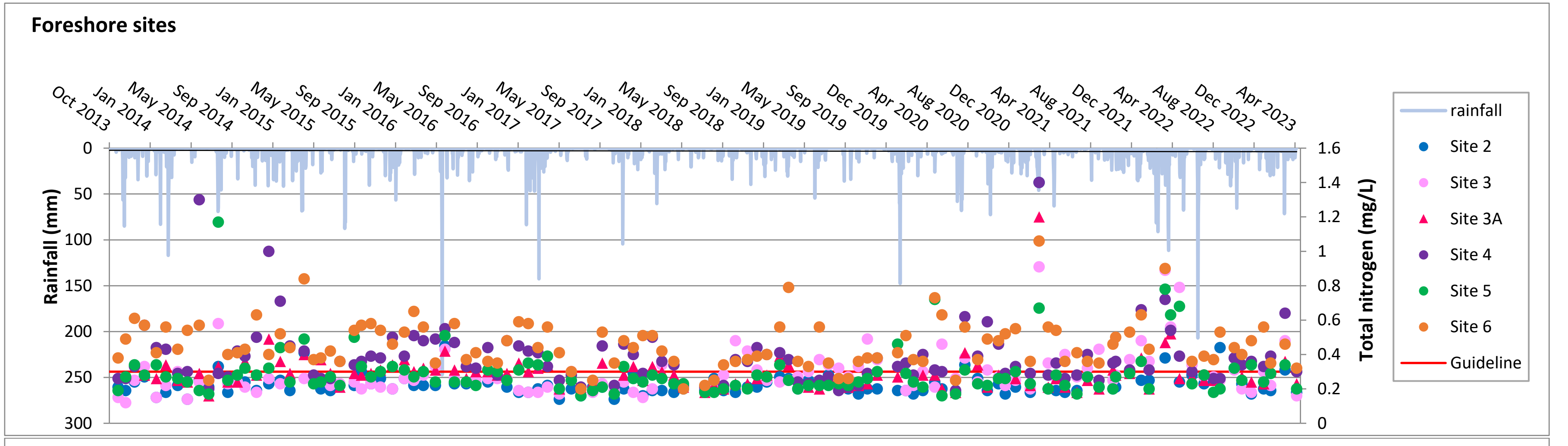


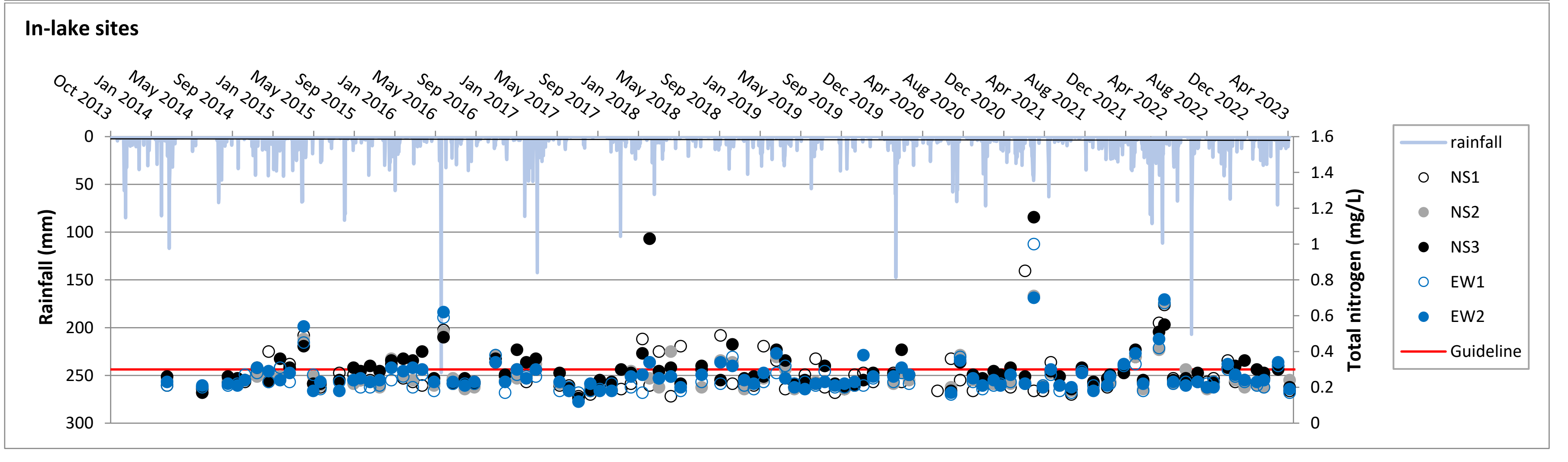
Plots of pH from 2014 to April 2023



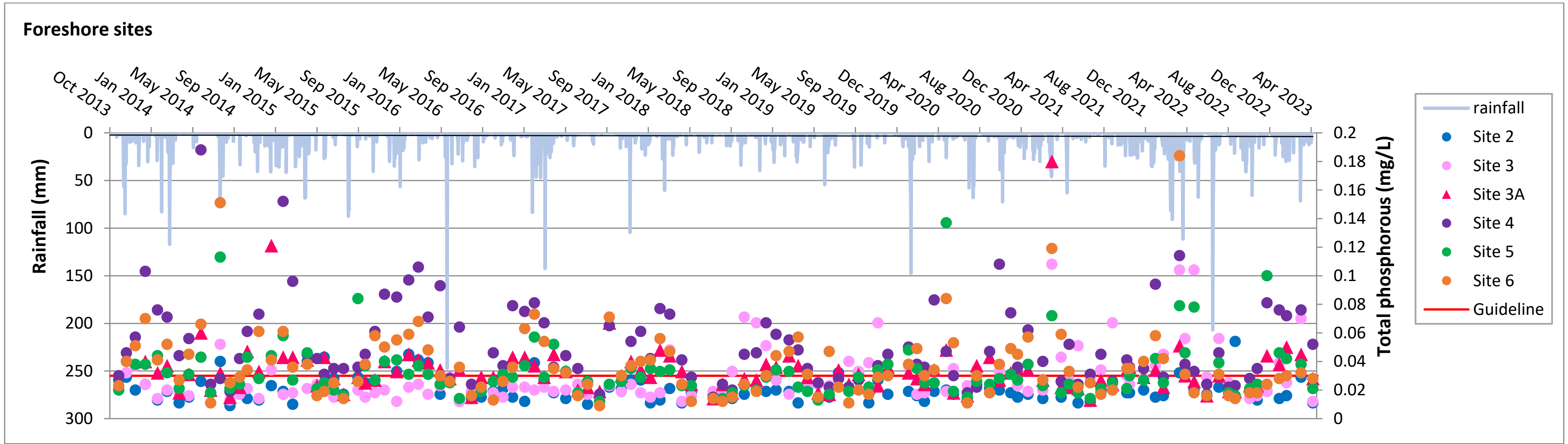


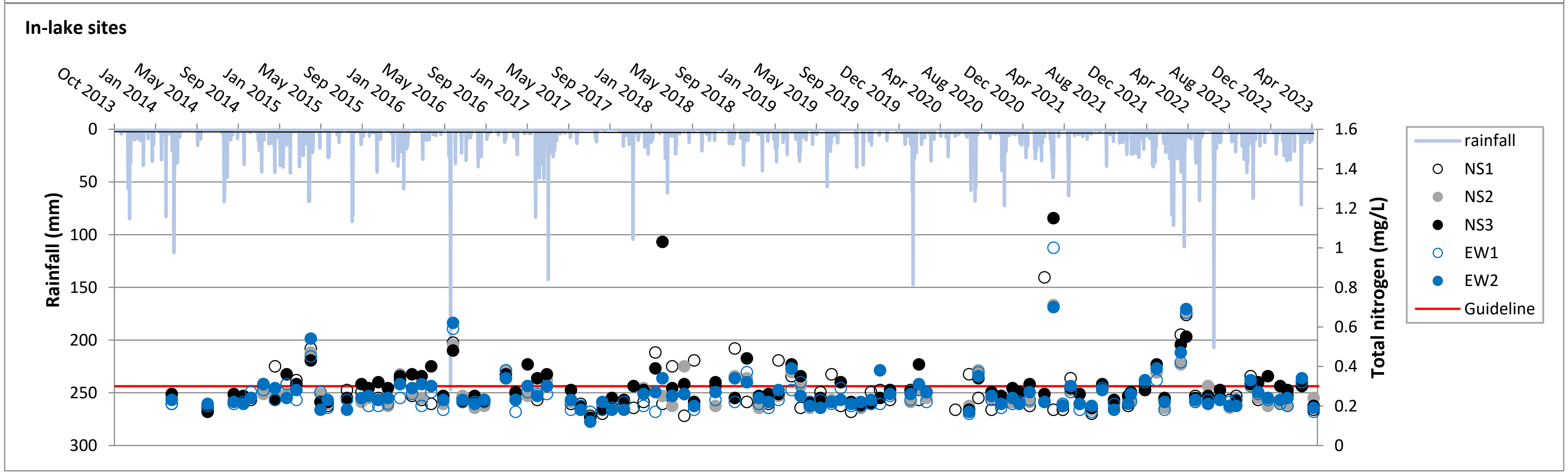
Plots of Total Nitrogen (mg/L) from 2013 to April 2023



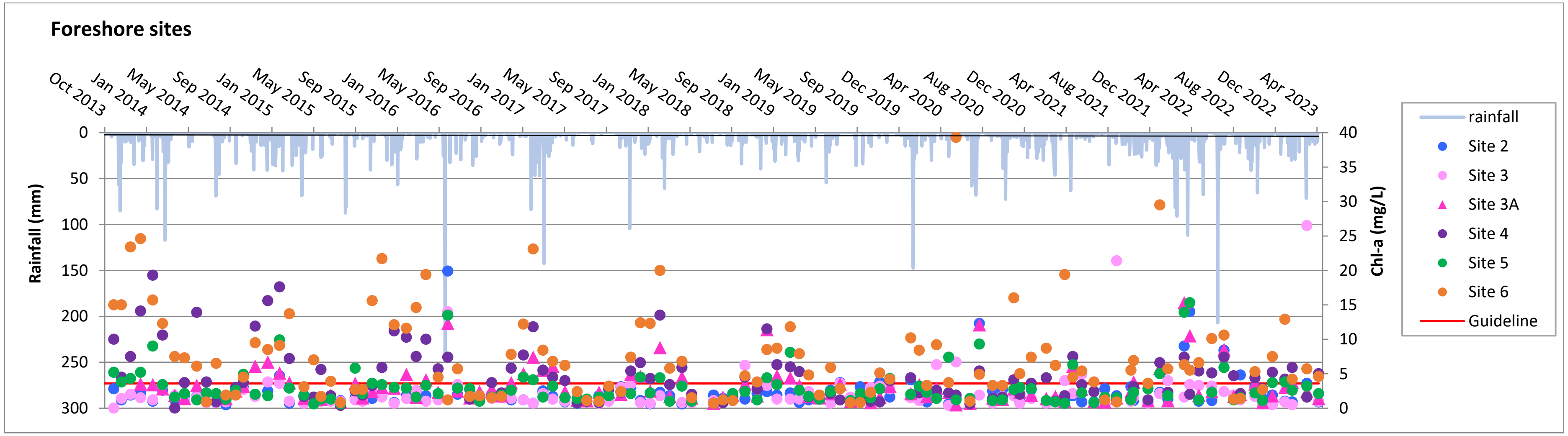


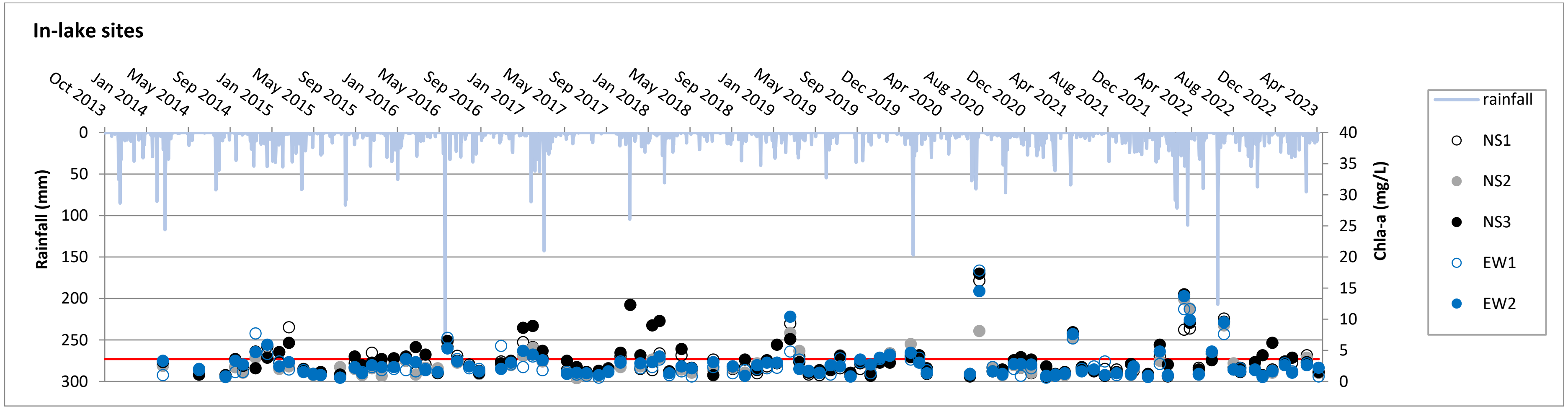
Plots of Total Phosphorous (mg/L) from 2013 to April 2023





Plots of Chlorophyll *a* (µg/L) from 2013 to April 2023





Plots of Turbidity (NTU) from 2013 to April 2023