Lake Illawarra Water Quality and Estuary Health Monitoring and Reporting

Summary Report

February 2020

Summary

Wollongong City Council, with support from Shellharbour City Council, has been monitoring water quality in Lake Illawarra since October 2013. Detailed reports on the results have been issued in August 2015, July 2016, June 2017 and June 2018. This is a summary report, focussing on those measurements that are especially important for assessing the lake condition for its ecosystem health and recreational use. Detailed reports will now only be prepared at longer intervals when considerably more new data has been collected to reliably assess changes in the lake condition over time. For lake ecosystem health, the measurements considered in this report are nitrogen and phosphorus, turbidity and chlorophyll *a* concentration, and for recreational use, the bacterial species enterococci, which has been measured for the first time at three locations within the lake.

For lake ecosystem health, the water quality trends observed for the 2018/19 period are not different from previous years. Temporal and spatial variations continue to be observed. Nitrogen, phosphorus, and chlorophyll *a* concentration, and turbidity peak over the summer months (November to April) in response to temperature and daylight changes, and the outer less flushed areas have poorer water quality than the entrance and main body of the lake. Water quality at some of the these outer less flushed sites appear to be improving over time, but this is most likely the result of the rainfall changes. Rainfall patterns have been observed to have a significant impact on water quality, and the 2018/19 summer has been the driest in the last ten years. Further monitoring over more average rainfall periods will show whether the observed improvement in water quality is a real trend.

For recreational use, the data being collected is meant to feed into the NSW Beachwatch Program and reported according to its protocols. This report has conducted only a preliminary analysis to test how often over the relatively short monitoring period the sites complied with primary and secondary recreational contact criteria. The results show relatively good compliance, but there is a correlation with rainfall, so these results could be due to the monitoring period being relatively dry. Whether more wet periods change this situation will become clearer with further monitoring.

Continued monitoring of the lake is recommended to gather the long-term dataset necessary to reliably assess the trends in water quality, and to assess the effectiveness of any management measures to protect the health of the lake going into the future.

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 2020 a). Wollongong City and Shellharbour City Councils 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, and targeted monitoring, evaluation and reporting of water quality and other health indicators is recommended to track the outcome of implementing these actions.

There is a long history of water quality monitoring in the Lake, with various agencies involved at various times. Wollongong City and Shellharbour City Councils took on this responsibility in October 2013, and since then, regular reports on the results have been issued (Wollongong City Council 2015, 2016, 2017, 2018). These reports have considerable detailed analysis and show that there can be considerable spatial and temporal variation in water quality, with season and weather (particularly rainfall) patterns having a major influence. As these results have remained generally consistent from year to year, detailed annual reports are considered no longer necessary. Only summary reports will be prepared annually, and more detailed reports prepared when at least a few years of new data has been collected, and water quality trends can be more reliably assessed. This is a summary report, covering the 2018/19 monitoring period, and focussing only on those measurements that are especially important for assessing the lake condition for its ecosystem health and recreational use.

2 Monitoring Program

Some changes were introduced into the monitoring program since the last report. The monitoring previously conducted by the Manly Hydraulics Laboratory was discontinued, as the indicators measured are also included in the Council program. The number of sites within the Council program was also reduced from 15 to 11, as this was considered adequate to cover the spatial variability of the Lake (Table 2-1, Figure 2-1). The sites continued to be monitored monthly and for the same indicators as in previous years. These indicators are temperature, pH, dissolved oxygen, salinity, turbidity, nitrogen, phosphorus, and chlorophyll *a*. From January 2019, the field sampling and analysis has been carried out by Sydney Water, who have been undertaking the laboratory analysis for this project since the 2013.

Over the 2018/19 summer, three new sites were included for recreational water quality testing, as part of the NSW Beachwatch Program. The NSW Beachwatch Program monitors and reports recreational water quality at swimming sites in the Sydney region, and partners with councils and wastewater managers for regional swimming locations along the NSW coast. This Program has previously included only one site in Lake Illawarra – named Entrance Lagoon Beach – in the entrance area of the Lake. The new sites added by Council are at Ski-Way Park, Kanahooka, and Purry Burry Point, which are popular launch sites for many recreational pursuits in the Lake (Figure 2-1). These three sites were tested on 21 occasions between October 2018 and April 2019. The testing is for the presence of enterococci – a group of bacteria indicating water quality condition for recreational use.

Table 2-1 Description of sites monitored for estuary ecosystem health

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	Lake Edge
Site 4	Jetty at Sailing Club at Burroo Bay	Lake Edge
Site 5	Boat ramp and jetty at Kanahooka	Lake Edge
Site 6	Jetty at Griffins Bay Wharf	Lake Edge
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

Figure 2-1 Map showing location of the sites monitored by Council for estuary ecosystem health (in blue) and for recreational use (in green)

3 Data Analysis

3.1 Water Quality 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 for an assessment of the spatial and temporal patterns evident from October 2013 to April 2019. All plots are stored in the Wollongong City Council records management system and can be accessed if required. The indicators discussed in this report are nitrogen, phosphorus, 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 utlised are given in Table 3-1.

Table 3-1 Guideline trigger values utilised

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)	0.015 mg/L	ANZECC (2000)
Ammonia	0.015 mg/L	ANZECC (2000)
Total Phosphorus	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[b]	State of NSW and Office of Environment and Heritage (2013)
Turbidity	5.7 NTU[a]	State of NSW and Office of Environment and Heritage (2013)

[a] This value has been updated to 6 NTU in State of NSW and Office of Environment and Heritage (2016)
[b] This value has been updated to 5 µg/L 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. The chlorophyll *a* and turbidity values in most areas of the Lake are close to or less than the 2013 guidelines trigger values, which are also triggers 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.

3.2 Estuary Ecosystem Health Condition

The estuary ecosystem health condition of each site has been determined on the basis of its chlorophyll a and turbidity status over the summer months (November to April). The methodolgy used is consistent with that recommended by the NSW Monitoring, Evaluation and Reporting (MER) Framework, 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 3-2 **(State of NSW and Office of Environment and Heritage 2013)**. As noted above, 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)**.

Table 3-2 Descriptors for estuary ecosystem health condition grades

Grade	Defintion
Very Good	The indicator meets the benchmark values for almost all of the time period.
Good	The indicator meets the benchmark values for most of the time period.
Fair	The indicator meets the benchmark value for some of the time period.
Poor	The indicator does not meet the benchmark value for most of the time period.
Very Poor	The indicator does not meet the benchmark value for almost all of the time period.

3.3 Water Quality for Recreational Use

The results of the monitoring for recreational water quality at the three new sites included by Council will feed into the Beachwatch Program, to be reported according to its protocols. This will be done when data over a longer term has been collected and can be reliably used with other site characteristics to grade the sites for swimming purposes. The results when available can be viewed at the webpage - https://www.environment.nsw.gov.au/topics/water/beaches/illawarra-beaches . The analysis carried out for this report is only preliminary and calculates the percentage of the testing occasions when the sites complied with the guidelines for primary and secondary recreational use contact criteria (Table 3-3).

Table 3-3 Guideline trigger values for recreational use

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

(source: ANZECC (2000))

4 Results and Discussion

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, as observed. Rainfall has a significant influence on water quality. Table 4-1 presents the rainfall records for the last ten years and it shows that 2018/19 summer has been the driest since 2009/10. This is an important factor for the water quality patterns observed in the 2018/19 period.

Table 4-1 Seasonal rainfall (mm) at Darkes Road for the past nine years

Year	Season		
	Winter	Summer	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

Winter – 1 May to 31 October

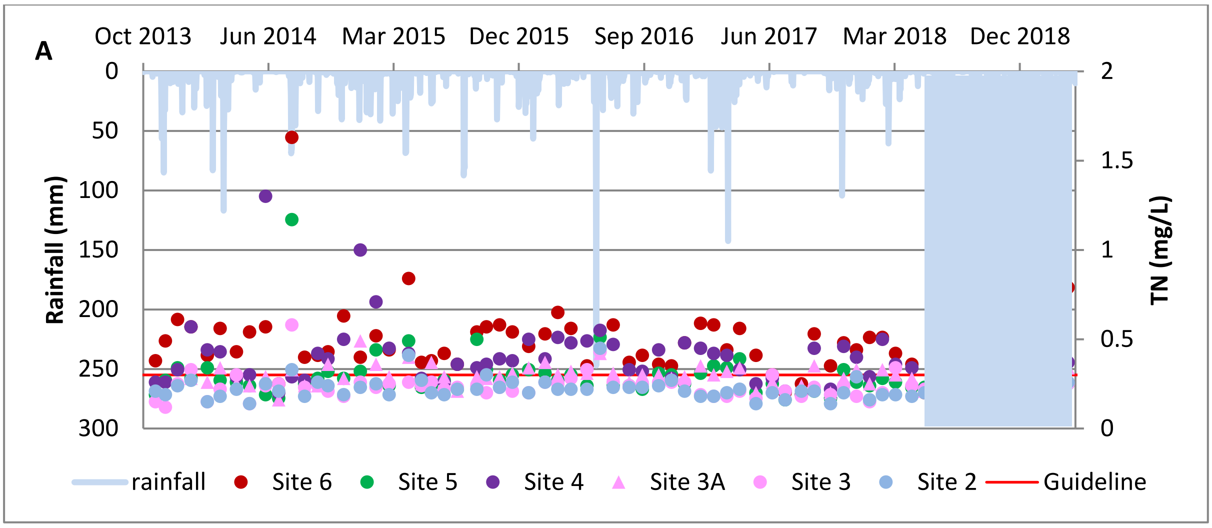
Summer – 1 November to 30 April

4.1 Nitrogen

Over the 2018/19 monitoring period, the concentrations of nitrate, nitrite, and ammonia were again generally below or close to their respective detection limits (0.01 mg/L for all), indicating that these more bio-available forms of nitrogen continue to be rapidly utilised by phytoplankton and other plant life in the Lake. Nitrogen is considered to be the limiting nutrient for primary production in Lake Illawarra and the results for nitrate, nitrite and ammonia for the recent 12 months lead further support to this hypothesis (WBM Oceanics Australia 2003). A limiting nutrient is a relatively scarce element which controls the amount of plant growth in the lake.

The exception to this trend has again been at Griffins Bay (Sites 6) where sporadic higher nitrate and ammonia concentrations are being detected. A new observation over the recent 12 months is higher than background ammonia concentrations at Picnic Island (Site 3). This is a relatively shallow site in the back channel where tidal flushing has recently been limited because of a sand bar formation at the seaward side of the channel.

Figure 4-1 shows the total nitrogen (TN) concentrations recorded in the recent 12 months together with previous results. The recent results are generally consistent with previous observations, showing much higher concentrations at some of the lake edge sites (especially Site 6 at Griffins Bay) than at the entrance sites or the in-lake zones; and higher values over the summer than over the winter months. The lake edge sites (except for Site 6 at Griffins Bay) recorded lower total nitrogen concentrations in the 2018/19 period than in any of the previous years. This is mostly likely the result of the reduced rainfall and consequently the runoff that is carried into the lake from the catchment.



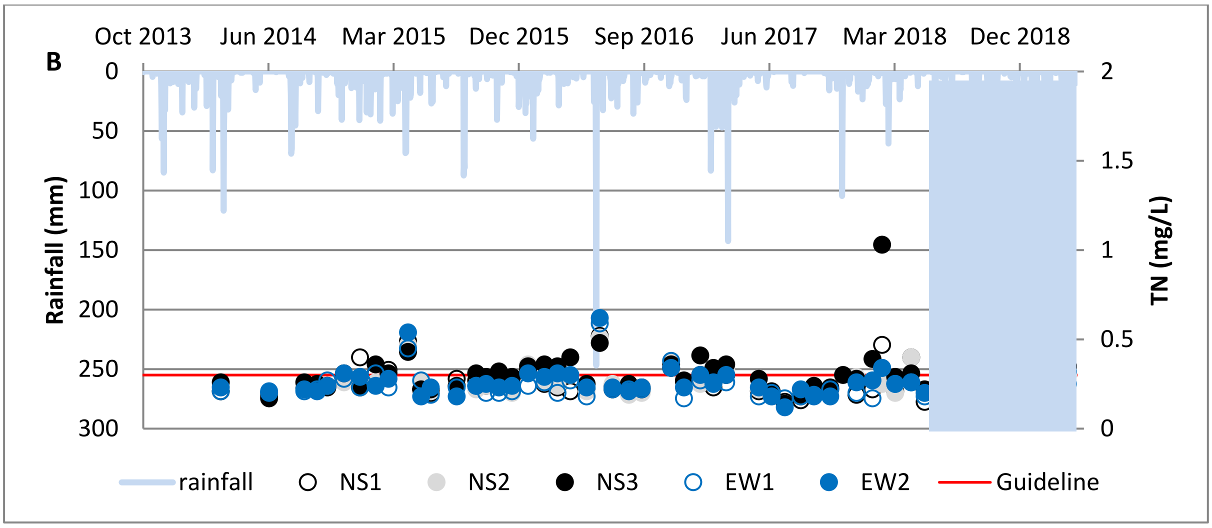


Figure 4-1 Plots of total nitrogen (TN) and rainfall against time for the lake edge and entrance sites (A) and in-lake locations (B) – shaded area shows the recent 12 months

The filtered total nitrogen (FTN) for the recent 12 months (Figure 4-2) continues to show better compliance with its guideline trigger value than total nitrogen. The TN value represents nitrogen that is present in water in both the dissolved and suspended forms, including microscopic algae and sediments, while the FTN excludes the suspended component, and so FTN can only be less than or equal to TN. The FTN (dissolved) fraction generally makes up about 70 to 80% of the TN (total nitrogen) regardless of the time of the year.

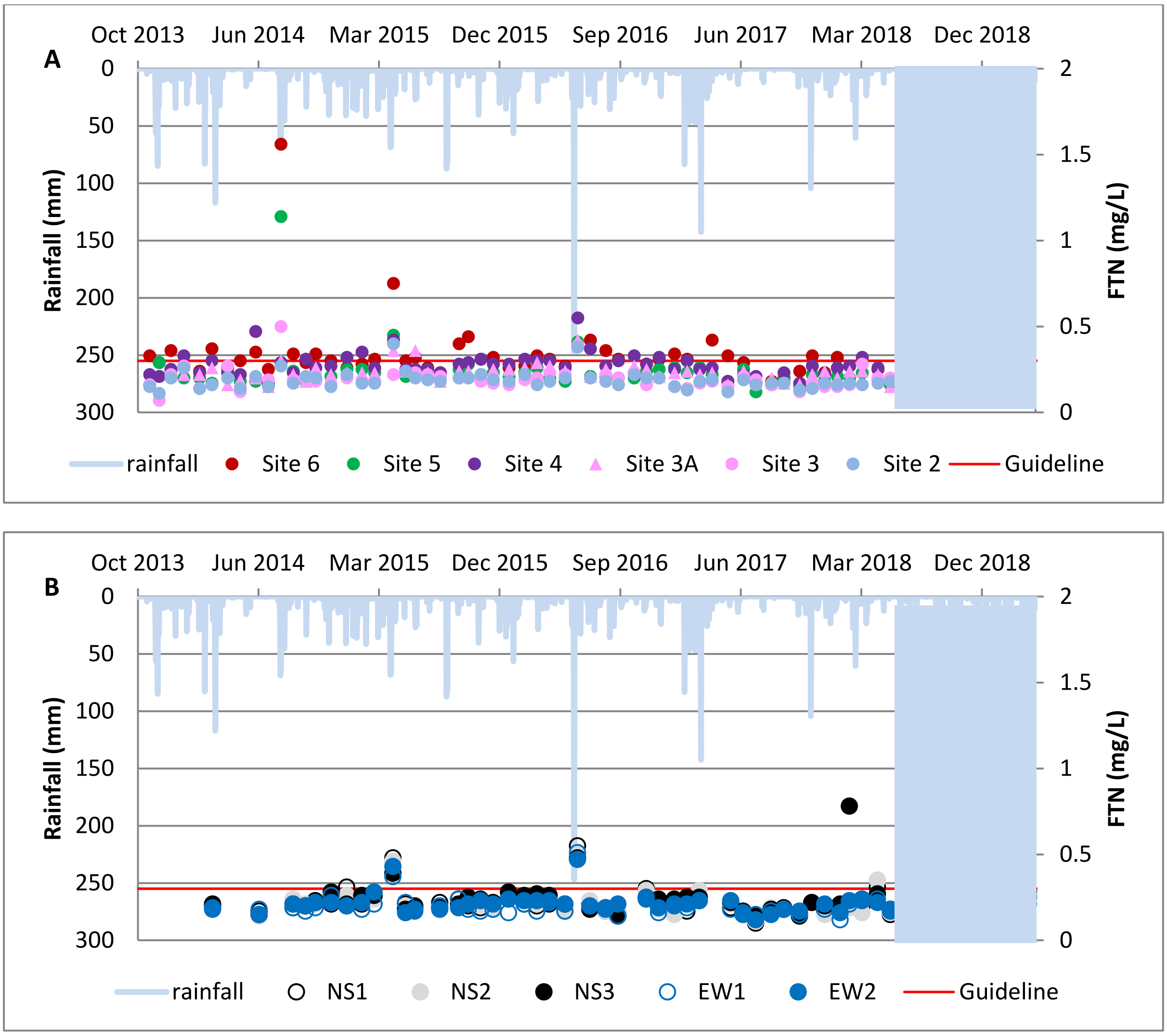
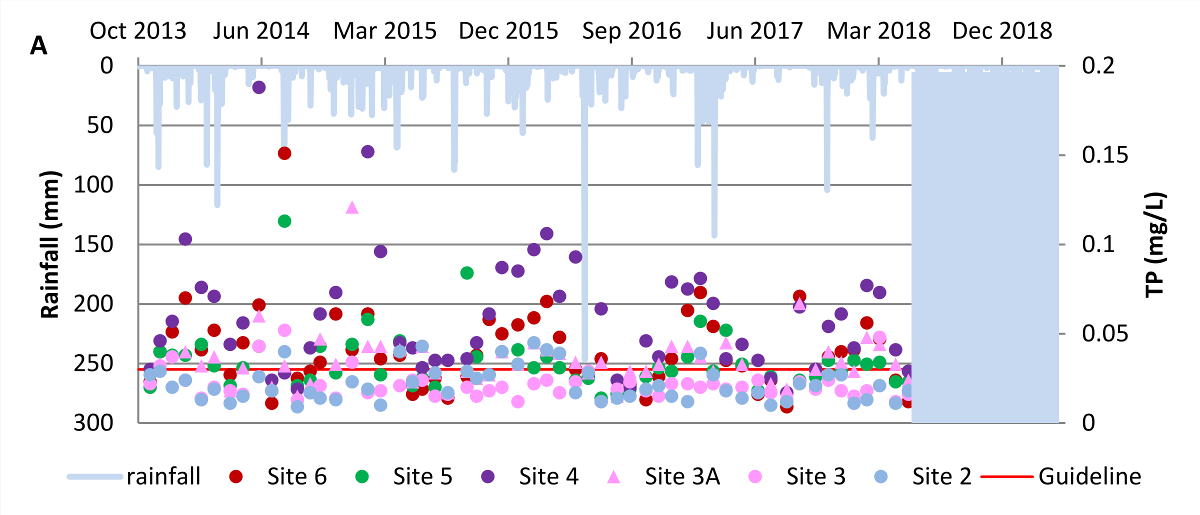


Figure 4-2 Plots of filtered total nitrogen (FTN) and rainfall against time for the lake edge and entrance sites (A) and in-lake locations (B) – shaded area shows the recent 12 months

4.2 Phosphorus

Figure 4-3 presents the total phosphorus (TP) concentrations measured in the lake over the recent 12 months alongside previously recorded measurements. The recent observations are very similar to previous observations, with several sites routinely exceeding the guideline value. Along the lake edges, Burroo Bay (Site 4) continued to have the highest concentrations, followed closely this time by Site 3 at Picnic Island. This is a new observation for Site 3, and this could be the result of limited tidal flushing of this area in recent months, as discussed in the section for nitrogen. At other sites, TP concentrations appear to show a reduction in the current year, which could be the case because of lower rainfall rather than any real improvement in water quality.



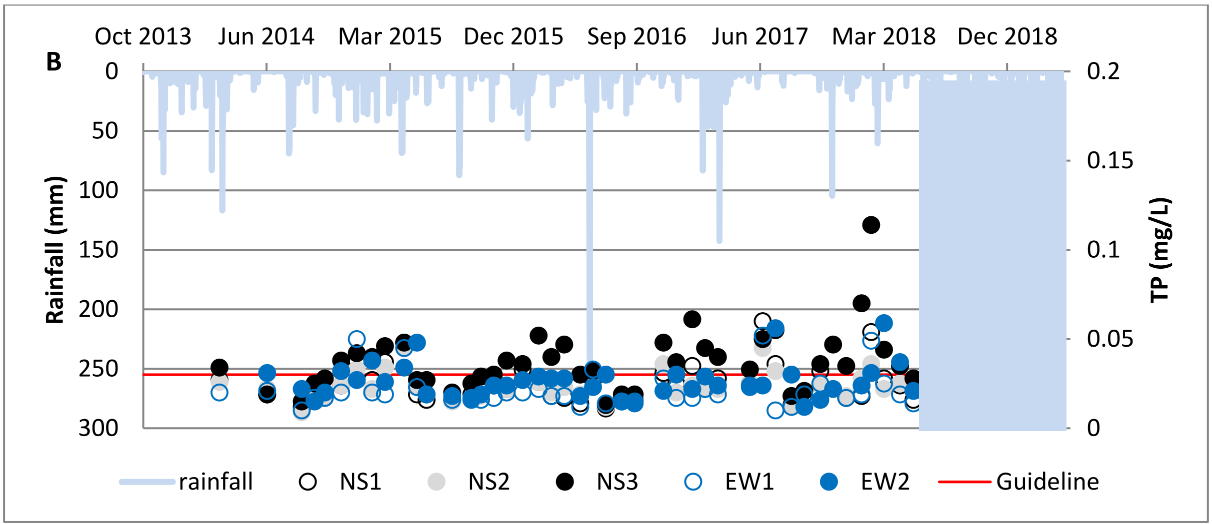
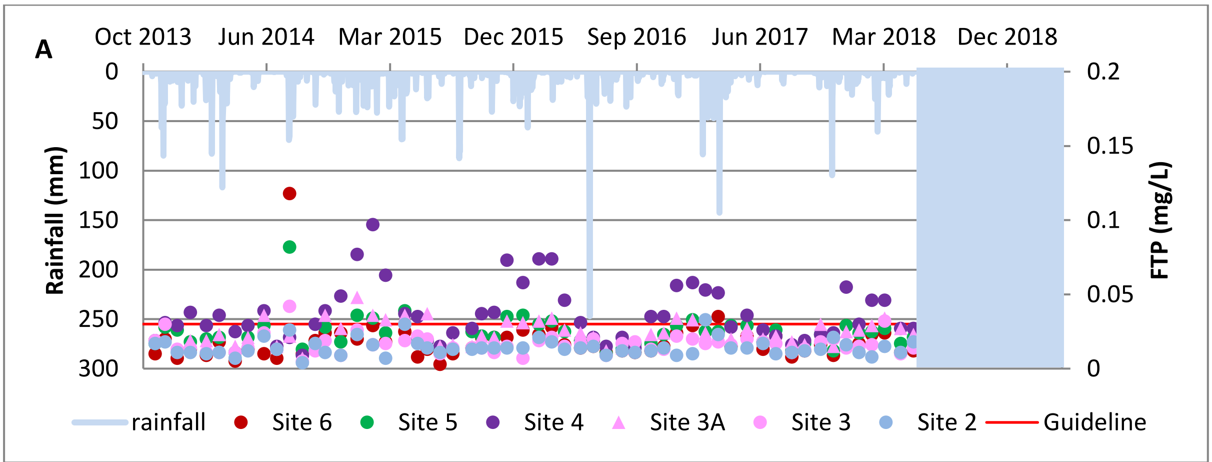


Figure 4-3 Plots of total phosphorus (TP) and rainfall against time for the lake edge and entrance sites (A) and in-lake locations (B) – shaded area shows the recent 12 months

The filtered total phosphorus (FTP) results are presented in Figure 4-4, and the recent 12 months continue to show better compliance with the guideline value at most sites, except at Picnic Island (Site 3) along the lake edge, as noted for nitrogen. The FTP fraction is about 70 to 80 % of the TP.



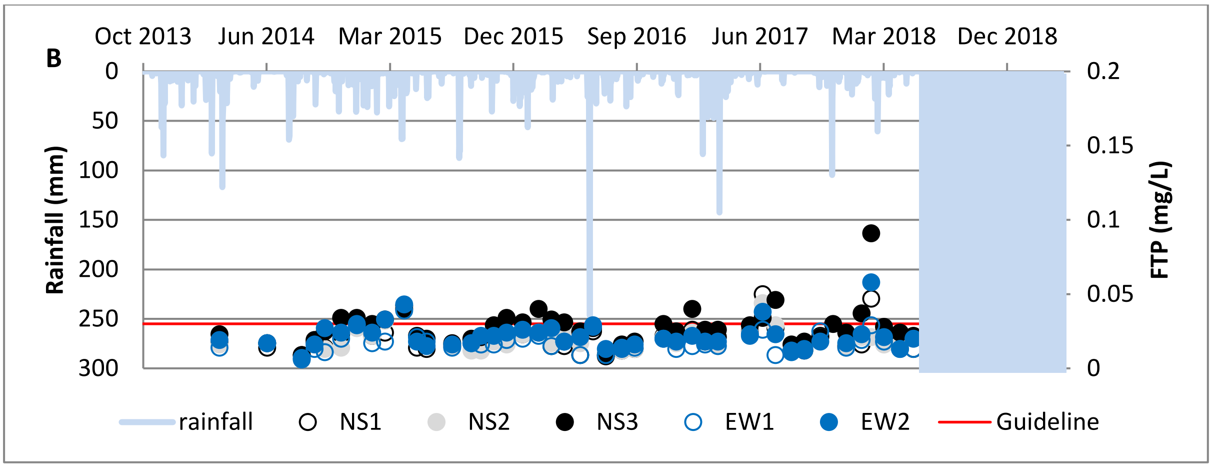
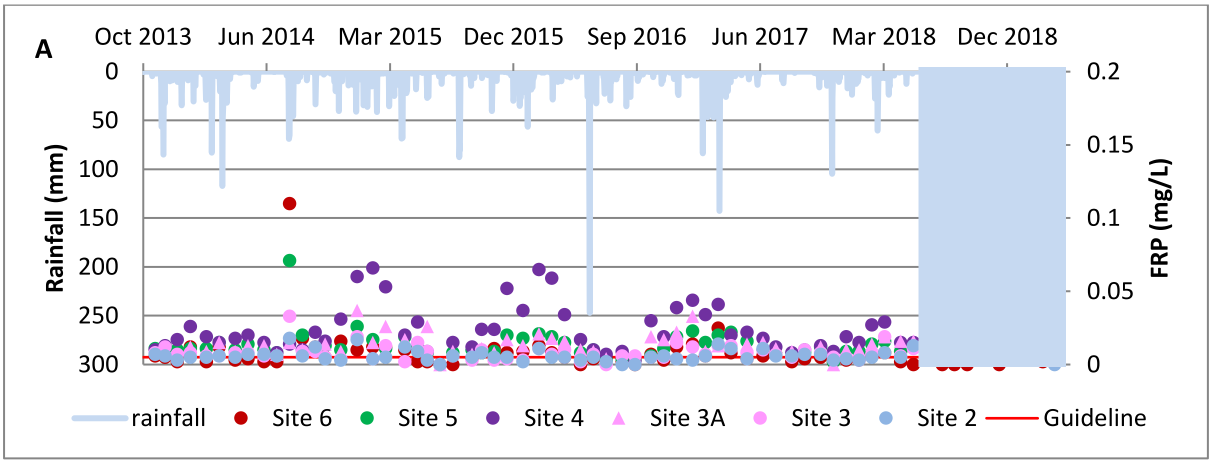


Figure 4-4 Plots of filtered total phosphorus (FTP) and rainfall against time for the lake edge and entrance sites (A) and in-lake locations (B) – shaded area shows the recent 12 months

The filterable reactive phosphorus (FRP) results are presented in Figure 4-5. The guideline value for FRP is only 0.005 mg/L, and in a phosphorus-rich environment such as Lake Illawarra (catchment soils are not phosphorus deficient), most sites easily exceed this guideline. The FRP fraction is about half of the FTP.



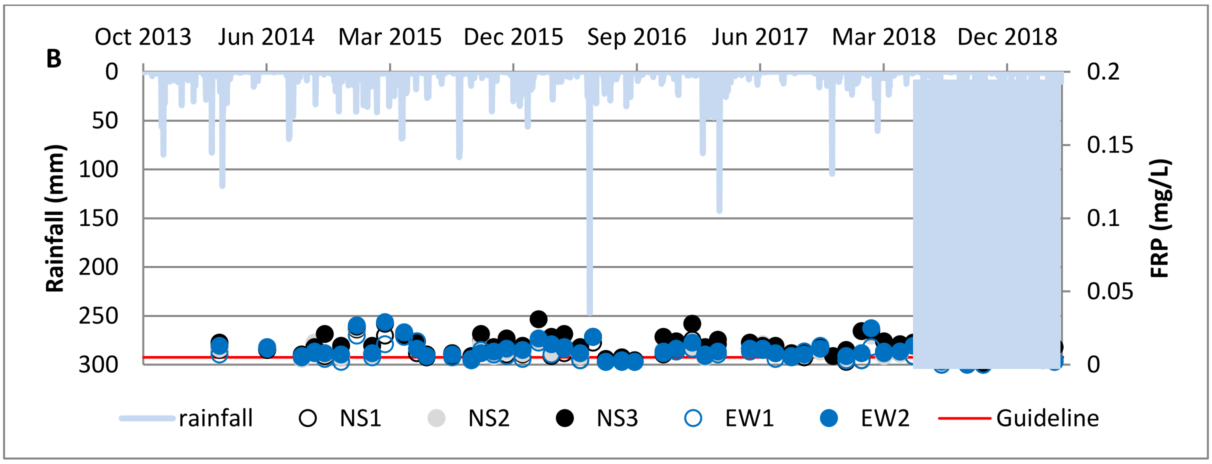
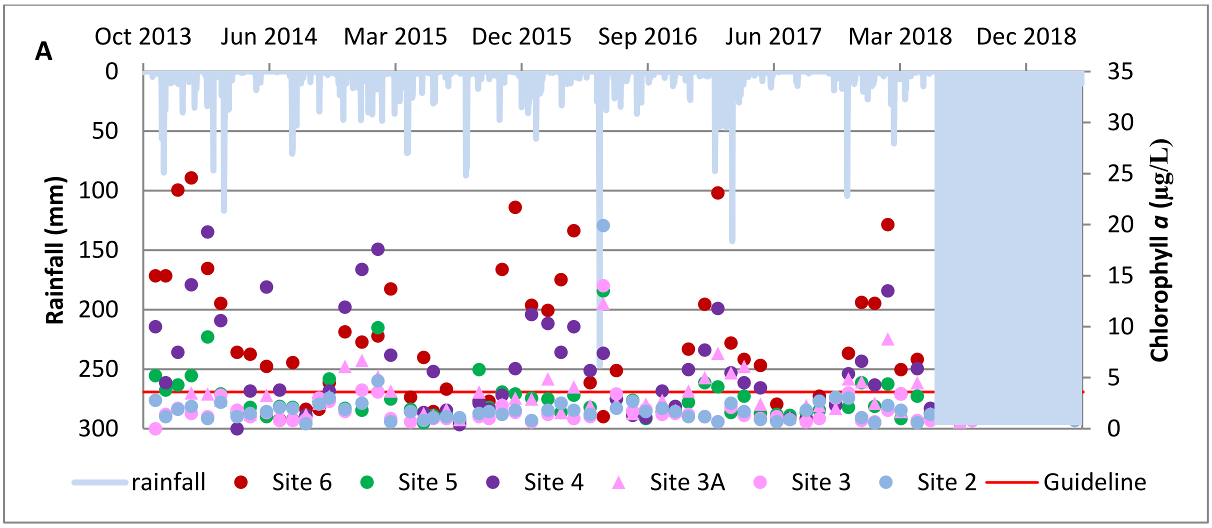


Figure 4-5 Plots of filtered reactive phosphorus (FRP) and rainfall against time for the lake edge and entrance sites (A) and in-lake locations (B) – shaded area shows the recent 12 months

4.3 Chlorophyll *a*

The results for chlorophyll *a* are presented in Figure 4-6, which show generally similar patterns in the recent 12 months as compared to previous data, with concentrations peaking in the summer months and reducing to around the guideline trigger value around the winter months. Variations between sites are like those for nitrogen and phosphorus. Along the edges of the lake, chlorophyll *a* is most abundant at Griffins Bay (Site 6) and this is followed closely by Picnic Island (Site 3). Within the main body of the lake, unusually higher concentrations were recorded in February 2019, but otherwise the pattern is like that in previous years.



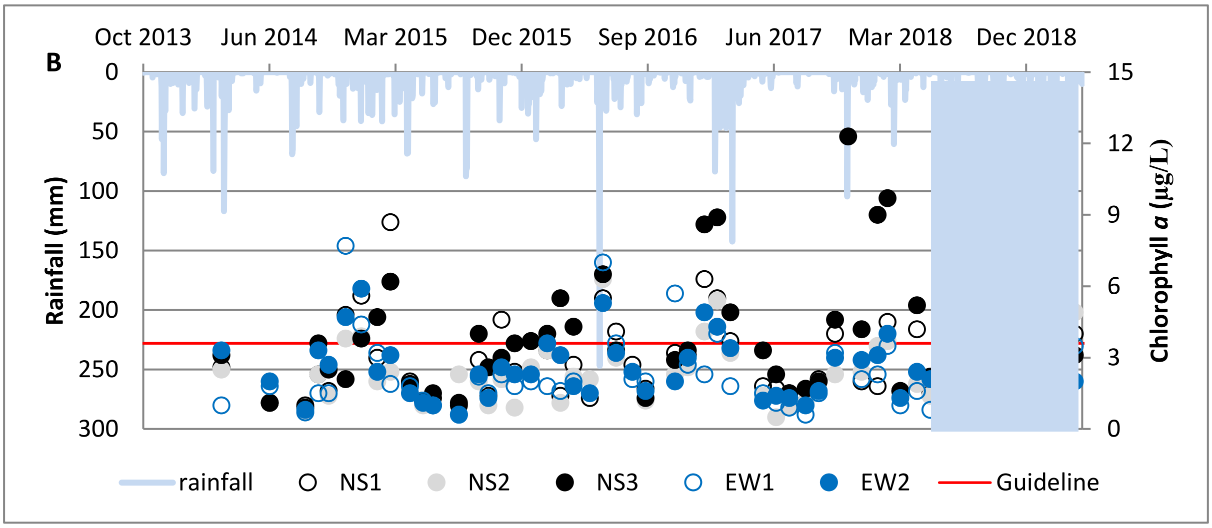
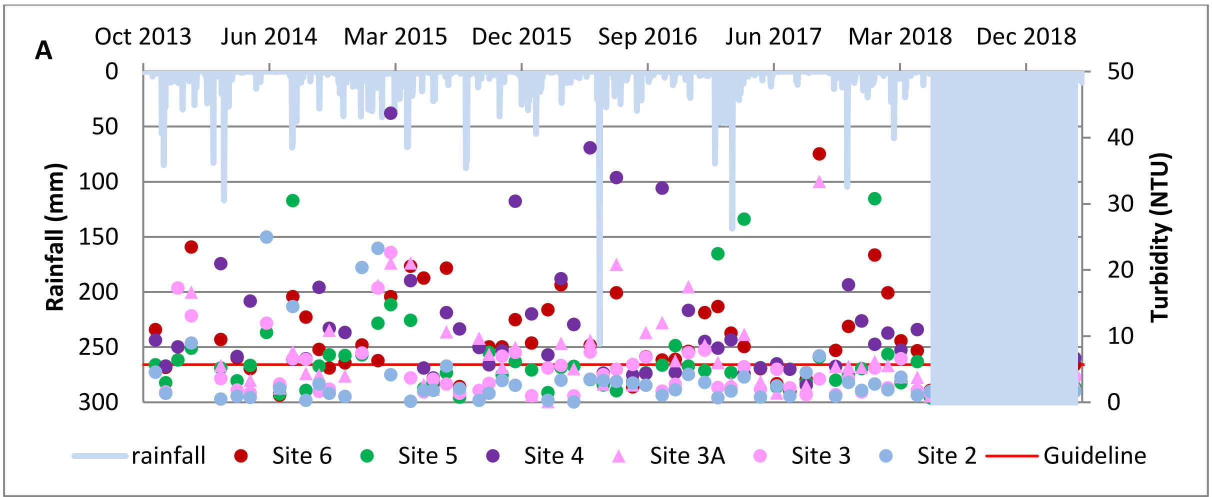


Figure 4-6 Plots of chlorophyll *a* and rainfall against time for the lake edge and entrance sites (A) and in-lake locations (B) – shaded area shows the recent 12 months

4.4 Turbidity

The results for turbidity are presented in Figure 4-7. A turbidity of 5.7 NTU was previously recommended as the trigger value for assessing the health of estuarine ecosystems that are classified as a "Lake" (State of NSW and Office of Environment and Heritage 2013), and this value was utilised in previous Council reports on lake water quality. This trigger has now been increased to 6 NTU (State of NSW and Office of Environment and Heritage 2016), but a trigger of 5.7 NTU will continue to be used for Lake Illawarra to maintain continuity with previous reports.

The results for the last 12 months again show greater exceedance of the trigger value at the edge sites than within the main body of the lake. In addition, although there is great variation at the edge sites, because of the many different factors that can influence turbidity in these locations (as discussed in previous reports), a background seasonal pattern is emerging suggesting a summer maximum (around January) and a winter minimum (around June). This is because the microscopic algal content of the water (indicated by the chlorophyll *a* content) is another influence on the turbidity and it peaks over summer.



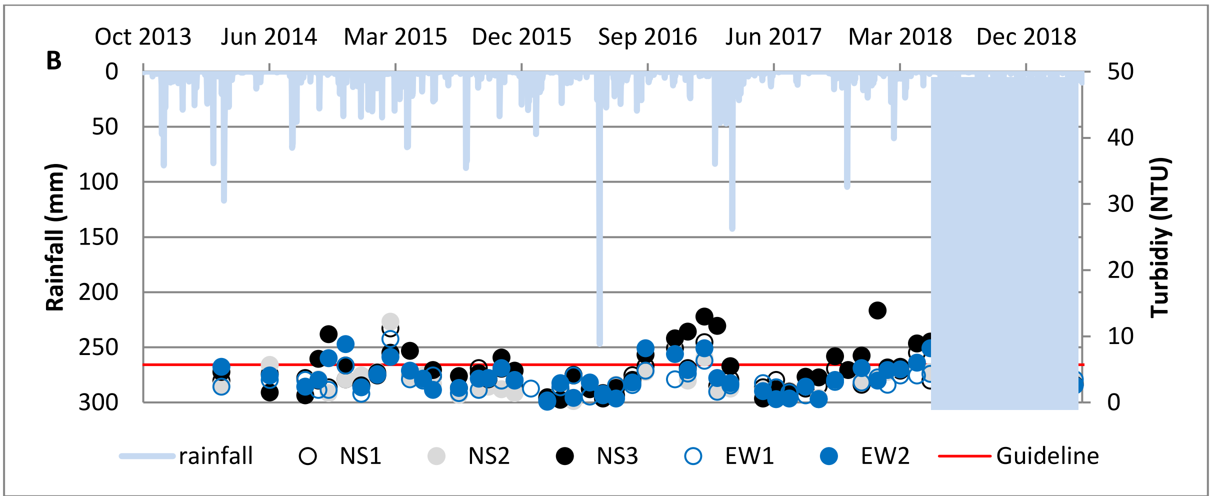


Figure 4-7 Plots of turbidity and rainfall against time for the lake edge and entrance sites (A) and in-lake locations (B) – shaded area shows the recent 12 months

4.5 Water Quality 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 Seasonal Kendall method has been selected for the trend analysis in these reports as it allows for seasonal differences in the data. 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. This resulted in a few (no more than five) data points being excluded from a dataset of more than 50 to 70 observations. The trend analysis was performed with the filtered data and a statistically significant decreasing trend could be detected only at some lake edge sites (Table 4-2). Theses sites are especially vulnerable to catchment runoff, and the results observed can therefore be explained by recent years being unusually dry.

Table 4-2 Sites showing a significant trend in water quality

Site	Region	Indicator(s)	Trend
LI4 – Burro Bay	Lake Edge	TP, Chlorophyll *a,* Turbidity	decreasing
LI5 - Kanahooka	Lake Edge	TN, TP, Turbidity	decreasing
LI6 – Griffins Bay	Lake Edge	TN, TP, Chlorophyll a, Turbidity	decreasing

4.6 Estuary Ecosystem Health Condition

The estuary ecosystem health condition is based on the chlorophyll *a* and turbidity, as recommended under the NSW MER program **(State of NSW and Office of Environment and Heritage 2016)**, but using guideline trigger values of 3.6 µg/L for chlorophyll *a* and 5.7 NTU for turbidity. The results for the recent summer are presented in Figure 4-8, together with the results for previous years.

The estuary ecosystem health condition of the lake is better represented by the results of the in-lake locations rather than the edge or entrance sites. Turbidity at the edges can be easily influenced by wind conditions prevailing at the time of sampling or disturbances from activities such as boating or other recreational activities. Entrance sites, on the other hand, may be more representative of the incoming ocean water than the main body of the lake. The in-lake zones rate as generally “good” for the 2018/19 summer compared to “very good” for the previous summer, despite continuing dry conditions in the current year. Continued monitoring will help to determine whether this is a permanent or more transient trend.

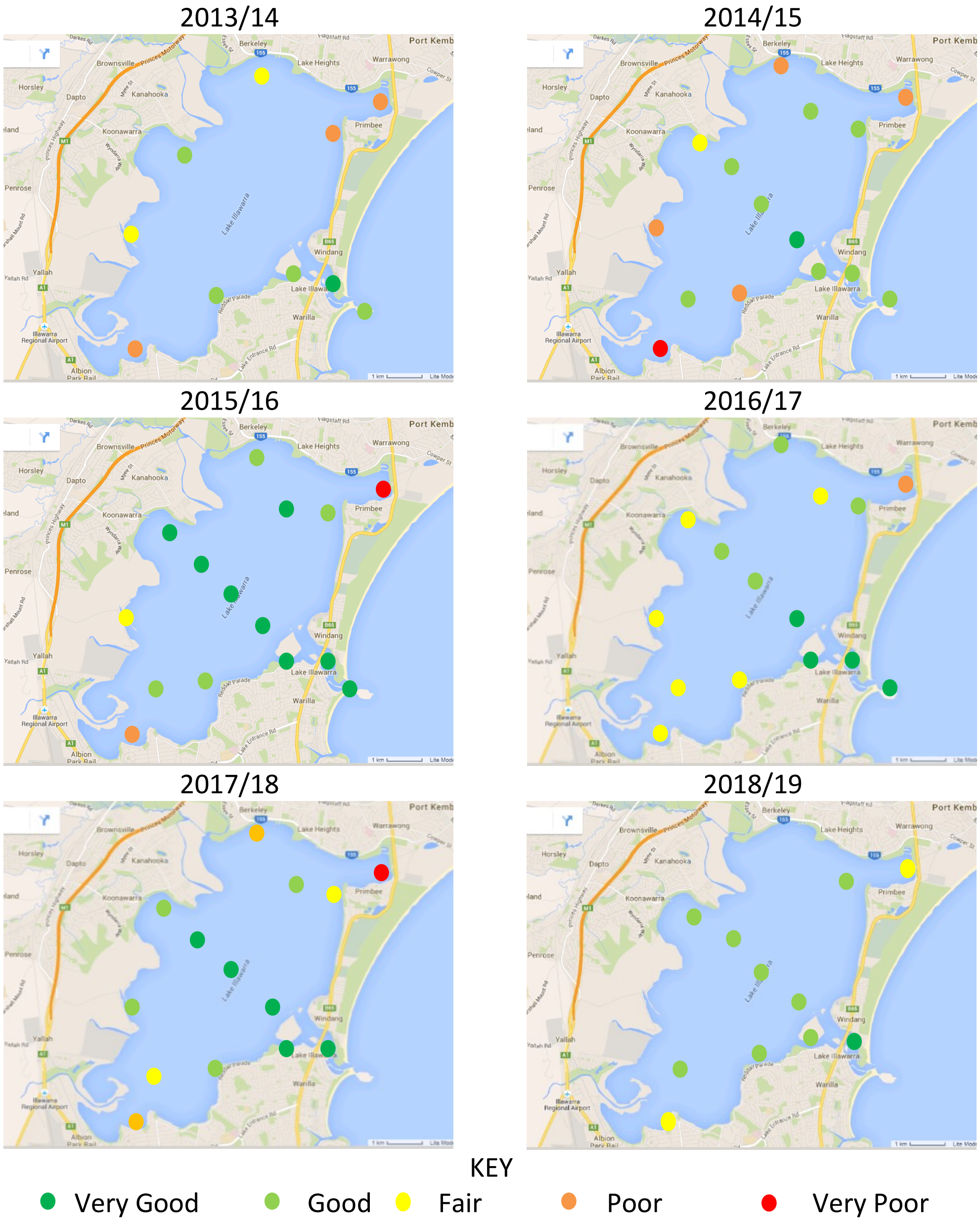


Figure 4-8 Estuary health condition over summer based on chlorophyll *a* and turbidity measurements in the lake

4.7 Recreational Water Quality

Figure 4-9 shows the percentage of the 21 test occasions meeting the recreational water guideline for primary (35 cfu/100 ml) and secondary (230 cfu/100 ml) contact. These results may look encouraging but need to be treated with caution as they may not be representative of the situation in these areas all the time. Rainfall is known to have a significant effect on water quality, and a plot of the results against rainfall shows that high levels of enterococci are clustered around rainfall events (Figure 4-10). Recent years have been unusually dry and continued monitoring over more wet years will provide better indication of the overall recreational water quality in the lake.

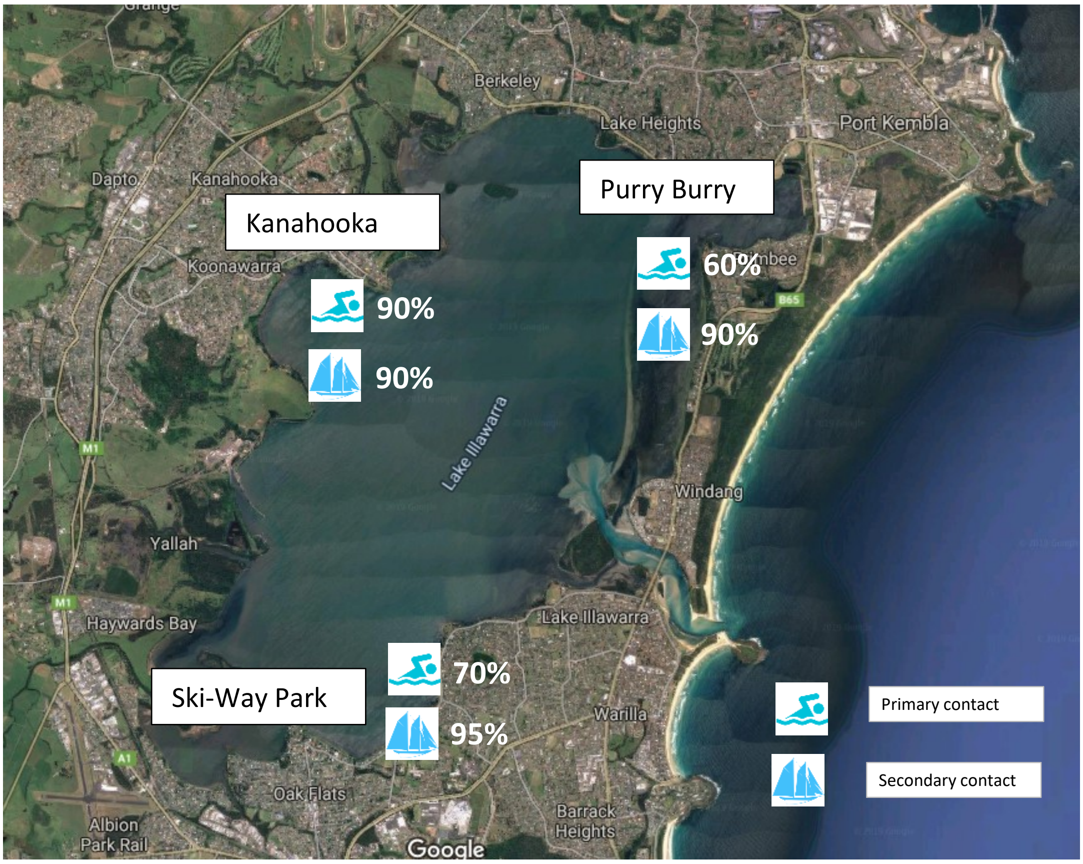


Figure 4-9 Percentage of the test occasions meeting primary (35 cfu/100 ml) and secondary (230 cfu/100 ml) contact recreational water quality guidelines

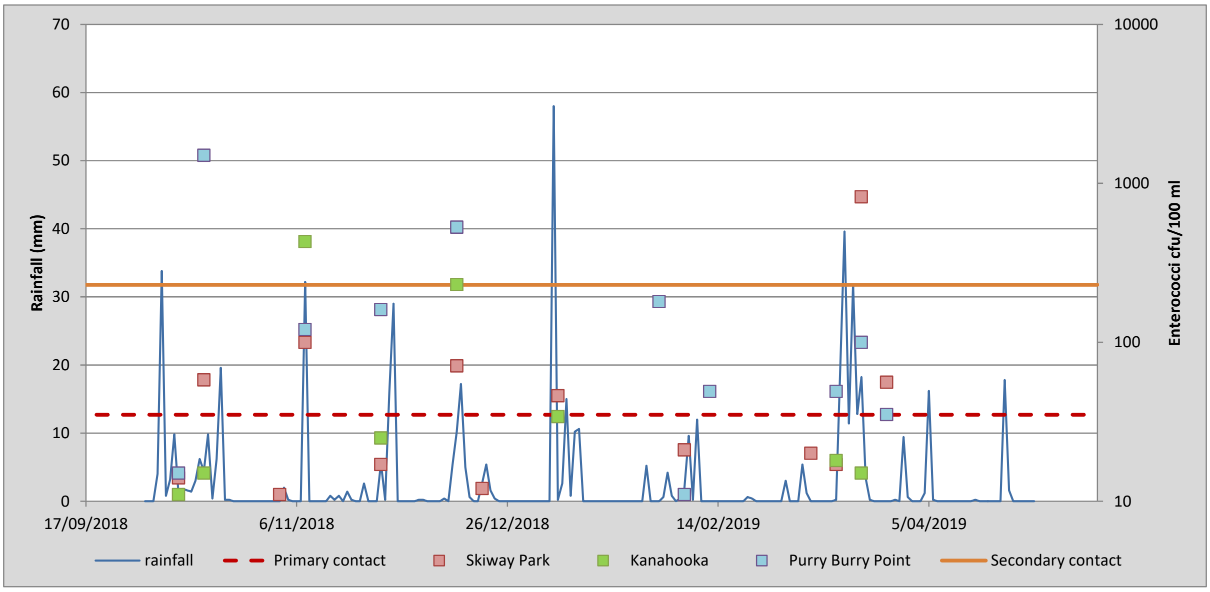


Figure 4-10 Plot of enterococci concentrations against rainfall

5 Conclusions

This report has reviewed selected indicators to describe the water quality trends evident in Lake Illawarra in the 12 months from May 2018 to April 2019. The indicators are nitrogen and phosphorus concentrations, turbidity, and chlorophyll *a* for estuary health, and the bacterial species enterococci for recreational use.

The estuary health indicators showed similar trends as in previous years, with concentrations peaking over the summer months, and in most parts of the lake generally exceeding the guideline trigger values. Overall, however, concentrations have decreased in comparison to previous years, especially at the outer edges, but this is attributed to very lower rainfall in recent years. The exception to this trend is the back channel along Picnic Island which appears to have degraded in the recent 12 months. The reason for this could be that increased sand deposition across the seaward end of this channel observed over recent months is restricting flushing of this area.

Water quality for primary as well as secondary contact recreational use of the lake was generally good over the testing period. However, a correlation with rainfall patterns was noted, and further monitoring under more average rainfall conditions is necessary for more reliable indication of the lake suitability for recreational use, as the current testing period was unusually dry.

6 Recommendations

Monitoring of the health of the lake to determine its condition for supporting its ecological ecosystem and recreational use should continue, as long-term datasets are required to get reliable insights into how the lake is changing. This will be especially important as the Coastal Management Program for Lake Illawarra is adopted and implemented. The results of the monitoring will help inform whether the investment in the lake is making a difference.

7 References

ANZECC. 2000. “Australia and New Zealand Guidelines for Fresh and Marine Water Quailty.”

BMT. 2020 a. “Community Uses, Values, Threats and Opportunities Lake Illawarra.”

BMT. 2020 b. “Lake Illawarra Coastal Management Program - Final Draft Report.”

Office of Environment and Heritage and the Environment Protection Authority. 2017. “Risk-based framwork for considering waterway health outcomes in strategic landuse planning decisions.”

State of NSW and Office of Environment and Heritage. 2013. “Assessing Estuary Ecosystem Health: Sampling, data analysis and reporting protocols.”

State of NSW and Office of Environment and Heritage. 2016. “Assessing estuary ecosystem health: sampling, data analysis and reporting protocols.”

Wollongong City Council. 2015. “Lake Illawarra Water Quality and Estuary Health Monitoring Program Report - August 2015.”

Wollongong City Council. 2016. “Lake Illawarra Water Quality and Estuary Health Monitoring Program.”

Wollongong City Council. 2017. *Lake Illawarra Estuary Health Monitoring and Reporting.* Wollongong: Wollongong City Council. Accessed May 18, 2018. http://wollongong.nsw.gov.au/services/sustainability/coastalandestuarymanagement/Documents/Lake%20Illawarra%20Estuary%20Health%20Monitoring%20Report%20June%202017.pdf.

Wollongong City Council. 2018. “Lake Illawarra Water Quality Monitoring and Reporting.”