Sewage Treatment System Impact Monitoring Program

Volume 1: Main Report

Data Report 2022-23

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Sydney Water

1 Smith Street, Parramatta, NSW Australia 2150

PO Box 399 Parramatta NSW 2124

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Acknowledgement of Country

Sydney Water respectfully acknowledges the Traditional Custodians of the land and waters on which we work, live and learn. We pay respect to Elders past and present.

Executive Summary

Background

Sydney Water operates 23 wastewater systems and each system has an Environment Protection Licence (EPL) regulated by the NSW Environment Protection Authority (EPA). Each EPL specifies the minimum performance standards, and monitoring and reporting requirements.

The Sewage Treatment System Impact Monitoring Program (STSIMP) was in place between July 2008 to June 2023 to satisfy condition M5.1 of our EPLs. In April 2023, the EPA approved a new monitoring program entitled 'Sydney Water Aquatic Monitoring (SWAM) program' to replace the STSIMP. The overarching aim of the SWAM program is:

> *'to monitor the performance of Sydney Water's water resource recovery facility (WRRF) discharges and quantify the impacts (positive or negative) of these discharges, and sewer overflows and leakage, on the aquatic environment''.*

The new SWAM program is now included in the EPLs, and key monitoring sub-programs commenced from July 2023.

The outcomes of these STSIMP/SWAM programs are reported to the NSW EPA at regular intervals to fulfil EPL conditions and posted on Sydney Water's website.

This STSIMP Data Report 2022-23 has been prepared to satisfy condition M5.1g of the EPLs. It consists of the following two volumes:

Volume 1 STSIMP Data Report 2022-23: the main volume of the 2022-23 report. It provides results using summary and inferential statistical methods to address sub-program specific objectives comparing the current year with relevant water/sediment quality objectives and the relevant historical record. A brief commentary commensurate with the results is provided. It also provides a summary of treated wastewater quality. This volume details the 'exceptions' where a significant trend is identified in the data (either positive or negative) or the results exceed the EPL guideline limits and/or other relevant guidelines (ANZG 2018, and NHMRC 2008)

Volume 2 STSIMP Data Report 2022-23 (Appendices): includes all wastewater and environmental monitoring data and statistical analysis summaries, and graphics. This volume is also supported by multiple electronic appendices of data summaries and raw data that have been provided to the EPA.

The format and content of this *STSIMP 2022-23 Data Report* has been revised in comparison to earlier reports, to align with the requirements of new SWAM program where possible. It incorporates a weight of evidence (WoE) approach in line with the *Australian and New Zealand Guideline for Fresh and Marine Water Quality* (ANZG 2018). The water quality and ecosystem health of the receiving environment was assessed using indicators/analytes from across the pressure, stressor and ecosystem receptor (P-S-ER) causal pathway elements.

Hawkesbury-Nepean River and tributaries

Pressure – WRRF effluent discharge quantity, quality and toxicity

Concentration

Table ES-1 Summary of EPL concentration limit exceedances, together with statistically significant increasing and decreasing trends of Hawkesbury-Nepean River WRRFs

Analytes / WRRFs	Nutrients			Conventional analytes					Trace metals							Other chemicals/organics		
	Ammonia nitrogen	Total nitrogen	Total phosphorus	Biochemical Oxygen Demand	Chlorine residual (total)	Faecal coliforms	Suspended solids	EC50 **Toxicity**	Aluminium	Cadmium	Chromium	Copper	Iron	Nickel	Zinc	Diazinon	Hydrogen sulphide	Nonyl phenol ethoxylate
Picton	↗	↘	↗	→		→	→											
West Camden	**↗**	**↗**	→	→	→	↗	→	→	→			↘	→		↘	→	→	
Wallacia	↗	↗	↗	→		→	→	→	→			→			→		→	→
Penrith	→	↘	↗	→	→	→	→	→	↘	→		↘	↗		→		→	
Winmalee	→	↗	↗	→	→	→	→	→	→			→	↘		→	→		
North Richmond	**↗**	↗	↗	↗		↗	↗	→	→			→	→		→	→	→	
Richmond	→	→	→	→	→	→	→	→										
St Marys	→	→	→	→	→	→	→	→	→			**↗**	↗	↗	↗	→	→	
Quakers Hill	↘	↘	↗	→	→	→	→	→	**→**	→	→	→			→		→	
Riverstone	→	↘	↘	→	→	→	→	→	→			→	→		→		→	
Castle Hill	↗	↘	↘	→		→	→	→	↗	→		→	→		↗	→	→	
Rouse Hill	↗	↗	→	→	→	→	→	→	→			→	→		→			
Hornsby Heights	→	→	→	→		→	→	→	→			→	→		↘	→	→	
West Hornsby	→	↘	→	→		→	→	→	→			→	→		↘		→	
Brooklyn	→	→	→	→		→	→	→										

→	No statistically significant trend in 2022-23		Analytes not required in the EPL or no concentration limit
↘	Statistically significant decreasing trend in 2022-23		Concentration value outside EPL limit
↗	Statistically significant increasing trend in 2022-23		Concentration value within EPL limit

Load

Table ES-2 Summary of EPL load limit exceedances of Hawkesbury-Nepean River WRRFs

WRRFs \ Analytes	Nutrients		Conventional analytes			Trace metals						Other
	Total nitrogen	Total phosphorus	Biochemical Oxygen Demand	Oil and grease	Suspended solids	Cadmium	Chromium	Copper	Lead	Mercury	Selenium	Pesticides and PCBs
Picton	Within	Outside	Within	Within	Outside	Not required	Not required	Not required	Not required	Not required	Not required	Not required
West Camden	Outside	Within	Within	Within	Within	Not required	Not required	Not required	Not required	Not required	Not required	Not required
Wallacia	Within	Within	Within	Within	Within	Not required	Not required	Not required	Not required	Not required	Not required	Not required
Penrith	Within	Within	Within	Within	Within	Within	Within	Within	Within	Within	Within	Within
Winmalee	Within	Within	Within	Within	Within	Not required	Not required	Not required	Not required	Not required	Not required	Not required
North Richmond	Within	Within	Within	Within	Within	Not required	Not required	Not required	Not required	Not required	Not required	Not required
Richmond	Within	Within	Within	Within	Within	Not required	Not required	Not required	Not required	Not required	Not required	Not required
St Marys	Within	Outside *	Within	Within	Within	Within	Within	Within	Within	Within	Within	Within
Quakers Hill	Within	Outside *	Within	Within	Within	Within	Within	Within	Within	Within	Within	Within
Riverstone	Within	Outside *	Within	Within	Within	Not required	Not required	Not required	Not required	Not required	Not required	Not required
Castle Hill	Within	Within	Within	Within	Within	Not required	Not required	Not required	Not required	Not required	Not required	Not required
Rouse Hill	Within	Within	Within	Within	Within	Not required	Not required	Not required	Not required	Not required	Not required	Not required
West Hornsby	Within	Within	Within	Within	Within	Not required	Not required	Not required	Not required	Not required	Not required	Not required
Hornsby Heights	Within	Within	Within	Within	Within	Not required	Not required	Not required	Not required	Not required	Not required	Not required
Brooklyn	Not required	Not required	Not required	Not required	Not required	Not required	Not required	Not required	Not required	Not required	Not required	Not required

* Aggregate loads of St Marys, Quakers Hill and Riverstone WRRFs

(yellow)	Load value outside EPL limit	(grey)	Analytes not required in the EPL or no load limit
(green)	Load value within EPL limit		

With the increasing pressure from a growing population and climate change, Sydney Water is challenged with:

- treating and discharging an increasing volume of wastewater
- aligning or managing treatment activities with more frequent and extreme weather events.

During the 2022-23 monitoring period, there were a total of nine concentration EPL limit exceedances across five WRRFs (two 50^{th} and 90^{th} percentiles for ammonia nitrogen, one 50^{th} and 90^{th} percentiles for total nitrogen, one 80^{th} percentile for faecal coliforms, one average and 90^{th} percentile for copper and one average aluminium). In addition, there were a total of four load EPL limit exceedances across three WRRFs (two total phosphorus, one total nitrogen and one total suspended solids). This is a decrease from eight concentration exceedances recorded from four facilities and eleven load exceedances recorded from six facilities respectively from the previous 2021-22 monitoring period.

Based on statistical analysis comparing the 2022-23 monitoring period to the previous nine monitoring periods, the following observations were made for effluent quality against concentration limits:

- ammonia nitrogen concentration continued to increase across the upper Nepean River WRRF discharges. An increase was also observed in two of the lower Hawkesbury-Nepean River WRRF discharges (Castle Hill and Rouse Hill)
- total nitrogen and total phosphorus concentrations showed an increasing trend across majority of Nepean River WRRF discharges
- all nutrient and conventional analytes concentrations in the discharge from North Richmond WRRF showed an increasing trend, with non-compliance against ammonia nitrogen limits
- there was a decreasing to no significant trends identified for the majority of metal concentrations in Nepean River WRRF discharges. The exceptions were copper concentration in St Marys WRRF discharge and aluminium concentration in Castle Hill WRRF discharge
- there was a decreasing to no significant trend in total nitrogen and total phosphorus concentrations in the lower Hawkesbury-Nepean River WRRF discharges.

Stressor – Water quality

Table ES-3 Summary of Hawkesbury-Nepean River water quality trends and comparison with guidelines (ANZG 2018)

WRRF	Monitoring sites	Nutrient analytes					Physico-chemical analytes					
		Ammonia nitrogen	Oxidised nitrogen	Total nitrogen	Filterable total phosphorus	Total phosphorus	Conductivity	Dissolved oxygen	Dissolved oxygen saturation	pH	Temperature	Turbidity
Picton	Upstream tributary (N911B)	→	→	→	↘	→	→	→	→	→	→	→
	Downstream tributary (N911)	→	→	→	→	→	→	→	→	→	→	→
	Upstream River (N92)	→	→	→	→	→	↘	→	→	↘	→	↗
	Downstream River (N91)	→	→	→	→	↗	→	→	↗	↘	→	↗
West Camden	Upstream tributary (N7824A)	→	→	→	↘	→	→	→	→	→	→	→
	Downstream tributary (N7824)	→	↗	↗	→	→	→	→	→	↘	→	→
	Upstream River (N78)	→	→	→	→	→	→	→	↗	→	→	→
	Downstream River (N75)	↗	↗	↗	→	→	→	→	→	→	→	→
Wallacia	Upstream tributary (N642A)	→	→	→	↗	↗	→	→	→	→	→	→
	Downstream tributary (N641)	→	↗	↗	→	↗	→	→	→	→	→	→
Penrith	Upstream tributary (N542)	→	↘	→	→	→	↗	→	→	→	→	→
	Downstream tributary (N541)	→	↘	↘	→	→	→	→	→	→	→	→
	Upstream River (N57)	→	↗	↗	↗	→	→	→	↗	→	→	→
	Downstream River (N53)	→	↗	→	→	→	→	→	↗	→	→	↗
Winmalee	Upstream River (N48A)	→	↗	↗	→	→	→	→	→	→	→	→
	Downstream River (N464)	→	→	→	→	→	→	→	→	→	→	↗
North Richmond	Upstream tributary (N412)	→	→	→	↘	↘	→	↗	↗	↗	→	→
	Downstream tributary (N411)	→	↘	↘	↘	↘	↘	→	→	→	→	→
	Upstream River (N42)	→	↗	↗	↗	→	→	↗	→	→	→	→
	Downstream River (N39)	→	↗	↗	↗	→	→	→	→	→	→	↗
Richmond	Upstream tributary (N389)	→	→	→	↘	↘	→	→	→	→	→	→
	Downstream tributary (N388)	→	→	→	↘	↘	↗	→	→	→	→	→
St Marys	Upstream tributary (NS26)	→	→	→	→	→	→	→	↗	→	→	→
	Downstream tributary (NS23A)	→	→	→	→	→	→	→	→	→	→	→
Quakers Hill	Upstream tributary (NS090)	→	→	→	→	→	→	→	→	↗	→	→
	Downstream tributary (NS087)	→	→	→	→	→	↗	→	↗	↗	→	→
Riverstone	Upstream tributary (NS082)	→	→	→	→	→	→	→	→	→	→	→
	Downstream tributary (NS081)	→	→	→	→	→	→	→	↗	→	→	→

WRRF	Monitoring sites	Nutrient analytes					Physico-chemical analytes					
		Ammonia nitrogen	Oxidised nitrogen	Total nitrogen	Filterable total phosphorus	Total phosphorus	Conductivity	Dissolved oxygen	Dissolved oxygen saturation	pH	Temperature	Turbidity
Rouse Hill	Upstream tributary (NC53)	→	→	→	→	→	→	→	→	→	→	→
	Downstream tributary (NC516)	→	→	→	→	→	→	↗	↗	→	→	→
Castle Hill	Upstream tributary (NC8)	→	→	→	→	→	→	→	→	↘	→	→
	Downstream tributary (NC75)	→	→	→	→	→	→	→	→	↘	→	→
West Hornsby	Upstream tributary (NB83)	→	↗	↗	→	↗	→	→	→	→	→	→
	Downstream tributary (NB825)	→	↘	↘	→	→	↘	→	→	→	→	→
Hornsby Heights	Upstream tributary (NB43)	→	→	→	→	→	↘	→	↗	→	→	→
	Downstream tributary (NB42)	→	→	→	→	→	→	→	↗	→	→	→

↗	Upward trend	↘	Downward trend	→	no trend, p>0.05

	2022-23 Median value within the guideline limit
	2022-23 Median value outside the guideline limit
	No guideline applicable

Based on statistical analysis comparing the 2022-23 monitoring period to the previous 2-9 years trends and, the upstream and downstream comparisons are mixed and highly variable. The following key observations were made on nutrient analytes:

- Oxidised nitrogen and total nitrogen concentrations increased significantly downstream of West Camden and Wallacia WRRFs. Ammonia nitrogen also increased downstream of West Camden WRRF. The increasing concentrations at these downstream sites are possibly linked with the increasing concentrations of these analytes in WRRF discharges.
- Total phosphorus concentration increased significantly upstream and downstream of Wallacia WRRF indicating upstream catchment factors also contributing to this trend.
- Trends in nutrient concentrations were mixed upstream and downstream of Penrith and North Richmond WRRFs. The downstream tributary sites indicated significant decreases in two or more nutrient analytes (oxidised nitrogen, total nitrogen and filterable total phosphorus). However, where these tributaries flow into main river, both the upstream and downstream sites significantly increased in the same nutrient concentrations.
- Filterable total phosphorus and total phosphorus concentrations decreased significantly upstream and downstream of Richmond WRRF.
- The significant decrease in total nitrogen concentration in the Penrith and West Hornsby WRRF discharges may have contributed to decreasing total nitrogen concentration at relevant downstream tributary sites.

During 2022-23 median oxidised and total nitrogen concentrations exceeded ANZG (2018) guideline at 34 of 36 upstream and downstream sites (exceptions being total nitrogen upstream of Picton WRRF and oxidised nitrogen upstream of West Camden WRRF).

Overall, ammonia nitrogen concentrations exceeded the ANZG (2018) guideline at over half (21 of 36) the upstream and downstream monitoring sites. Median ammonia concentrations were within ANZG (2018) guideline at all upstream and downstream sites at Picton, Wallacia and Winmalee WRRFs. Median ammonia concentrations were also within the guideline at the upstream tributary sites at West Camden, Rouse Hill and Hornsby Heights WRRFs, upstream river at Penrith WRRF, upstream and downstream river sites at North Richmond WRRF, and downstream site at West Hornsby WRRF.

Median total phosphorus concentrations were within the ANZG (2018) guideline at 12 of 16 upstream Nepean River and tributary sites monitored from Picton to Winmalee WRRFs. However, median total phosphorus concentrations mostly exceeded the guideline at other downstream Hawkesbury River and tributary monitoring sites (16 of 20) from North Richmond to Hornsby Heights WRRFs.

Ecosystem receptor – Phytoplankton

Table ES-4 Summary of Hawkesbury-Nepean River phytoplankton trends and comparison with guidelines (ANZG 2018 or NHMRC 2008)

WRRF	Monitoring sites	Phytoplankton analytes			
		Chlorophyll-a	Total phytoplankton biovolume*	Blue-green biovolume*	Toxic blue-green count*
Picton	Upstream tributary (N911B)	→			
	Downstream tributary (N911)	→	→	→	→
	Upstream River (N92)	→	→	→	→
	Downstream River (N91)	→	→	→	→
West Camden	Upstream tributary (N7824A)	→	↗	→	→
	Downstream tributary (N7824)	→			
	Upstream River (N78)	→	→	→	→
	Downstream River (N75)	↗	↗	→	
Wallacia	Upstream tributary (N642A)	→			
	Downstream tributary (N641)	→	→	→	
Penrith	Upstream tributary (N542)	→	↗	→	→
	Downstream tributary (N541)	→			
	Upstream River (N57)	→	↗	→	→
	Downstream River (N53)	→	→	→	

WRRF	Monitoring sites	Phytoplankton analytes			
		Chlorophyll-a	Total phytoplankton biovolume*	Blue-green biovolume*	Toxic blue-green count*
Winmalee	Upstream River (N48A)	→	→	↗	→
	Downstream River (N464)	→	→	→	→
North Richmond	Upstream tributary (N412)	→	→	→	
	Downstream tributary (N411)	→			
	Upstream River (N42)	↘	→	↗	→
	Downstream River (N39)	→	→	→	→
Richmond	Upstream tributary (N389)	→	→	→	→
	Downstream tributary (N388)	→	→	→	→
St Marys	Upstream tributary (NS26)	→	→	↗	→
	Downstream tributary (NS23A)	→	→	→	→
Riverstone	Upstream tributary (NS082)	→	→	→	
	Downstream tributary (NS081)	→			
Quakers Hill	Upstream tributary (NS90)	→	→	→	→
	Downstream tributary (NS87)	→			
Rouse Hill	Upstream tributary (NC53)	→			
	Downstream tributary (NC516)	↘			
Castle Hill	Upstream tributary (NC8)	→			
	Downstream tributary (NC75)	→			
West Hornsby	Upstream tributary (NB83)	→			
	Downstream tributary (NB825)	→			
Hornby Heights	Upstream tributary (NB43)	→			
	Downstream tributary (NB42)	→			

*phytoplankton biovolume and species counts are only undertaken if chlorophyll-a exceeds 7 µg/L

↗	Upward trend	↘	Downward trend	→	no trend, p>0.05

	2022-23 Median value within the guideline limit		No guideline applicable
	2022-23 Median value outside the guideline limit		Insufficient data

Phytoplankton as chlorophyll-a, algal biovolume and species counts were relatively stable in 2022-23 in comparison to previous years. There were no significant changes in chlorophyll-a at 33 of 36 monitoring sites. Chlorophyll-a concentration increased significantly in the Nepean River downstream of Matahil Creek (West Camden WRRF) and decreased upstream of North Richmond WRRF and in the tributary downstream of Rouse Hill WRRF.

The trends in the limited total phytoplankton biovolume data were relatively stable, increasing significantly at three upstream sites (tributary West Camden WRRF, both tributary and river Penrith WRRF) and one downstream river site (West Camden WRRF).

Overall, the 2022-23 median chlorophyll-a concentrations exceeded the ANZG (2018) guideline at 19 of 36 sites. The median chlorophyll-a concentration was within the guideline mostly in the lower Hawkesbury River tributaries (upstream and downstream).

Median toxic blue-green counts exceeded the NHMRC (2008) Amber Alert level at Stonequarry Creek downstream of Picton WRRF in 2022-23. This is the only site where, potentially toxic blue-green counts reached NHMRC (2008) Red Alert level (twice in May 2023).

Ecosystem receptor – Macroinvertebrates

In 2022-23, stream ecological health was assessed using the macroinvertebrate index, Signal-SG (Sydney genus). Impacts were detected in the tributaries downstream of Castle Hill, Hornsby Heights, West Camden, West Hornsby and Winmalee WRRFs. Further multivariate statistical analysis investigating differences at these sites was performed. There was no indication that impacts extended beyond these immediate tributaries into the Hawkesbury-Nepean River.

Georges River and tributaries

Pressure – WRRF effluent quantity, quality and toxicity

Table ES-5 Summary of EPL concentration limit exceedances, together with statistically significant increasing and decreasing trends of Georges River and tributary WRRFs

Analytes / WRRFs	Conventional analytes	
	Biochemical Oxygen Demand	Suspended solids
Glenfield	→	↗
Fairfield	→	→
Liverpool	↗	↗

→	No statistically significant trend in 2022-23		Analytes not required in the EPL or no concentration limit
↘	Statistically significant decreasing trend in 2022-23		Concentration value outside EPL limit
↗	Statistically significant increasing trend in 2022-23		Concentration value within EPL limit

All concentration limits in Glenfield WRRF discharges were within the Malabar EPL 372 limits during the 2022-23 reporting period. Under EPL 372 condition L3.5, as set by the EPA, the 100th percentile limits can be exceeded during wet weather where it was the sole cause of the exceedance. This condition was met at Glenfield WRRF discharge for total suspended solids on 2 July 2022.

Statistical analysis identified a significantly increasing trend in total suspended solids concentration in Glenfield WRRF wet weather discharge compared to the past nine years. This can be associated with extreme wet weather events since February 2020, with prior drought conditions magnifying the effect of recent wetter years.

Under dry weather conditions, flows received at Glenfield WRRF are transferred to Liverpool WRRF where it is sent to Malabar WRRF or diverted to Rosehill and Camelia recycled water facilities for further treatment.

All concentration limits in Fairfield WRRF discharges were within the Malabar EPL 372 limits during the 2022-23 reporting period. Under EPL 372 condition L3.5, as set by the EPA, the 100th percentile limits can be exceeded during wet weather where it was the sole cause of the exceedance. This condition was met at Fairfield WRRF discharge for biochemical oxygen demand and total suspended solids on 6 July and 6 October 2022.

Statistical analysis did not identify significant trends in biochemical oxygen demand or total suspended solids concentration in Fairfield WRRF wet weather discharge compared to the past nine years.

All concentration limits in Liverpool WRRF discharges were within the Malabar EPL 372 limits during the 2022-23 reporting period. Under EPL 372 condition L3.5, as set by the EPA, the 100th

percentile limits can be exceeded during wet weather where it was the sole cause of the exceedance. This condition was met at Liverpool WRRF discharge for:

- biochemical oxygen demand on 21, 24 and 26 July, 24 August, 5 and 24 September 2022 and 14 March 2023
- total suspended solids on 24 July 2022 and 14 March 2023

Stressor – Water quality

A monitoring program commenced at three Georges River sites upstream and downstream of Glenfield WRRF from July 2023. Feasibility studies for a new monitoring program for Fairfield and Liverpool WRRFs is under investigation. The outcome of the monitoring results for Glenfield WRRF will be included in SWAM report from 2023-24.

Ecosystem receptor – Phytoplankton and Macroinvertebrates

A monitoring program commenced at three Georges River sites upstream and downstream of Glenfield WRRF from July 2023. Feasibility studies for a new monitoring program for Fairfield and Liverpool WRRFs is under investigation. The outcome of the monitoring results for Glenfield WRRF will be included in SWAM report from 2023-24.

Nearshore marine waters

Pressure – WRRF effluent quantity, quality and toxicity

Concentration

Table ES-6 Summary of EPL concentration limit exceedances, together with statistically significant increasing and decreasing trends of nearshore marine discharging WRRFs

Analytes / WRRFs	Nutrient	Conventional analytes					Trace metals			Other chemicals/organics				
	Ammonia nitrogen	Biochemical Oxygen Demand	Faecal coliforms	Oil and grease	Suspended solids	EC_{50} **Toxicity**	Aluminium	Copper	Zinc	Chlorpyirfos	Cyanide	Diazinon	Hydrogen sulphide	Nonyl phenol ethoxylate
Warriewood	n/a	n/a	→ within	n/a	→ within	↗ within	→ within	↗ within	n/a	n/a	→ within	n/a	n/a	→ within
Cronulla	↗ within	→ within	→ within	→ within	→ within	→ within	→ within	→ within	↘ within	→ within	→ within	→ within	→ within	→ within
Wollongong	n/a	→ within	n/a	n/a	↗ within	n/a	→ within	↘ within	n/a	n/a	n/a	→ within	→ within	n/a
Shellharbour	→ within	→ within	→ within	n/a	↗ within	→ within	↗ outside	↘ within	n/a	n/a	n/a	→ within	→ within	→ within
Bombo	→ within	→ within	→ within	n/a	→ within	→ within	→ within	→ within	n/a	n/a	n/a	→ within	→ within	→ within

→	No statistically significant trend in 2022-23	n/a (grey)	Analytes not required in the EPL or no concentration limit
↘	Statistically significant decreasing trend in 2022-23	outside (yellow)	Concentration value outside EPL limit
↗	Statistically significant increasing trend in 2022-23	within (green)	Concentration value within EPL limit

Load

Table ES-7 Summary of EPL load limit exceedances of nearshore marine discharging WRRFs

Analytes / WRRFs	Nutrient		Conventional analytes			Trace metals							Other
	Total nitrogen	Total phosphorus	Biochemical Oxygen Demand	Oil and grease	Suspended solids	Cadmium	Chromium	Copper	Lead	Mercury	Selenium	Zinc	Pesticides and PCBs
Warriewood	within	within	within	within	within	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Cronulla	within	within	within	within	within	within	within	within	within	within	within	within	within
Wollongong	within	within	outside	within	outside	within	within	within	within	within	within	within	within
Shellharbour	within	within	within	within	outside	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Bombo	within	within	within	within	outside	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a

outside (yellow)	Load value outside EPL limit	n/a (grey)	Analytes not required in the EPL or no load limit
within (green)	Load value within EPL limit		

Similar to the Hawkesbury-Nepean River WRRF discharges, Sydney Water is challenged with increasing pressure from a growing population and climate change in WRRF discharges to the nearshore marine environment.

During the 2022-23 monitoring period, EPL limits were exceeded at three nearshore discharging plants including aluminium concentration at Shellharbour WRRF, biochemical oxygen demand load limit at Wollongong WRRF and suspended solid load limits at Wollongong, Shellharbour and Bombo WRRFs. This is an increase from 2021-22 where no EPL concentration and only three load limits exceedances were reported.

Wet weather influence on load and concentration non-compliances for the 2022-23 monitoring period from nearshore marine environment discharges was evident, with a continuation of La Niña weather patterns during this period.

Based on statistical analysis comparing the 2022-23 monitoring period to the previous nine monitoring periods, the following observations were made:

- toxicity increased in Warriewood WRRF discharge
- suspended solid concentrations increased in Shellharbour and Wollongong WRRF discharges
- copper concentrations decreased or showed no statistical trend across nearshore discharges, except Warriewood WRRF which increased.

Stressor – Water quality

- Water quality pilot program to be investigated.

Ecosystem receptor – Microalgae and invertebrates

Assessment of the 2022-23 monitoring data from the Shellharbour WRRF and two control sites indicated a relatively stable equilibrium in the rocky-intertidal community structure. These results also suggest no measurable impact had developed in the intertidal rock platform community near the outfall at Barrack Point from wastewater discharges from the Shellharbour WRRF.

Offshore marine waters

Pressure – WRRF effluent quantity, quality and toxicity

Concentration

Table ES-8 Summary of EPL concentration limit exceedances, together with statistically significant increasing and decreasing trends of offshore marine discharging WRRFs

Analytes / WRRFs	Conventional analytes		EC$_{50}$ **Toxicity**	Trace metals		Other chemicals/organics		
	Oil and grease	Suspended solids		Aluminium	Copper	Chlorpyirfos	Hydrogen sulphide	Nonyl phenol ethoxylate
North Head	→	→	→	→	↘	→	→	→
Bondi	↘	↘	↗	→			→	→
Malabar	↗	↗	→	↗			→	→

→	No statistically significant trend in 2022-23		Analytes not required in the EPL or no concentration limit
↘	Statistically significant decreasing trend in 2022-23		Concentration value outside EPL limit
↗	Statistically significant increasing trend in 2022-23		Concentration value within EPL limit

Load

Table ES-9 Summary of EPL load limit exceedances of offshore marine discharging WRRFs

Analytes / WRRFs	Nutrients		Conventional analytes			Trace metals and others							Other
	Total nitrogen	Total phosphorus	Biochemical Oxygen Demand	Oil and grease	Suspended solids	Cadmium	Chromium	Copper	Lead	Mercvury	Selenium	Zinc	Pesticides and PCBs
North Head													
Bondi													
Malabar													

	Load value outside EPL limit
	Load value within EPL limit
	Analytes not required in the EPL or no load limit

No concentration or load limit EPL exceedances occurred from the offshore WRRF discharges during the 2022-23 monitoring period. This is a decrease from two concentration EPL limit exceedances from one facility in the previous 2021-22 monitoring period.

Based on statistical analysis comparing the 2022-23 monitoring period to the previous nine monitoring periods, the following observations were made:

- toxicity increased in the Bondi WRRF discharge
- oil and grease and suspended solid concentrations increased in the Malabar WRRF discharge and decreased in the Bondi WRRF discharge.

Stressor – Ocean receiving water quality

Of eight chemicals assessed in 2022-23, modelled copper concentrations in the initial dilution zones of North Head and Malabar deepwater ocean outfalls exceeded the ANZECC (2000) guideline of 1.3 ug/L for protection of 95% of marine species.

Stressor – Ocean sediment quality

- The total organic carbon content (%) was less than 1.2% for all samples collected from Malabar, North Head and Bondi outfall locations, below the NSW EPA specified 99th percentile trigger value
- Average levels of fine sediments in 2022-23 were similar to those in past years, with no apparent build up of fine particles. As such, metals concentrations in the sediment were unlikely to have increased at the deepwater outfall locations

Ecosystem receptor – Ocean sediment ecosystem health

- The benthic community structure was assessed at the Malabar deepwater outfall location in the 2022-23 surveillance year
- Taxonomic compositions suggested that Polychaetes and Crustaceans continue to dominate the number of taxa collected at this site. While the total number of individuals was lower than the previous year, there has not been a sustained decline or increase in the main taxonomic groups over the 23 years of monitoring.

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1. Introduction

1.1 Background

One of Sydney Water's principal objectives is to protect the environment by conducting its operations in compliance with the principles of ecologically sustainable development. We are supported in this capacity by a comprehensive regulatory framework. The New South Wales (NSW) Environment Protection Authority (EPA) regulates Sydney Water's wastewater operational activities with one Environment Protection Licence (EPL) for each of the 23 Wastewater Treatment Systems (WTSs) currently operated across the greater Sydney, Blue Mountains and Illawarra region. Generally, each WTS consists of a Water Resource Recovery Facility (WRRF) and its reticulation system. The Malabar WTS includes three Georges River WRRFs (Fairfield, Glenfield and Liverpool), while the Wollongong WTS includes the Bellambi and Port Kembla WRRFs. Altogether, these 28 WRRFs provide an integrated wastewater treatment service to more than 5 million people across Greater Sydney.

The physical environment in which we conduct our discharge operations varies widely across our area of operations. Monitoring activities cover a broad range of receiving water environments including freshwater (tributary creeks and rivers), estuarine, nearshore and offshore marine environments. The WTSs are distinct in terms of the nature of the discharge operations, the nature of environmental processes and the management objectives. This distinctiveness is considered in the design of the monitoring programs targeting each respective system.

The Sydney, Blue Mountains and Illawarra region is a major centre of economic, industrial and agricultural activity with high density residential growth. These diverse activities all contribute to the environmental health of the region. Sydney Water's activities represent just one input to the complex system of local riverine, estuarine and ocean environments. Our challenge is to identify the effects of our wastewater operations against the background of diverse human activities. We aim to address this challenge by implementing well-designed monitoring that target key impact indicators sensitive to our activities.

1.2 Sewage Treatment System Impact Monitoring Program

The Sewage Treatment System Impact Monitoring Program (STSIMP) was developed in consultation with the NSW Department of Planning and Environment (DPE) and implemented from July 2008, to monitor greater Sydney's waterways (Sydney Water 2008). The NSW EPA endorsed the program in 2008, with a slight amendment to one of its sub-programs in 2010 (Sydney Water 2010).

The STSIMP aimed to monitor the environment within Sydney Water's area of operations to determine general trends in water quality over time, monitor our performance and determine where our contribution to water quality may pose a risk to environmental ecosystems and human health. The indicators selected were based on the knowledge of the relationship between pollutants and ecological or human health impacts. Sydney Water's overall approach to monitoring (design and methodology) and reporting was consistent with the national water quality guidelines (ANZG 2018) and the objectives of previous monitoring programs run by Sydney Water, DPE and other agencies.

The EPLs have referenced the STSIMP to specify environmental monitoring and reporting requirements for our wastewater operations. Each EPL directly specifies the types of monitoring requirements, such as wastewater discharge quantity and quality, and compliance standards. Sydney Water is required to prepare annual reports on monitoring from all these programs to assess environmental performance in relation to the EPLs issued by the EPA. A summary of all wastewater and environmental monitoring programs including the rationale behind each program, indicators, frequency and monitoring history is provided in Table 1-1.

1.3 Sydney Water Aquatic Monitoring Program

The Sydney Water Aquatic Monitoring (SWAM) program (Sydney Water 2023) was developed by a review panel in consultation with the EPA, DPE and Sydney Water to replace the STSIMP. The review panel included four independent specialists with complementary expertise across marine science, freshwater science, biostatistics, and relevant state and national water quality policies and/or guidelines. The findings and recommendations are detailed in van Dam et al. (2023).

A key focus of the review was to ensure that a revised monitoring program was able to differentiate the impacts of Sydney Water's activities from the impacts of all other anthropogenic activities occurring concurrently. The review looked at the design of the monitoring program, as well as the statistical analysis and annual reporting structure.

The overarching aim of the revised program (SWAM) is:

> '*to monitor the performance of Sydney Water's WRRF discharges and quantify the impacts (positive or negative) of these discharges, and sewer overflows and leakage, on the aquatic environment*'.

A key focus of the SWAM program is alignment with the ANZG (2018) water quality management framework (WQMF) to represent the nationally agreed process for managing, assessing and monitoring water quality. Amongst other aspects, it incorporates a weight of evidence (WoE) approach to water quality assessment that promotes the measurement of indicators from across the pressure, stressor and ecosystem receptor (P-S-ER) causal pathway (Table 1-2). For example, WRRF discharge quantity, quality and toxicity represent pressure indicators, while concentrations of key discharge constituents in the receiving waters represent stressor indicators, and phytoplankton and macroinvertebrate parameters represent ecosystem receptor indicators. Data from across these multiple P-S-ER lines of evidence are to be used to determine whether WRRF discharges are impacting the aquatic environment.

The new SWAM program was approved by the EPA in April 2023 (Sydney Water Aquatic Monitoring program) and referenced in each EPL. The key monitoring and reporting requirements outlined in the SWAM program will be gradually implemented from July 2023.

Table 1-1 Summary of the STSIMP

Wastewater catchment or receiving water	Sydney Water activities	Operating WRRFs	Monitoring program and rationale	Monitoring requirements
Ocean, beaches, estuaries and lagoons	Treated wastewater discharges (near shore and offshore), partially treated wastewater discharge events and wastewater overflows	Warriewood North Head Bondi Malabar - Fairfield - Glenfield* - Liverpool* Cronulla Wollongong* - Bellambi - Port Kembla Shellharbour Bombo*	Wastewater quantity, quality and toxicity: To measure WRRF performance, compliance limits on discharge volumes and pollutant loads	*In-situ* online monitoring: volume of discharges (treated and partially treated). Wastewater quality: biochemical oxygen demand (BOD), carbonaceous BOD, oil and grease, suspended solids, every 6 days; toxicity testing by sea urchin sperm and eggs (excluding Wollongong and other storm plants), every month; metal and organic contaminants, every month where applicable. Minor WRRF specific variations and other requirements as per EPL
			Ocean reference station: To estimate potential water quality disturbance from the ocean outfalls. Measures ocean currents and stratification, which are used as input to the deepwater ocean outfall models	Numerical modelling: Prediction of dispersion of the wastewater plume using ocean reference station data
			Ocean sediment program: To measure impacts on marine benthic organisms and sediments	In surveillance years, total organic carbon and sediment grain size is measured at North Head, Bondi and Malabar deepwater ocean outfall locations and benthic community is checked at the Malabar deepwater ocean outfall location. In assessment years, nine locations are assessed for additional chemical analysis and benthic community assessment
			Beachwatch program: To identify high *Enterococci* densities that are related with the potential dry weather overflow/ leakage issues	Sanitary inspection, conductivity and *Enterococci*: Sydney ocean beaches (41 sites) Illawarra region (18 sites) Sydney Harbour (56 sites) Some sites every 6 days throughout the year, others every 6 days during October to April and monthly during the rest of the year Sydney Water only monitors 18 sites in the Illawarra region. Other data is collected by DPE

Wastewater catchment or receiving water	Sydney Water activities	Operating WRRFs	Monitoring program and rationale	Monitoring requirements
			Urban rivers, estuaries and lagoons: Estimate trophic status, combined impact from all catchment sources	Sydney lagoons (7 sites): Chlorophyll-*a*, conductivity and *Enterococci* Urban rivers and estuaries (16 sites): Chlorophyll-*a* Monthly
			Shellharbour shoreline outfall program: To estimate the impact on ecosystem health due to shoreline discharges of wastewater	Composition and abundance of intertidal biota: three sites in the Illawarra catchments, once every year
			Sydney estuarine intertidal communities: Estimate ecosystem health status, combined impact from all catchment sources	Port Jackson, Botany Bay, Port Hacking: 26 sites, once per year (spring/summer)
			Urban rivers freshwater macroinvertebrates: Estimate ecosystem health status, combined impact from all catchment sources	Major rivers feeding the Sydney estuary: 11 sites, two times per year, macroinvertebrates diversity, calculation of the biotic index SIGNAL-SG
Hawkesbury-Nepean River and tributaries	Treated wastewater discharges, partially treated wastewater discharge events and wastewater overflows	Picton* West Camden* Wallacia* Penrith* Winmalee North Richmond Richmond* St Marys* Quakers Hill* Riverstone Castle Hill* Rouse Hill* Hornsby Heights	Wastewater quantity, quality and toxicity: To measure WRRF performance, compliance limits on discharge volumes and pollutant loads	*In-situ* online monitoring: volume of discharges (treated and partially treated) Wastewater quality: ammonia nitrogen, total nitrogen, total phosphorus, residual chlorine (for WRRFs with disinfection systems), faecal coliforms, suspended solids, biochemical oxygen demand (BOD) and carbonaceous BOD, every 6 days; toxicity testing with *Ceriodaphnia dubia*, every month (excluding Picton); metal and organic contaminants, every month Minor WRRF specific variations and other requirements as per EPL
			Hawkesbury-Nepean River: water quality and phytoplankton Estimate trophic status, nutrient and phytoplankton dynamics, combined impact from all catchment sources	Hawkesbury-Nepean River and tributaries: Eighteen sites, every 3 weeks; chlorophyll-*a*, phytoplankton identification and counting triggered by elevated chlorophyll-a (7 µg/L), associated nutrients and physico-chemical measurements

Wastewater catchment or receiving water	Sydney Water activities	Operating WRRFs	Monitoring program and rationale	Monitoring requirements
		West Hornsby Brooklyn	Hawkesbury-Nepean River: freshwater macroinvertebrates: Estimate ecosystem health status, targeted study to assess the impact of wastewater discharges	Hawkesbury-Nepean River and tributaries: Thirty-two sites, twice per year; macroinvertebrates diversity, calculation of the biotic index SIGNAL-SG, upstream and downstream of WRRFs
All ocean and inland catchments	Wastewater overflows and leakage from distribution networks	All	Dry weather overflows: Measure wastewater overflows during dry weather	Dry weather overflow monitoring: Determine total number of overflows and volume per system (where applicable[1]) and SCAMP and the proportion that reach receiving waters
		All	Wet weather overflows: Estimate wastewater overflows during wet weather	Modelling: Annual runs to determine overflow frequency and volume information
		All	Dry weather leakage program: To find and fix sewer leaks	Dry weather leakage detection program: Assessment of 223 sewer catchments for sewer leakage at least once per year

[1] Warriewood, North Head, Bondi, Malabar, Cronulla, Wollongong, Shellharbour, West Camden, Penrith, Winmalee, St Marys and Quakers Hill, as per EPL condition L7.4

* These facilities are also called Water Recycling Plants (WRPs), where in addition to discharges to the environment a smaller or greater proportion of the treated wastewater is recycled onsite or elsewhere. For the purpose of simplicity in plots, tables and interpretations all facilities are termed as WRRF in this document.

Table 1-2 Summary of the new Sydney Water Aquatic Monitoring (SWAM) program and status of implementation.

Pressure	Catchment / Zone	Sub-program	P-S-ER [a]	Overview/ monitoring programs	Status of implementation
WRRF discharges	Hawkesbury-Nepean River and tributaries	Hawkesbury-Nepean River WRRF effluent quantity, quality and toxicity	P	Treated wastewater quantity, quality and toxicity for 15 WRRFs as per specific EPL requirements	Yes. Ongoing as per EPL and approved variation
		Hawkesbury-Nepean River water quality and ecosystem health	S, ER	• Water quality and chlorophyll-a (3-weekly) and macroinvertebrates (bi-annually), upstream and downstream of WRRF discharges • Water quality, chlorophyll-a and phytoplankton at 10 (long-term) sites known to be prone to high phytoplankton growth	Yes, implemented fully. Monitoring commenced from July 2023: • Water quality at 52 sites • Chlorophyll-a at 50 sites • Macroinvertebrates at 39 sites
	Georges River and tributaries	Georges River WRRF effluent quantity, quality and toxicity	P	Treated wastewater quantity and quality	Yes. Ongoing as per EPL and approved variation
		Georges River water quality and ecosystem health [b]	S, ER	• Water quality and chlorophyll-a (3-weekly) and macroinvertebrates (bi-annually) at three sites, upstream and downstream of Glenfield WRRF discharge • Monitoring for Liverpool and Fairfield WRRF discharges will be added at a later date, following monitoring feasibility studies	Partially implemented: • Monitoring commenced from July 2023 at three sites upstream and downstream of Glenfield WRRF • Feasibility studies or new monitoring program for the Fairfield and Liverpool WRRFs yet to be designed
	Other freshwater	Reference sites water quality and ecosystem health	S, ER	Water quality (3-weekly) and macroinvertebrates (biannually) at seven reference sites without urban or rural influences on water quality. Monitoring data are used to re-calibrate macroinvertebrate SIGNAL-SG scores	Yes. Monitoring reduced to seven sites from July 2023 as recommended

Pressure	Catchment / Zone	Sub-program	P-S-ER [a]	Overview/ monitoring programs	Status of implementation
	Nearshore marine	Nearshore marine WRRF effluent quantity, quality and toxicity	P	Treated wastewater quantity, quality and toxicity for eight WRRFs as per specific EPL requirements	Yes. Ongoing as per EPL and approved variation
		Nearshore marine water quality and ecosystem health	S, ER	• Water quality and intertidal macroalgae and macroinvertebrates (annually) at nine sites as groups of one outfall and two reference sites for three WRRFs • Water quality and subtidal macroalgae and macroinvertebrates (annually) at 24 sites as a gradient of 0 m, 50 m, 100 m, 200 m, 500 m and 1 km from each outfall for one WRRF and three untreated cliff face discharges	No. • Preliminary discussion held on feasibility and implementation of new monitoring methods at all 33 proposed sites. • Exploring option whether to include water quality monitoring at least at three Shellharbour sites in addition to intertidal macroalgae.
	Offshore marine	Offshore marine WRRF effluent quantity, quality and toxicity	P	Treated wastewater quantity, quality and toxicity for three WRRFs as per specific EPL requirements.	Yes. Ongoing as per EPL and approved variation
		Offshore receiving water quality	S	Water quality based on measured effluent concentrations and modelled dispersion of the effluent plume using ocean reference station data	Yes. Ongoing as usual
		Offshore sediment quality and ecosystem health	S, ER	• Surveillance Year: Sediment quality and benthic infauna (annually) at 18 sites and two sites respectively, at outfall and control locations • Assessment Year: Sediment quality and benthic infauna (aligned with the Independent Pricing and Regulatory Tribunal reporting cycle) at 18 sites, at outfall and control locations	Yes. 2023-24 is a Surveillance year, monitoring to commence based on new monitoring analytes, sites

Pressure	Catchment / Zone	Sub-program	P-S-ER [a]	Overview/ monitoring programs	Status of implementation
Wet and dry weather overflows and leakage [c]	Estuaries, lagoons and beaches	Dry weather overflows – volume, frequency and trends	P	Determine total number of overflows and volume per system (where applicable in EPLs) and Sewer Catchment Area Management Plan (SCAMP), and the proportion that reach receiving waters	Yes. Ongoing as usual
		Dry weather leakage detection	P	Assessment of 226 sewer catchments for sewer leakage at least once per year	Yes. Monitoring program continued at all sites
		Wet weather overflows – modelled volume, frequency and trends	P	Annual model runs to determine overflow frequency and volume information	Yes. Ongoing as usual
		Water quality and ecosystem health	S, ER	To be determined following completion of Wet Weather Overflow Abatement Program (WWOAP)	No. Waiting for the completion of WWOAP and recommendations
		Recreational water quality	S	To be determined following completion of WWOAP	• Joint monitoring programs continued by Sydney Water and DPE • To be revised after the completion of WWOAP and recommendations

a P-S-ER: Refers to whether the sub-program is measuring pressure (P), stressor (S) and/or ecosystem receptor (ER) indicators.

b Only developed for Glenfield WRRF at present; additional studies required to develop monitoring details for Liverpool and Fairfield WRRFs.

c A complete set of sub-programs for assessing wet and dry weather overflows and dry weather leakage will be developed following completion of the WWOAP. This might include separate sub-programs for wet weather overflows and dry weather overflows and leakage, and is also likely to capture inland (i.e. freshwater

1.4 Report objectives and structure

The STSIMP data report for 2022-23 has been prepared to meet condition M5.1d and M5.1g under Sydney Water's EPLs. This year, the report includes all monitoring data collected under the STSIMP (noting that the recommendations of the SWAM program was not in effect until the commencement of the 2023-24 monitoring period, ie from July 1, 2023). However, the format of the 2022-23 data report has been modified to align with the new objectives of the SWAM program where practical.

1.4.1 Scope and objectives

The aim of this STSIMP data report is to provide data summaries and trends in Sydney Water's wastewater and wastewater overflows data with respect to regulatory limits. More importantly, it aims to assess the environmental monitoring data including water quality, phytoplankton and macroinvertebrates to determine the impacts of Sydney Water's wastewater operations, and compare these with the established guidelines or protocols to determine the general status of each monitoring site.

The more detailed scope or specific objectives of the STSIMP 2022-23 data report are to:

- detail the monitoring program design, sites, sampling methodology, analytes and indicators
- present annual wastewater discharge quality, quantity, load and toxicity data with respect to EPL limits, and identify temporal trends of current year against previous nine years results
- present the trends in wastewater overflow, leakage and recycled water data with a special attention to compliance with EPL conditions and continuous improvement initiatives
- present the trends in water quality, phytoplankton and macroinvertebrates data against previous nine years results
- identify exceptions and catchment/zone specific summary results outside EPL limits and water quality guidelines or significant upward or downward trends identified
- assess WWRF specific and catchment specific impact from discharges on water quality, phytoplankton and macroinvertebrates and other indicators (sediment quality and infauna)
- summarise data and data trends that are collected by the other long-term monitoring program (State of the Environment, SoE) and where possible identify the links with the Sydney Water's wastewater overflows.

The scope of this year's STSIMP data report is extended to include analyses and assessment on receiving water environment using indicators from across the pressure, stressor and ecosystem receptor (P-S-ER) causal pathway elements where data is available. The objectives of each STSIMP sub-monitoring programs are aligned with the newly recommended objectives of the SWAM sub-programs where effective and/or practical. All associated data collected by the STSIMP has been analysed and assessed in terms of these objectives where possible.

To achieve the broader objectives for the Hawkesbury-Nepean River sub-program, monitoring results from the STSIMP sites are not enough to assess the stressor and ecosystem receptors indicators fully. Therefore, receiving water quality data from other ongoing monitoring programs have been used to assess the impact from 14 Hawkesbury-Nepean River WRRFs. These special projects monitored receiving water quality analytes upstream and downstream of these WRRFs intermittently over the past two to seven years.

1.4.2 Format and structure

The format and structure of this STSIMP 2022-23 Data Report has been revised in comparison to earlier reports, to start aligning with the requirements of new SWAM program where possible or where monitoring data permits.

The report has been structured and formatted with following principles or concepts. It contains:

1. ***Supporting common sections*** such as introduction, scope, monitoring programs and analytical methods, glossary, references etc.
2. ***Main sections*** to assess the impact of Sydney Water's wastewater operations. These sections present and assess the monitoring results using following principles or rules:

- Ordering of the monitoring program/ sub-program results based on pressure (WRRF discharges), followed by region/zone (ie "catchment to coast" approach) ie inland catchment first then the ocean catchments:
    a. Hawkesbury-Nepean River
    b. Georges River
    c. Nearshore marine waters
    d. Offshore marine environment.
- For each sub-program related to WRRF discharges, presenting the results for each WRRF discharge one by one:
    a. Hawkesbury-River WRRFs, ordered from their location in upstream to downstream for the Hawkesbury-Nepean River catchment (Picton WRRF, West Camden WRRF…………… Brooklyn WRRF)
    b. Nearshore and Offshore discharging WRRFs, ordered from North to South (eg North Head, Bondi and Malabar for the offshore discharging WRRFs).
- For each Inland WRRF discharges, ordering the results according to the pressure, stressor and ecosystem receptor data:
    a. Pressure – Wastewater quality and discharge load analytes grouped first in the order of significance and then presented alphabetically:
        i. Nutrients
        ii. Major conventional analytes
        iii. Trace metals
        iv. Other chemicals and organics (including pesticides).
    b. Stressor – Water quality analytes grouped first in the order of significance and then presented alphabetically:
        i. Nutrients
        ii. Physico-chemical water quality.
    c. Ecosystem receptor – Ecosystem health indicators
        - Phytoplankton

  - Macroinvertebrates.

- For each nearshore and offshore WRRF discharges, ordering the results for the pressure indicator using the above approach. However, the stressor and ecosystem receptor indicators are presented together for these two sub-programs (nearshore and offshore).
- Ordering of the monitoring results for the Pressure – Wastewater overflows are grouped into three broad categories:
  a. Wet weather overflows
  b. Dry weather overflows
  c. Dry weather leakage monitoring program.

3. ***A separate synthesis section*** provides a summary of what the combined monitoring results reveal about the impact of Sydney Water's operations on the aquatic environment. This focuses on each catchment/region/zone (eg riverine, nearshore and offshore)
4. ***Sections on SoE type*** monitoring programs including those STSIMP sub-programs that were decommissioned in July 2023
5. ***The main results and discussion sections*** remain succinct, with key or exception results (eg where differences are detected) and associated figures and tables being presented in the main report, and tables and figures of all results being provided in supplementary report and electronic appendices.

The 2022-23 STSIMP Data Report consists of the following 2 volumes:

Volume 1 STSIMP Data Report 2022-23: the main volume of the 2022-23 report. It provides results using summary and inferential statistical methods to address sub-program specific objectives comparing the current year with relevant water/sediment quality objectives and the relevant historical record. A brief commentary commensurate with the results is provided. It also provides a summary of treated wastewater quality. This volume details the 'exceptions' where a significant trend is identified in the data (either positive or negative) or the results exceed the EPL guideline limits and/or other relevant guidelines (ANZG 2018, and NHMRC 2008).

Volume 2 STSIMP Data Report 2022-23 (Appendices): includes all wastewater and environmental monitoring data and statistical analysis summaries, and graphics. This volume is also supported by multiple electronic appendices of data summaries and raw data that have been provided to the EPA.

2. Monitoring programs – aims, objectives and methods

This chapter describes all monitoring programs including site details, analytes and method of sampling and analyses. Sampling and analyses are undertaken in accordance with internal work instructions or methods, ensuring quality of data through quality control measures. For more details see Chapter 2.9.

Sydney Water Laboratory Services is NATA certified to *ISO 9001:2015 Quality management systems*, *ISO 14001: 2015 Environmental Management Systems* and *Occupational Health & Safety Management System AS/NZS 4801: 2001*. All analytical work is performed to the requirements of *AS ISO/IEC 17025: 2015 General requirements for the competence of testing and calibration laboratories*.

2.1 Wastewater discharge quantity, quality and toxicity

2.1.1 Rationale

Currently, there are 28 WRRFs operating in the greater Sydney catchment. Discharge quantity, quality and locations of these facilities vary widely from the inland riverine environment to nearshore or offshore deep ocean outfalls.

The EPLs for each WRRF specify the effluent quantity, quality and toxicity monitoring requirements. Requirements are referenced in Sydney Water's Water Resource Recovery Facilities Compliance Monitoring Plan (Sydney Water 2023a). These requirements vary between WRRFs and can also be varied for each WRRF from time to time. This could include changes to the analyte suite for assessing discharge quality as a result of comprehensive sampling studies recommended by van Dam et al. (2023).

Treatment levels and monitoring requirements for the four key groups of WRRFs are specified in Table 2-4. Data on the quantity, quality and toxicity of each WRRF discharge are representative of the condition of the pressure (P) in the P-S-ER approach to monitoring of the impacts of Sydney Water's WRRF discharges on the aquatic environment (see Section 1.3).

2.1.2 Aim and objectives

The aim and specific objectives for this monitoring sub-program are presented in Table 2-3.

Table 2-3 Aim and objective for the wastewater discharge quantity, quality and toxicity monitoring sub-program

Aim	Objectives
To characterise and assess the quantity, quality and toxicity of the WRRF discharges, as specified in their respective Environment Protection Licences.	• To compare WRRF discharge quantity, quality and toxicity with relevant EPL limits (where available), for the current year
	• To compare WRRF discharge quantity, quality and toxicity over the relevant historical record.

Table 2-4 Summary of wastewater discharge quantity, quality and toxicity monitoring program

Wastewater catchment or receiving water	Discharge and treatment level	Operating WRRFs	Monitoring requirements
Hawkesbury-Nepean River and tributaries	Routine discharges are treated to high standard ie tertiary treatment with disinfection	Picton# West Camden# Wallacia# Penrith# Winmalee North Richmond Richmond# St Marys# Quakers Hill# Riverstone Castle Hill# Rouse Hill# Hornsby Heights West Hornsby Brooklyn	*In-situ* online monitoring: volume of discharges (treated and partially treated) Wastewater quality: ammonia nitrogen, total nitrogen, total phosphorus, residual chlorine (for WRRFs with disinfection systems), faecal coliforms, suspended solids and biochemical oxygen demand (BOD) every six days; toxicity testing with *Ceriodaphnia dubia*, every month (excluding Picton); metal and organic contaminants, every month Minor WRRF specific variations and other requirements as per EPL
Georges River and tributaries	Occasional discharges, and treatment level varies from primary or secondary level with disinfection	Fairfield #*	Georges River and tributaries
Nearshore marine environment (outfalls)	Routine and infrequent discharges; treatment level varies from primary to tertiary level with disinfection	Warriewood Cronulla Wollongong# - Bellambi* - Port Kembla* Shellharbour Bombo#	*In-situ* online monitoring: volume of discharges (treated and partially treated). Wastewater quality: biochemical oxygen demand (BOD), oil and grease, suspended solids, every six days; toxicity testing by sea urchin sperm and eggs (excluding Wollongong), every month; metal and organic contaminants, every month where applicable. Minor WRRF specific variations and other requirements as per EPL
Offshore marine environment (deep ocean outfalls)	Routine discharges and primary treatment	North Head Bondi Malabar	As above

These facilities are also called Water Recycling Plants (WRPs), where in addition to discharges to the environment a smaller or greater proportion of the treated wastewater is recycled onsite or elsewhere. For the purpose of simplicity in plots, tables and interpretations all facilities are termed as WRRF in this document

* Part of larger WRRFs, wastewater is discharged during wet weather only.

2.1.3 Monitoring approach

Design and sites

Hawkesbury-Nepean River WRRFs

The discharge monitoring sites for each WRRF are specified in the relevant EPL. Currently, there are 15 WRRFs operating in the greater Hawkesbury-Nepean River catchment (Figure 2-1). Listed generally from upstream to downstream, they include: Picton, West Camden, Wallacia, Penrith, Winmalee, North Richmond, Richmond, St Marys, Quakers Hill, Riverstone, Castle Hill, Rouse Hill, West Hornsby, Hornsby Heights and Brooklyn. All WRRFs except Brooklyn discharge to freshwater environments, with Brooklyn discharging to an estuarine environment.

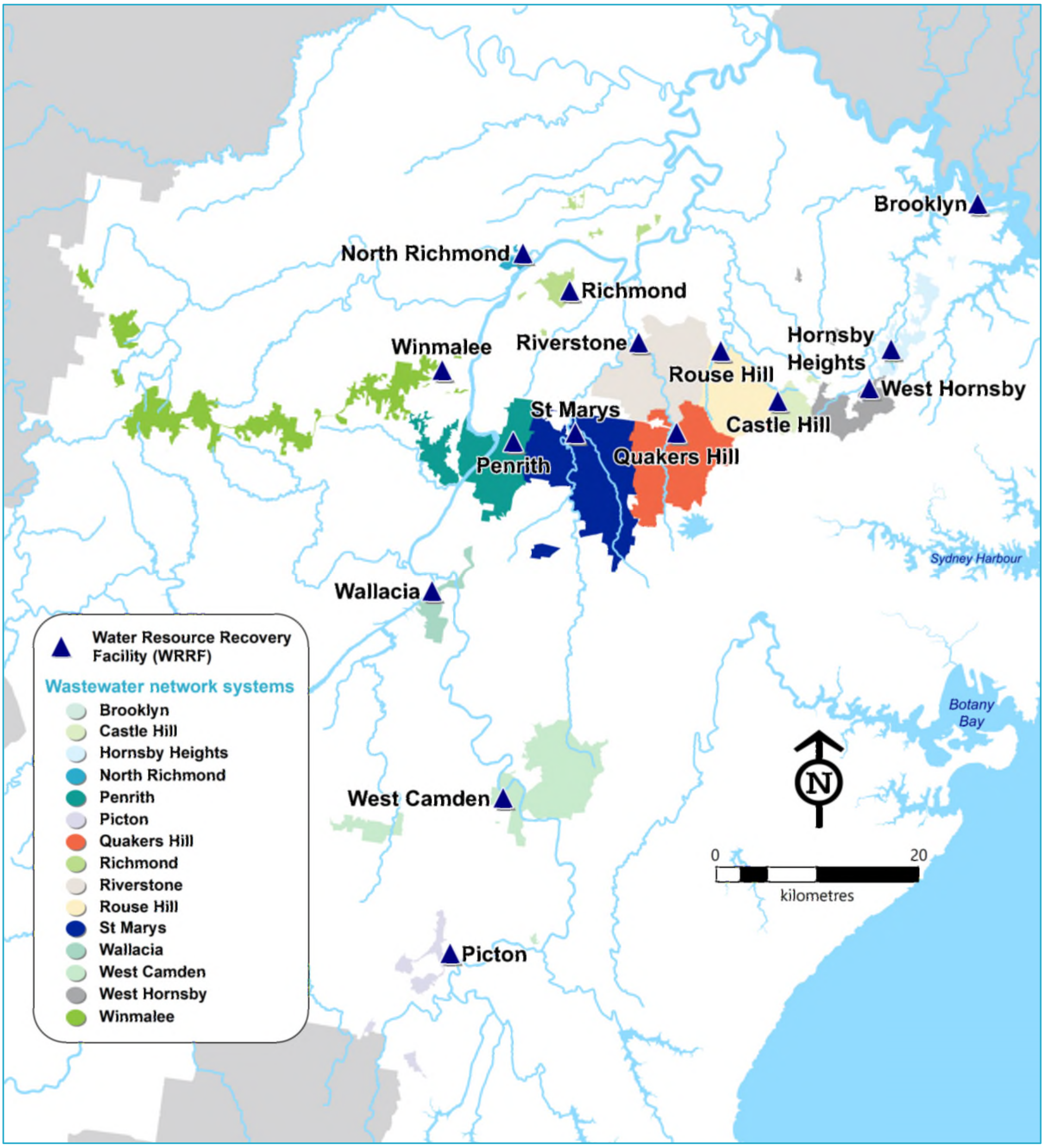
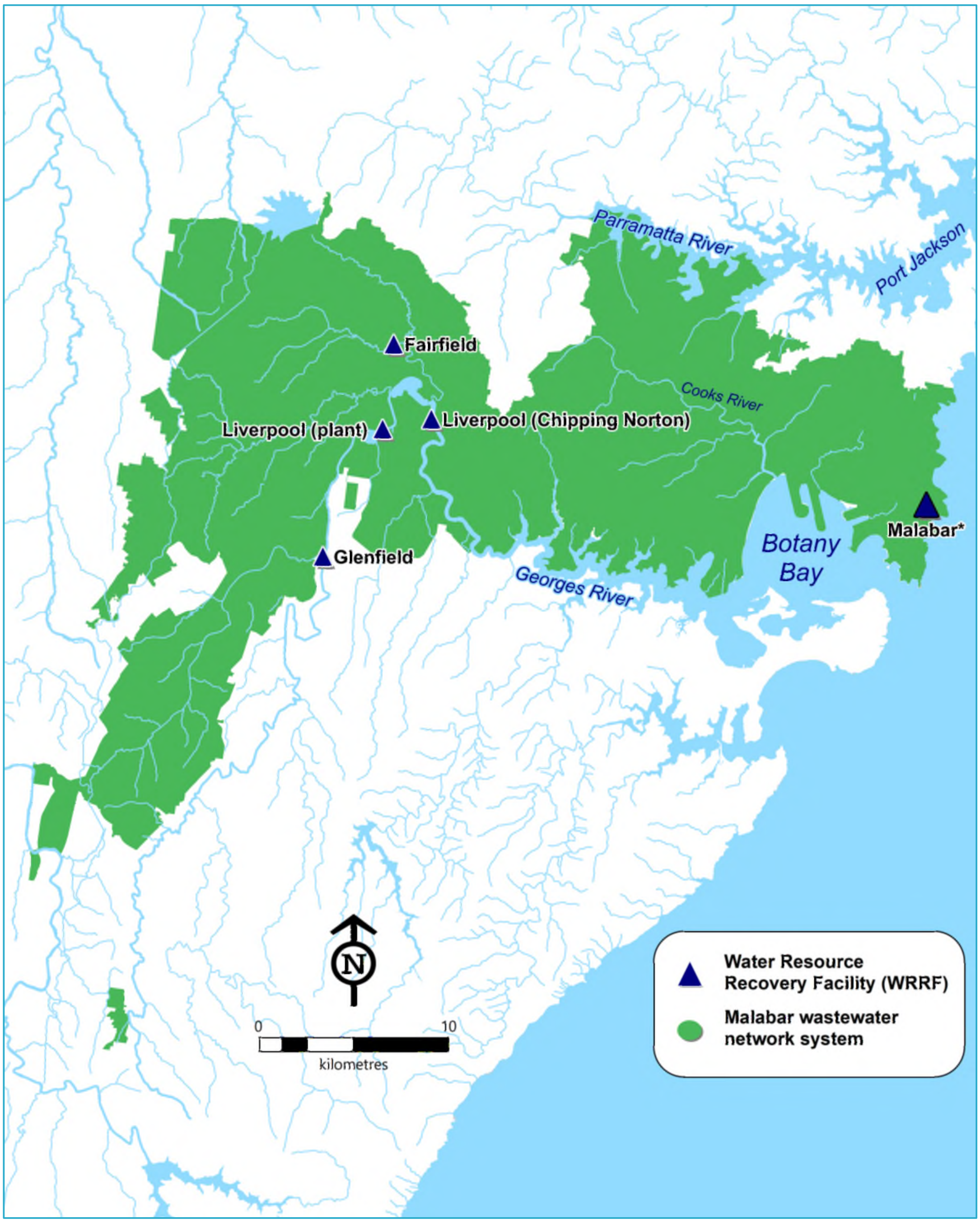


Figure 2-1 Location of WRRFs in the Hawkesbury-Nepean River catchment

Georges River WRRFs

Three WRRFs operate in the Georges River catchments (Figure 2-2). Listed from upstream to downstream, they include: Glenfield, Liverpool and Fairfield. Glenfield WRRF is located in the freshwater reaches of the Georges River, upstream of the Liverpool Weir. Liverpool WRRF is located just below the Liverpool Weir, which marks the upper tidal/estuarine limit of the Georges River. Fairfield WRRF is located in Orphan School Creek, which turns into Prospect Creek and flows into the Georges River (seaward end of Chipping Norton Lakes), approximately 7 km downstream of the WRRF. Most of the treated wastewater from these WRRFs is diverted to the Malabar WRRF, and only discharge partially-treated wastewater during wet weather.



* 96% of wastewater from Malabar system discharged to ocean via deep ocean outfall, the remaining 4% (2012-22 average) discharged to Georges River in wet weather

Figure 2-2 Location of WRRFs in the Georges River catchment

Nearshore WRRFs

Sydney Water discharges wastewater of differing quality into the marine environment. These outfalls are categorised by the location of discharge and include deep ocean outfalls, nearshore outfalls, cliff face outfalls and shoreline outfalls.

The locations of the nearshore, cliff face and shoreline WRRFs are shown in Figure 2-3. Sydney Water's license permits an impact within the effluent mixing zone (ie a zone in which the salinity is below that of normal seawater. The mixing zone dilutions for each of the nearshore WRRF discharges are shown in Table 2-5.

There are two nearshore outfalls that discharge secondary (Shellharbour) and tertiary (Wollongong) treated wastewater. Both outfalls have diffusers fitted with duckbill valves to minimise saline and sediment intrusion. The Wollongong outfall is about 1000 m long extending offshore in water about 20 m deep and has 400 neoprene duckbill valves. The Shellharbour outfall is about 220 m long extending offshore in water about 8 m deep and has 200 neoprene duckbill valves.

There are seven cliff face outfalls. North Head (two outfalls), Malabar (four outfalls), Bondi and Wollongong only operate in an emergency as a backup to deep ocean or nearshore outfalls, while Vaucluse, Diamond Bay 1 and Diamond Bay 2 continuously discharge untreated wastewater with a combined average daily volume of 4 ML/day. Vaucluse is situated at the base of an 80 m high cliff and discharges approximately 2.8 ML of untreated wastewater daily. Diamond Bay 1 (DB1) is situated south of Rosa Gully at the base of a 25-30 m high cliff and discharges 0.7 ML of untreated wastewater daily. Diamond Bay 2 is located 250 m south of DB1 at the base of a 25-30 m high cliff and discharges 0.5 ML of untreated wastewater daily.

Additionally, there are six shoreline outfalls. Bellambi and Port Kembla shoreline outfalls discharge primary treated wastewater, but only operate in wet weather when required. Bombo, Cronulla, Warriewood and Brooklyn discharge effluent on a continuous basis. Bombo and Warriewood discharge secondary treated wastewater while Cronulla and Brooklyn discharge tertiary treated wastewater. Bombo, Cronulla and Warriewood outfalls are located at depths of 3-6 m. Brooklyn outfall is located in the Hawkesbury River at 14 m depth on the second pylon of the old road bridge adjacent to Kangaroo Point.

Table 2-5 Summary of discharge information for each nearshore and shoreline outfalls

WRRF	Outfall	Water Depth	Median dilution within 50 m of discharge	Mixing zone dilution
Wollongong	1 km offshore	20m	75	
Shellharbour	220m offshore	8m	100	250 within 300 m
N/A	Vaucluse	1m		1000 within 500 m
N/A	Diamond Bay 1 & 2	1m		1000 within 500 m
Bellambi	Bellambi Pt	5m	50	
Port Kembla	Red Pt	5-8m	50	400 within 300 m
Bombo	Bombo Headland	5m	50	
Cronulla	Potter Pt	6m	50	
Warriewood	Turimetta Head	3m	100	350 within 300 m
Brooklyn	Kangaroo Pt	14m	160	400-800 within 10 m

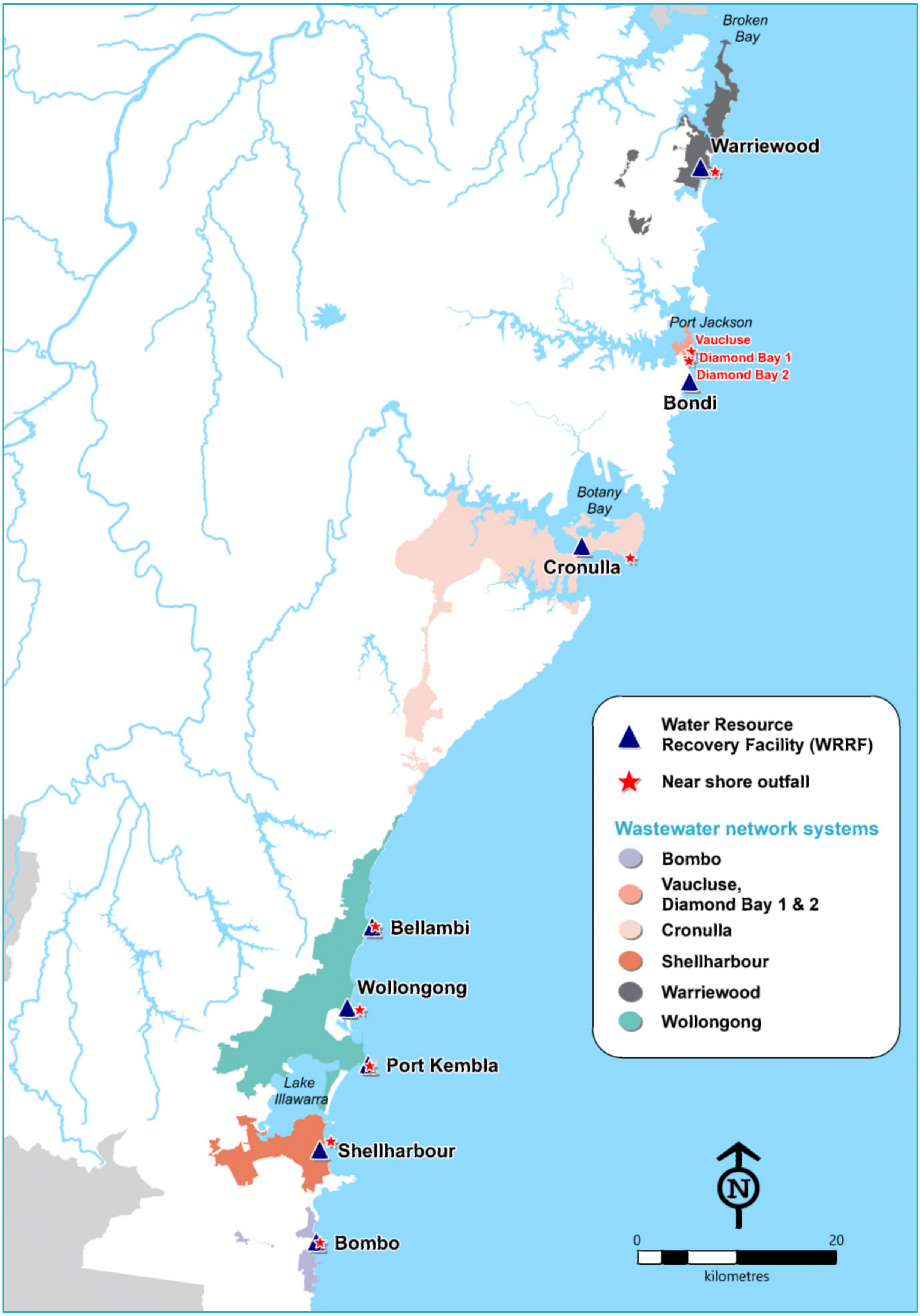


Figure 2-3 Location of WRRFs discharging to the nearshore marine environment (includes nearshore, cliff face and shoreline discharges).

Offshore WRRFs

There are three deep ocean outfalls that discharge primary treated wastewater (Figure 2-4). The Malabar diffuser system consists of 28 diffusers and one sludge riser approximately 25 m apart in 80 m of water. This is located approximately 3.6 km from the shore. The Bondi diffuser system consists of 26 diffusers and one sludge riser approximately 20 m apart in 60 m of water. This is located approximately 2.2 km from the shore. The North Head diffuser system consists of 36 diffusers and one sludge riser approximately 21 m apart in 60 m of water. This is located approximately 3.7 km from the shore.

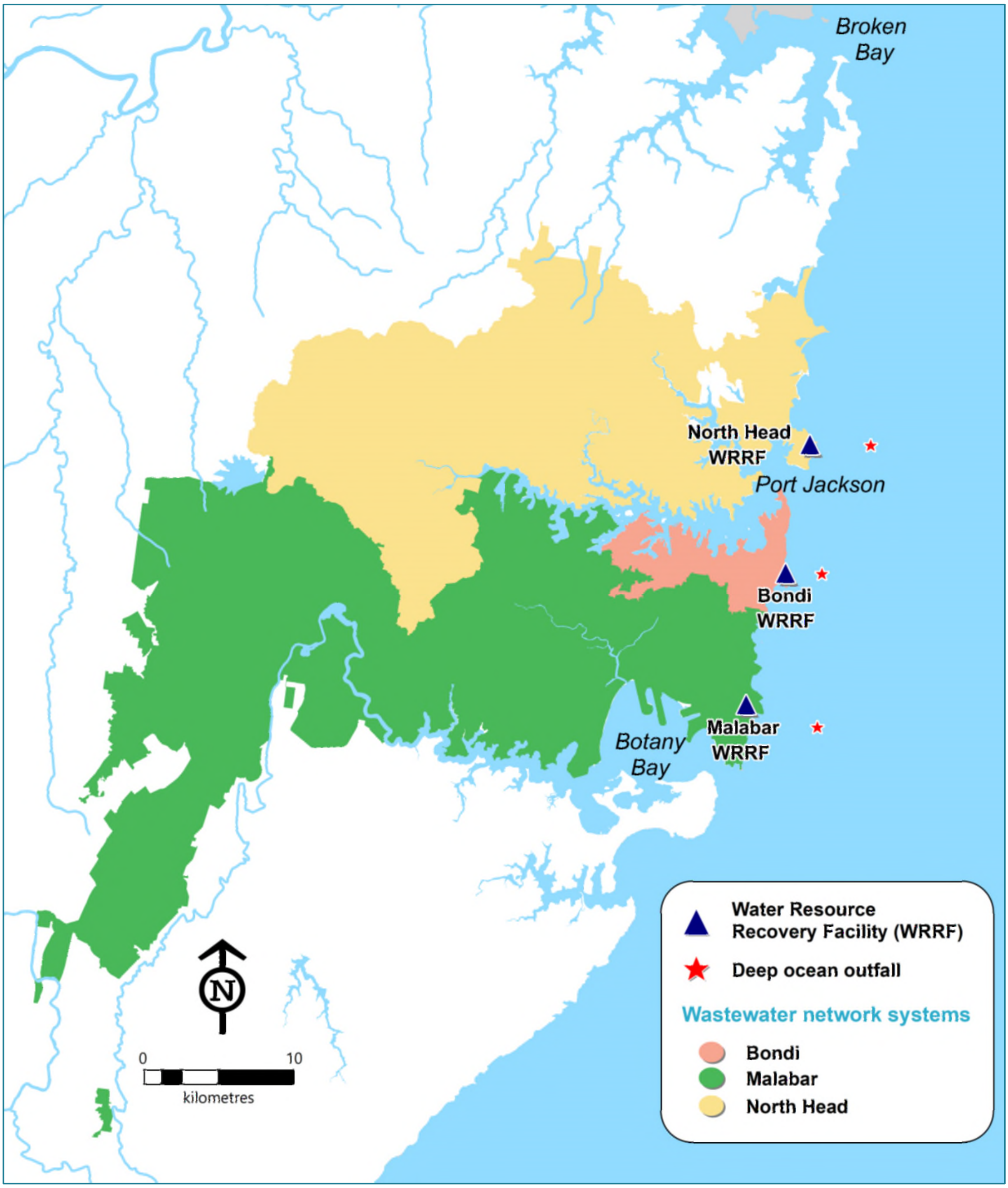


Figure 2-4 Location of WRRFs discharging to the offshore marine environment.

Analytes, indicators and sampling

Relevant quantity, quality and toxicity indicators and associated parameters and details (eg. sampling frequency and method) for each WRRF are specified in the relevant EPL and summarised in Sydney Water's Water Resource Recovery Facilities Compliance Monitoring Plan (Sydney Water 2023a), which is reviewed and updated annually.

Details of each EPL can be accessed via links to individual NSW EPA EPLs [Environment & Heritage | PRPOEO (nsw.gov.au)](nsw.gov.au)

A summary of the tests conducted on wastewater and details of the specific method used in respective laboratory analyses is presented in Table 2-6.

Table 2-6 List of analytes and methods for wastewater quality monitoring

Analytes	Detection limit	Unit of measurement	Reference
Nutrients			
Ammonia nitrogen (low level)	0.01	mg/L	APHA (2017) 4500-NH3 H
Ammonia nitrogen (high level)	0.1	mg/L	As above
Total nitrogen (by FIA)	0.05	mg/L	APHA (2017) 4500- Norg/NO3- I/J
Total phosphorus	0.01	mg/L	APHA (2017) 4500-P – H/J
Major conventional analytes			
Biochemical Oxygen Demand^	2	mg/L	APHA (2017) 5210B
Chlorine residual (total)	0.04	mg/L	APHA (2017) 4500-Cl G
Faecal coliforms	1	cfu/100mL	APHA (2017) 9222D
Oil and grease	5	mg/L	APHA (2017) 5520D
Total suspended solids	2	mg/L	APHA (2017) 2540D
pH	0.01	pH units	APHA 4500H+B & Instrument manual
Toxicity testing			
Ecotoxicological Endpoint: 48 hrs. Water Flea EC_{50} immobilisation	n/a	% wastewater	Based on methods described by USEPA (2002a) and ESA SOP 101 and adapted for use with the locally collected *Ceriodaphnia dubia* by Bailey et al. (2000).
Ecotoxicological Endpoint: 1 hr. Sea Urchin EC_{50} fertilisation	n/a	% wastewater	Based on methods described by USEPA (2002b) and ESA SOP 104 and adapted for use with *H. tuberculata* by Simon and Laginestra (1997) and Doyle et al. (2003).
Trace metals			
Aluminium	5	µg/L	USEPA (2014) 6020B
Cadmium	0.1	µg/L	USEPA (2014) 6020B
Chromium	0.2*	µg/L	USEPA (2014) 6020B
Copper	0.5*	µg/L	USEPA (2014) 6020B
Iron	5*	µg/L	USEPA (2014) 6020B

Analytes	Detection limit	Unit of measurement	Reference
Lead	0.1*	µg/L	USEPA (2014) 6020B
Mercury	0.01	µg/L	USEPA (2005) 245.7(Rev2.0)
Nickel	0.2*	µg/L	USEPA (2014) 6020B
Selenium	0.2*	µg/L	USEPA (2014) 6020B
Zinc	1*	µg/L	USEPA (2014) 6020B
Other chemicals and organics (including pesticides)			
Cyanide	5	µg/L	APHA (2017) 4500CN-C and E
Diazinon and Parathion	0.1	µg/L	USEPA (1998) 8141B
Ethyl chlorpyrifos and Malathion	0.05	µg/L	USEPA (1998) 8141B
Heptachlor	0.005	µg/L	USEPA (1998) 8081B
Aldrin, Dieldrin, Endosulfan (a, b), Lindane, pp-DDE (4, 4), pp-DDT (4, 4) and Total Chlordane	0.01	µg/L	USEPA (1998) 8081B
Hydrogen sulphide (un-ionised)	30*	µg/L	APHA (2017) 4500-S2- D & H
Nonyl phenol ethoxylates	5	µg/L	Naaim et al. 1996
Total PCBs	0.1	µg/L	USEPA (2000) 8082A

* method detection limit changed in recent years (2016-17)

^ Sydney Water commenced Biochemical Oxygen Monitoring from September 2020. Historically Sydney Water have monitored Carbonaceous Biochemical Oxygen Demand in WRRF discharges.

2.2 Hawkesbury-Nepean River water quality and ecosystem health

2.2.1 Rationale

The Hawkesbury-Nepean River system is one of the longest coastal rivers in eastern Australia with a catchment area of approximately 22,000 km^2. The river drains most of the fastest growing developing areas to the west of Sydney. This development and associated activities in the catchment can adversely affect the health of the river due to a range of factors, including altered water regime, habitat modification and inputs of contaminants such as nutrients and metals. Treated wastewater is discharged to the river system from 15 Sydney Water WRRFs. However, there are also numerous other point and diffuse sources of pollution to the river, such as sewage effluent from council STPs, stormwater and agricultural runoff.

Distinguishing impacts associated with Sydney Water's WRRF discharges to the Hawkesbury-Nepean River system from other pressures requires a strong focus on monitoring of stressors and ecosystem receptors both upstream and downstream of the WRRF discharges, where possible. However, it is also known that impacts of nutrient inputs on phytoplankton do not necessarily occur immediately downstream of WRRF discharges, as physical factors like stream/river morphology, flow rate and light penetration are also important determinants of the potential for phytoplankton growth. Thus, maintaining a surveillance on locations known to be susceptible to high phytoplankton growth is still important, even if the exact causes of such events cannot be fully separated.

Acknowledging the above context, Sydney Water's Hawkesbury-Nepean River water quality and ecosystem health sub-program integrates the water quality, algae and stream health monitoring components together. This sub-program is intended to monitor:

- the direct aquatic environmental impacts of Sydney Water's WRRF discharges, and
- assess the State of Environment (SoE) at other long-term monitoring sites.

2.2.2 Aim and objectives

The aims and objectives of this monitoring sub-program are to:

- Assess the direct impacts of Sydney Water's Hawkesbury-Nepean River WRRF discharges on (a) water quality, and (b) ecosystem health as measured by responses of phytoplankton (as chlorophyll-a) and macroinvertebrates.
- Assess the general SoE in terms of water quality, phytoplankton as chlorophyll-a, phytoplankton as biovolume and toxic species counts at other long-term sites of the Hawkesbury-Nepean River and tributaries.

2.2.3 Monitoring approach

Design and sites

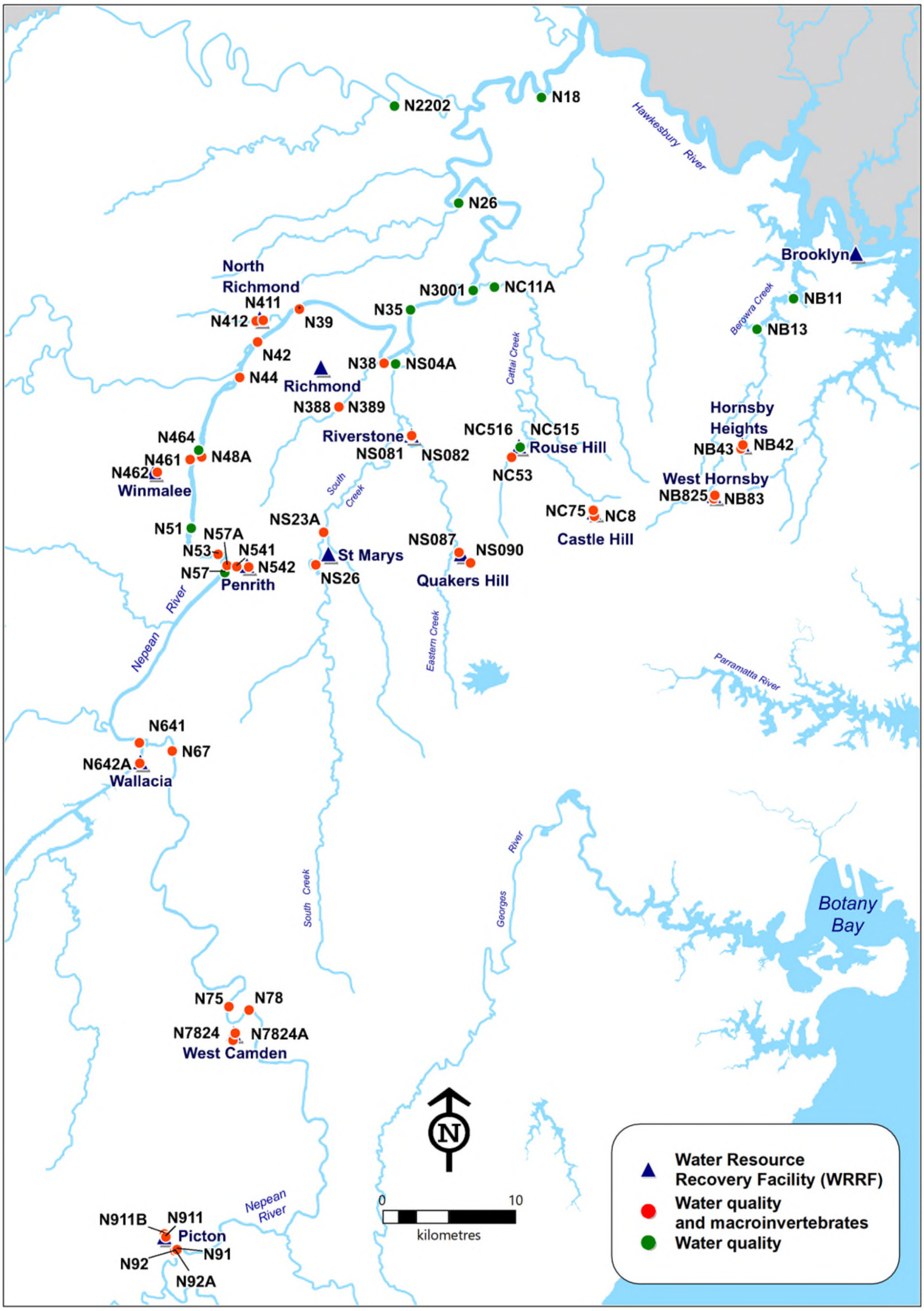
Eighteen sites are monitored for the receiving water quality and phytoplankton for the STSIMP since 2008 (Figure 2-5 and Table 2-7). Thirteen of these sites are along the Hawkesbury-Nepean River from the upstream freshwater reaches of the Nepean River at Maldon Weir to downstream Hawkesbury River at Leets Vale. Another five sites are in four major tributaries, namely South Creek, Cattai Creek, Colo River and Berowra Creek.

To achieve the broader objectives for the Hawkesbury-Nepean River, water quality monitoring results from the 18 routine STSIMP sites are not enough to assess the impact of our WRRFs. In 2015, three additional sites were included in STSIMP for feeding information to other ongoing monitoring and assessment on Picton WRRF (N911B and N911) and Winmalee WRRF (N464). Sites upstream and downstream of all 14 WRRFs or tributaries are also monitored intermittently by Sydney Water as a part of other ongoing monitoring and assessment.

The water quality data from these additional 31 sites has been used in this report for analysis and assessment of potential impact. These sites are located upstream and downstream of each WRRF discharge point, either in receiving water tributaries or in the Nepean River (Figure 2-5 and Table 2-7). Generally, data from other projects are only included when these are collected using the same sampling methodology and monitoring frequencies (see section 3.2.2).

Freshwater macroinvertebrates were monitored at 36 sites. The majority of these sites are at receiving streams or tributaries, immediately upstream and downstream of discharges points from 12 WRRFs (West Camden, Wallacia, Penrith, Winmalee, North Richmond, St Marys, Quakers Hill, Riverstone, Castle Hill, Rouse Hill, Hornsby Heights and West Hornsby). These streams are in rural or urban areas of the Hawkesbury-Nepean River catchment.

In the case of West Camden, Penrith and North Richmond where these streams are not far from the Hawkesbury-Nepean River, secondary paired assessment sites are placed above (upstream) and below (downstream) the junction or confluence of the discharge stream with the Hawkesbury-Nepean River. In the case of Picton, due to historical intermittent discharge regimes, the paired assessment is only conducted on Nepean River sites, however tributary upstream-downstream sites will be assessed as part of the SWAM program from 2023-24. In the case of Richmond, monitoring was not conducted historically due to the ephemeral nature of the creek and extreme wet/dry periods, however new sites have been established and will be assessed from 2023-24. In the case of Winmalee, the unnamed stream to which Winmalee WRRF discharges is ephemeral, this prevents the upstream-downstream design applied to other WRRF discharge points. Below the Winmalee WRRF discharge point, two sites are placed on the receiving stream, one site 300 m downstream and another site 3 km downstream. In the stream reach between these two sites, there are only a few houses and no other anthropogenic influences that could confound the assessment of Winmalee. A secondary paired assessment sites are placed above (upstream) and below (downstream) the junction or confluence of the unnamed stream with the Hawkesbury-Nepean River is also conducted for Winmalee.



Notes: N92A, N57A, N462, N461, N38, NC515 macroinvertebrates only

Figure 2-5 Receiving water monitoring sites for the Hawkesbury-Nepean River water quality and ecosystem health sub-program

Table 2-7 Receiving water monitoring sites for the Hawkesbury-Nepean River water quality and ecosystem health sub-program

Site code	Site description	Latitude	Longitude	STSIMP (2010)		Other projects	
				Water quality [a]	Macroinvertebrates	Water quality	Macroinvertebrates*
N92	Nepean River immediately upstream of Maldon Weir, upstream of all Sydney Water WRRFs, Reference site	-34.20373	150.630148	✓		✓	
N92A	Nepean River immediately downstream of Maldon Weir, upstream of all Sydney Water WRRFs, Reference site	-34.202826	150.63027				✓
N911B	Stonequarry Creek at Picton Farm, upstream of discharge gully	-34.191368	150.622137			✓	✓
N911	Stonequarry Creek at Picton Farm, downstream of Picton WRRF discharge point	-34.19336	150.62339			✓	✓
N91	Nepean River at Maldon Bridge, downstream of Stonequarry Creek and Picton WRRF	-34.20221	150.63219			✓	✓
N78	Nepean River at Macquarie Grove Rd, upstream of Matahil Creek and West Camden WRRF	-34.0413	150.69509		✓	✓	
N7824A	Matahil Creek, upstream of West Camden WRRF	-34.061571	150.681514		✓	✓	
N7824	Matahil Creek, downstream of West Camden WRRF	-34.0569	150.6835		✓	✓	
N75	Nepean River at Sharpes Weir, downstream of Matahil Creek and West Camden WRRF	-34.03892	150.67873	✓	✓		
N67	Nepean River at Wallacia Bridge, upstream of Warragamba River	-33.86517	150.63771	✓	✓		
N642A[a]	Warragamba River upstream of Wallacia WRRF, downstream of Warragamba Dam e-flows discharge point	-33.87311	150.61094		✓	✓	
N641	Warragamba River at Nortons Basin Road downstream of Wallacia WRRF	-33.85915	150.61104		✓	✓	
N57	Nepean River at Penrith Rowing Club ramp, upstream of Penrith Weir and Penrith WRRF	-33.74553	150.68333	✓			
N57A	Nepean River downstream of Penrith Weir and upstream of Penrith WRRF	-33.7406983	150.6853149		✓		
N542	Boundary Creek, upstream of Penrith WRRF	-33.7419	150.70274		✓	✓	
N541	Boundary Creek, downstream of Penrith WRRF	-33.74149	150.69333		✓	✓	
N53	Nepean River at BMG Causeway, downstream of Penrith WRRF	-33.7329385	150.6783369		✓	✓	
N51	Nepean River opposite Fitzgeralds Creek, downstream of Penrith WRRF	-33.7150	150.657	✓	✓		

Site code	Site description	Latitude	Longitude	STSIMP (2010)		Other projects	
				Water quality [a]	Macroinvertebrates	Water quality	Macroinvertebrates*
N48A	Nepean River at Smith Road, Princes farm, upstream of Winmalee WRRF	-33.666865	150.666989	✓	✓		
N462	Unnamed Creek, 0.3 km downstream of Winmalee WRRF	-33.676657	150.6306413		✓		
N461	Unnamed Creek 3 km downstream of Winmalee WRRF	-33.66856	150.65736		✓		
N464	Nepean River (Winmalee Lagoon) at Springwood Road, downstream of Winmalee WRRF, before Shaws Creek	-33.662269	150.664531			✓	
N44	Nepean River at Yarramundi Bridge, downstream of Winmalee WRRF	-33.61387	150.69899	✓	✓		
N42	Hawkesbury River upstream of North Richmond WRRF, downstream of Grose River	-33.58997	150.71421	✓	✓		
N412	Redbank Creek, upstream of North Richmond WRRF	-33.57592	150.7133		✓	✓	
N411	Redbank Creek, downstream of North Richmond WRRF	-33.5756	150.71892		✓	✓	
N39	Hawkesbury River at Freemans reach, downstream of North Richmond WRRF, upstream of South Creek	-33.568495	150.748611	✓			
N389	Rickabys Creek, upstream of with confluence of unnamed creek below Richmond WRRF discharge	-33.63535	150.77792			✓	✓
N388	Rickabys Creek, downstream of confluence of unnamed creek, below Richmond WRRF discharge	-33.635258	150.77877			✓	✓
N38	Hawkesbury River at Windsor Bridge, upstream South Creek	-33.6064	150.816		✓		
NS26	South Creek, upstream of St Marys WRRF	-33.741499	150.757202		✓	✓	
NS23A	South Creek, downstream of St Marys WRRF	-33.7196858	150.7640454		✓	✓	
NS082	Eastern Creek, upstream of Riverstone WRRF	-33.6695	150.851		✓	✓	
NS081	Eastern Creek, downstream of Riverstone WRRF	-33.668	150.846		✓	✓	
NS090	Breakfast Creek, upstream of Quakers Hill WRRF	-33.7450	150.884		✓	✓	
NS087	Breakfast Creek, downstream of Quakers Hill WRRF	-33.7361	150.872		✓	✓	
NS04A	Lower South Creek at Fitzroy pedestrian bridge, Windsor	-33.606975	150.82528	✓			
N35	Hawkesbury River at Wilberforce, Butterfly farm, downstream of South Creek	-33.57049	150.83947	✓	✓		
NC53	Second Ponds Creek upstream of Rouse Hill WRRF at Withers Road	-33.671582	150.917452		✓	✓	

Site code	Site description	Latitude	Longitude	STSIMP (2010)		Other projects	
				Water quality [a]	Macroinvertebrates	Water quality	Macroinvertebrates*
NC515	Second Pond Creek, downstream of Rouse Hill WRRF	-33.6648	150.9248		✓		
NC516	Second Pond Creek, downstream of Rouse Hill wetland and bypass from Rouse Hill WRRF	-33.6649248	150.924718			✓	
NC8	Cattai Creek, upstream of Castle Hill WRRF	-33.7124884	150.9836459		✓	✓	
NC75	Cattai Creek, downstream of Castle Hill WRRF	-33.70858	150.98277		✓	✓	
NC11A	Lower Cattai Creek at Cattai Road Bridge, 100m downstream of bridge	-33.556405	150.906359	✓			
N3001	Hawkesbury River Off Cattai State Recreation Area (SRA), downstream of Cattai Creek	-33.55834	150.8892771	✓			
N26	Hawkesbury River at Sackville Ferry, downstream of Cattai Creek	-33.499151	150.878928	✓	✓		
N2202	Lower Colo River at Putty Road Bridge, Reference site	-33.432578	150.828639	✓			
N18	Hawkesbury River at Leets Vale, opposite Leets Vale Caravan Park, downstream of Colo River	-33.4288432	150.9475432	✓			
NB83	Waitara Creek, upstream of West Hornsby WRRF	-33.702226	151.080488		✓	✓	
NB825	Waitara Creek, downstream of West Hornsby WRRF	-33.699967	151.081299		✓	✓	
NB43	Calna Creek, upstream of Hornsby Heights WRRF	-33.668949	151.1032852		✓	✓	
NB42	Calna Creek, downstream of Hornsby Heights WRRF	-33.666237	151.104908		✓	✓	
NB13	Berowra Creek at Calabash Bay (Cunio Point)	-33.588428	151.118016	✓			
NB11	Berowra Creek, Off Square Bay (Oaky Point)	-33.568084	151.147966	✓			
		Total number of sites==➔		**18**	**36**	**31**	**6**

[a] Site was not accessible on every sampling occasion.

Analytes, indicators and sampling

The full list of analytes and monitoring methods of Stressor analytes and Ecosystem Receptor indicators and associated monitoring parameters are listed in Table 2-8.

Water quality and macroinvertebrates are monitored, depending on the site, as listed in Table 2-7. The analytes and indicators have been selected on the basis of knowledge of the stressors present in WRRF discharges and key components of the aquatic ecosystem that are known to be responsive to WRRF discharges and that represent broadly accepted indicators of ecosystem health.

Water quality and phytoplankton

For water quality and chlorophyll-a, field measurements and samples are collected at an interval of three weekly ± four days ie 17 to 25 days. It is not possible to sample all the sites along the river and tributaries on a single day. However, upstream and downstream site pairs for each WRRF are sampled on the same day (eg N57, N53, N542 and N541 for Penrith WRRF). River and tributary sites of the uppermost river zone (Picton and West Camden WRRF) are sampled first at a date closer to each other. Then mid river and lower river zones sampled in subsequent days.

For the 18 routine STSIMP water quality monitoring sites, two replicate samples are collected for analysis to assess local variability. Depending on the waterway and local conditions, replicate samples are obtained either by one of two methods. The first method is to obtain samples about 100 m apart while the second method is to obtain samples from one site about 5 minutes apart. Each replicate is made up of a composite of the two sub-samples collected, where possible.

For the other projects, two replicate samples were collected first using the above approach for making a composite sample for analysis to minimise local variability.

Water samples were collected at a depth of 0.5 m below the water surface to avoid surface scum where feasible, and also above the sediment where the water depth is too low ie middle of water column.

Field measurements (Table 2-8) were taken at each site after sample collection on one of the replicate samples, especially dissolved oxygen that many change during mixing samples. Duplicates samples are then mixed into one sample for each site. These composited samples were analysed in Sydney Water laboratories by NATA (National Association of Testing Authorities) accredited methods for the selected analytes (Table 2-8). Quality control samples are also collected and analysed. A duplicate was collected on each run and field blank/ trip blank was collected on alternate runs.

Phytoplankton abundance and identification to genus level are determined when chlorophyll-a concentrations exceed 7 µg/L. This level is a site-specific trigger based on the Healthy Rivers Commission water quality objective for the Hawkesbury-Nepean River (HRC, 1998).

Macroinvertebrates

Macroinvertebrate samples are collected on a bi-annual basis every autumn and spring. At each site, samples are collected for up to four habitat types (pool edges, pool rock, macrophytes, and riffles). If not all habitats are present at a site during a sampling period, the corresponding habitat(s) from the other upstream/downstream site pair is not used in the analysis. If only one habitat is available from a site, a replicate sample for this habitat is collected.

Macroinvertebrates sample are sorted in the field using a specific rapid biological assessment (RBA) method developed by Chessman (1995) and subsequently refined by others (eg Chessman et al. 2007, Besley and Chessman 2008), to obtain the range of animals present at each site. Sorted collections of freshwater macroinvertebrates are then returned to Sydney Water's laboratories for identification. All samples are examined using high magnification to identify and count all organisms up to genus level using published keys (Hawking 2000), or using descriptions and reference specimens maintained by the Sydney Water Laboratory (accreditation number 610 issued by NATA). The QA/QC procedures are consistent with those developed for the Monitoring River Health Initiative (Humphrey et al. 1998), and involve the regular assessment of sorters (once every 2 years) to a benchmark laboratory sorted 'truth' performed by experts.

A key metric used to analyse the macroinvertebrate data is the univariate biotic index known as the Stream Invertebrate Grade Number - Average Level, Sydney Genus (SIGNAL-SG). SIGNAL-SG is a biotic index that indicates the condition of a waterbody based on the response of the macroinvertebrate community to the presence of pollutants, particularly those associated with sewage pollution (Besley and Chessman 2008). The significant development effort that has gone into SIGNAL-SG (in addition to identifying macroinvertebrates to genus level) has resulted in a metric that possesses:

(i) good specificity and relative sensitivity for detecting responses of macroinvertebrate communities to water quality perturbations, particularly sewage pollution, and

(ii) relatively low dependence on other (ie non water quality) environmental variables.

For the purposes of univariate statistical analysis, eight "replicates" for each site (four habitats x two sampling occasions) from one financial year (spring and autumn) are pooled.

Table 2-8 Stressor (analytes) and ecosystem receptor indicators, methods and other associated parameters for the Hawkesbury-Nepean River water quality and ecosystem health sub-program [a]

P-S-ER element	Indicator	Analyte / parameter				
		Analyte	Detection limits	Unit of measurements	Analyte method code / Reference	Place of measurements
Stressor	Physico-chemical	General Comments	-	Comments	FS001	Field
		Temperature	-	°C	FS010, APHA (2017) 2510 B, 4500-O G, 4500-H B	Field
		Dissolved oxygen (DO)	-	mg/L and % saturation	FS067, APHA (2017) 2510 B, 4500-O G, 4500-H B	Field
		pH	0.01	pH unit	As above	Field
		Conductivity	-	µS/cm	As above	Field
		Turbidity	-	NTU	FS090, APHA (2017) 2510 B, 4500-O G, 4500-H B	Field
Stressor	Nutrients	Ammonia nitrogen	0.01	mg/L	NU40, APHA (2017) 4500-NH3-H	Laboratory
		Oxidised nitrogen	0.01	mg/L	NU43, APHA (2017) 4500 NO3-I	Laboratory
		Total nitrogen	0.01	mg/L	NU57, APHA (2017) 4500- Norg/NO3-	Laboratory
		Filterable total phosphorus	0.002	mg/L	NU60, APHA (2017) 4500-P-H	Laboratory
		Total phosphorus	0.002	mg/L	NU57, APHA (2017) 4500- Norg/NO3-	Laboratory
Ecosystem receptor	Phytoplankton communities	Chlorophyll-a	0.2	µg/L	MC02, APHA (2017) 10200-H ½	Laboratory
		Phytoplankton biovolume and cell count to genus level [b]	-	mm^3/L and cells/mL	MA70CENT, APHA (2017) 10200-F	Laboratory
	Macroinvertebrate communities	SIGNAL-SG, community structure	-	-	Hawking 2000, Besley and Chessman 2008	Field & Laboratory

[a] Refer to Table 2-7 or details of sites at which analytes/indicators were measured.

[b] Other variables eg blue-green biovolume and toxic blue-green count are derived from the individual biovolume and cell counts of each relevant taxa. These measurements were made when chlorophyll-a exceeded 7 µg/L at all sites

2.3 Other urban rivers and reference sites ecosystem health

2.3.1 Rationale

Sydney Water maintain a series of reference sites to help understand how the ecosystem health of freshwater sites potentially impacted by Sydney Water WRRF discharges in the Hawkesbury-Nepean River/Georges River compare with sites in streams of bushland areas without urban or rural influences on water quality. Macroinvertebrate data from these sites are also used to periodically calibrate the macroinvertebrate SIGNAL-SG biotic index used for both the Hawkesbury-Nepean River and Georges River (Glenfield WRRF only) water quality and ecosystem health monitoring sub-programs.

Four other sites are monitored for freshwater macroinvertebrate communities to measure the general ambient condition of freshwater sites in the major rivers feeding the Sydney estuaries that may be impacted by wastewater overflows and stormwater. As such, the ecological health of these streams cannot be directly attributed to Sydney Water's operations.

2.3.2 Aim and objectives

The aim and specific objective for the sub-program are presented in Table 2-9.

Table 2-9 Aim and objective for the reference sites ecosystem health sub-program

Aim	Objective
To maintain a baseline of macroinvertebrate communities at reference sites, to assist with assessing impacts of Sydney Water's WRRF discharges on macroinvertebrate communities.	To assess temporal trends in SIGNAL-SG for the reference sites.
To measure the general ambient condition of freshwater sites in the other* major rivers feeding the Sydney estuaries that may be impacted by wastewater overflows and stormwater	To assess temporal trends in SIGNAL-SG

* Hawkesbury-Nepean River has a separate program

2.3.3 Monitoring approach

Design and sites

There were 11 sites monitored by the STSIMP for this sub-program (Table 2-10 and Figure 2-6). Seven of those sites are reference sites. Four other sites are from three major urban rivers: Georges River, Lane Cove River and Parramatta River.

Analytes, indicators and sampling

Freshwater macroinvertebrates are monitored twice a year (autumn and spring) using the same sampling methods and laboratory analysis as those described for upstream-downstream sites sa mpled around inland WWRFs of Hawkesbury-Nepean River system (Section 2.2.3).

Table 2-10 Sites for the other urban river and reference sites and ecosystem health sub-program

Site code	Site description	Latitude	Longitude
GE510*	O'Hares Creek u/s confluence with Georges River	-34.0943667	150.8348658
GR24*	Georges River at Ingleburn Reserve Weir	-34.0067166	150.8881742
GR22	Georges R, upstream of Liverpool Weir	-33.92555	150.92863
GR23	Georges R, Cambridge Causeway	-33.97004	150.91224
PJLC	Lane Cove R, upstream of Lane Cove Weir	-33.79118	151.15445
PJPR	Parramatta R, upstream of Parramatta Weir	-33.8127	151.00629
PH22*	Hacking River at McKell Avenue	-34.1524329	151.0286218
LC2421*	Unnamed tributary of Devlin's Creek, Lane Cove River	-33.75087	151.08427
NP001*	McCarrs Creek	-33.662873	151.250209
N628*	Bedford Creek	-33.772116	150.499056
N451*	Lynchs Creek	-33.65117	150.66492

* Reference sites

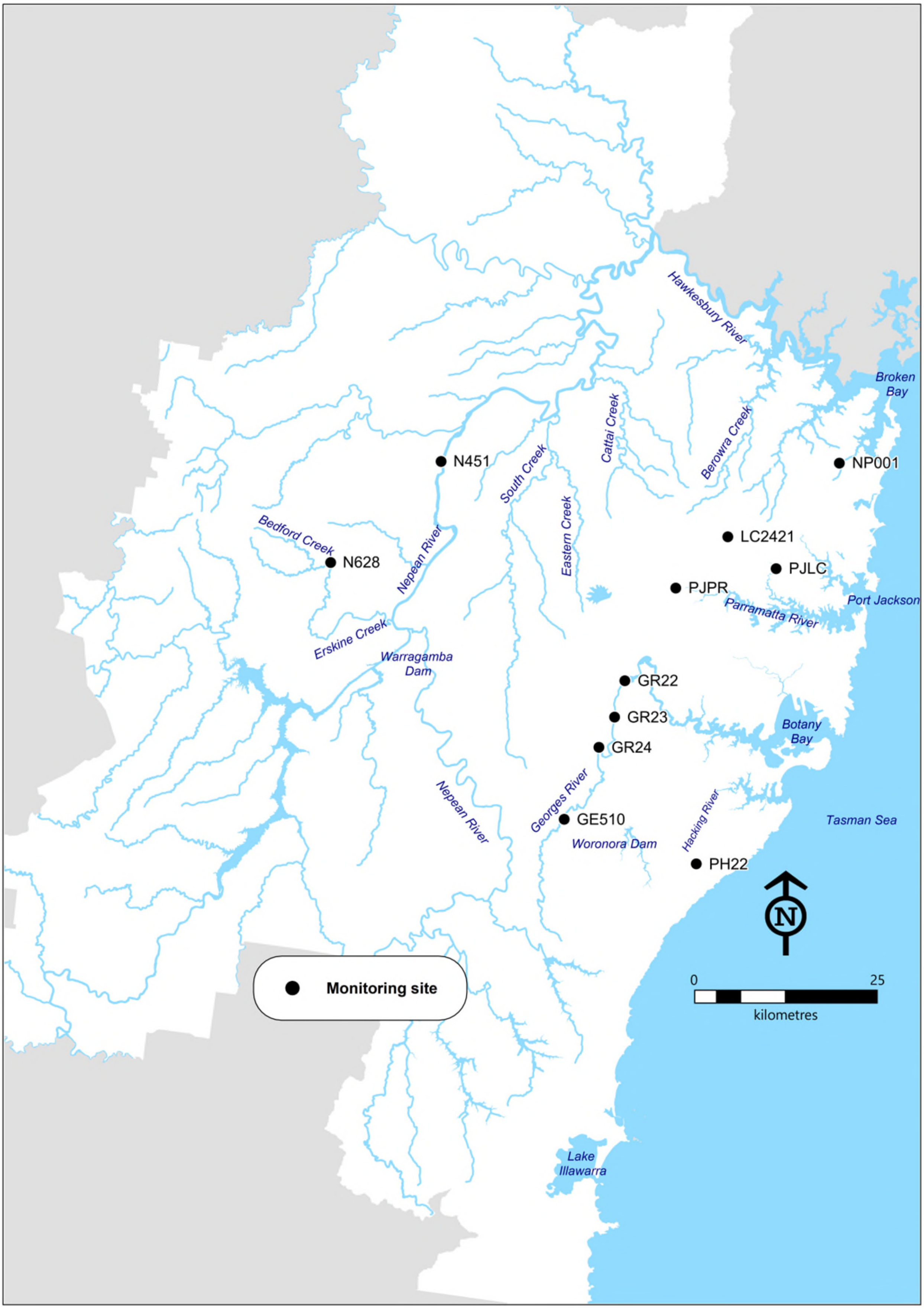


Figure 2-6 Site locations for the other urban river and reference sites ecosystem health sub-program

2.4 Nearshore marine ecosystem health

2.4.1 Rationale

Sydney Water discharges wastewater of differing quality into the marine environment. These outfalls are categorised by the location of discharge and include:

- three deep ocean outfalls (North Head, Bondi and Malabar, discussed in sections 2.5 and 2.6)
- two nearshore outfalls (Shellharbour, Wollongong)
- seven cliff face outfalls (Malabar 4, North Head 2 and Wollongong 1) and
- six shoreline outfalls (Bellambi, Port Kembla, Bombo, Cronulla, Warriewood and Brooklyn).

Treatment levels at these nearshore discharges varies at different levels:

- tertiary treated (Cronulla and Brooklyn)
- secondary treated (Bombo and Warriewood)
- primary treated (Bellambi and Port Kembla), only operate in wet weather
- untreated (Vaucluse and Diamond Bay)

Current EPLs allow for an impact from these nearshore discharges within the mixing zone for each of these outfalls. But Sydney Water's outfalls may impact the local aquatic ecology outside the mixing zone. Other studies of impacts of sewage discharges on intertidal biota in NSW have shown the responses by marine organisms are site specific and highly variable. The extent of the impact differs with level of treatment, type of disinfection process and the dilution of the effluent around the discharge site.

Distinguishing impacts associated with Sydney Water's WRRF discharges to the nearshore marine environment from other pressures requires a strong focus on monitoring of stressors and ecosystem receptors at outfall and reference sites, where possible. The sub-program is designed to monitor the direct aquatic environmental impacts of Sydney Water's WRRF discharges on the rocky intertidal and subtidal communities.

2.4.2 Aim and objectives

The aim of the nearshore marine program is to assess any significant change in ecological communities (macroalgal % covers and macroinvertebrate counts) from Sydney Water's WRRFs discharging into the nearshore ocean environment.

2.4.3 Monitoring approach

Design and sites

An earlier assessment on accessibility to the five key outfall sites identified a health and safety access issue to all but one outfall (Shellharbour). The rock platform at Turimetta Headland

(Warriewood WRRF discharge area) is flat with frequent wave wash up to the vertical cliff. On the day of inspection, the waves were only about 1 metre and this was sufficient to produce regular inundation of the site. Similarly, Diamond Bay, Cronulla and Bombo discharge to inaccessible sites that cannot be safely measured. Hence, these sites are not assessed, and Shellharbour is the only outfall monitored (Figure 2-7).

Analytes, indicators and sampling

Measurements are taken in spring each year under suitable weather and tidal conditions at the outfall and from two control sites. An underlying assumption of this study is that the extent of the impacted area is solely determined by the quality and/or volume of the wastewater discharge.

To assess if any significant ecological change has occurred, the littoral flora and fauna composition and abundance are measured as an indicator of ecological health. The littoral flora and fauna composition of natural communities at control sites were used to provide a baseline for calibrating the degree and the scale of any change.

Rocky-intertidal communities are comprised of macro algae and macro invertebrate animals. These organisms colonise a variety of man-made structures such as breakwaters, jetties, docks, groynes, dykes and seawalls (Crowe et al. 2000). Wave exposure influences the distribution and abundance of rocky-intertidal communities between exposed headlands and sheltered bays or inlets (Crowe et al. 2000). To control this natural influence, sites with similar levels of wave exposure were selected for analyses. Rocky-intertidal community structure was monitored from wave-exposed ocean headland locations on naturally occurring rock platforms that could be safely accessed at low tide.

At each site, community composition and enumeration were recorded yearly during the period of late winter to late spring. Monitoring in this period reduces the influence of annual recruitment of most species of settling larvae that mainly occurs in summer to autumn. Photographs of a 0.25 m^2 quadrat were taken within 2 hours either side of low tide. To help encapsulate variation between sites and across years, 14 randomly selected 0.25 m^2 quadrats were photographed between the low and high tide marks in the mid-littoral zone at each site visit. Using these photographs, counts were recorded for macroinvertebrate taxa and estimates of percentage cover were made for macro algae. The taxonomic level recorded was based on morphological characters that could be seen with the naked eye. Identification of macro invertebrate taxa and macroalgae were checked against taxonomic works of Edgar (1997) and Dakin (1987).

Seasonal variation is expected to be low because the dominant processes in the littoral community are competition for space and grazing through most of the year. Another controlling process on hot days in summer is potentially from desiccation from sun-exposure of the rock platform communities.

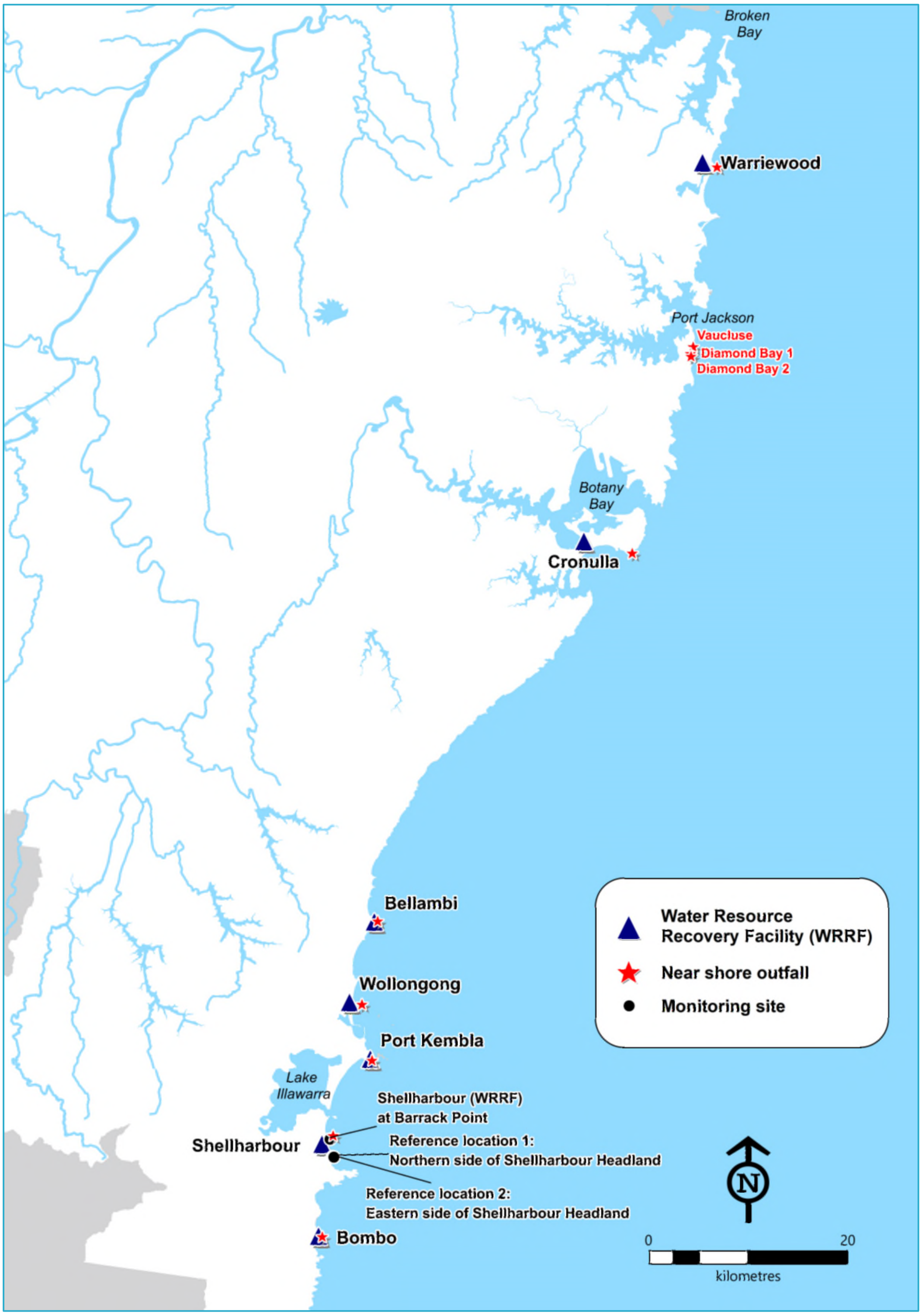


Figure 2-7 Site locations for nearshore marine ecosystem health sub-program

2.5 Ocean receiving water quality

2.5.1 Rationale

Sydney has three deepwater outfalls that are located 2-4 km offshore in 60-80 m of water. These deep ocean outfalls were constructed in 1989-1990 to provide more remote and rapid dilution of wastewater plumes. The location of the plume and dilution factors of the wastewater are critical to assess potential impacts from the discharges and these are mainly determined by ocean currents and density stratification of the water column. In order to assess the behaviour and model the outfall plumes on a routine basis, an ocean reference station (ORS) was established to collect wind and ocean current, temperature and wave data (Miller et al 1996).

Sydney Water has been collecting oceanographic data from the ocean reference station (ORS) since 1990. The ORS is positioned 3 km east of Bondi Beach in 67 m of water. Data from the ORS is collected and processed by Oceanographic Field Services under contract to Sydney Water. Apart from Sydney Water uses, the ORS is one of seven regional moorings in New South Wales that contribute data to Australia's Integrated Marine Observing System (IMOS).

The ocean receiving water quality sub-program makes predictions of the dispersion and dilution of the wastewater plume from North Head, Bondi and Malabar deep ocean outfalls using numerical modelling of the data collected by the ocean reference station. This enables important stressor information to be predicted by numerical modelling (ie concentrations of substances derived from the effluent are calculated from the concentrations in effluent and the dilution factors determined from the numerical modelling). These results are reported as an annual average distribution of concentrations around the outfall, based on monthly runs of the near field models. These data are then interrogated alongside patterns in benthic infauna communities and the accumulation of contaminants in sediments.

2.5.2 Aim and objectives

The aim of this sub-program is to:

1 Assess the oceanographic processes that affect the advection and dispersion of Sydney Water's deep ocean WRRF discharges.

Specific objectives for the above aim, focusing on the relevant stressors (ie the water quality predictions), are presented in Table 2-11 .

Table 2-11 Aims and objectives for the ocean receiving water quality sub-program

Aim	Objectives
Assess the oceanographic processes that affect the advection and dispersion of	**Surveillance Years (annually in between assessment years)** a. To compare trends in contaminant concentrations at the boundary of the initial dilution zone to water quality guidelines over the relevant historical record.
	Assessment Years (aligned to IPART cycle)

Aim	Objectives
Sydney Water's deep ocean WRRF discharges	b. To compare trends in contaminant concentrations at the boundary of the initial dilution zone to water quality guideline values over the relevant historical record. c. To measure current speed and direction throughout the water column. d. To measure temperature throughout the water column and estimate the water density profile. e. To assess the oceanographic processes that affect the advections and dispersion of Sydney Water's WRRF deepwater ocean discharges. f. To estimate the location and dilution of wastewater plumes and particle settling with near-field models. g. To compare the interannual variability of waves including maximum wave height, significant wave height and significant wave period. h. To summarise plume dilution and percentage of time exceeded over the current assessment year. i. To model spatial distribution of negatively buoyant particles and time taken to settle during the current assessment year. j. To model sediment movement by currents during the current assessment year. k. To model effluent discharge flows and loads over the current assessment year and relevant historical records

2.5.3 Monitoring approach

Design and sites

Sydney Water has been collecting data from the oceanographic reference station 3 km east of Bondi Beach in 67 m of water since 1990. Since a major reconfiguration in 2006, the instrumentation now includes a bottom mounted Acoustic Doppler Current Profiler (ADCP) that returns current speed and direction data from every 2 m in the water column, 14 temperature sensors located every 4 m in the water column to estimate density, and two conductivity, temperature, and depth sensors (CTD) located ~10 m above the sea floor and ~10 m below the sea surface.

Data are collected every 5 minutes and the equipment is serviced monthly with data being uploaded from the instruments at the same time. All data are quality checked prior to storage (Data Warehouse) and transmission to EPA within approximately two weeks of servicing the system.

The data collected by the ORS is complemented by wind data from the Bureau of Meteorology station located at Sydney Airport and wastewater flow volume obtained from stations at the North Head, Bondi and Malabar WRRFs. Numerical modelling with this data is used to predict the location and dilution of deep ocean outfall plumes.

More than 90% of the dispersion of wastewater from the deep ocean outfalls occurs in the near-field. Therefore, the near-field model PLOOM was developed specifically for the Sydney Water deep ocean outfalls and has been calibrated and validated. PLOOM3 is the latest version that has been used to estimate behaviour of the WRRF discharges at North Head, Bondi and Malabar since 2006.

The model is run annually undertaking simulations every hour and the output includes distance to the boundary of the initial dilution zone (varies depending on ocean and discharge conditions), location and 3D trajectory of the wastewater plume, and dilution of the wastewater plume (combined with data on measured contaminant concentrations in the wastewater) to predict concentrations at the boundary of the initial dilution zone. Most guideline values apply at this boundary.

Further details on ORS and outfalls modelling system is included at the end of this section.

Analytes, indicators and sampling

The suites of stressor analytes and associated parameters assessed in the 2022-23 surveillance year are listed in Table 2-12.

Table 2-12 Stressor (analytes) and ecosystem receptor indicators and associated parameters modelled for the ocean receiving water quality sub-program

PSER element	Line of evidence	Indicator	Analyte / parameter
Stressor	Chemical	Metals	Cadmium, chromium, copper, mercury, lead and zinc
	Chemical	Organic contaminants	Endosulphan and chlorpyrifos

Deepwater Outfall Modelling System (DOMS)

The Deepwater Outfall Modelling System (DOMS) is an integrated numerical modelling and data collection sub-program designed to meet Sydney Water licence requirements of environmental pollution licence 378, and includes provision of (a) Ocean Reference Station data to EPA unit head of Metropolitan Infrastructure (Water) (or nominee) and (b) input data for a suite of numerical models that estimate the trajectory and dilution of effluent plumes from the three deepwater ocean outfalls (North Head, Bondi and Malabar) to help assess the water quality disturbance of these discharges and potential impact on the marine environment.

DOMS comprises:

- Wind data from Sydney Airport (or from Kurnell if Sydney Airport data are unavailable)
- Wave data from Long Reef (data from Port Kembla can be requested if Long Reef data are unavailable)

- Effluent flow data from each of the three wastewater treatment plants located at North Head, Bondi and Malabar
- Oceanographic data from the Ocean Reference Station (ORS)
- Data checking, storage and routine delivery of data to the NSW EPA
- The near-field numerical model PLUME, designed specifically for the Sydney deepwater ocean outfalls.

The ORS is an instrumented mooring designed to provide oceanographic data from the vicinity of the three deepwater ocean outfalls. The ORS is located approximately 3 km east of Bondi, in waters approximately 65 m deep (Figure 2-8).

By continuously monitoring the currents and water density, ORS data provide an integrated estimate of the ocean currents from all current producing forces. This information is then used as boundary data to drive the numerical models.

The ORS comprises the following subsurface components (Figure 2-9):

- One x 600kHz RDI ADCP, bottom mounted. 5 minute data averaging, bin size = 2 m. The first data bin is located approximately 3 m above the sea floor.
- 13 x AQUA TEC temperature sensors at 4 m intervals from the sea floor to approximately 10 m below the sea surface. The lowest thermistor is approximately 1m above the sea floor. The uppermost thermistor also contains a pressure sensor to assist in determining exactly where each thermistor lies in the water column (the mooring string will bend over in response to strong current and wave action). Data are recorded at 5-minute intervals.
- Approximately 11 m and 52 m above the sea floor are located SeaBird SBE37 CTDs, returning temperature, salinity and depth data. Data are recorded every 5 minutes.

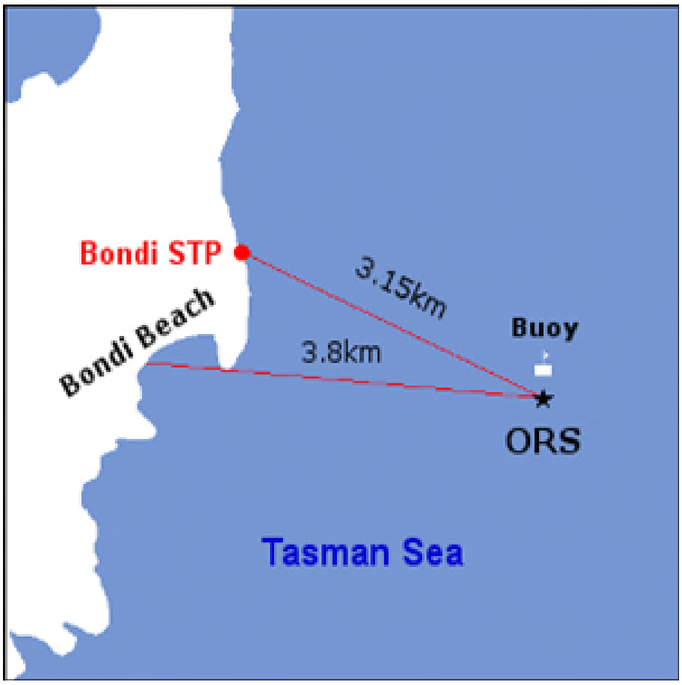


Figure 2-8 Location of ORS

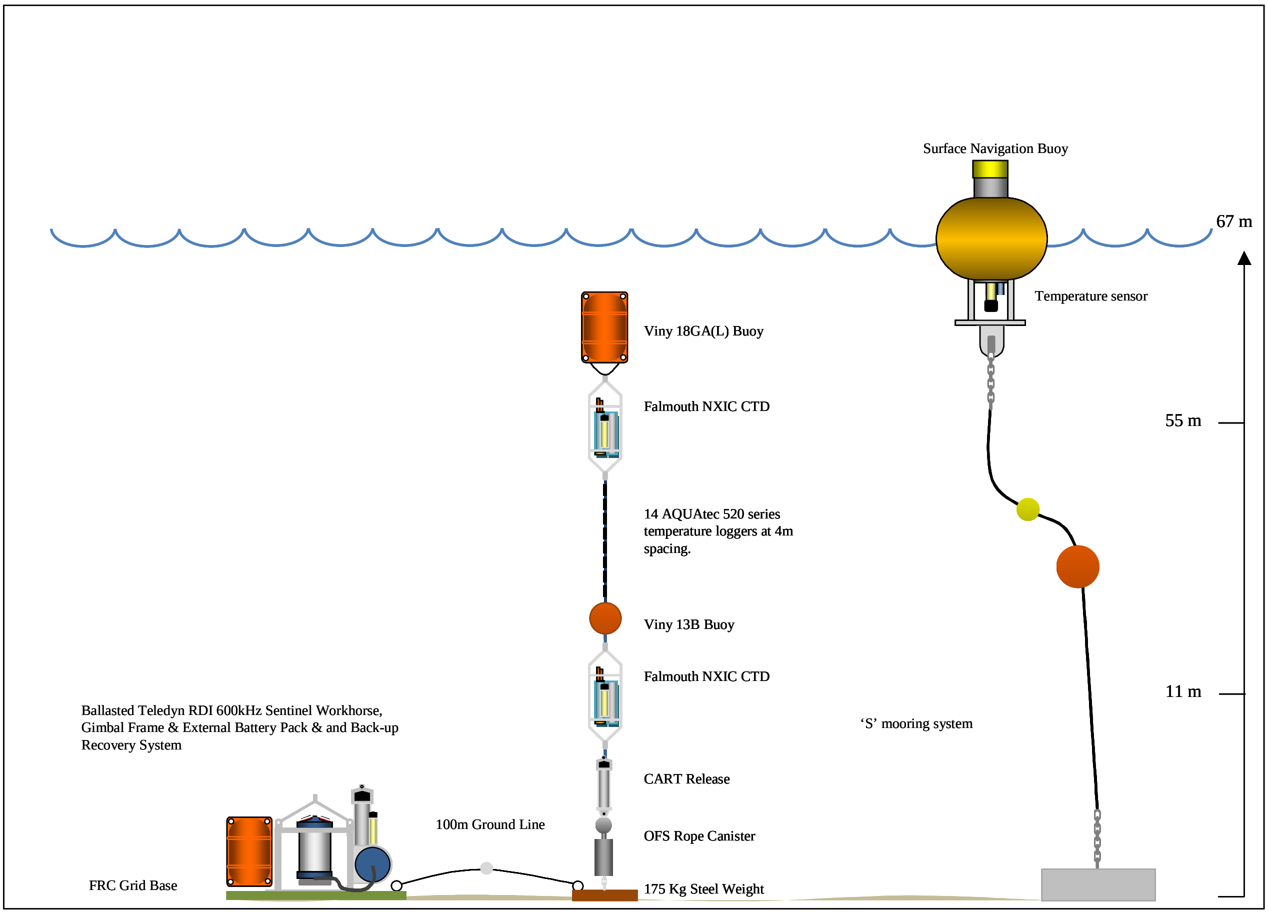


Figure 2-9 Configuration of the ORS Mk2

2.6 Ocean sediment quality and ecosystem health

2.6.1 Rationale

Sydney has three deep ocean outfalls that are located 2-4 km offshore in 60-80 m of water – North Head, Bondi and Malabar in order from north to south. Distinguishing impacts associated with Sydney Water's WRRF discharges to the offshore marine environment from other environmental gradients requires a strong focus on monitoring of stressors and ecosystem receptors at both outfall and control sites. Malabar has been subject to more sampling effort to investigate if any potential impact is spreading south. This is because Malabar has some of the highest discharges, including industrial waste, and the original plume modelling for particle settlement suggested that "the bulk of the particulate matter settled parallel to the Sydney coast within 4 to 5 km of the outfall diffuser arrays 80% of time, with minimal settling beyond this distance extending up to 10 km from the diffuser arrays" (Tate et al. 2019). Based on previous monitoring results there has been no evidence of an impact from Malabar outfall at southern control locations.

Deep ocean outfalls discharge effluent through multiple diffusers that spread it over 500 to 750 m, which achieves rapid dilution. The purpose of the diffusers is to release effluent into the ocean at concentrations that are unlikely to be toxic once mixing has occurred.

Effluent from the three deepwater ocean outfalls contains particulate matter to which contaminants may be attached. Under particular environmental conditions, negatively buoyant particles may settle and this may lead to a possible accumulation of contaminants in the sediments. Ocean currents and internal ocean waves may be sufficiently large to re-suspend the sediments, with the potential release of contaminants into the water column over a widespread area.

Once mixing has occurred, three checks are undertaken to determine that effluent is being released at non-toxic concentrations. Firstly, the diffusers are visually inspected using a remotely operated submersible equipped with a camera; this is a check to confirm that all diffusers are working. Secondly, the effluent is checked monthly to determine that it is not toxic at the concentrations achieved after mixing. These two checks are conducted under separate monitoring.

The first check Is performed under Professional Services Contract. While the second check Is performed under the monitoring plan titled 'Wastewater Treatment Plant Compliance and Operational Monitoring Plan'.

This monitoring sub-program represents the third check and satisfies requirements of new SWAM programs (Sydney Water 2023).

Sydney Water's offshore sediment quality and ecosystem health sub-program is designed to monitor (i) the direct marine environmental impacts of SydneyWater's WRRF discharges, and to investigate (ii) if any potential impact from Malabar outfall is spreading southwards.

In addition to the overview below, details of the changes to the monitoring sub-program can be found in the STSIMP recommendations report (van Dam et al. 2023).

2.6.2 Aim and objectives

The aims of this sub-program are to:

- Assess the direct impacts of Sydney Waters deep ocean WRRF discharges on (a) sediment quality and (b) ecosystem health as measured by responses of sediment infauna.
- Investigate if any potential impact from Malabar outfall is spreading southwards.

In brief, the sampling is conducted under two regimes:

- '**Assessment**' monitoring: includes a biotic component with identification and counting of the benthic macrofauna; and a physico-chemical component with analysis of sediment quality (metals, organic compounds, and physical parameters) at all sites. 'Assessment' sampling previously occurred in 1998-99, 2001-02, 2004-05, 2007-08, 2010-11, 2013-14, 2015-16 and 2019-20. The next assessment year is 2024-25, to align with the IPART cycle.
- '**Surveillance**' monitoring: has a reduced suite of physico-chemical parameters (particle size distribution and total organic carbon) and the biotic component is only assessed at the Malabar outfall site. 'Surveillance' monitoring is conducted in non-assessment years (2017-18, 2018-19, 2020-21, 2021-22, 2022-23 and so on).

As presented in EPA (1998), the 99th percentile value for total organic carbon (TOC) data or trigger threshold is 1.2%. If in a surveillance year the EPA TOC trigger value for Malabar is exceeded, further investigation of sediment quality may be instigated.

2.6.3 Monitoring approach

Design and sites

Aim 1 – assessment of direct impacts of WRRF discharges

The design focuses on assessment of stressors and ecosystem receptors to directly assess the impacts of the discharges. The northern most study locations of North Head and Bondi, are in waters approximately 60 m deep. The Malabar 0km outfall is located in waters approximately 80 m deep. Two sites are sampled at each location and five sub-sites are sampled to yield 10 replicate samples from each study location on each sampling occasion. The gradient locations at Malabar (3 km, 5 km and 7 km) are only sampled in assessment years.

Aim 2 – investigation of potential impacts from Malabar outfall spreading southwards

The design focuses on assessment of stressors and ecosystem receptors only at the Malabar outfall in surveillance years and compares the Malabar outfall with Malabar gradient locations (3 km, 5 km, 7 km) and southern control locations (Port Hacking and Marley) with previous assessment years.

In total there are three locations and six sites that address Aim 1 for stressor analytes in surveillance years, and one location and two sites that address Aims 1 and 2 for ecosystem receptors in surveillance years (Table 2-13, Figure 2-10). Sediment quality and benthic macroinvertebrates are sampled from the same grab so that representative sediment quality data are available for all ecosystem receptor indicator data.

Sub-site selection:

The method used for sub-site selection is consistent with the method outlined in EPA (1998). In order to select random sub-sites (5 or 10 as detailed in Table 2-13 for each site) a 250 m x 250 m spatial grid was constructed and centred on the sampling site whose grid coordinates are referred to in EPA (1998). The grid is subdivided into 50 m lengths along each axis, 50 m equivalent to one length unit. Therefore, the grid consists of 50 m x 50 m cells and each point in the grid is allocated (x,y) co-ordinates ranging from 0 to 5, illustrated in Volume 2 Table E-13.

To establish the grid position of (0,0) the sample positions are converted from latitude and longitude to easting and northing in Australian Map Grid (AGD 66, AMG zone 56). Prior to this, 125 m is subtracted from both the easting and northing of the original reference positions, which allows the grid to be centred on these positions.

The co-ordinates for the sub-sites are produced by randomly generating two sets of numbers (each representing either the x or y co-ordinates) ranging from 0 to 5. An example is shown in Figure 2-11 with the co-ordinates (3,1). These co-ordinates are converted to easting and northing by adding the appropriate lengths that corresponded to the (x,y) co-ordinates. Since each cell is 50 m x 50 m, each co-ordinate 'unit' corresponds to a length of 50 m. The positions for each site are provided in Table 2-13.

Table 2-13 Receiving water monitoring sites and number of samples for the offshore marine sediment quality and ecosystem health sub-program in 2022-23

Category	Location	Site codes	Depth (m)	Stressors		Ecosystem receptor		Coordinates	
				Surveillance	Assessment	Surveillance	Assessment	Latitude	Longitude
Control	Long Reef	LR-1C	60		5		5	-33.72726872	151.3786946
		LR-2C	60		5		5	-33.74532758	151.3732145
Outfall	North Head	NH-1C	60	10	5		5	-33.80778469	151.3517427
		NH-2C	60	10	5		5	-33.82472204	151.3517036
Outfall	Bondi	B-1C	60	10	5		5	-33.89472367	151.3065893
		B-2C	60	10	5		5	-33.8716801	151.3136225
Outfall	Malabar 0km	M0-1C	80	10	5	10	10	-33.97810419	151.2983515
		M0-2C	80	10	5	10	10	-33.97677202	151.3055366
Control	Malabar 3km	M3-1C	80		5		5	-34.00006851	151.2824469
		M3-2C	80		5		5	-33.99914653	151.2847567
Control	Malabar 5km	M5-1C	80		5		5	-34.01688851	151.2740868
		M5-2C	80		5		5	-34.0183596	151.2769219
Control	Malabar 7km	M7-1C	80		5		5	-34.03102797	151.2617666
		M7-2C	80		5		5	-34.03386952	151.2602759
Control	Port Hacking	PH-1C	80		5		5	-34.07018599	151.2308685
		PH-2C	80		5		5	-34.07233234	151.2308238
Control	Marley Beach	MB-1C	80		5		5	-34.13519402	151.1741488
		MB-2C	80		5		5	-34.1368761	151.1749733

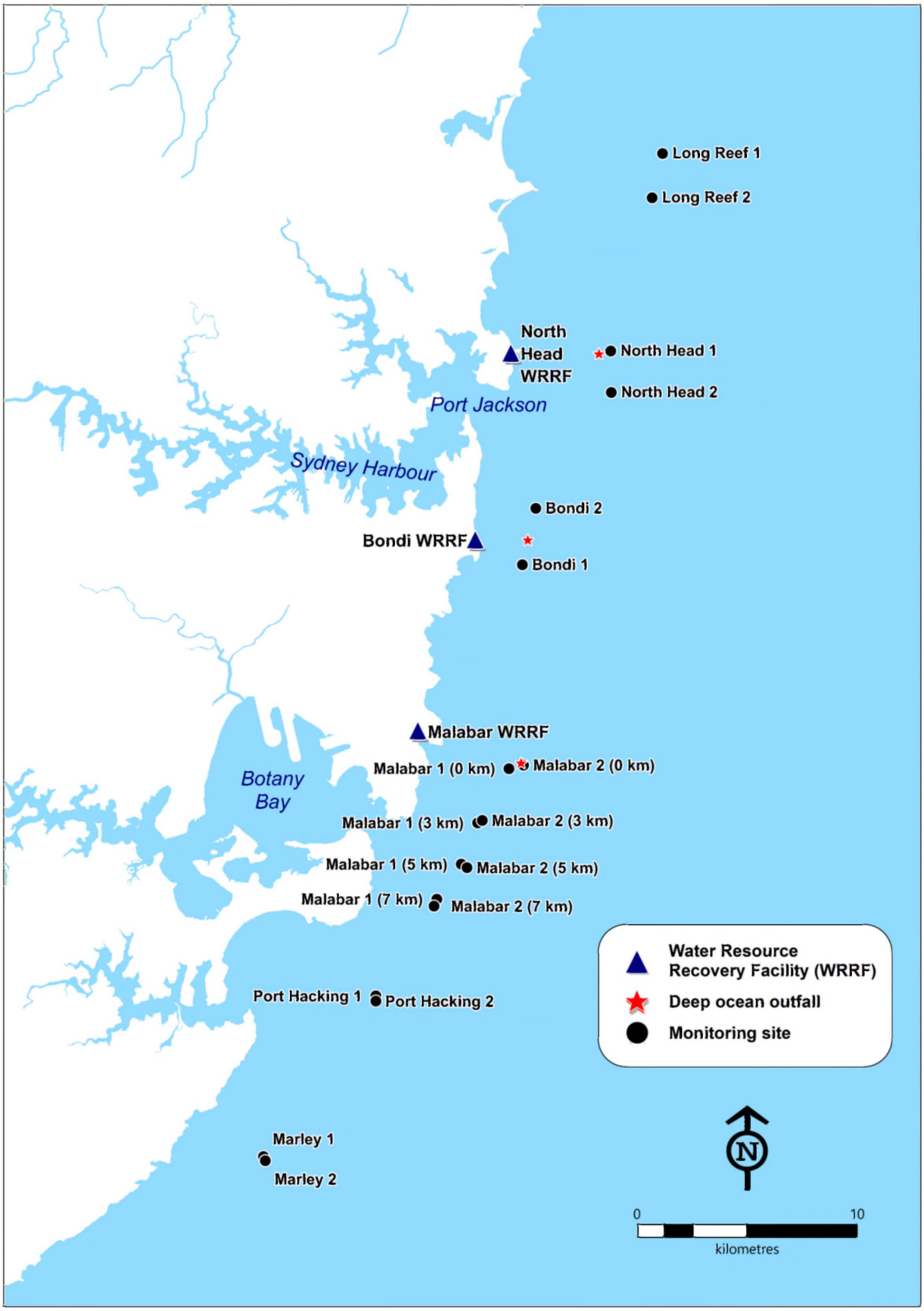


Figure 2-10 Site locations for offshore marine sediment quality and ecosystem health sub-program

A single sediment sample is collected from each subsite, for which there are 5 subsites for a site. This results in 5 samples being collected from each of two sites, with 10 samples in total collected from each location (Figure 2-11). An exception to this is the requirement for the Malabar 0 km location, where 10 sub-site samples are to be collected from each of the two sites, with 20 samples in total collected from the Malabar 0 km location (Table 2-14).

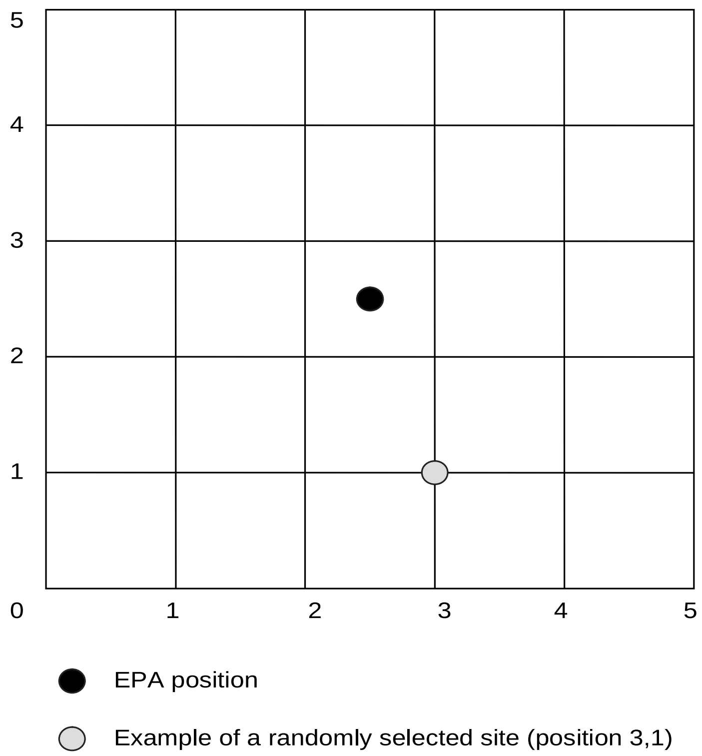


Figure 2-11 Grid used to randomly select sub-sites at each of the EPA (1998) sites

Analytes, indicators and sampling

Sampling of ocean sediments is conducted annually during February to allow comparability of data between years.

This year (2022-23) is a surveillance year and altogether 30 sediment samples were collected for the physico-chemical analyses, and 20 for the infaunal community analysis as per Table 2-14.

Table 2-14 Stressor (analytes) and ecosystem receptor indicators and associated parameters for the offshore marine sediment quality and ecosystem health sub-program, for surveillance and assessment years[a]

PSER element	Line of evidence	Indicator	Analyte / parameter			
			Analyte	Practical quantitation limit (PQL)	Unit of measurements	Analyte method code / Reference
Stressor	Physico-chemical	General sediment quality	Total organic carbon (TOC)*	0.01	%	XAL_TOC_S, External, ALS, APHA (2017) 5310C
			Grain size*	-	mm	TM54WET, In house method derived from AS1289.C6.1 – 1997 for sizes >2mm, + TM71 For sizes <2mm, by Laser Diffraction inhouse method non NATA
			Moisture content		%	TM35GRIND, TM35MKG
	Chemical [b]	Nutrients	Total Kjeldahl nitrogen (TKN)	20	mg/kg	NU72, APHA (2017) 4500- Norg/NO3 – I/J
			Total phosphorus	10	mg/kg	TM70MKG, USEPA 6010D
Stressor	Chemical [b]	Total acid extractable metals	Aluminium (Al)	2	mg/kg	TM70MKG, USEPA (2014) 6010D
			Arsenic (As)	0.02	mg/kg	TM66MKG, USEPA (2014) 6020B
			Cadmium (Cd)	0.01	mg/kg	as above
			Chromium (Cr)	0.02	mg/kg	as above
			Cobalt (Co)	0.01	mg/kg	as above
			Copper (Cu)	0.05	mg/kg	TM66MKG, USEPA (2014) 6020B
			Iron (Fe)	2	mg/kg	TM70MKG, USEPA (2014) 6010D
			Lead (Pb)	0.01	mg/kg	TM66MKG, USEPA (2014) 6020B
			Mercury (Hg)	0.005	mg/kg	TM01MKG, APHA (2012) 3112B
			Nickel (Ni)	0.02	mg/kg	TM66MKG, USEPA (2014) 6020B
			Selenium (Se)	0.02	mg/kg	as above

PSER element	Line of evidence	Indicator	Analyte / parameter			
			Analyte	Practical quantitation limit (PQL)	Unit of measurements	Analyte method code / Reference
			Silver (Ag)	0.01	mg/kg	as above
			Zinc (Zn)	0.1	mg/kg	as above
Stressor	Chemical [b]	Organic compounds: (PAHs, pesticides and PCBs)*	PAHs (Acenaphthene, Acenaphthylene, Anthracene, Benzo(a)anthracene, Benzo(a)pyrene, Benzo(a)pyrene TEQ, Benzo(b)fluoranthene, Benzo€pyrene, Benzo(a)pyrene TEQ, Benzo(ghi)perylene, Benzo(k)fluoranthene, Chrysene, Coronene, Dibenzo(a,h)anthracene, Fluoranthene, Fluorene, Indeno(1,2,3-cd)pyrene, Naphthalene, Perylene, Phenanthrene and Pyrene)	10	µg/kg	TC004SLL, In-house method based on USEPA 8270C; TC012SLL, , In-house method based on USEPA 8260B
			Organochlorine pesticides: 4,4-DDD, 4,4-DDE, 4,4-DDT; Aldrin, Dieldrin, Endosulfan sulphate, Endrin, Heptachlor, Heptachlor Epoxide, Hexachlorobenzene Lindane (gamma-BHC); Methoxychlor, alpha-BHC, alpha-Chlordane, alpha-Endosulfan, beta-BHC, beta-Endosulfan, delta-BHC, gamma-Chlordane)	5	µg/kg	TC001SLL, In-house method based on USEPA 8081B, APHA (2012) 6630 (modified)
			Polychlorinated Biphenyls (PCB) total	25	µg/kg	TC003SLL, APHA (2012) 6630 (modified), based on USEPA 8082A
			Coronene	100	µg/kg	TC004COR, based on USEPA 8270C
			2-ChloroPhenol, M-Cresol, O-Cresol and P-Cresol	10	µg/kg	XAL_PHENOL, APHA (2012) 6420

PSER element	Line of evidence	Indicator	Analyte / parameter			
			Analyte	Practical quantitation limit (PQL)	Unit of measurements	Analyte method code / Reference
Ecosystem receptor	Biodiversity	Sediment infaunal communities	Richness (total and families for main functional groups), Abundance (total and families for main functional groups), Community structure and composition			

[a] Refer to Table 2-13 for details of sites at which analytes/indicators should be measured in surveillance and assessment years

[b] The recommended suite of chemical analytes should be considered as interim, and needs to be more comprehensively determined through sampling studies for treated wastewater and receiving water and associated screening-level risk assessments

* Surveillance years only

2.7 Wastewater overflows and leakage

2.7.1 Wet weather overflows

Wastewater overflows under wet weather conditions occur when the hydraulic capacity of the sewers or WRRFs treatment capacities are exceeded due to excessive inflow and infiltration of stormwater. The primary sources of stormwater in the wastewater system comes from incorrectly connected private stormwater and inflow into faulty Sydney Water assets. Saltwater ingress, particularly during large tidal events, is also known to affect assets located within the intertidal zone. Groundwater is similarly known to infiltrate the wastewater network.

Sydney Water estimates the volume of wet weather overflows via wastewater network hydraulic models under the established protocol ‘Trunk Wastewater System Model Update, Re-calibration and Annual Reporting Procedure’. This model allows the performance of a system to be tracked through time independently of changes in performance from year-to-year due to climate (Sydney Water 2023c). Each year the model is updated when significant growth or changes in the geometry or operation of the system has occurred. The model is then validated and recalibrated using that year rainfall and sewer flow and level data (Sydney Water 2023c).

2.7.2 Dry weather overflows

Dry weather overflows predominantly occur due to blockages caused by tree roots. Inappropriate disposal of solids, such as ‘wet wipes’, sanitary products, oil and grease, and construction debris, exacerbate the blockages caused by tree roots. Pipe and structural faults are less common than blockages.

We calculate dry weather overflow volumes using the date and time when an incident is reported to Sydney Water, the date and time the leak/overflow ceases, the assumed flow rate and the number of properties upstream of the overflow. We record the total number of overflows and the overflow volume for each EPL and Sewer Catchment Area Management Plan (SCAMP) and report the portion that reaches the receiving waters via annual returns under EPL condition L7.4 for EPL where applicable.

2.7.3 Dry weather leakage detection monitoring program

Sydney Water has divided its wastewater network into 232 SCAMPs, each equivalent to about 100 km of sewer. Dry and wet weather overflows and dry weather wastewater leakage from these catchments can impact recreational water quality at designated swimming areas and biological communities in receiving waters. The information from this program is used to reduce the risk to public health and receiving water ecosystems by identifying dry weather leakage, enabling repairs to the system and providing an overall assessment of the condition of the sewers in each SCAMP. The dry weather component of this program aligns with the respective EPL conditions that require dry weather leakage monitoring, investigation and remedial actions.

The SCAMPs provide a basis for site selection under the dry weather wastewater leakage detection monitoring program. Typically, one sampling site has been identified for each SCAMP. These sites have been designed to best represent the stormwater quality draining the SCAMP and to enable the detection of wastewater leakage in the stormwater system. However, there are six SCAMPs where sites have not been allocated yet as they represent new systems where leaks are not expected, or all residents are not yet connected to the wastewater network. These areas are mostly located to the south of the city (Gerringong, Gerroa) or in underdeveloped areas (Douglas Park, Duffy’s Forest, Luddenham, Wilton). With gaps in connection due to some residents still being on septic services, the stormwater quality may be impacted by contamination from these septic systems, which would yield misleading information if sampling was to be conducted. The current 226 dry weather leakage detection monitoring sites are identified in Table 2-16, Figure 2-12, Figure 2-13, Figure 2-14, Figure 2-15, Figure 2-16, Figure 2-17, Figure 2-18 and Figure 2-19.

Dry weather leakage monitoring consists of 3 phases:

- Routine surveillance: All 226 SCAMP sites are sampled at least once every 12 months as per the EPL requirements and the results are compared against the revised faecal coliform 10,000 cfu/100 mL threshold (the threshold was increased from 5,000 cfu/100 mL to 10,000 cfu/100 mL on 1 January 2015 following negotiations with the EPA). The annual sampling can be spread throughout the year to balance sampling workloads and is dependent on dry weather. When a routine sample exceeds the threshold, a resample is required to be collected.

  If a SCAMPs faecal coliform result exceeds the threshold value for three consecutive events, the sampling frequency transitions to a quarterly sampling regime. When three consecutive quarterly monitoring results are below the threshold, the SCAMP reverts to the standard annual routine surveillance.

- Resample: When a routine faecal coliform result exceeds 10,000 cfu/100 mL, a resample is required to be completed in dry weather at the routine monitoring site. Resamples help to determine if the exceedance is attributed to a recorded and/or rectified fault within the catchment and whether the leakage is persistent or intermittent. The timeframe for a resample is dictated by the associated risk to the receiving waterway. When the resample also exceeds the 10,000 cfu/100 mL threshold, a Source Detection Investigation is initiated.
- Source detection investigation: A source detection investigation is initiated to investigate leaking infrastructure within the SCAMP. Source detection investigations may be instigated during a routine or resample monitoring event if there is evidence of the presence of wastewater, but are mostly initiated following a resample exceedance.

The source detection process involves a ‘catchment walk’, taking a semi-instantaneous field-based ammonia test (HACH ammonia test strips) at the catchment outlet, then assessing the stormwater channel for any obvious signs of contamination at each stormwater junction. At key points (that is, branches in the line) composited grab samples are collected for faecal coliform analysis. These sampling points are geocoded and described for future reference to site locations. If the investigation determines that the leak is emanating from Sydney Water’s reticulation system, remedial action is required. If the leak is associated with private services or infrastructure, the appropriate authorities are notified and repairs are requested.

All sampling and the source detection process are done in dry weather conditions. The dry weather leakage program defines ‘dry weather’ as a period when less than 2 mm of rain has fallen in the previous 24 hours and has an Antecedent Wetness Index (AWI) of less than 5 mm. The AWI is calculated using the following equation:

$$AWI_{\ today} = 0.7 \times \left(Rain_{24hr} + AWI_{yesterday}\right)$$

The AWI is based on the relaxation time from wet weather events in urban stormwater catchments and is specific to the Sydney region. In the above equation, the factor 0.7 is the remaining moisture fraction. The difference (1.0-0.7) is equivalent to assumed drainage yield/storage depletion factor/rate. The remaining moisture fraction (0.7) depends on the catchment run-off characteristics. The larger the remaining moisture fraction, the slower the catchment responds. Whereas lower remaining moisture fractions represent fast responding catchments.

Daily rainfall data is obtained for each SCAMP from the nearest available Sydney Water rain gauge. For all sites affected by tidal influence, samples are collected at low tide to ensure stormwater is representative of the catchment and not affected by tidal activity. If a site is dry or ponded because no flow is prevalent in the stormwater channel, then no sample is collected. Dry and ponded sites mean that no leaks are active within the SCAMP and thus represent a pass.

Table 2-15 contains the list of analytes monitored for the dry weather leakage detection monitoring program. The faecal coliform bacterial indicator is cost effective in detecting the presence of wastewater in SCAMPS and for leakage detection investigations.

Table 2-15 List of analytes, SCAMP Dry Weather Leakage Detection Program

Water quality analyte	Detection limit	Unit	Method/Reference	Place of measurement
Faecal coliforms	<1	cfu/100 mL	APHA (2017) 9222D	Laboratory
Ammonia Test Strip (Spot Test)	0.5	mg/L	In house test	Field
Conductivity	<7	µS/cm	APHA (2017) 2510 B, 4500-O G, 4500-H B	Field
pH	-	pH unit	APHA (2017) 2510 B, 4500-O G, 4500-H B	Field
Dissolved oxygen	-	mg/L and % sat	APHA (2017) 2510 B, 4500-O G, 4500-H B	Field
Temperature	-	°C	APHA (2017) 2510 B, 4500-O G, 4500-H B	Field
Field observation and assessment of wastewater indicators	-	-	-	Field

Table 2-16 List of Dry Weather Leakage Detection Program monitoring sites

Region	Site Code	SCAMP	EPL	Waterway	Latitude	Longitude
Blue Mountains	BHBLH1	Blackheath	1712	Popes Glen Creek	-33.62794	150.30136
	MVMVC1	Mount Victoria	1716	Fairy Dell Creek	-33.5814028	150.2552529
	PREMP1	Emu Plains	1409	Lapstone Creek	-33.738093	150.654999
	PRGLB1	Glenbrook	1409	Glenbrook Creek	-33.757347	150.627719
	PRGNP1	Glenmore Park	1409	School House Creek	-33.775443	150.665481
	PRJMT1	Jamisontown	1409	Peach Tree Creek	-33.759962	150.677740
	PRMPL1	Mount Pleasant	1409	Unnamed Creek	-33.713491	150.700428
	PRMRV1	Mount Riverview	1409	Unnamed Creek	-33.731120	150.651241
	PRPNR1	Penrith	1409	Peach Tree Creek	-33.749299	150.684740
	WGWAR1	Warragamba	12235	Megarritys Creek	-33.87447	150.611411
	WLWAL2	Wallacia	12235	Scotcheys Creek	-33.8973627	150.6234339
	WMHAZ1	Hazelbrook	1963	Hazelbrook Creek	-33.71272	150.45457
	WMMEB1	Medlow Bath	1963	Adams Creek	-33.670198	150.285413
	WMNKT2	North Katoomba	1963	Katoomba Creek	-33.70017	150.31216
	WMSKT1	South Katoomba	1963	Katoomba Cascades	-33.725121	150.306496
	WMWIN1	Winmalee	1963	Springwood Creek	-33.69720	150.55780
	WMWWF1	Wentworth Falls	1963	Valley of the Waters Creek	-33.71596	150.34734
BOOS	BNBNB1	Bondi Beach	1688	Bondi Beach Inflow	-33.8924119	151.2741713
	BNBNJ1	Bondi Junction	1688	Musgrave Pond	-33.9024078	151.2445898
	BNCMD1	Camperdown	1688	Johnstons Creek	-33.882605	151.176167
	BNEDG1	Edgecliff	1688	Rushcutters Bay	-33.875671	151.229774
	BNROZ2	Rozelle	1688	Unnamed Creek	-33.865914	151.176522
	BNRSB1	Rose Bay	1688	Rose Bay Channel	-33.877040	151.263864

Region	Site Code	SCAMP	EPL	Waterway	Latitude	Longitude
	BNSYE1	Sydney East	1688	Woolloomooloo Bay	-33.871290	151.219929
	BNSYW2	Sydney West	1688	Cockle Bay	-33.885858	151.206841
	BNVAU2	Vaucluse	1688	Unnamed Creek	-33.852357	151.278351
COOS	CRBAG1	Bangor	1728	Still Creek	-34.0056477	151.0164489
	CRCRN2	Cronulla	1728	Unnamed Creek	-34.054445	151.145222
	CRCRS1	Caringbah South	1728	Unnamed Creek	-34.060757	151.127934
	CRENG1	Engadine	1728	Forbes Creek	-34.036713	151.036804
	CRGYM2	Gymea	1728	Coonong Creek	-34.048799	151.09109
	CRJAN1	Jannali	1728	Carina Creek	-34.008022	151.070687
	CRLOF1	Loftus	1728	Loftus Creek	-34.0388473	151.0400352
	CRMEN2	Menai	1728	Unnamed Creek	-33.987750	151.021697
	CRMIR1	Miranda	1728	Gwawley Creek	-34.0211773	151.1008282
	CRSUT1	Sutherland	1728	Unnamed Creek	-34.0190038	151.0756332
	CRWOL1	Woolooware	1728	Unnamed Creek	-34.042972	151.112255
Illawarra	BOJAM1	Jamberoo	2269	Unnamed Creek	-34.647549	150.780226
	BOKIA1	Kiama	2269	Unnamed Creek	-34.6773117	150.8532904
	SHALP2	Albion Park	211	Unnamed Creek	-34.565882	150.813662
	SHLIL1	Lake Illawarra	211	Bensons Creek	-34.5510703	150.8635116
	SHSLH1	Shellharbour	211	Oak Park Creek	-34.5601806	150.8300457
	WOBSV1	Brownsville	218	Brookes Creek	-34.498069	150.806478
	WOBUL1	Bulli	218	Bellambi Creek	-34.3612061	150.9167495
	WOCOR1	Corrimal	218	Towradgi Creek	-34.3804334	150.8951622
	WODAP1	Dapto	218	Mullet Creek	-34.4797786	150.7978399
	WOFGT2	Figtree	218	American Creek	-34.444392	150.860962
	WOFMW1	Fairy Meadow	218	Cabbage Tree Creek	-34.398415	150.8957814

Region	Site Code	SCAMP	EPL	Waterway	Latitude	Longitude
	WOGWY1	Gwynneville	218	Unnamed Creek	-34.4163954	150.8887018
	WOKGR1	Kembla Grange	218	Unnamed Creek	-34.470877	150.778892
	WOPKB1	Port Kembla	218	Minnegang Creek	-34.4916091	150.8735226
	WOTHI1	Thirroul	218	Hewitts Creek	-34.3223961	150.921729
	WOUNA1	Unanderra	218	Allans Creek	-34.4554794	150.8466842
	WOWOL1	Wollongong	218	Unnamed Creek	-34.4356715	150.8931144
NSOOS	NHAUB1	Auburn	378	Duck River	-33.863205	151.015178
	NHBAH1	Baulkham Hills	378	Toongabbie Creek	-33.758402	150.965363
	NHBCT1	Beecroft	378	Trib. Of Devlins Creek	-33.763509	151.064171
	NHBGH1	Balgowlah Heights	378	Unnamed Creek	-33.800450	151.265235
	NHBLR1	Belrose	378	French’s Creek	-33.734629	151.208696
	NHBLV1	Bella Vista	378	Lalor Creek	-33.770398	150.941269
	NHBRK1	Brookvale	378	Brookvale Creek	-33.770955	151.268276
	NHCCL1	Curl Curl	378	Greendale Creek	-33.765745	151.279202
	NHCHW1	Chatswood	378	Scotts Creek	-33.784651	151.198027
	NHCLR1	Collaroy	378	Unnamed Creek	-33.745528	151.291260
	NHCMR1	Cromer	378	South Creek	-33.732287	151.276400
	NHCRM1	Cremorne	378	Unnamed Creek	-33.835094	151.233179
	NHCSH1	Castle Hill	378	Darling Mills Creek	-33.765096	151.008612
	NHDUN1	Dundas	378	Subiaco Creek	-33.807107	151.033551
	NHDVY1	Dundas Valley	378	Vineyard Creek	-33.803015	151.032199
	NHEAS1	Eastwood	378	Terrys Creek	-33.771247	151.093745
	NHEBL1	East Blacktown	378	Blacktown Creek	-33.773055	150.935750
	NHEPP1	Epping	378	Devlin Creek	-33.765392	151.082210
	NHFRV1	Forestville	378	Carroll Creek	-33.754194	151.207353

Region	Site Code	SCAMP	EPL	Waterway	Latitude	Longitude
	NHGIW1	Girraween	378	Girraween Creek	-33.783487	150.952245
	NHGLF1	Guildford	378	Duck Creek	-33.835973	151.011882
	NHGRW1	Greenwich	378	Unnamed Creek	-33.826493	151.159794
	NHHOL1	Holroyd	378	A'Becketts Creek	-33.827284	151.010063
	NHHOR1	Hornsby	378	Cockle Creek	-33.706612	151.118154
	NHHUN1	Hunters Hill	378	Tarban Creek	-33.834908	151.135049
	NHKIL1	Killara	378	Rocky Creek	-33.751378	151.172093
	NHKLH1	Killarney Heights	378	Bates Creek	-33.769053	151.220064
	NHLID1	Lidcombe	378	Haslams Creek	-33.860417	151.041489
	NHLIN1	Lindfield	378	Gordon Creek	-33.768193	151.177673
	NHLNC2	Lane Cove	378	Swaines Creek	-33.798949	151.161888
	NHMNY2	Manly Beach	378	Manly Beach	-33.7958739	151.2878308
	NHMOS1	Mosman	378	Unnamed Creek	-33.8268207	151.2515979
	NHMQP1	Macquarie Park	378	Shrimptons Creek	-33.774865	151.122591
	NHNEP1	North Epping	378	Unnamed Creek	-33.750955	151.084174
	NHNPR1	North Parramatta	378	Hunts Creek	-33.781766	151.024995
	NHNRB1	Naremburn	378	Unnamed Creek	-33.813078	151.199429
	NHNRD1	North Ryde	378	Unnamed Creek	-33.806494	151.137870
	NHNSY1	North Sydney	378	Unnamed Creek	-33.841224	151.198286
	NHPAR1	Parramatta	378	Parramatta River	-33.811823	151.007205
	NHPNH1	Pendle Hill	378	Pendle Creek	-33.784264	150.955375
	NHRSH2	Rosehill	378	Unnamed Creek	-33.820320	151.018746
	NHRSV1	Roseville	378	Moores Creek	-33.770158	151.195439
	NHRYD1	Ryde	378	Strangers Creek	-33.810789	151.129099
	NHRYL1	Rydalmere	378	Unnamed Creek	-33.817501	151.040676

Region	Site Code	SCAMP	EPL	Waterway	Latitude	Longitude
	NHSEA1	Seaforth	378	Burnt Bridge Creek	-33.787393	151.266574
	NHSIL1	Silverwater	378	Unnamed Creek	-33.849943	151.052336
	NHSVH1	Seven Hills	378	Unnamed Creek	-33.778425	150.938318
	NHSWT1	South Wentworthville	378	Finlaysons Creek	-33.803429	150.978454
	NHTUR1	Turramurra	378	South Branch of Cowan Creek	-33.707437	151.155009
	NHWAH1	Wahroonga	378	Lovers Jump Creek	-33.707352	151.143270
	NHWIL1	Willoughby	378	Sugarloaf Creek	-33.798845	151.209808
	NHWLI2	West Lindfield	378	Blue Gum Creek	-33.791787	151.161741
	NHWMN1	Westmead North	378	Quarry Branch Creek	-33.784183	150.989531
	NHWMS1	Westmead South	378	Domain Creek	-33.810932	150.991714
	NHWPH1	West Pennant Hills	378	Darling Mills Creek	-33.759626	151.017602
	NHWRY1	West Ryde	378	Charity Creek	-33.814465	151.089658
	NHWTH1	Winston Hills	378	Unnamed Creek	-33.783138	150.972779
	NHWTU1	West Turramurra	378	Unnamed Creek	-33.758311	151.118939
	NHWWA1	West Wahroonga	378	Coups Creek	-33.733100	151.092573
	NHWWV1	Wentworthville	378	Coopers Creek	-33.799083	150.974613
	NHYAG2	Yagoona	378	Duck River	-33.886724	151.016596
SWOOS	MAACT1	Ashcroft	372	Cabramatta Creek	-33.923076	150.889642
	MAALX1	Alexandria	372	Unnamed Creek	-33.9074255	151.193935
	MAARN1	Arncliffe	372	Unnamed Creek	-33.932051	151.154151
	MAAPP1	Appin	372	Kennedy Creek	-34.200564	150.791276
	MAASF1	Ashfield	372	Iron Cove Creek	-33.874824	151.126494
	MAAVL1	Ambarvale	372	Mansfield Creek	-34.111745	150.80524
	MABEX1	Bexley	372	Muddy Creek	-33.960034	151.132282
	MABKH1	Blakehurst	372	Unnamed Creek	-33.983475	151.120173

Region	Site Code	SCAMP	EPL	Waterway	Latitude	Longitude
	MABKN1	Bankstown	372	Salt Pan Creek	-33.932122	151.036489
	MABKS1	Banksia	372	Unnamed Creek	-33.945399	151.148868
	MABLM1	Belmore	372	Unnamed Creek	-33.903962	151.094790
	MABLS1	Belmore South	372	Cup and Saucer Creek	-33.916499	151.119752
	MABOT1	Botany	372	Unnamed Creek	-33.946795	151.196261
	MABRG1	Bonnyrigg	372	Clear Paddock Creek	-33.876138	150.912765
	MABRT1	Brighton	372	Muddy Creek	-33.957246	151.143948
	MABSP1	Bossley Park	372	Orphan School Creek	-33.865449	150.9006112
	MABVH1	Beverly Hills	372	Wolli Creek	-33.9439818	151.0900862
	MACAB1	Cabramatta	372	Orphan School Creek	-33.885867	150.946204
	MACAS1	Casula	372	Brickmakers Creek	-33.910577	150.930115
	MACBT1	Campbelltown	372	Bow Bowing Creek	-34.057184	150.8198727
	MACDP1	Condell Park	372	Unnamed Creek	-33.93276	150.97659
	MACGE1	Coogee	372	Coogee Beach	-33.919310	151.259620
	MACHF2	Malabar beach	372	Malabar Beach	-33.960834	151.249372
	MACMP1	Campsie	372	Unnamed Creek	-33.9036447	151.0991055
	MACNE1	Concord East	372	Unnamed Creek	-33.856988	151.107213
	MACNW1	Concord West	372	Unnamed Creek	-33.840861	151.092278
	MACPN1	Chipping Norton	372	Drain to Amaroo Wetland	-33.908043	150.982269
	MACTB1	Canterbury	372	Unnamed Creek	-33.8991517	151.1046665
	MADRU2	Drummoyne	372	Unnamed Creek	-33.852161	151.135765
	MADUL1	Dulwich Hill	372	Unnamed Creek	-33.910280	151.138630
	MAEAR1	Earlwood	372	Unnamed Creek	-33.916518	151.132011
	MAEGV1	Eagle Vale	372	Thompson Creek	-34.021200	150.839360
	MAFAR1	Fairfield	372	Unnamed Creek	-33.8785305	150.9538165

Region	Site Code	SCAMP	EPL	Waterway	Latitude	Longitude
	MAFVD1	Five Dock	372	Unnamed Creek	-33.868308	151.118791
	MAGNF1	Glenfield	372	Macquarie Creek	-33.984768	150.895072
	MAGRA1	Greenacre	372	Cooks River	-33.8975866	151.0826365
	MAHOM1	Homebush	372	Unnamed Creek	-33.8574031	151.0776039
	MAHOX1	Hoxton Park	372	Maxwells Creek	-33.9267883	150.897793
	MAHUR1	Hurstville	372	Bardwell Creek	-33.9344583	151.1327922
	MAING1	Ingelburn	372	Redfern Creek	-33.983319	150.880929
	MAKEN1	Kensington	372	Unnamed Creek	-33.925091	151.221139
	MAKGB1	Kogarah Bay	372	Unnamed Creek	-33.990013	151.137847
	MAKOG1	Kogarah	372	Unnamed Creek	-33.976139	151.129820
	MAKSG1	Kingsgrove	372	Wolli Creek	-33.930684	151.125128
	MALAK1	Lakemba	372	Coxs Creek	-33.899443	151.078632
	MALCH1	Leichhardt	372	Whites Creek	-33.879021	151.168008
	MALEU1	Leumeah	372	Leumeah Creek	-34.055559	150.827367
	MALIV2	Liverpool	372	Unnamed Creek	-33.931867	150.924800
	MALNV1	Lansvale	372	Long Creek	-33.888413	150.957380
	MALUG1	Lugarno	372	Boggywell Creek	-33.979833	151.050782
	MAMAR1	Maroubra	372	Unnamed Creek	-33.958894	151.224938
	MAMAS1	Mascot	372	Unnamed Creek	-33.939132	151.196541
	MAMIN1	Minto	372	Bow Bowing Creek	-34.016924	150.847323
	MAMOB1	Moorebank	372	Anzac Creek	-33.929324	150.941388
	MAMPR1	Mount Pritchard	372	Green Valley Creek	-33.877943	150.925146
	MAMRB2	Maroubra Beach	372	Unnamed Creek	-33.946403	151.258109
	MAMRV2	Marrickville	372	Unnamed Creek	-33.9193193	151.1540963
	MAPAD1	Padstow	372	Unnamed Creek	-33.933018	151.042154

Region	Site Code	SCAMP	EPL	Waterway	Latitude	Longitude
	MAPAN1	Panania	372	Kelso Creek	-33.947767	150.995946
	MAPHS1	Penhurst	372	To Poulton Creek	-33.984288	151.096078
	MAPKH1	Peakhurst	372	Unnamed Creek	-33.975034	151.068208
	MARAN1	Randwick	372	Stormwater drain	-33.929330	151.223784
	MARBY1	Raby	372	Bunbury Curran Creek	-34.005847	150.837823
	MAREV1	Revesby	372	Little Salt Pan Creek	-33.955995	151.021674
	MARUS1	Ruse	372	Smiths Creek	-34.051287	150.831306
	MARVW1	Riverwood	372	Unnamed Creek	-33.938514	151.049724
	MASMF1	Smithfield	372	Prospect Creek	-33.860508	150.957804
	MASSY1	South Sydney	372	Alexandria Canal	-33.903999	151.199013
	MASTR1	Strathfield	372	Powells Creek	-33.862265	151.086357
	MASUM1	Summer Hill	372	Hawthorne Canal	-33.891806	151.144474
	MASYD2	Sydenham	372	Unnamed Creek	-33.921699	151.156777
	MAVIL2	Villawood	372	Unnamed Creek	-33.873420	150.966287
	MAWAK2	Wakeley	372	Orphan School Creek	-33.877456	150.928437
	MAWHO1	West Hoxton	372	Unnamed Creek	-33.910774	150.821057
	MAWOD1	Woodbine	372	Bow Bowing Creek	-34.034790	150.831703
	MAWPK2	Wetherill Park	372	Prospect Creek	-33.849245	150.939151
	MAYEN2	Yennora	372	Orphan School Creek	-33.879362	150.960716
Warriewood	WWAVA2	Avalon	1784	Careel Creek	-33.630964	151.332970
	WWELH1	Elanora Heights	1784	Mullet Creek	-33.691922	151.282893
	WWNEW1	Newport	1784	McMahons Creek	-33.657814	151.315693
Brooklyn & Hornsby	BKBKL1	Brooklyn	12438	Hawkesbury River	-33.548675	151.228709
	HHCOW1	Cowan	750	Kimmerikong Creek	-33.585628	151.172362
	HHHHT1	Hornsby Heights	750	Walls Gully	-33.670957	151.102368

Region	Site Code	SCAMP	EPL	Waterway	Latitude	Longitude
	WHCHB1	Cherrybrook	1695	Pyes Creek	-33.704180	151.053207
	WHTHO2	Thornleigh	1695	Waitara Creek	-33.702315	151.080528
West Camden & Picton	PIPIC1	Picton	10555	Redbank Creek	-34.189402	150.607521
	WCCMD1	Camden	1675	Unnamed Creek	-34.077803	150.702417
	WCMAN1	Mount Annan	1675	Kenny Creek	-34.039767	150.769537
	WCNRL1	Narellan	1675	Narellan Creek	-34.028048	150.736923
	WCOKD1	Oakdale	1675	Back Creek	-34.075328	150.537106
	WCSPF1	Spring Farm	1675	Unnamed Creek	-34.069462	150.720637
Western Sydney	CHCHS1	Castle Hill WTS	1725	Cattai Creek	-33.7122818	150.983797
	NRNRC1	North Richmond	190	Redbank Creek	-33.572819	150.730599
	QHBLT1	Blacktown	1724	Breakfast Creek	-33.751324	150.897256
	QHDON1	Doonside	1724	Eastern Creek	-33.754334	150.859422
	QHOKH1	Oakhurst	1724	Bells Creek	-33.717219	150.846287
	QHQHL1	Quakers Hill	1724	Breakfast Creek	-33.742509	150.882700
	RHKEL1	Kellyville	4965	Smalls Creek	-33.687804	150.943774
	RHNKE1	North Kellyville	4965	Cattai Creek	-33.664706	150.938478
	RHRHL2	Rouse Hill	4965	Caddies Creek	-33.687840	150.928921
	RHTOP1	The Ponds	4965	Second Ponds Creek	-33.673249	150.915805
	RMFRE1	Freemans Reach	1726	Unnamed Creek	-33.554750	150.797018
	RMGLO1	Glossodia	1726	Unnamed Creek	-33.527410	150.769034
	RMHOB1	Hobartville	1726	Unnamed Creek	-33.604518	150.752005
	RMRIC2	Richmond	1726	Unnamed Creek	-33.596998	150.763076
	RMWLB1	Wilberforce	1726	Unnamed Creek	-33.559091	150.844748
	RSRVS1	Riverstone	1796	Unnamed Creek	-33.675420	150.857906
	SMBCT1	Blackett	1729	Little Creek	-33.722022	150.798306

Region	Site Code	SCAMP	EPL	Waterway	Latitude	Longitude
	SMMDR1	Mount Druitt	1729	Ropes Creek	-33.740901	150.783919
	SMSMY1	St Marys	1729	Byrnes Creek	-33.769515	150.766633
	SMWER1	Werrington	1729	Werrington Creek	-33.749862	150.756716

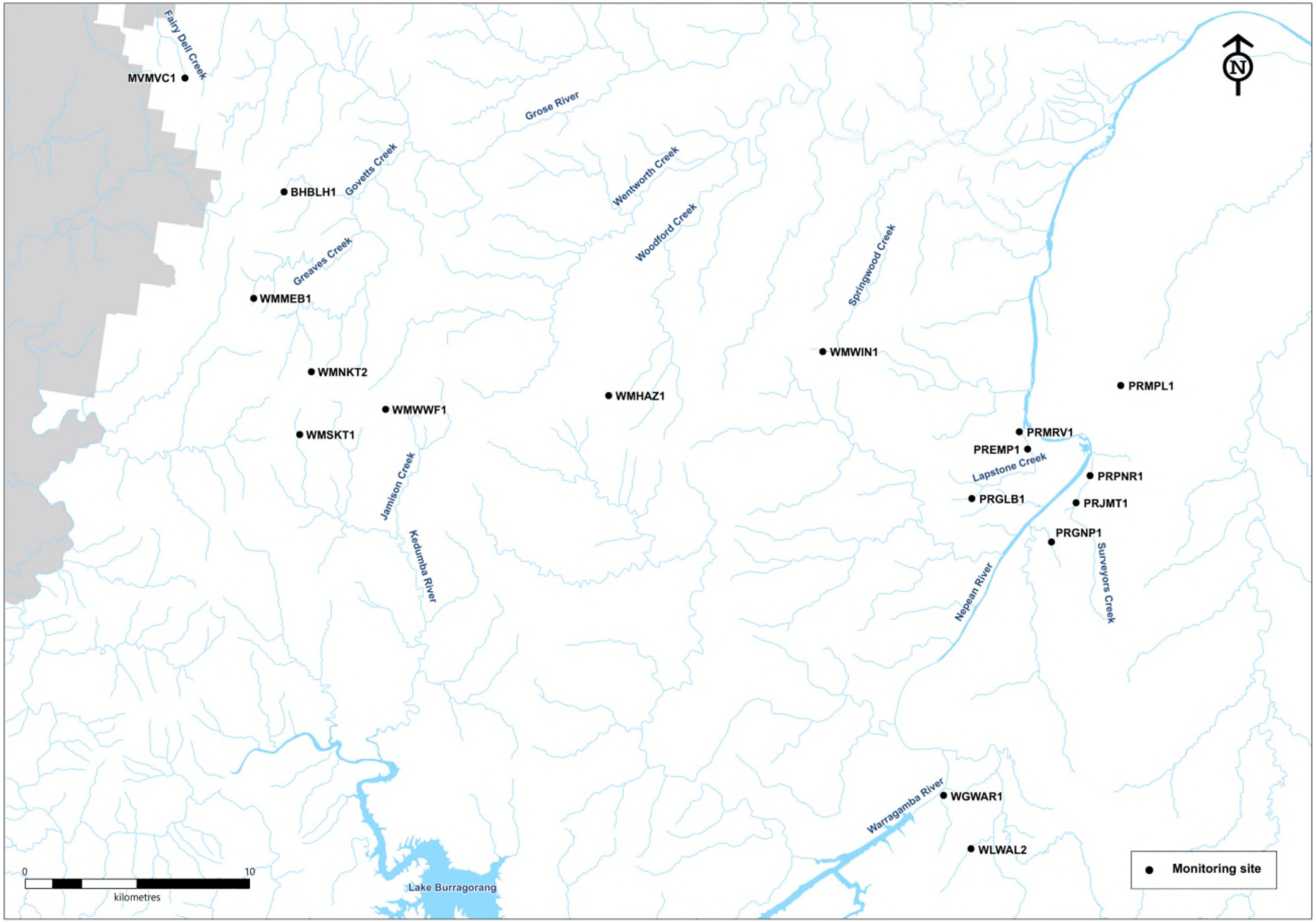


Figure 2-12 SCAMPs dry weather leakage detection monitoring sites: Blue Mountains

Figure 2-13 SCAMPs dry weather leakage detection monitoring sites: Bondi Ocean Outfall System and Cronulla Ocean Outfall System

Figure 2-14 SCAMPs dry weather leakage detection monitoring sites: Illawarra

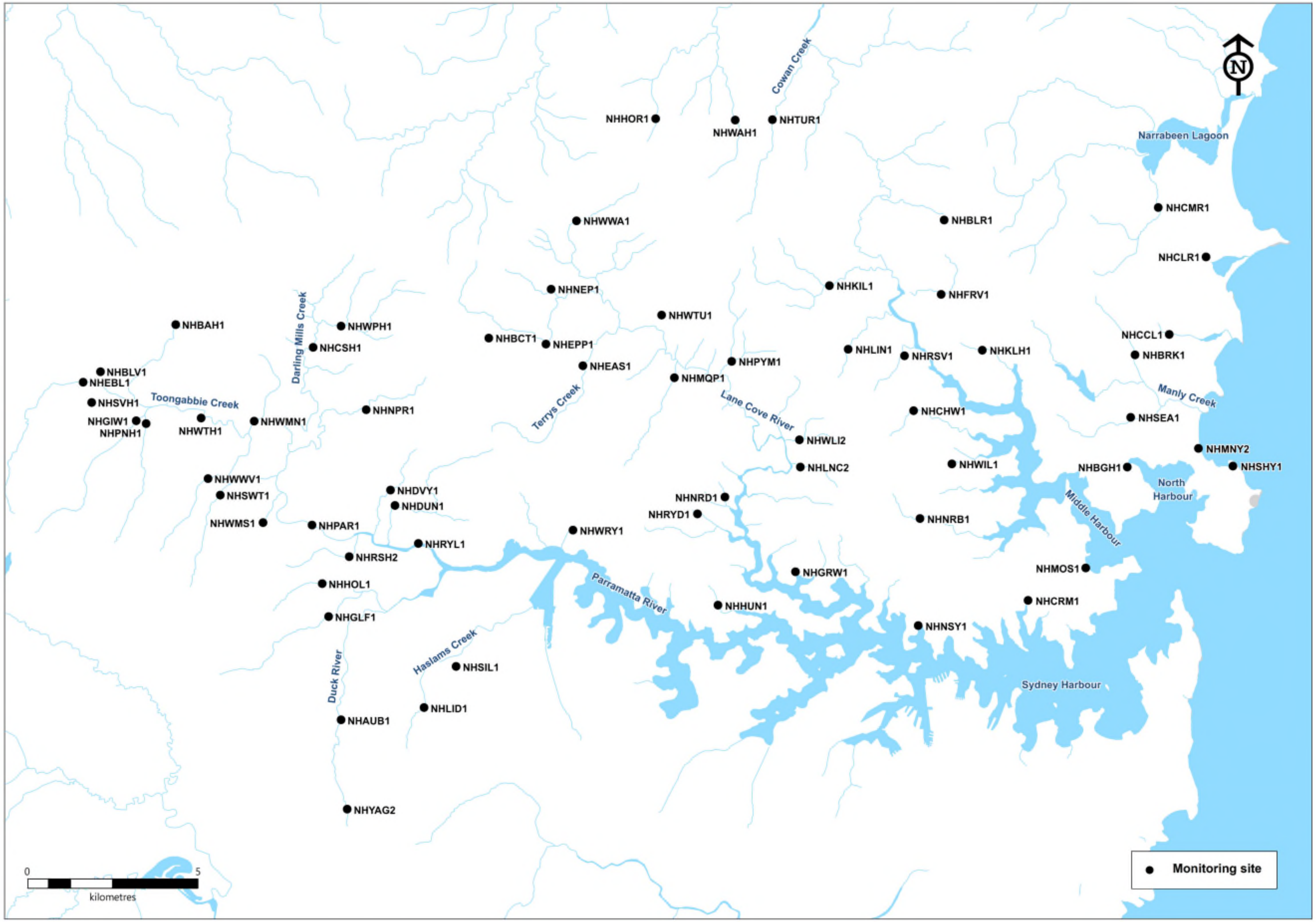


Figure 2-15 SCAMPs dry weather leakage detection monitoring sites: Northern Suburbs Ocean Outfall System

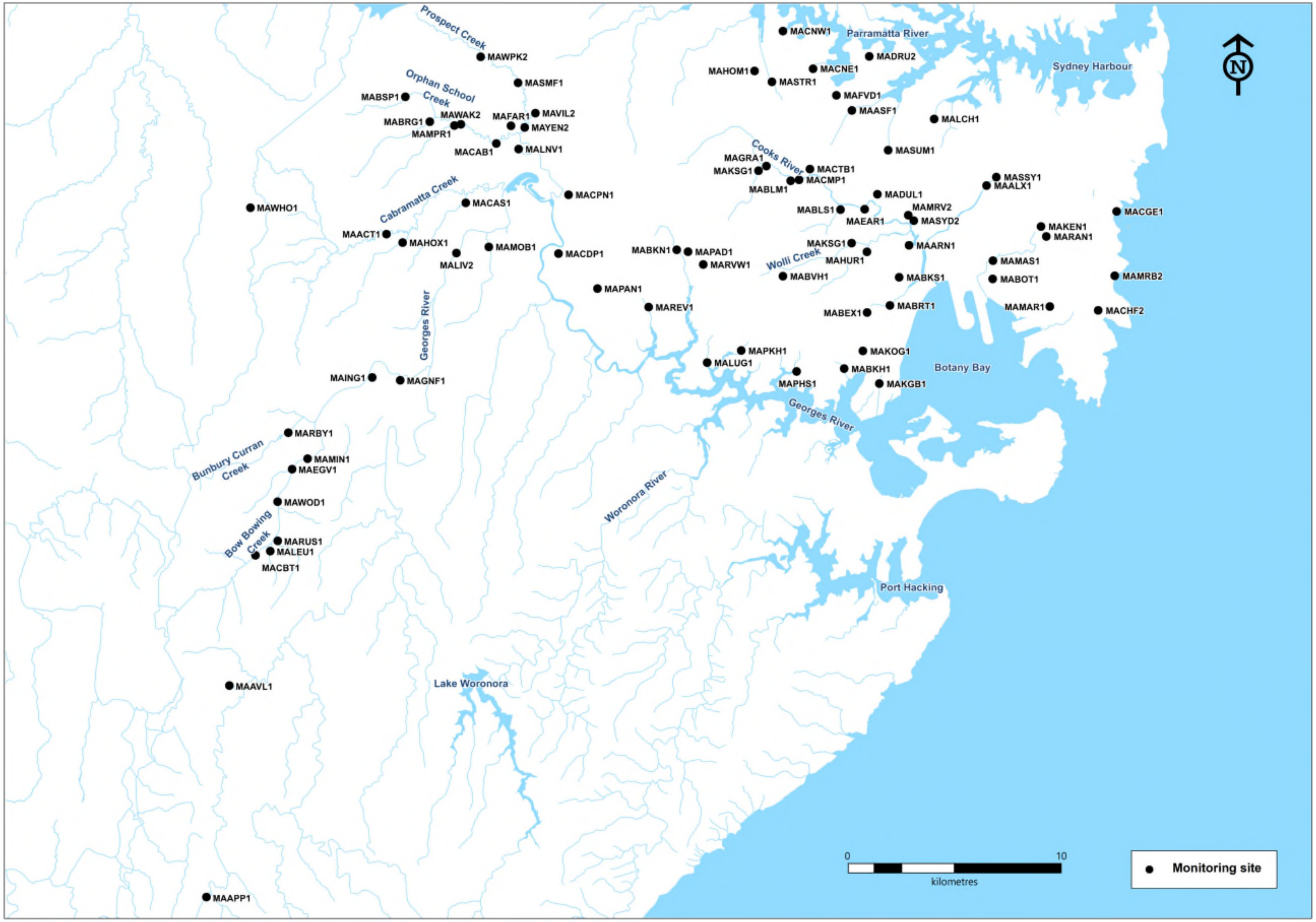


Figure 2-16 SCAMPs dry weather leakage detection monitoring sites: South Western Ocean Outfall System

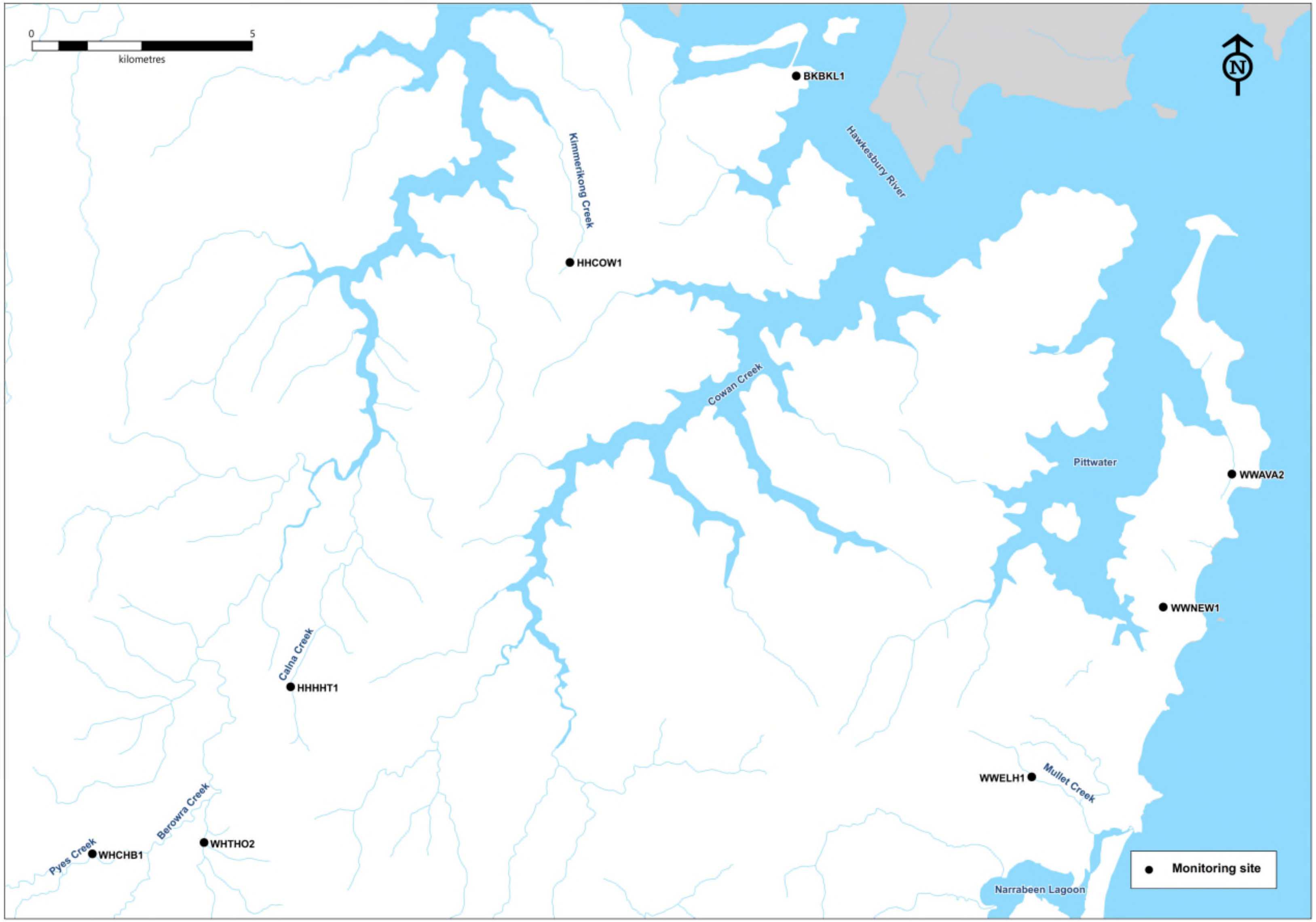


Figure 2-17 SCAMPs dry weather leakage detection monitoring sites: Warriewood and Brooklyn

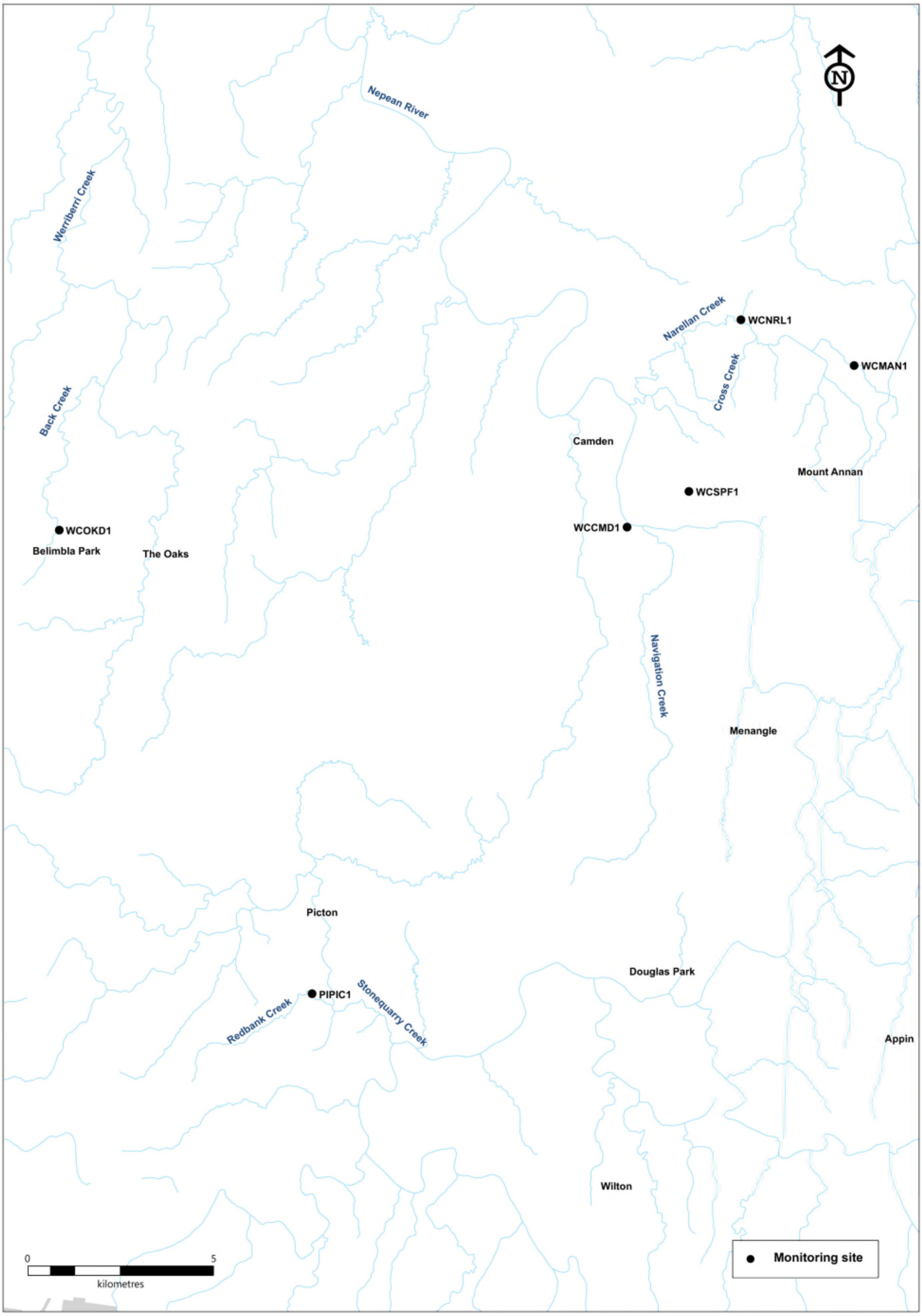


Figure 2-18 SCAMPs dry weather leakage detection monitoring sites: West Camden and Picton

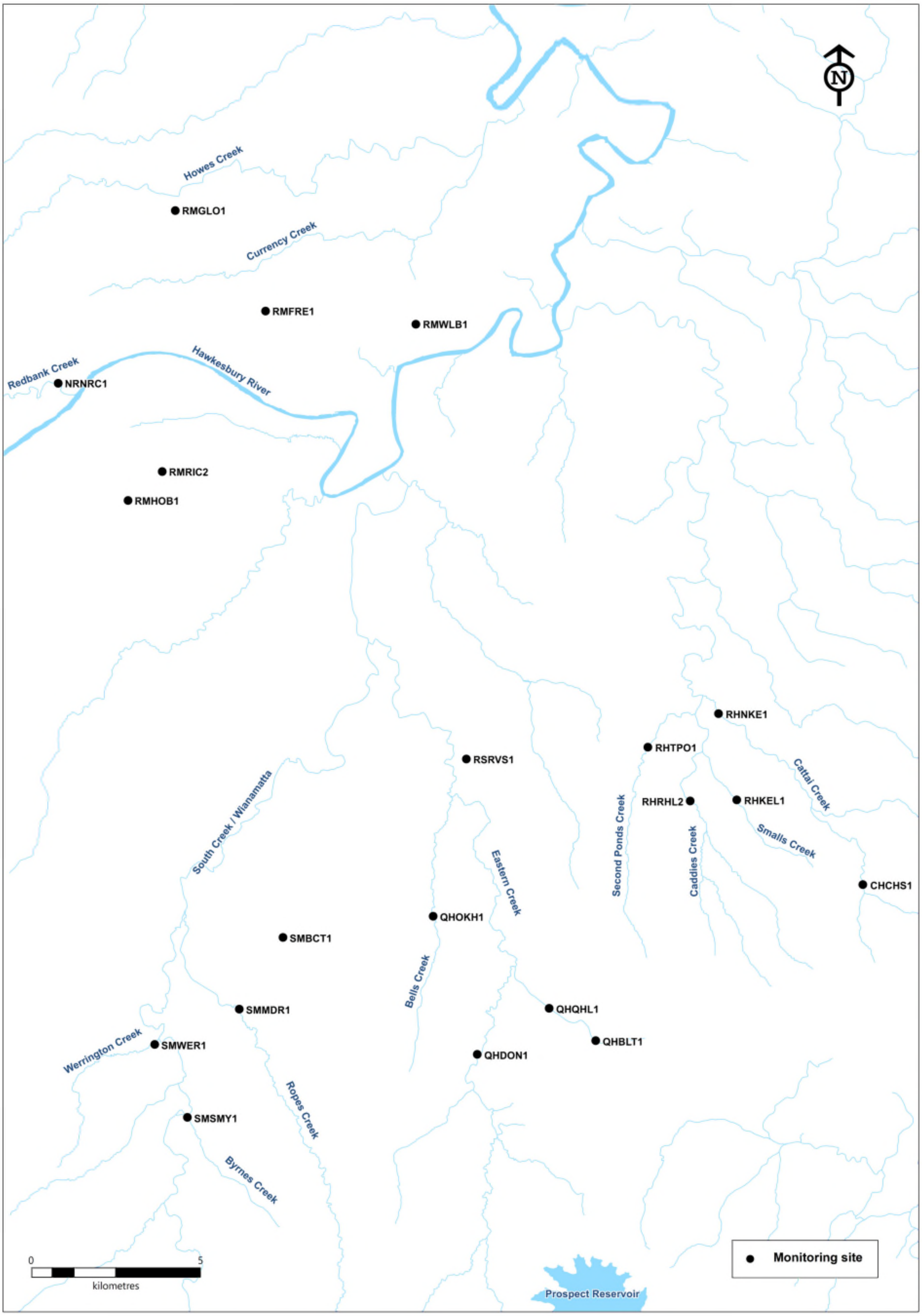


Figure 2-19 SCAMPs dry weather leakage detection monitoring sites: Western Sydney

2.8 Other monitoring programs

This section describes five other monitoring programs to understand the overall ambient condition of Sydney and Illawarra’s coastal environment:

- chlorophyll-a in estuarine sites
- water quality in lagoons
- intertidal communities (Sydney’s estuaries)
- Beachwatch

These programs are tailored to understand the general state of environment and to find (where possible) any linkage between wastewater overflows from Sydney Water’s networks reaching the environment.

2.8.1 Chlorophyll-a in estuarine sites

Rationale

The estuarine water quality monitoring program was conceptualised in 2008 based on the review and assessment of previous monitoring data. Chlorophyll-a was chosen as a sole indicator for eutrophication impacts at key sites in estuaries. In many cases, and where possible, the selected sampling sites were at or near existing Beachwatch sites in consideration of links to phytoplankton blooms and potential adverse public health outcomes.

Monitoring Program

The 16 estuarine sampling sites and the organisation responsible for sampling (Sydney Water or DPE) are listed in Table 2-17 and shown in Figure 2-20. It is noted that if any of these sampling sites be enclosed bathing areas, then sampling is to be done in open waters in the vicinity of the nominated beach. Samples are collected monthly. All samples are analysed for chlorophyll-a using the grinding method (APHA 2017, 10200-H). There is no requirement that all sites must be sampled on the same day. However, if multiple subsequent runs are arranged, then these should be within one week from each other.

Table 2-17 List of chlorophyll-a monitoring sites

Estuary	Site code	Site description	Sample collection by	Latitude	Longitude
Port Jackson	PJDR	Davidson Reserve	DPE	-33.767929	151.200343
	PJCB1	Chinamans Beach	DPE	-33.814094	151.248971
	PJLC	Lane Cove River Weir	Sydney Water	-33.791309	151.15559
	PJTB	Lane Cove River (near Tambourine Bay)	DPE	-33.828066	151.161315
	PJPRA*	Parramatta River Weir	Sydney Water	-33.813326	151.009955
	PJ015	Parramatta River at Ermington	Sydney Water	-33.819026	151.072926
	PJCB2	Cabarita Beach	DPE	-33.841448	151.11863
	PJDFP	Dawn Fraser Pool	DPE	-33.853237	151.172823
Botany Bay and Georges River	CR04A*	Alexandria Canal	Sydney Water	-33.926305	151.172497
	GR01	Cooks River (downstream Muddy Creek)	Sydney Water	-33.946731	151.164142
	GR22	Liverpool Weir	Sydney Water	-33.925077	150.928399
	GR19A*	Upper Georges River (downstream of Harris Creek)	Sydney Water	-33.952433	150.978981
	GROB	Oatley Baths	DPE	-33.987645	151.083994
	GRRB	Ramsgate Baths	DPE	-33.997622	151.144673
	GRFB	Frenchman's Bay	DPE	-33.987235	151.231264
Port Hacking	PHLPB	Lilli Pilli Baths	DPE	-34.069481	151.110795

* Site GR19 is GR19A since Jan 2018, CR04 was CR04A from Jan 2018 and CR04A to CR04B since August 2022. Site PJPR is PJPRA since Nov 2017.

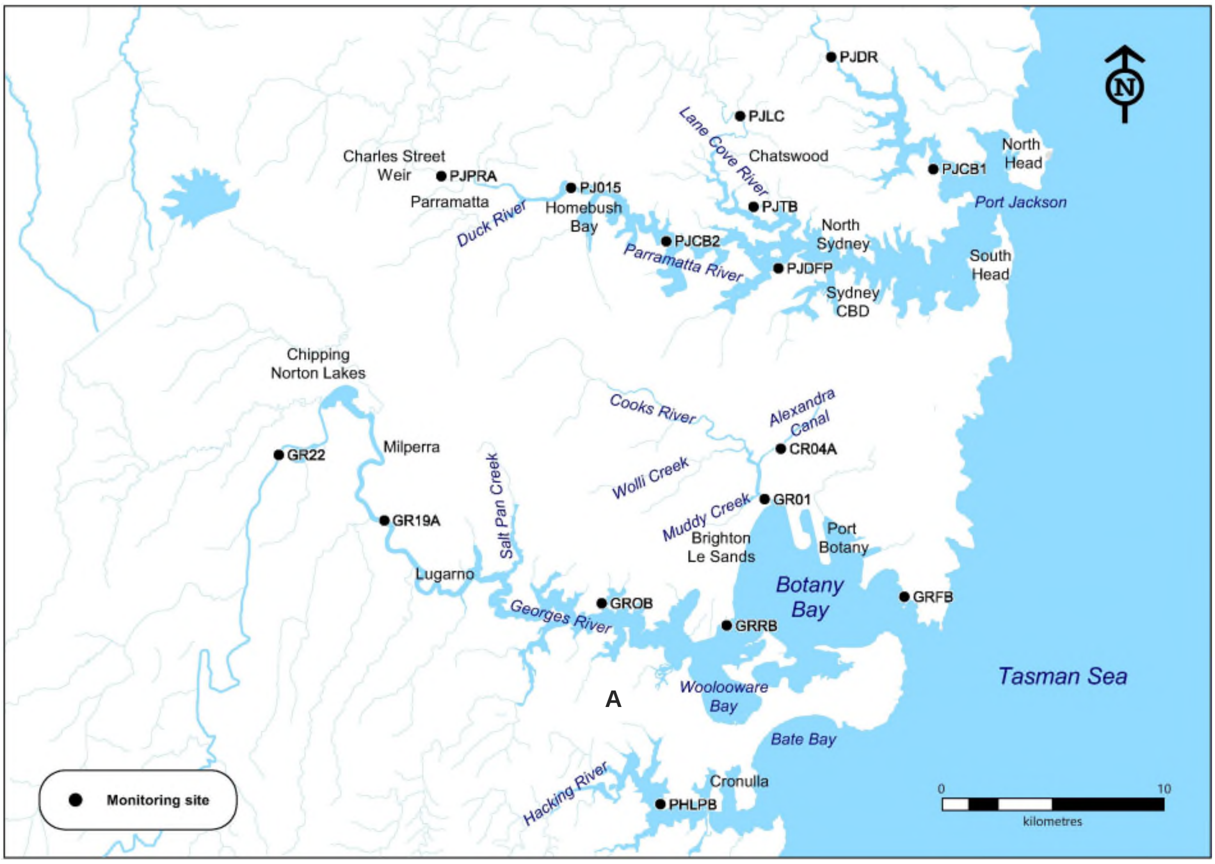


Figure 2-20 Estuarine chlorophyll-a monitoring sites

2.8.2 Water quality in lagoons

Monitoring Program

The coastal lagoons program monitors conductivity, chlorophyll-a and *Enterococci* monthly (Table 2-19). All monitoring sites are listed in Table 2-18 and shown in Figure 2-21.

Once in every 3 years these sites are monitored more frequently at 6-day intervals. These high frequency campaign monitoring data are intended for a more comprehensive assessment on recreational water quality of these lagoons. High frequency campaign monitoring occurred in 2009-10, 2012-13, 2015-16, 2018-19 and 2021-22.

Table 2-18 List of coastal lagoon monitoring sites

Site code	Site description	Longitude	Latitude
NL01	Narrabeen Lagoon, Canal entrance upstream of Ocean Bridge	151.3019	-33.7029
NL06	Narrabeen Lagoon, 150 m Nth of confluence of South Creek	151.2717	-33.7196
DW01	Dee Why Lagoon, entrance at Long Reef	151.3023	-33.7461
CC01	Curl Curl Lagoon, entrance at North Curl Curl	151.2968	-33.7650
ML03	Upper Manly Lagoon at footbridge in Nolan Reserve	151.2719	-33.7795
ML01	Mouth Manly Lagoon, upstream Queenscliff Beach Bridge	151.2864	-33.7853
WL83	Wattamolla Lagoon	151.11544	-34.1375

Table 2-19 List of analytes and methods for coastal lagoon monitoring

Water quality analyte	Detection limit	Unit of measurement	Method/Reference	Place of measurement
Conductivity	7	µS/cm	APHA (2017) 2510 B, 4500-O G, 4500-H B	Field
Chlorophyll-*a*	0.2	µg/L	APHA (2017) 10200-H	Laboratory
Enterococci	<1	cfu/100 mL	AS/NZS 4276.9 :2007	Laboratory

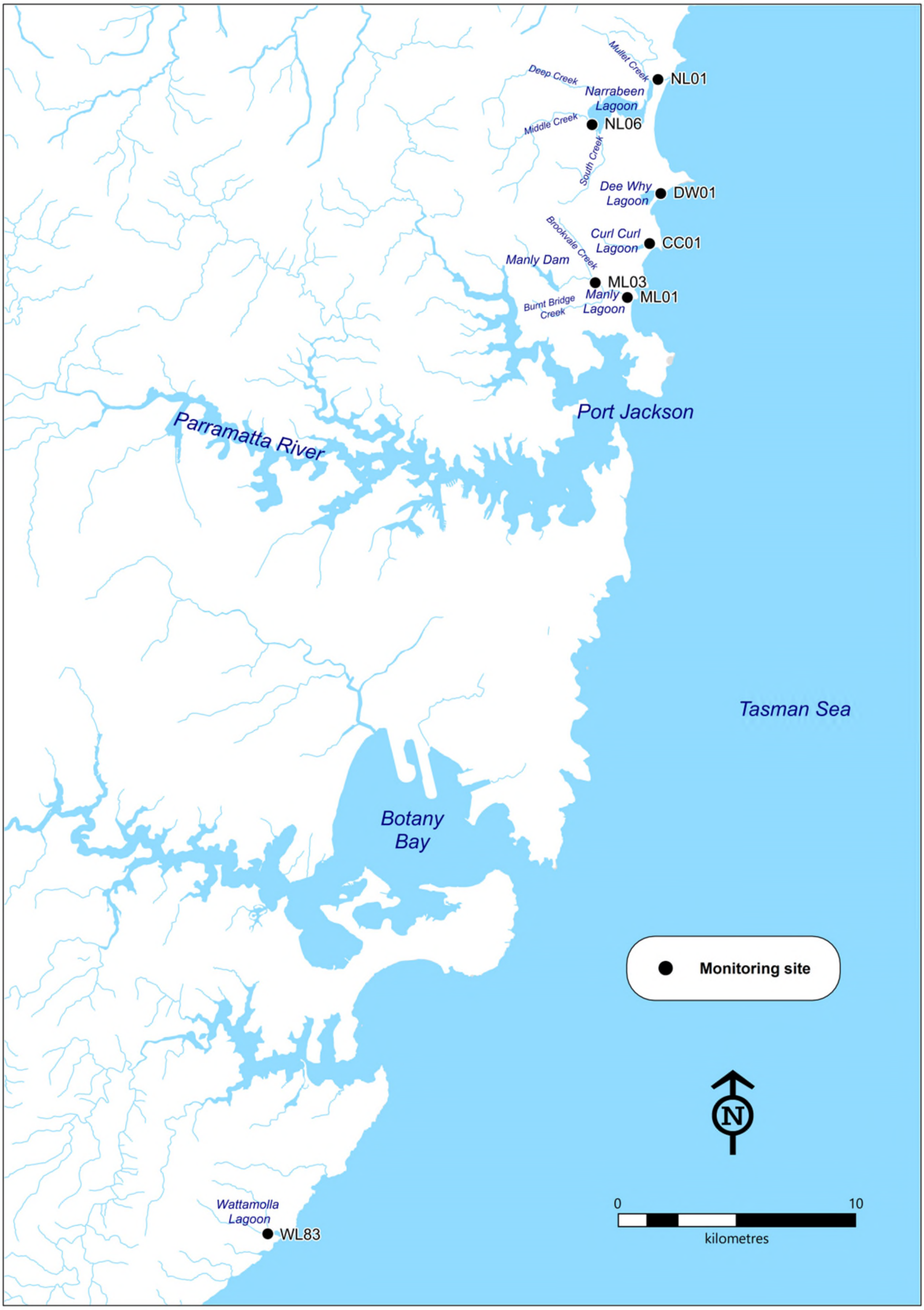


Figure 2-21 Water quality monitoring sites, lagoons

2.8.3 Intertidal communities – Sydney estuaries

Rationale

The objective of this program is to measure the general ambient condition of estuaries that may be impacted by Sydney Water's activities.

Monitoring Program

This monitoring program assesses the community assemblages on rocky substrates in the intertidal zone at 27 sites in Port Jackson, Botany Bay, Port Hacking and the Lower Hawkesbury once per year during the period of late winter to late spring (Table 2-20 and Figure 2-22). Monitoring in this period reduces the influence of annual recruitment of settling larvae from most species that mainly happens in summer to autumn.

The species types and abundance of organisms are measured on suitable intertidal rocky substrates across seven quadrats (0.25 m^2) at each site. The method focuses on the oyster habitat in the mid tidal area of the littoral zone. The position of each replicate within a site is re-randomised on each occasion. The quadrat technique for sampling an intertidal community has been a standard method in marine ecology for at least two decades. For a more detailed description of the technique refer to Kingsford and Battershill (1998).

All settlement organisms within each quadrat are identified to the lowest taxonomic level that is practical in the field using a standard taxonomic reference (Edgar, 1997). We measure seven randomly allocated quadrats at each site.

If suitable mud flats occur near the rock platform site, artificial substrates (untreated hardwood panels) are deployed to measure recruitment (settlement) of intertidal organisms.

We deploy four hardwood panels for four months of exposure (January to May and July to November each year) in the intertidal zone. Most settling organisms are clearly visible without a microscope and are either barnacles (predominantly *Balanus spp.* But with a number of other genera belonging to the suborder Balanomorpha, eg *Elminius* and *Hexaminius*), tube worms (*Galeolaria spp.*) or green algae (dominated by *Entromorpha spp* and *Ulva lactuca*).

Table 2-20 Estuarine intertidal communities monitoring sites

Estuary	Site code	Site description	Longitude	Latitude
Port Jackson	PJ01	Silverwater Bridge-Wilson Park	151.05619	-33.82469
	PJ025	Kissing Point Bay	151.10365	-33.83020
	PJ082	Iron Cove-Hawthorn Canal arm	151.15007	-33.87219
	PJ115	Lavender Bay	151.20740	-33.84414
	PJ33	Rushcutters Bay	151.23158	-33.87167
	PJ13	Little Sirius Cove	151.23773	-33.84083
	PJ28	Quakers Hat Bay	151.23910	-33.81562
	PJ05	Lane Cove River-Woolwich Baths	151.17029	-33.83905
	PJ295	Sugarloaf Bay-Castlecrag, control site	151.23058	-33.79120
	PJ315	Bantry Bay, control site	151.22978	-33.77867
	PJ245*	Balmoral	151.25240	-33.82292
Botany Bay	CR04	Alexandra Canal at Canal Bridge Road	151.17910	-33.91997
	CR06	Wolli Creek	151.15370	-33.92685
	GR01	Cooks River (d/stream Muddy Creek)	151.16050	-33.94601
	GR085	Quibray Bay-Kurnell	151.18882	-34.00771
	GR175	Georges River (Edith Bay)	151.04501	-33.99098
	GR115	Georges River (Kyle Bay)	151.10406	-33.98964
	GR15	Woronora River/Como	151.06197	-33.99460
	GR18	Salt Pan Creek downstream road bridge	151.04418	-33.97025
Port Hacking	PH04	Gunnamatta Bay	151.14848	-34.05494
	PH05	Maianbar	151.12663	-34.08032
	PH10	Wants Beach Port Hacking River	151.07684	-34.06182
	Phe05	Southwest Arm	151.09639	-34.08595
Pittwater	PW10	McCarrs Creek, control site	151.27405	-33.64979
	PW12	The Basin, control site	151.29298	-33.60576
Hawkesbury	N06**	Marlo Bay Hawkesbury River	151.16301	-33.46998
	NB115**	Kimmerikong Bay Hawkesbury River	151.15595	-33.54929
	NCC01***	Coal and Candle Creek, control site	151.24543	-33.64463
	NCC02***	Smiths Creek, control site	151.21154	-33.64588

* Atypical site that is predominantly wave exposed, no further monitoring after 2012

** monitoring finished 2012 – at these 2 sites the oyster disease QX occurred in oyster leases in the Hawkesbury estuary (Summerhayes et al. 2009a) in inland areas west of the Brooklyn Road bridge (Summerhayes et al. 2009b)

*** monitoring commenced at these 2 sites situated east of the Brooklyn Road bridge in 2012 to replace N06 and NB115

Figure 2-22 Estuarine intertidal communities monitoring sites

2.8.4 Recreational water quality – Harbour beaches

Rationale

Sydney Water contributes to DPE's Beachwatch Monitoring Program by collecting samples and undertaking conductivity and *Enterococci* testing for 18 beaches in the Illawarra region. DPE shares Beachwatch data for 97 other beaches collected under DPE's Beachwatch Monitoring Program. Results from DPE's Beach Monitoring Program are then analyzed to understand potential impact of dry weather wastewater leakages on beach water quality.

Beachwatch monitoring program overview

Enterococci and conductivity data are collected predominantly by DPE for the Beachwatch program. DPE monitors 41 Sydney coastal beaches and 56 harbour beaches of Botany Bay, lower Georges River, Port Hacking, Port Jackson, Middle Harbour and Pittwater at locations listed in Table 2-21 and Table 2-22 as part of the Beachwatch Program. Location maps for these Beachwatch sites are provided in Figure 2-23, Figure 2-24, Figure 2-25 and Figure 2-26. Sydney Water monitors 18 Illawarra coastal beach monitoring sites on behalf of DPE (Table 2-23, Figure 2-27).

Sydney and Illawarra coastal beach sites are monitored for *Enterococci* and conductivity (Table 2-24 Figure 2-27) at 6-day intervals throughout the year, except Austinmer, Thirroul and Kiama, which are only monitored from October to April. Harbour beaches are monitored for *Enterococci* and conductivity at 6-day intervals from October to April and monthly outside of this period.

Please see the [State of the beaches 2022–23 | NSW Environment and Heritage] for more information on this program.

Table 2-21 List of Beachwatch coastal monitoring sites, monitored by DPE

Northern Sydney	Central Sydney	Southern Sydney
Palm Beach	Bondi Beach	Boat Harbour
Whale Beach	Tamarama Beach	Greenhills Beach
Avalon Beach	Bronte Beach	Wanda Beach
Bilgola Beach	Clovelly Beach	Elouera Beach
Newport Beach	Gordons Bay	North Cronulla Beach
Bungan Beach	Coogee Beach	South Cronulla Beach
Mona Vale Beach	Maroubra Beach	Shelly Beach (Sutherland)
Warriewood Beach	South Maroubra Beach	Oak Park
Turimetta Beach	South Maroubra Rockpool	
Narrabeen Lagoon (Birdwood Park)	Malabar Beach	
North Narrabeen Beach	Little Bay	
Bilarong Reserve		
Collaroy Beach		
Long Reef Beach		
Dee Why Beach		
North Curl Curl Beach		
South Curl Curl Beach		
Freshwater Beach		
Queenscliff beach		
North Steyne Beach		
South Steyne Beach		
Shelly Beach (Manly)		

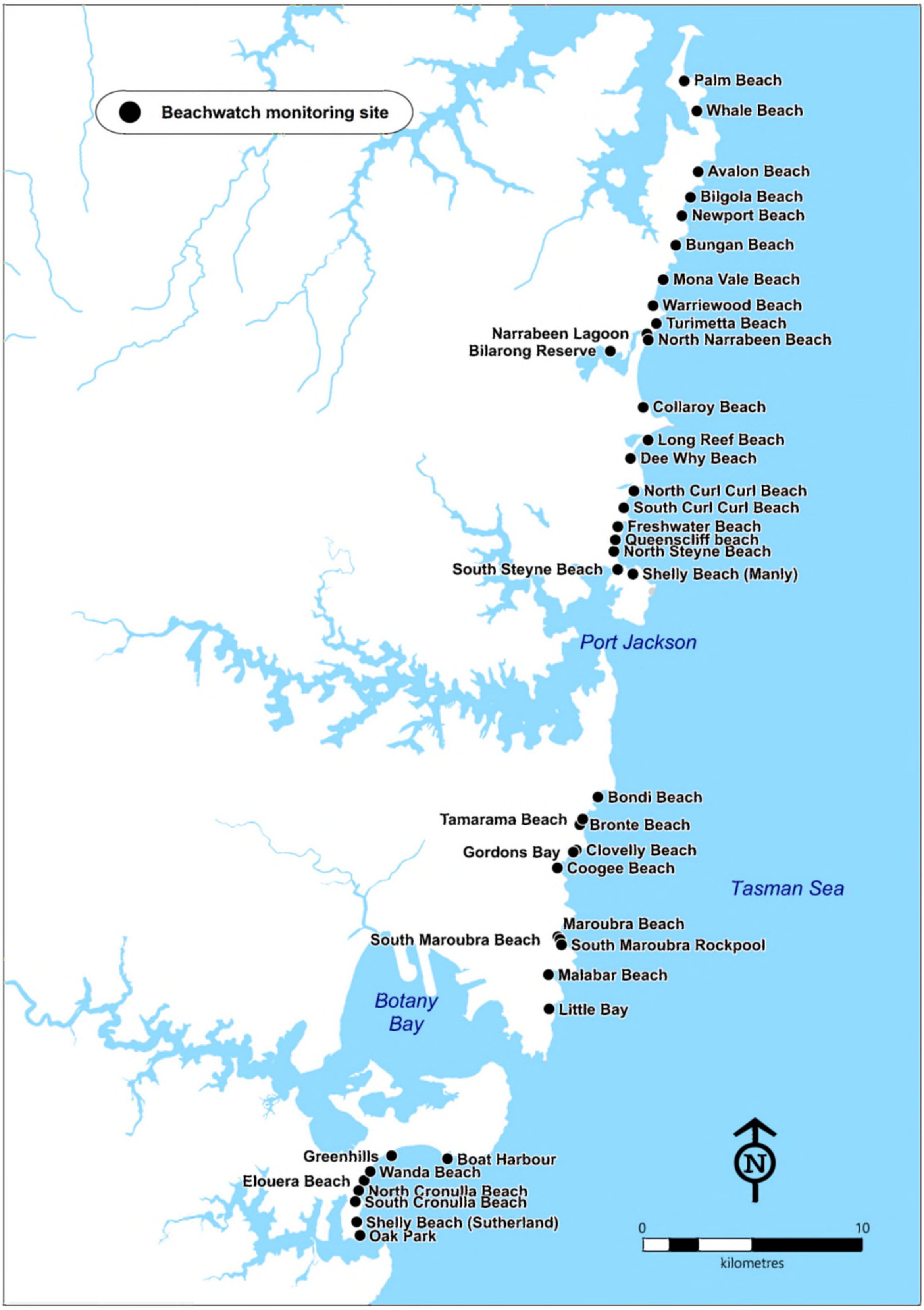


Figure 2-23 Beachwatch Sydney coastal monitoring sites

Table 2-22 List of Beachwatch harbour monitoring sites, monitored by DPE

Botany Bay and Georges River	Port Hacking	Port Jackson	Middle Harbour	Pittwater
Silver Beach	Jibbon Beach	Watsons Bay	Balmoral Baths	Great Mackerel Beach
Como Baths	Hordens Beach	Parsley Bay	Edwards Beach	The Basin
Jew Fish Bay Baths	Lilli Pilli Baths	Nielsen Park	Chinamans Beach	Elvina Bay
Oatley Bay Baths	Gymea Bay Bath	Rose Bay Beach	Northbridge Baths	Bayview Baths
Carss Point Baths	Gunamatta Bay Baths	Murray Rose Pool (formerly Redleaf Pool)	Davidson Reserve	South Scotland Island
Sandringham Baths		Dawn Fraser Pool	Gurney Cr Baths	North Scotland Island
Dolls Point Bath		Chiswick Baths	Clontarf Pool	Taylors Point Baths
Ramsgate Bath		Cabarita Beach	Forty Baskets Pool	Clareville Beach
Monterey Baths		Woolwich Baths	Fairlight Beach	Paradise Beach Baths
Brighton Le Sands Bath		Tambourine Bay	Manly Cove	Barrenjoey Beach
Kyeemagh Baths		Woodford Bay	Little Manly Cove	
Foreshores Beach		Greenwich Baths		
Yarra Bay		Hayes St Beach		
Frenchmans Bay		Clifton Garden		
Congwong Bay		Camp Cove*		

* Monitored from 2015

Figure 2-24 Beachwatch monitored harbour sites in Botany Bay, Georges River and Port Hacking

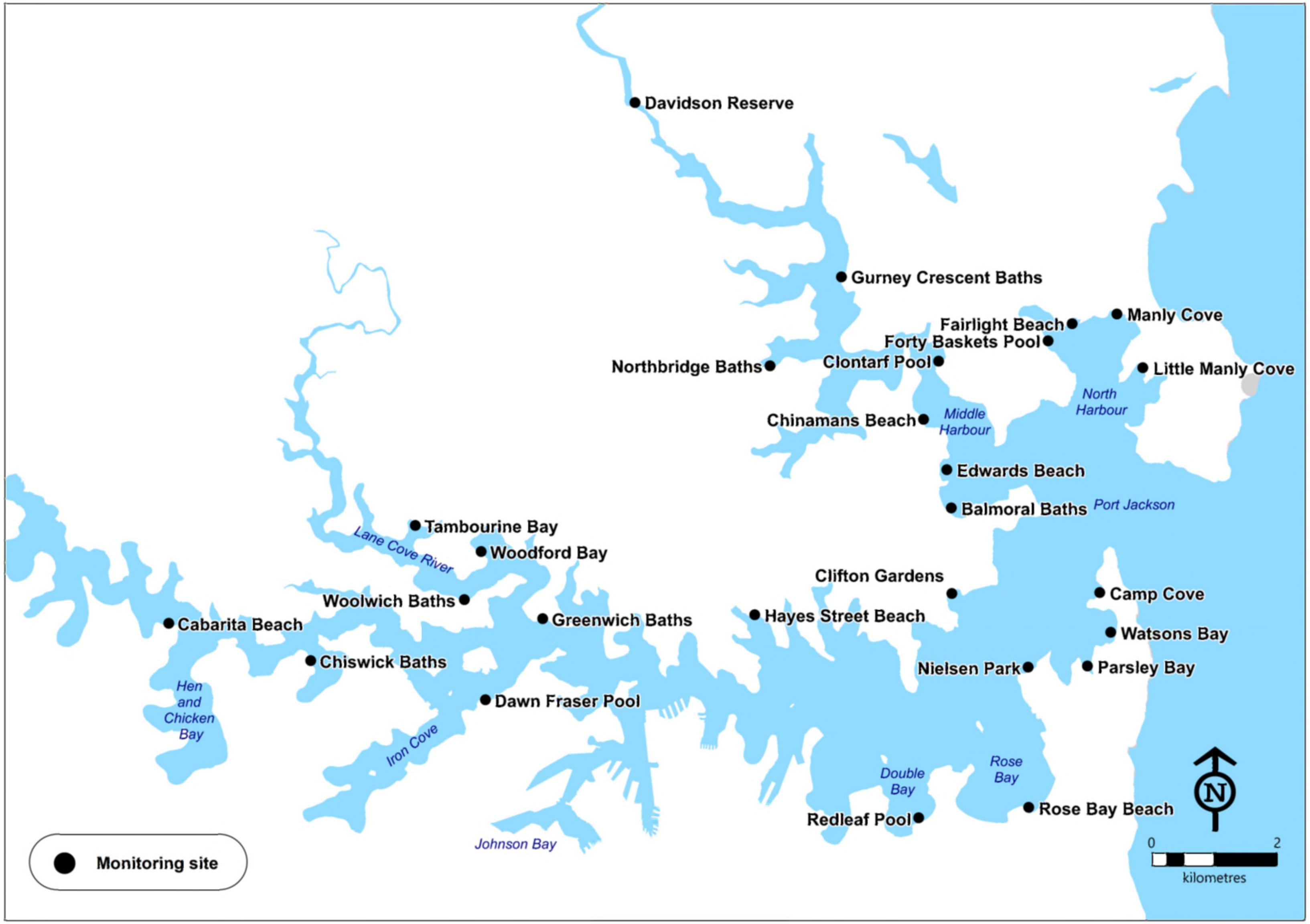


Figure 2-25 Beachwatch monitored harbour sites in Middle Harbour and Port Jackson

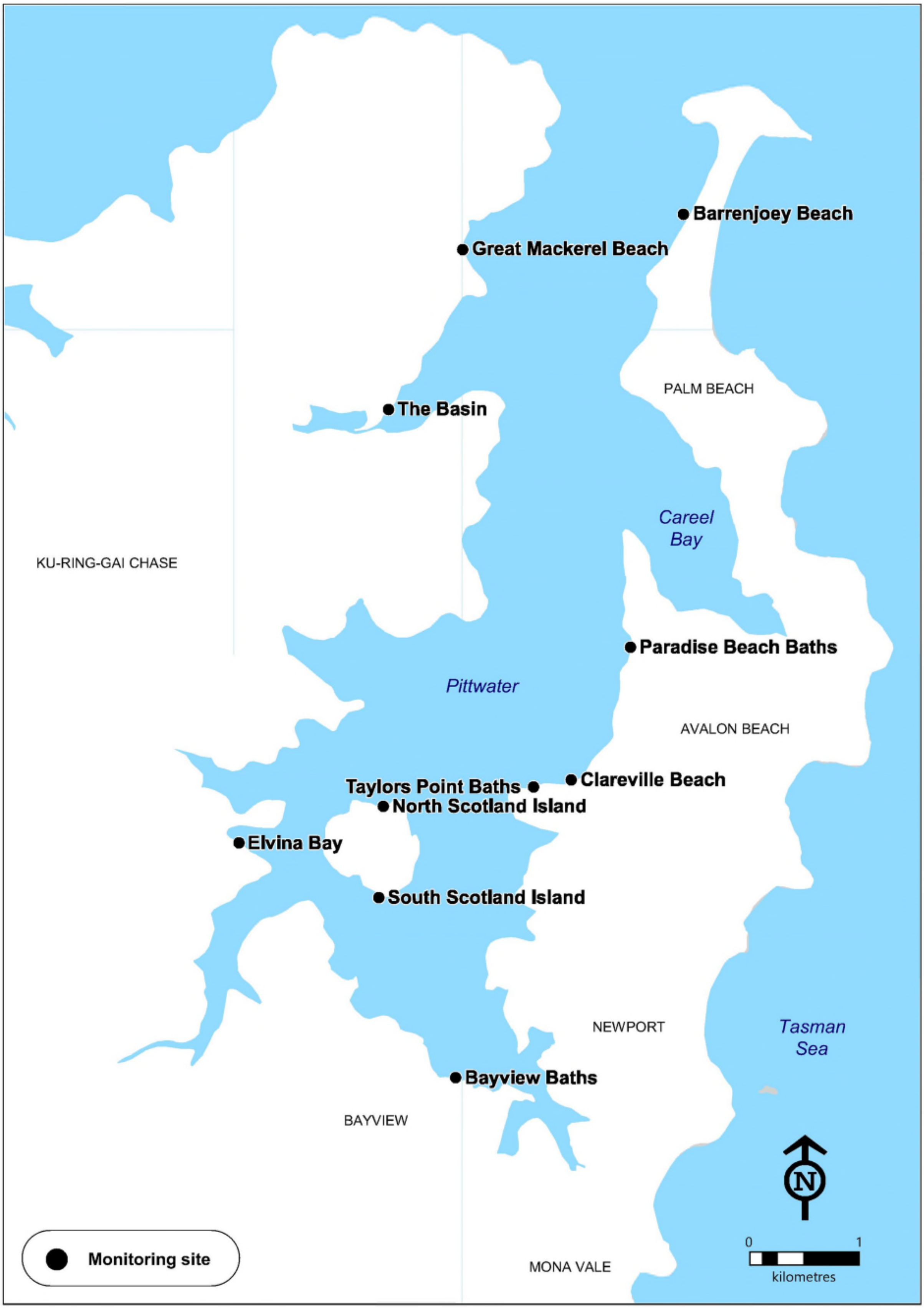


Figure 2-26 Beachwatch monitored harbour sites in Pittwater

Table 2-23 List of Beachwatch Illawarra beach sites, monitored by Sydney Water on behalf of DPE

Wollongong	Shellharbour	Bombo
Austinmer Beach	Entrance Lagoon Beach	Boyd's Jones Beach
Thirroul Beach	Warilla Beach	Bombo Beach
Bulli Beach	Shellharbour Beach	Kiama beach
Woonona Beach		Werri Beach
Bellambi Beach		
Corrimal Beach		
North Wollongong Beach		
Wollongong Beach		
Coniston Beach		
Fisherman's Beach		
Port Kembla Beach		

Table 2-24 List of analytes and methods for Beachwatch monitoring

Water quality analyte	Detection limit	Unit of measurement	Method/Reference	Place of measurement
Conductivity	7	µS/cm	APHA (2017) 2510 B, 4500-O G, 4500-H B	Field
Enterococci	<1	cfu/100mL	AS/NZS 4276.9 :2007	Laboratory

Figure 2-27 Beachwatch Illawarra coastal beach monitoring sites

2.9 Quality control and quality assurance

Sydney Water's Laboratory Services is accredited by NATA for technical competence to operate according to *ISO/IEC17025 for sampling and testing under the scope of accreditation No.63*.

2.9.1 Water quality sampling and quality control

The sampling quality control procedures routinely applied to field collection activities are:

- appropriate sample container type and pre-preparation
- field decontamination procedures
- field validation sample collection
- suitable sample preservation
- sample handling and storage procedures
- chain of custody procedures.

The following descriptions provide further detail for each of the above procedures.

Sample containers, pre-preparation and preservation

The container types required for each sample matrix were identified in work specifications. Containers are chosen to limit the potential for contamination. Sample containers, pre-preparation and preservation measures are consistent with Australian Standards, APHA or USEPA standards.

Field decontamination

Decontamination procedures are applied to all equipment used in the field that come into direct contact with any sample to be chemically analysed. The use of surfactants, acid and acetone is kept to a minimum. Sampling equipment is decontaminated after sampling and before sampling at the next site. Sampling equipment is rinsed three times with the water body. Sample containers are generally rinsed with the sample matrix (including filtered sample) at least once, with the exception of sample containers that contain a preservative.

Sample handling and storage

All sample handling and storage follows appropriate methods described in APHA and the USEPA guidelines. Contracted analytical laboratories generally commence analysis within 24 hours of sample collection. Where samples are not analysed within 24 hours, approved sample preservation method followed.

Chain of custody

Every sample collected in the field is labelled with a unique identifier code. At the completion of each sampling event, a chain of custody form is prepared to document the number, date, and type of samples collected. The chain of custody form accompanies the sample to document the handling and transfer of samples from the time they are collected to their receipt into the laboratory. These forms trace the possession and handling of samples by all parties. Chain of custody forms are signed, and copies retained by each party involved in sample transfer.

2.9.2 Analytical quality control

The analysis of samples is done by a NATA accredited laboratory, generally Sydney Water Laboratory Services or a suitably qualified external laboratory. Each laboratory is required to implement a range of quality control checks on laboratory procedures and subsequent sampling and handling procedures. The number, type and frequency of these checks vary depending on the size and range of analyses required.

The types of quality control samples used are described below:

Field duplicate

Field duplicates are collected by field sampling teams and analysed by the contracted laboratory to verify the precision of laboratory and/or sampling methodology. The samples are labelled so the laboratory cannot discern these quality control samples from environmental samples.

Field blank

To identify contamination introduced during field activities, field blanks are collected during field sampling operations. A field blank consists of ultra-pure water (17-18.4 megaohm resistivity) decanted into appropriate sample containers at a nominated sample collection site. The samples are labelled so the laboratory cannot discern these quality control samples from environmental samples.

Trip blank

Trip blanks are used to identify contamination that may occur during sample transportation or from the containers themselves. The trip blanks consist of a prepared water sampling container filled with ultra-pure water (17-18.4 megaohm resistivity) before commencement of field collection operations. These samples are transported together with all other sampling containers to the sampling site. The trip blanks remain unopened for the duration of the sampling event and are transported under the same conditions as environmental samples to the contracted laboratory for analysis. The samples are labelled so the laboratory cannot discern these quality control samples from environmental samples.

Method blank

Method blanks are used to detect laboratory contamination. Method blanks contain all reagents and undergo all procedural steps used for analysis. If the equipment used for sampling is dedicated equipment, that is not reused to obtain other samples, no method blank is necessary.

Laboratory duplicate

A laboratory duplicate is an environmental sample that is split into two separate samples by the contracted laboratory and analysed as separate samples. They are used to verify that the per cent difference between each separate result is within acceptable control limits. Per cent differences exceeding the specified limits signal the need for procedure evaluation, provided that the excessive difference between the samples is not matrix-related.

Certified reference material (CRM)

A material containing known quantities of target analytes in solution or in a homogeneous matrix. CRMs are used to document the bias of the analytical process. CRM's are reference standards with documented traceability back to core SI units.

Laboratory fortified matrix and duplicate

A matrix spike is an environmental sample to which known quantities of selected compounds have been added. Matrix spikes are processed as part of the analytical batch and used to verify method accuracy. Analysed in duplicate, matrix spikes verify both method accuracy and precision. If recovery values for the added compounds fall within specified limits, the analytical process is considered in control. Recovery values not within the specified limits, signal the need for procedure evaluation, provided that unacceptable recoveries are not related to the sample matrix.

Laboratory fortified blank

A blank spike is an aliquot of water or solid matrix to which selected compounds are added in known quantities. The blank spike is processed as part of the analytical batch and is used to determine method efficiency. If recovery values for the added compounds fall within specified limits, the analytical process is considered in control. Recovery values not within the specified limits signal the need for procedure evaluation.

Surrogate

Surrogate compounds are virtually identical to the analytes of interest but do not occur in nature and are added to samples prior to extraction in a known amount to document analytical performance.

Calibration

Calibration of analytical instruments followed the requirements specified by the appropriate method and NATA and/or Australian Standards. For all analyses, calibration is checked (or conducted) at the beginning of each analytical sequence or as necessary if the continuing calibration acceptance criteria are not met.

3 Data analysis and graphical presentation methods

3.1 Data collation

Generally, all STSIMP project data are used for presenting and assessing in this report. However, for the Hawkesbury-Nepean River sub-program receiving water quality and freshwater macroinvertebrates data collected by other monitoring programs are also used for assessing the i mpact of WRRF discharges (see sections 2.2.3 and 3.2.2).

In addition to presenting the various wastewater and environmental information collected by the STSIMP, this report also uses *Enterococci* and conductivity data of 97 Sydney Beaches and Harbour sites collected by the DPE.

Rainfall data are also collated from the catchment specific gauging stations run by Sydney Water or Bureau of Meteorology (BOM) (for details see 3.2.1).

Data collected between July 2022 and June 2023 was used to assess the current year's performance. However, historical data collected over the previous years (where available) was also used to compare 2022-23 performance to the last nine years or to a period available under the respective indicators.

Data visualisation and statistical analyses vary considerably across monitoring programs but there are also some similarities. Some improvements were made in this year's data report to apply unified approach across programs where possible as recommended by Van Dam et al. 2023.

3.2 Data analysis and presentation

A formal gated analysis workflow has been included as recommended by van Dam et al (2023). This allows a clear, efficient and consistent step through the process of analysing and interpreting the results with the aim of identifying whether Sydney Water's operations have resulted in an impact and, if so, the nature, magnitude and causes of the impact.

The unified analysis workflow comprises three formal Gates, as follows:

- Gate 1 – Undertake routine annual analyses of monitoring data
- Gate 2 – Assessment of results of Gate 1 analyses to determine the likelihood that any identified impacts were caused by Sydney Water
- Gate 3 – Where Sydney Water impacts are identified, undertake more detailed analyses to better establish the cause(s), nature and magnitude of impacts.

For this data report, Gate 1 workflows are implemented. Gate 2 and Gate 3 analysis workflows will be considered subsequently in next data report (2023-24) and interpretive report (2024-25).

3.2.1 Wastewater quantity, quality, toxicity and pollutant loads

Data preparation and analysis

Wastewater quantity and quality data sets were used to determine the performance of each WRRF during 2022-23 with respect to the EPLs. To understand how 2022-23 compared to recent years (previous nine years) all wastewater pollutant analytes were tested statistically for any significant differences under an Analysis of Variance (ANOVA) with a single fixed factor ‘Period’, with two levels. These levels were represented by data from ‘the current 2022-23 year’ compared against the ‘previous nine years of data (2013-14 to 2021-22)’ when applicable.

Sydney Water commenced Biochemical Oxygen Demand (BOD) monitoring from September 2020. Historically Sydney Water have monitored Carbonaceous Biochemical Oxygen Demand (CBOD) in WRRF discharges. Therefore, 2022-23 data for BOD could only be compared against previous 2 years (2020-22).

Method detection limits for nine other analytes were higher after July 2016 (hydrogen sulphide, copper, iron, zinc, arsenic, nickel, chromium, manganese and molybdenum), following an in-house shift to more standard detection limits. Statistical tests for these analytes were based on 2022-23 data with the previous 6 years (2016-22). Statistical tests were performed for all analytes with licence concentration limits. The results are shown on the plots. Statistical tests for some of the analytes were not performed when 90% or more results were less than the detection limits (for example, diazinon, hydrogen sulphide).

Statistical tests were performed in R/R Studio, using package ‘stats’ and ‘cars’ to determine significant difference using linear models and Analysis of Variance. The trend was considered significantly downward or upward when the p-value was <0.05.

The wastewater quality data are presented as box plots by each WRRF to show the trends and comparisons over the years (Figure 3-1). The lower and upper hinges correspond to the 25^{th} and 75^{th} percentiles. The median/50^{th} percentile is presented as dot within the box and connected by line. The upper whisker extends from the hinge to the largest value no further than 1.5 * IQR (Interquartile Range) from the hinge. The lower whisker extends from the hinge to the smallest value at most 1.5 * IQR of the hinge. (1.5 x IQR is the default setting for the whiskers). Blue dots outside of whiskers are outliers.

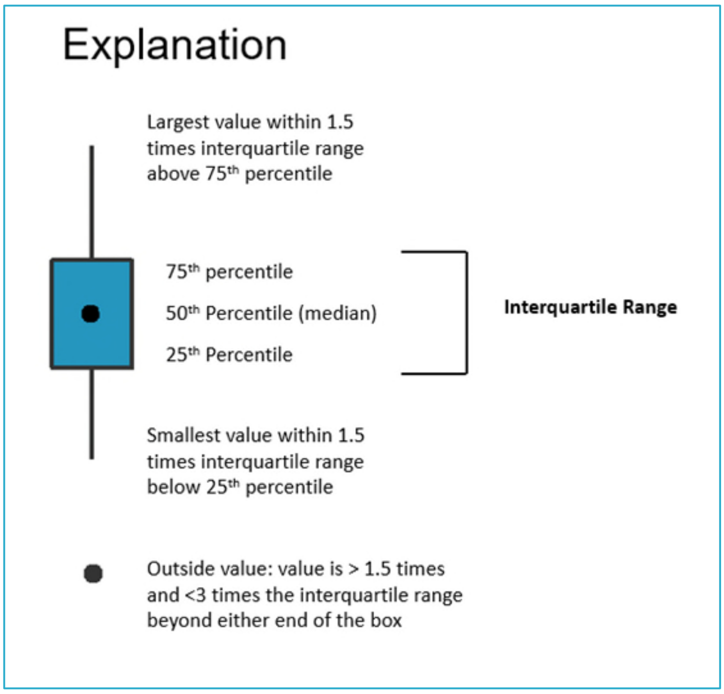


Figure 3-1 Example box plot for presenting the wastewater data

Where the recorded measurement was below the detection limit, half the detection limit value was used as the recorded measurement for calculations and graphics. These box plots also include other important information, such as the detection limit of that particular analyte, WRRF specific EPL concentrations limits etc.

All box plots on wastewater quality are presented in Volume 2: Appendix A, B, D, and E.

If the 2022-23 data was significantly different from the previous nine years, then these were identified as an exception and presented in the main body of this report (Volume 1).

The load of key pollutants (oil and grease, total suspended solids, nitrogen and phosphorus, as applicable to each EPL) was determined following the Load Calculation Protocol, where the total wastewater discharge volume was multiplied by the flow-weighted mean concentration of the pollutant (DECC 2009).

Raw data and summary statistics on wastewater discharge volume, characteristics load data by WRRFs (all analytes) and year are provided as electronic Appendices (H-1 and H-3).

Daily average rainfall data for the 35 gauging stations are used to generate WRRF catchment specific trends in rainfall in comparison to wastewater inflows and discharges (Table 3-1 and Figure 3-2). These data are provided as an electronic appendix (Appendix H-1)

Figure 3-2 Rainfall gauging stations used for assessing the wastewater data

Table 3-1 List of wastewater catchment specific rainfall station and WRRF zones

Catchments	Rainfall station (Hydstra code and site name/ description)	Latitude	Longitude	Owner	WRRF
Upper Nepean	568053 Picton WRRF	-34.2029	150.6148	Sydney Water	Picton and West Camden WRRFs
	568130 West Camden WRRF (composite)	-34.0590	150.6809	Sydney Water	
Mid Nepean	567163 Regent Ville Rural Fire Service	-33.7745	150.6716	BOM	Penrith, St Marys, Glenbrook*, Warragamba* and Wallacia WRRFs
	567087 St Marys WRRF	-33.7342	150.7692	Sydney Water	
	568044 Warragamba Water Filtration Plant	-33.8915	150.5983	Sydney Water	
Lower Nepean	567084 Quakers Hill WRRF	-33.7365	150.8783	Sydney Water	Quakers Hill, Richmond, North Richmond, Winmalee and Riverstone WRRFs
	567085 Richmond WRRF	-33.6080	150.7671	Sydney Water	
	563069 North Richmond WRRF	-33.5748	150.7156	Sydney Water	
	563146 Winmalee WRRF	-33.6767	150.6250	Sydney Water	
	567100 Riverstone WRRF	-33.6562	150.8477	Sydney Water	
Lower Hawkesbury	567076 Castle Hill WRRF	-33.7111	150.9842	Sydney Water	Castle Hill and Rouse Hill WRRFs
	567102 Dural (WPS14)	-33.6969	151.0277	Sydney Water	
Berowra	567120 Brooklyn WRRF	-33.5513	151.1959	Sydney Water	Brooklyn, West Hornsby and Hornsby Heights WRRFs
	566055 Hornsby Bowling Club*	-33.7067	151.1070	BOM	
	566073 Pymble Bowling Club	-33.7408	151.1394	BOM	
	566053 Hornsby Heights WRRF	-33.6672	151.1047	Sydney Water	
South West Sydney	567077 Fairfield WRRF	-33.8807	150.9504	Sydney Water	Fairfield, Glenfield and Liverpool WRRFs
	567078 Glenfield WRRF	-33.9827	150.9071	Sydney Water	
	566049 Liverpool WRRF	-33.9218	150.9386	Sydney Water	
Cronulla	566078 South Cronulla	-34.0700	151.1517	Sydney Water	Cronulla WRRF
	566018 Cronulla WRRF	-34.0307	151.1635	Sydney Water	
Illawarra	568162 Balgownie Reservoir	-34.3928	150.8703	BOM	Bellambi, Port Kembla, Shellharbour, Wollongong and Bombo WRRFs
	568173 Berkeley (Berkeley Sports and Social Club)	-34.4830	150.8473	BOM	
	568171 Albion Park Bowling Club	-34.5703	150.7684	Sydney Water	
	568181 Figtree Bowling Club	-34.4363	150.8646	BOM	

Catchments	Rainfall station (Hydstra code and site name/ description)	Latitude	Longitude	Owner	WRRF
	568188 Kiama Water Tank	-34.6735	150.8434	BOM	
North Sydney Coast	566089 Manly Croquet Club (formerly Manly Golf Course)*	-33.7906	151.2758	Sydney Water	North Head and Warriewood WRRFs
	566100 North Head WRRF	-33.8080	151.3019	Sydney Water	
	566051 Warriewood WRRF (Composite)	-33.6912	151.2993	Sydney Water	
Malabar	566026 Marrickville Bowling Club	-33.9099	151.1641	BOM	Malabar WRRF
	567077 Fairfield WRRF	-33.8807	150.9504	Sydney Water	
	567078 Glenfield WRRF	-33.9827	150.9071	Sydney Water	
	566049 Liverpool WRRF	-33.9218	150.9386	Sydney Water	
Bondi	566032 Paddington (Composite)	-33.8870	151.2253	BOM	Bondi WRRF
	566038 Vaucluse Bowling club	-33.8578	151.2788	BOM	

*Not monitored after 2016

3.2.2 Hawkesbury-Nepean River water quality and ecosystem health

Data availability and data selection – Water quality

During 2022-23, all scheduled STSIMP sampling events were completed at 12 of the 18 monitoring sites. Extreme preceding wet weather and unsafe roads or site condition interrupted water quality sample collection at three monitoring sites of the Nepean River in October 2022. These sites were Nepean River at Maldon Weir (N92), Sharpes Weir (N75) and Smith Road (N48A). At N48A, another sampling event was missed due to safe access issues via Penrith Lakes (22 July 2022). All other scheduled sampling events for these sites were completed.

Receiving water quality data for the 18 STSIMP routine monitoring sites were generally complete for the previous nine years period with the exception few site-specific extreme conditions like 2022-23.

Data availability period for 31 other sites that were considered for water quality assessment varied between two to 10 years. Data for some these sites were collected by multiple projects with different monitoring protocols eg high monitoring frequency, monitoring tailored to special discharge events or other WRRF specific operational activities. Data was only included in this data report for sites sampled at a comparable frequency to the routine STSIMP monitoring ie three weekly.

Data preparation – Water quality

Where the recorded measurement was below the detection limit, half the detection limit value was used for calculations and graphics. The replicate water quality results for each monitoring site and date were averaged first to use in subsequent data analysis and plots.

Data analysis and presentation – Water quality

Data from 50 monitoring sites are analysed under the following two sub-groups in line with the underlying two key objectives of the monitoring program:

- Assessing the impact of each WRRF by comparing the upstream and downstream sites (Table 3-2)
- Assessing the SoE at 12 other routine STSIMP sites (Table 3-3).

Table 3-2 Monitoring sites, water quality data availability and statistical design for assessing the impact of each WRRF

Zone/ WRRF	Site code	Site description	Monitoring period	Site pair water quality (comments)
Picton WRRF	N911B	Stonequarry Creek at Picton Farm, upstream of discharge gully	2021-2023	N911B vs N911
	N911	Stonequarry Creek at Picton Farm, downstream of Picton WRRF discharge point		
	N92	Nepean River immediately upstream of Maldon Weir, upstream of all Sydney Water WRRFs, Reference site	2013-2023	N92 vs N91
	N91	Nepean River at Maldon Bridge, downstream of Stonequarry Creek and Picton WRRF	2015-2023	
West Camden WRRF	N7824A	Matahil Creek, upstream of West Camden WRRF	2017-2023*	N7824A vs N7824
	N7824	Matahil Creek, downstream of West Camden WRRF		
	N78	Nepean River at Macquarie Grove Rd, upstream of Matahil Creek and West Camden WRRF	2017-2023	N78 vs N75
	N75	Nepean River at Sharpes Weir, downstream of Matahil Creek and West Camden WRRF	2013-2023	
Wallacia WRRF	N642A	Warragamba River upstream of Wallacia WRRF, downstream of Warragamba Dam e-flows discharge point	2019-2023*	N642A vs N641
	N641	Warragamba River at Nortons Basin Road downstream of Wallacia WRRF	2019-2023*	
Penrith WRRF	N542	Boundary Creek, upstream of Penrith WRRF	2018-2023	N542 vs N541
	N541	Boundary Creek, downstream of Penrith WRRF		
	N57	Nepean River at Penrith Rowing Club ramp, upstream of Penrith Weir and Penrith WRRF	2013-2023	N57 vs N53
	N53	Nepean River at BMG Causeway, downstream of Penrith WRRF	2017-2023	
Winmalee WRRF	N462	Unnamed Creek, 0.3 km downstream of Winmalee WRRF	No data	No comparison made, insufficient data
	N461	Unnamed Creek 3 km downstream of Winmalee WRRF	2016	
	N48A	Nepean River at Smith Road, Princes farm, upstream of Winmalee WRRF	2013-2023	N48A vs N464
	N464	Nepean River (Winmalee Lagoon) at Springwood Road, downstream of Winmalee WRRF, before Shaws Creek	2015-2023	
North Richmond WRRF	N412	Redbank Creek, upstream of North Richmond WRRF	2018-2023	N412 vs N411
	N411	Redbank Creek, downstream of North Richmond WRRF		
	N42	Hawkesbury River upstream of North Richmond WRRF, downstream of Grose River	2013-2023	N42 vs N39
	N39	Hawkesbury River at Freemans reach, downstream of North Richmond WRRF, upstream of South Creek	2013-2023	
Richmond WRRF	N389	Rickabys Creek, upstream of with confluence of unnamed creek below Richmond WRRF discharge	2021-2023	N389 vs N388
	N388	Rickabys Creek, downstream of confluence of unnamed creek, below Richmond WRRF discharge		

Zone/ WRRF	Site code	Site description	Monitoring period	Site pair water quality (comments)
St Marys WRRF	NS26	South Creek, upstream of St Marys WRRF	2018-2023	NS26 vs NS23A
	NS23A	South Creek, downstream of St Marys WRRF		
Riverstone WRRF	NS082	Eastern Creek, upstream of Riverstone WRRF	2016-2023	NS082 vs NS081
	NS081	Eastern Creek, downstream of Riverstone WRRF		
Quakers Hill WRRF	NS090	Breakfast Creek, upstream of Quakers Hill WRRF	2017-2023	NS090 vs NS087
	NS087	Breakfast Creek, downstream of Quakers Hill WRRF		
Rouse Hill WRRF	NC53	Second Ponds Creek upstream of Rouse Hill WRRF at Withers Road	2017-2023	NC53 vs NC516
	NC516	Second Pond Creek, downstream of Rouse Hill wetland and bypass from Rouse Hill WRRF	2017-2023	
Castle Hill WRRF	NC8	Cattai Creek, upstream of Castle Hill WRRF	2017-2023	NC8 vs NC75
	NC75	Cattai Creek, downstream of Castle Hill WRRF		
West Hornsby WRRF	NB83	Waitara Creek, upstream of West Hornsby WRRF	2017-2023	NB83 vs NB825
	NB825	Waitara Creek, downstream of West Hornsby WRRF		
Hornsby Height WRRF	NB43	Calna Creek, upstream of Hornsby Heights WRRF	2017-2023*	NB43 vs NB42
	NB42	Calna Creek, downstream of Hornsby Heights WRRF		

Table 3-3 Monitoring sites, data availability and statistical design for assessing the SoE at each site

Site code	Description	Data availability
N67	Nepean River at Wallacia Bridge, upstream of Warragamba River	2013-2023
N51	Nepean River opposite Fitzgeralds Creek, downstream of Penrith WRRF	
N44	Nepean River at Yarramundi Bridge, downstream of Winmalee WRRF	
NS04A	Lower South Creek at Fitzroy pedestrian bridge, Windsor	
N35	Hawkesbury River at Wilberforce, Butterfly farm, downstream of South Creek	
NC11A	Lower Cattai Creek at Cattai Road Bridge, 100m downstream of bridge	
N3001	Hawkesbury River Off Cattai State Recreation Area (SRA), downstream of Cattai Creek	
N26	Hawkesbury River at Sackville Ferry, downstream of Cattai Creek	
N2202	Lower Colo River at Putty Road Bridge, Reference site	
N18	Hawkesbury River at Leets Vale, opposite Leets Vale Caravan Park, downstream of Colo River	
NB13	Berowra Creek at Calabash Bay (Cunio Point)	
NB11	Berowra Creek, Off Square Bay (Oaky Point)	

Assessing the WRRF impact – upstream vs downstream

The statistical and graphical presentation methods for assessing the WRRF impact in line with the underlying objectives of the monitoring sites are stated in Table 3-2. Data summaries or descriptive statistics (number of total observations, number of observations above the respective guideline, minimum, 10th percentile, 20th percentile, median/ 50th percentile, average, 80th percentile and maximum) were produced for each site and financial years. All these outputs are included in Appendix A (Volume 2) or respective electronic Appendices.

Each water quality analyte (nutrients, other physico-chemical analytes, phytoplankton as chlorophyll-a, biovolume/ species counts) are plotted as box plots for the 18 paired sites (upstream and downstream) to understand the generalised trends and differences between upstream and downstream sites for each WRRF and catchment (tributary/ river). An example box plot for these paired sites is shown in (Figure 3-3). The box plots graphed the 25th percentile value, median/50th percentile (dot) and 75th percentile values. The whiskers point to the 10th (bottom line) and 90th (top line) percentile values. Blue and orange circles outside of whiskers are outliers. These box plots also contain annotated guidelines as horizontal lines for comparison when available (Table 3-6).

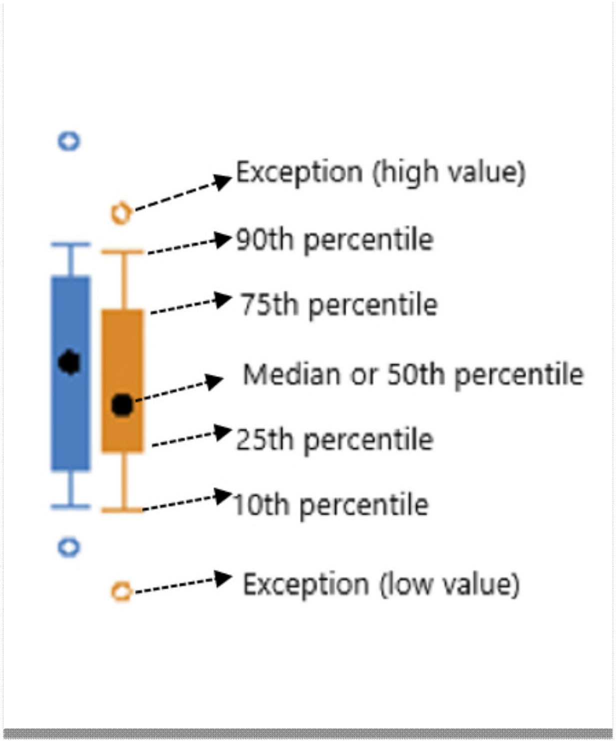


Figure 3-3 Example box plot for presenting water quality at upstream downstream site pairs

The ANZG 2018 guidelines recommend developing site-specific guidelines. As these have not been developed for the Hawkesbury-Nepean River, default trigger values for NSW lowland river or estuaries or NSW/VIC east flowing coastal river were used for most of the water quality analytes (ANZECC 2000).

To understand how 2022-23 compared to recent years for all analytes were tested statistically for any significant differences using PROC GLM module of SAS 9.4 with a single factor ‘Period’ with two levels. These levels were represented by data from ‘the current 2022-23 year’ compared against the ‘previous one to nine years of data (up to 2021-22)’. The trend was considered significantly downward or upward when the p-value was <0.05. The trend plots with significant upward or downward trends are graded with different shade or colour in each plot (Table 3-4).

Table 3-4 Trends and level of significance and colour coding in plots

Trend	Pr>F
Increasing	<0.05
Decreasing	<0.05
Stable	≥0.05

GLM analysis outcomes for some of these sites and analytes should be considered with caution due to some limitations in the data sets:

- Phytoplankton analytes (total biovolume, blue-green biovolume and toxic blue-green counts) were selectively measured depending on chlorophyll-a >7 µg/L for all sites.
- Sampling frequency was three weekly for all sites and data sets selected for analysis. The only exceptions were up to three extra samples for West Camden, St Marys and Castle Hill sites, Apr-Jun 2019.
- There were inconsistencies or data gaps for some site pairs to make the comparison effectively.

The outcome of GLM of graphical presentation for the phytoplankton analytes (total phytoplankton biovolume, blue-green biovolume and potentially toxic blue-green counts) was considered valid (or presentable) for the site or pair of sites when:

- total number of observations for the current year (2022-23) was ≥3
- total number of observations for the entire period (2013-23): >10% of chlorophyll-a samples.
- no/zero cell counts/biovolume for the potentially blue-green biovolume or toxic blue-green (2013-23): < 90%

All box plots for the paired sites and analytes are presented in Appendix A (Volume 2). If the 2022-23 data for either upstream or downstream monitoring site were significantly different from the previous one to nine years or exceeded the guideline limits, then these were identified as exceptions and presented in the main body of this report (Volume 1, Chapter 4).

Table 3-5 Monitoring program objectives and respective data analysis and graphical presentation methods for water quality and phytoplankton, for assessing the WRRF impact

Objectives/ Hypothesis	Data analysis and graphical presentation methods
***Stressors: nutrients and* physico-chemical water quality**	
1 To compare for each WRRF downstream/upstream site pair with relevant water quality objectives (where available), for the current year	Summary stats table: Number of observations above the respective guideline limits in 2022-23
2 .To compare downstream with upstream site physico-chemical water quality, including nutrients, for each downstream/upstream	• Paired box plots: general trends in data and distribution by each year

Objectives/ Hypothesis		Data analysis and graphical presentation methods
	site pair for the current year and over the relevant historical record.	• Generalised linear model (GLM): current year (2022-23) vs previous years (2014-2022)
***Ecosystem receptors:* (phytoplankton as chlorophyll-a, biovolume, cell counts)**		
3	To compare for each WRRF downstream/upstream site pair with relevant water quality objectives/health alerts, for the current year.	Summary stats table: Number of observations above the respective guideline limits in 2022-23
4	To compare downstream with upstream site concentrations/ counts for each WRRF downstream/upstream site pair for the current year and over the relevant historical record.	• Paired box plots: general trends in data and distribution by each year • GLM: current year (2022-23) vs previous years (2014-2022)

Table 3-6 Water quality and phytoplankton guidelines used in box plots and summary statistics calculation and interpretation.

Water quality and phytoplankton analytes	Freshwater	Estuarine and brackish sites	Guideline references
Nutrients, chlorophyll-a and phytoplankton analytes			
Ammonia nitrogen (mg/L)	<0.020[a]	<0.015[c]	ANZG 2018
Oxidised nitrogen (mg/L)	<0.040[a]	<0.015[c]	
Total nitrogen (mg/L)	<0.35[b]	<0.30[c]	
Total phosphorus (mg/L)	<0.025[b]	<0.030[c]	
Chlorophyll-a (µg/L)	<3.0[b]	<4.0[c]	
Blue-green biovolume (mm^3/L)	Green alert: >0.04; Amber alert ≥0.4; Red alert ≥10 for combined total blue-greens, Or* biovolume equivalent of ≥4 where a known toxin producer is dominant for red alert		Blue-greens alert levels for recreational water (NHMRC 2008)
Toxic blue-green counts (cells/mL)	Green alert >500; Amber alert ≥5,000; Red alert ≥ 50,000		
Physico-chemical analytes			
Conductivity (µS/cm)	125 to 2200	No guideline applied	ANZG 2018
Dissolved oxygen saturation (%)	>85 and <110[a]	>80 and <110[c]	
pH	>6.5 and <8.5[d]	>6.5 and <8.5[c]	
Turbidity (NTU)	6 to 50[a]		

a: Default trigger value for lowland river
b: Default trigger values for NSW and VIC east flowing coastal river
c: Default trigger values for estuaries
d: Default trigger values for NSW lowland river

* not applied in this report

Assessing the SoE at 12 other STSIMP sites

The statistical and graphical presentation methods for the SoE type sites and the underlying objectives of the monitoring program are stated in Table 3-3. All receiving water quality data (nutrient, physico-chemical analytes, phytoplankton as chlorophyll-a, biovolume, counts) for these sites were presented as single box plot (Figure 3-4) and statistically analysed to understand how the current year (2022-23) compared to the previous nine years (2013-14 to 2021-22). Significant differences were determined using PROC GLM in SAS 9.4. The trend was considered significantly downward or upward when the p-value was <0.05. These box plots also contain annotated guidelines (Table 3-6) as horizontal lines for comparison when available.

If the 2022-23 data was significantly different from the previous nine years or exceeded guideline/alert limits, then these were identified as exceptions and presented in the main body of this report (Volume 1, Chapter 5.1). These exceptions could either denote improvement or deterioration in water quality. All box plots for these single sites are included in Appendix C (Volume 2).

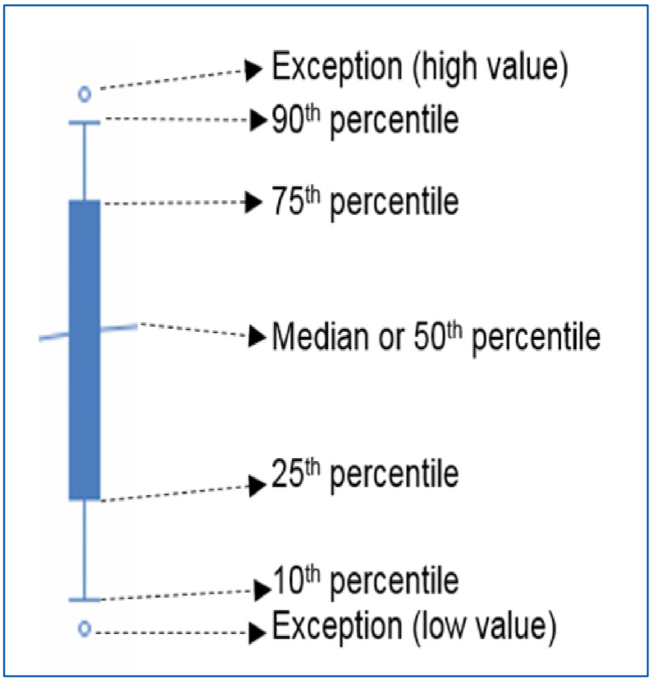


Figure 3-4 Example box plot for the single water quality site

Table 3-7 Monitoring program objectives and respective data analysis and graphical presentation methods for assessing SoE at other STSIMP sites

Objectives	Data analysis and graphical presentation methods
a. To compare physico-chemical water quality, including nutrients, and phytoplankton as chlorophyll-a or biovolume concentrations/ cell counts with the water quality objectives/ alert (where available), for the current year	Summary stats table: Number of observations above the respective guideline limits in 2022-23
b. To compare physico-chemical water quality, including nutrients, and phytoplankton as chlorophyll-a or biovolume concentrations/ cell counts for the current year and over the relevant historical record.	• Box plots: general trends in data and distribution by each year • Generalised linear model (GLM): current year (2022-23) vs previous years (2014-2022)

Data analysis and presentation – Macroinvertebrates

Assessment of freshwater macroinvertebrate data for each inland WRRF was based on scores from the SIGNAL-SG biotic index. These scores were calculated as described by Besley and Chessman (2008). In brief, a SIGNAL-SG biotic index pollution sensitivity score is calculated as follows:

- The first step was to apply predetermined sensitivity grade numbers (from 1, tolerant to 10, highly sensitive) to genera counts that occur within a sample.
- Then multiply the square root transformed count of each genus by the sensitivity grade number for that genus, summing the products, and dividing by the total square root transformed number of individuals in all graded genera.
- Genera that were present in the samples but with no grade numbers available (relatively few) were removed from the calculation of the SIGNAL-SG score for the sample.
- These steps were repeated for each habitat sampled.

Analysis of SIGNAL-SG scores from different habitats at the same site and time have shown pool edges are on average 0.1 units higher than riffles or pool rocks. This habitat adjustment value (Besley and Chessman, 2008) was therefore applied to habitats other than pool edges, when collected, to provide a location specific average score and a measure of variation (one standard deviation of the average) through time as recommended by ANZECC (2000) for ecosystem health comparisons.

In other words, a SIGNAL-SG score can simplistically be thought of as an average of the pollution sensitivity grades of the macroinvertebrate types present that also incorporates a measure of the animal counts (abundance).

Average SIGNAL-SG scores and standard deviations are calculated so that a comparison between sites can be made. Typically, Sydney Water's monitoring of the WRRF point source discharges is conducted upstream-downstream of the WRRF discharge point to determine if any impact has occurred from operation of these facilities. Upstream-downstream (paired site) comparisons in this manner allows for separation of WRRF discharge impacts on ecosystem health from upstream catchment influences on ecosystem health.

SIGNAL-SG is a region-specific version of SIGNAL (Chessman, 1995) which was raised in response to suggestions that region specific models are more suitable than those derived for the broad scale as was the case for the original version of SIGNAL (Bunn 1995, Bunn and Davies 2000). The Sydney region specific version of SIGNAL-SG (Chessman et al. 2007) has benefited from development and testing since the original version (Chessman, 1995). This testing included the response of SIGNAL to natural and human influenced (anthropogenic) environmental factors (Growns et al. 1995), variations in sampling and sample processing methods (Growns et al. 1997; Metzeling et al. 2003) and most importantly setting sensitivity grades of the taxa objectively (Chessman et al. 1997; Chessman 2003).

An interpretation of organic pollution impacts with this tool was demonstrated in Besley and Chessman (2008). They presented univariate analysis of paired (upstream-downstream) sites for five decommissioned Blue Mountains WRRFs using the tolerance based SIGNAL-SG statistical analysis tool. The analysis was based on temporal replication (each six months as per national protocol) and within time replication (from collection of multiple habitats at each visit). Within time replication was made possible by applying habitat correction factors to SIGNAL-SG scores of habitats other than pool edge waters.

Primary assessment of scores calculated from the SIGNAL-SG biotic index was done visually using plots along the lines of a process control chart for ecological monitoring presented by Burgman et al. (2012) to display information in a simple, practical and scientifically credible way. This style of control chart illustrates temporal trends and allows interpretation of data against background natural disturbance and variation of the respective streams. In these control chart plots, the range of each site period has the mean plotted together with error bars of ± one standard deviation of the mean, as recommended by ANZECC (2000) for basing ecological decisions. These ± one standard deviation of the mean formed ranges of stream health for period displayed. These charts were plotted on a financial year basis. Calculating a site-specific guideline value such as this range is valid as ANZECC (2000) indicates this can be done, provided at least three years of baseline data have been gathered. This has been done for all upstream sites of the program. In each year's report, this range is recalculated including the last years upstream data to keep refining each upstream site-specific range.

In the control chart plots, the mean stream health for the most recent financial year that the report covers (for example 2022-23) for the downstream site was assessed against the range of stream health recorded over all previous financial years (for example 1995-22) for the upstream site. Downstream mean stream health for the most recent financial year that the report covers (for example 2022-23) was also compared against the range of stream health collected from the upstream site in the same financial year (for example 2022-23). These comparisons had three possible outcomes:

- Mean downstream stream health was within the range recorded for the upstream site over the longer overall monitoring period.
- Mean downstream stream health was within the range recorded for the current financial year at the upstream site.
- Mean downstream stream health lay outside these two upstream stream health ranges listed above.

Univariate t-tests were also done and provided a more stringent assessment as statistical test ranges approximated generally tighter two standard errors of the mean. Previous STSIMP reports adopted a two-stage process involving an equality of variance test prior to a Pooled or Satterthwaite t-test. As advised In the STSIMP Recommendations Report, the two-stage method may lead to poorer results due to low power from small sample sizes (van Dam et al, 2023). Conversely, the Welch t-test performs well in terms of Type I error and has similar power. Therefore, the Welch t-test method was adopted this year as recommended (van Dam et al, 2023). If the t-test confirmed significant differences between sites, then multivariate statistics were used to further examine the ecological response for the respective WRRF.

Multivariate data analyses were performed using statistical routines of the PRIMER Version 7.0.13 software package (Clarke et al. 2014) and the add-on module PERMANOVA+ (Anderson et al. 2008).

Balanced designs have been found to provide more reliable test outcomes when heterogeneity of dispersions is present in a dataset (Anderson and Walsh 2013). Heterogeneity of dispersions is a common feature of ecological data. To balance datasets for multivariate analysis, samples were omitted if they were not collected from the same habitat at both sites for each time period (Table 3-8). Habitat presence through time was influenced by broad climate conditions and stream reach specific characteristics. Under drought conditions macrophytes typically dominate, covering pool edge and pool rock habitats. Under drier climatic conditions riffle habitats can diminish due to reduced flow. After floods the opposite pattern was generally observed. If habitats formed less than 10% of the nominal site area on a sample occasion, then those habitats would not be sampled (Chessman 1995). These constraints saw inconsistent collection of some habitat samples though time as outlined in Table 3-8.

Table 3-8 Summary of monitoring periods omitted from multivariate analysis of freshwater macroinvertebrate data due to unbalanced sample habitats

WRRF	Stream	Periods with unbalanced sample habitats
North Richmond	Redbank Ck	N/A
North Richmond	Hawkesbury-Nepean River 'macrophyte'	spring 2005, autumn 2012, spring 2012, spring 2013, spring 2017 and spring 2018
West Camden	Hawkesbury-Nepean River 'edge'	autumn 2004, autumn 2005, spring 2005, autumn 2006, spring 2006, autumn 2007, spring 2007, autumn 2008, spring 2008, autumn 2009, spring 2009, autumn 2010, spring 2010, autumn 2011, spring 2011 and autumn 2013
West Camden	Matahill Creek 'edge'	spring 2004, autumn 2006, autumn 2009, spring 2010, spring 2011, autumn 2012, autumn 2014 and autumn 2018
Winmalee	Hawkesbury-Nepean River 'edge'	autumn 2012 and autumn 2018
Winmalee	Hawkesbury-Nepean River 'macrophyte'	autumn 2012, spring 2013, spring 2016 and spring 2020
Hornsby Heights	Calna Creek 'edge'	spring 2012 and autumn 2018

WRRF	Stream	Periods with unbalanced sample habitats
Hornsby Heights	Calna Creek 'riffle'	autumn 1998, spring 2002, autumn 2003, spring 2004, autumn 2013 and autumn 2016
West Hornsby	Waitara Creek 'edge'	N/A
West Hornsby	Waitara Creek 'riffle'	autumn 2002, spring 2003, spring 2009, autumn 2016, spring 2022 and autumn 2023
Castle Hill	Cattai Creek 'edge'	spring 1995
Castle Hill	Cattai Creek 'riffle'	spring 1995, spring 1999, autumn 2016 and spring 2016

N/A = samples from same habitat collected at both upstream and downstream sites in the same season has occurred to date

Dispersion weighting was done on site replicates to down-weight the contribution of highly abundant, but highly variable genera without also effectively squashing genera with low counts (Clark et al. 2014). For example, it helps smooth out erratic counts of motile species occurring in schools such as the water bug *Micronecta*.

Then data were transformed with a square root transformation to avoid over transforming the data matrix and squeezing out too much of the quantitative information from mid to low abundance genera.

An association matrix was then constructed based upon the Bray-Curtis resemblance measure. This measure was used as the basis for classification, ordination and hypothesis testing of site sample data. The Bray-Curtis resemblance measure is focused on compositional changes in taxa identities (Anderson and Walsh 2013). As such, this is an appropriate choice since we understand downstream measurable organic pollution impacts recorded at former aged Blue Mountains WRRFs did cause a change in the composition of the freshwater macroinvertebrate community (Besley and Chessman 2008).

The group average classification technique was used to place the sampling sites into groups, each of which had a characteristic invertebrate community based on relative similarity of their attributes. The group average classification technique initially forms pairs of samples with the most similar taxa and gradually fuses the pairs into larger and larger groups (clusters) with increasing internal variability.

Classification techniques will form groups even if the data set actually forms a continuum. To determine whether the groups were 'real', the samples were ordinated using the non-metric multidimensional scaling (nMDS) technique. Ordination produces a plot of sites on 2 or 3 axes so that sites with similar taxa lie close together and sites with a differing taxon composition lie farther apart. Output from classification analysis was then checked against sample groupings on the ordination plot to see if site pre-post (a-priori) groups of samples occurred which would indicate a response from wastewater discharge.

An example of an impact pattern is provided in Figure 3-5 where the first division shows a clear difference between upstream and downstream samples from the (before) period when the former Blackheath WRRF which ceased operation in 2008 was active. This WRRF had poor control of ammonia output. Ammonia was thought to be the likely cause of impact on the downstream macroinvertebrate community. All other inland tertiary WRRFs Sydney Water operates have better control of the ammonia bi-product of wastewater treatment.

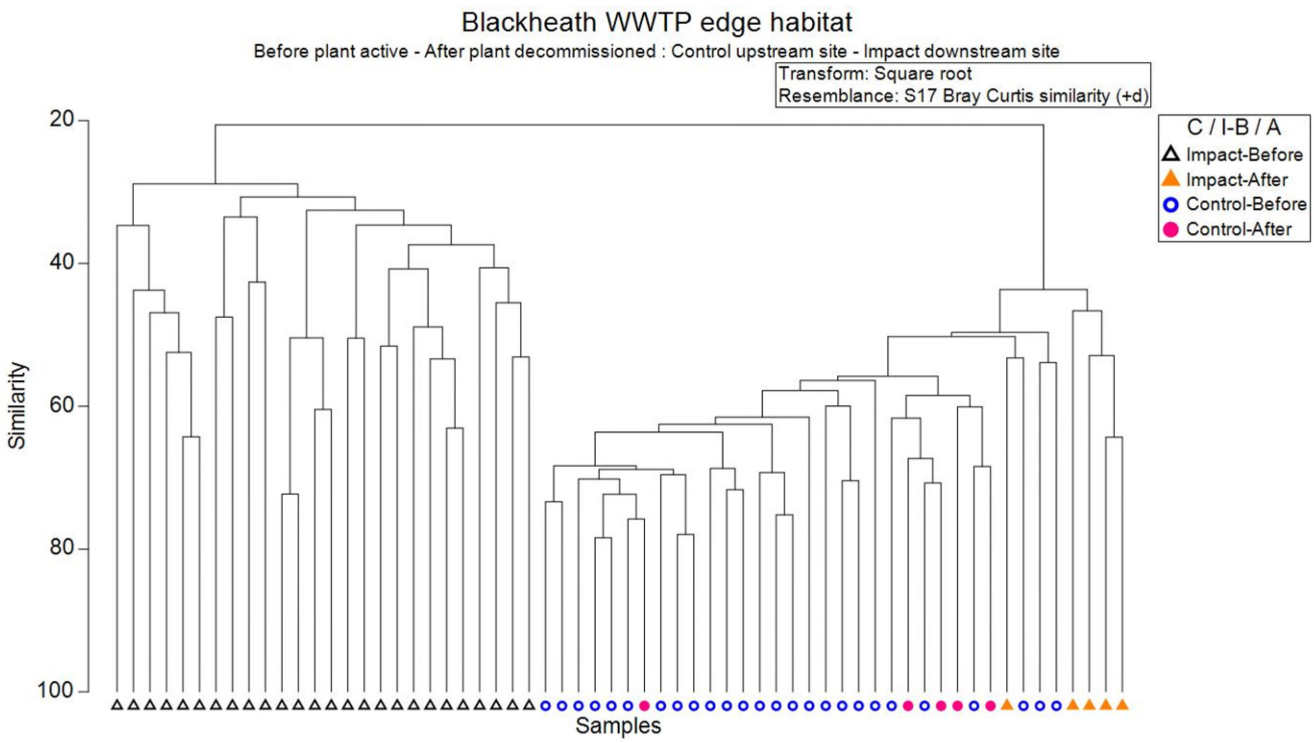


Figure 3-5 Example of classification plot showing a distinct organic pollution impact and recovery

An unconstrained ordination procedure such as nMDS usually introduces distortion when trying to represent the similarities between large numbers of samples in only two or three dimensions. The success of the procedure is measured by a stress value, which indicates the degree of distortion imposed. In the PRIMER software package, a stress value of below 0.2 indicates an acceptable representation of the original data although lower values are desirable.

Hypothesis testing of multivariate macroinvertebrate assemblage data was conducted with the PERMANOVA routine. This routine was able to mirror univariate t-tests of SIGNAL-SG scores. PERMANOVA was run with 10,000 permutations with the ‘Permutation of residuals under a reduced model’ option as outlined in Anderson et al. (2008).

Anderson et al. (2008) states increases or decreases in the multivariate dispersion of ecological data has been identified as a potentially important indicator of stress in marine communities (Warwick and Clarke 1993, Chapman et al. 1995). A freshwater example of multivariate dispersion together with taxonomic compositional change under the Bray-Curtis similarity measure is provided by the before period samples collected from the downstream (impact) site when the former Blackheath WRRF was active. In contrast, the downstream samples collected after decommissioning displayed a decrease in dispersion as well a change in taxonomic composition toward that of the upstream control site in the ordination plot in Figure 3-6.

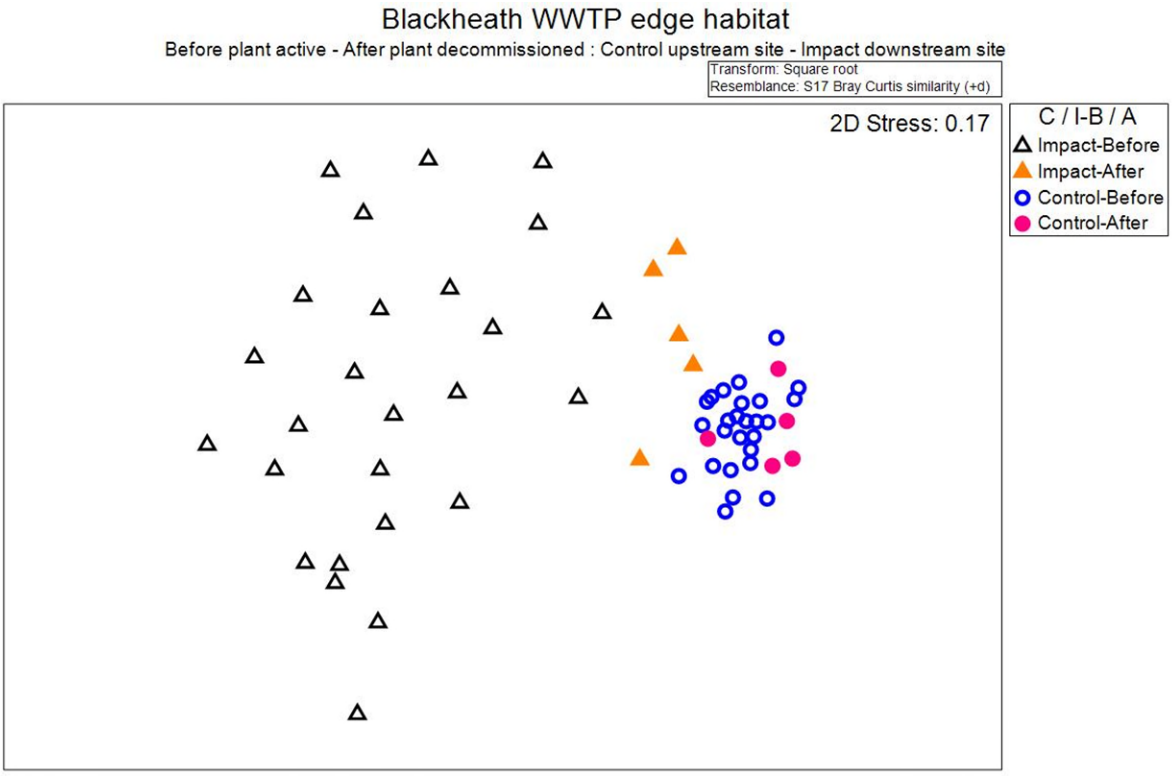


Figure 3-6 Example of nMDS ordination plot showing a distinct organic pollution impact and recovery

Dispersion was also graphically illustrated in the corresponding shade plot for the before period samples collected from the downstream Blackheath site with more taxa having sporadic occurrences, compared with the upstream site in the before period that had many more taxa with relatively consistent presence (Figure 3-7).

Shade plots provide a visual display in the form of the data matrix with a rectangle display for each sample. White represents zero counts, while black rectangles represent maximum abundance after dispersion weighting and square root transformation. Increasing grey shading represents increasing abundance. Thus, shade plots represent the patterns of dominant and less abundant genera collected in each sample. To improve visualisation of data patterns in shade plots, genera were serially reordered based on classification of genera (Figure 3-7). Classification on genera was based on square root transformed data that were standardised by total followed by construction of a data matrix based on Whittaker’s (1952) Index of Association resemblance measure. SIGNAL-SG grades of each genus level taxon were also annotated onto these plots

(Figure 3-8). These grades provided an indication of sensitivity to organic pollution that each taxon had which in turn aided interpretation of data patterns.

To statistically test for multivariate dispersion the PERMDISP routine of PERMANOVA+ was run on the factor ‘site’. If PERMDISP analysis returned a non-significant result, that indicated a similar pattern of dispersion (spacing between same site samples) for the 2 sites of the habitat samples being analysed. A non-significant outcome would suggest the variability in taxonomic make-up of samples collected over time was at similar levels for both sites through the period tested. This result then also implies subsequent results of ANOSIM tests are focused on community structure differences between sites. In contrast, if dispersion was significant, then subsequent results of ANOSIM tests are describing both the variability in taxonomic make-up of samples collected over time as well as community structure differences between sites.

If dispersion was present then PERMANOVA tests may not be as effective at detecting community structure changes as this test has an assumption of constant dispersion, although recent simulation work of Anderson and Walsh (2013) suggests it is not too sensitive to dispersion.

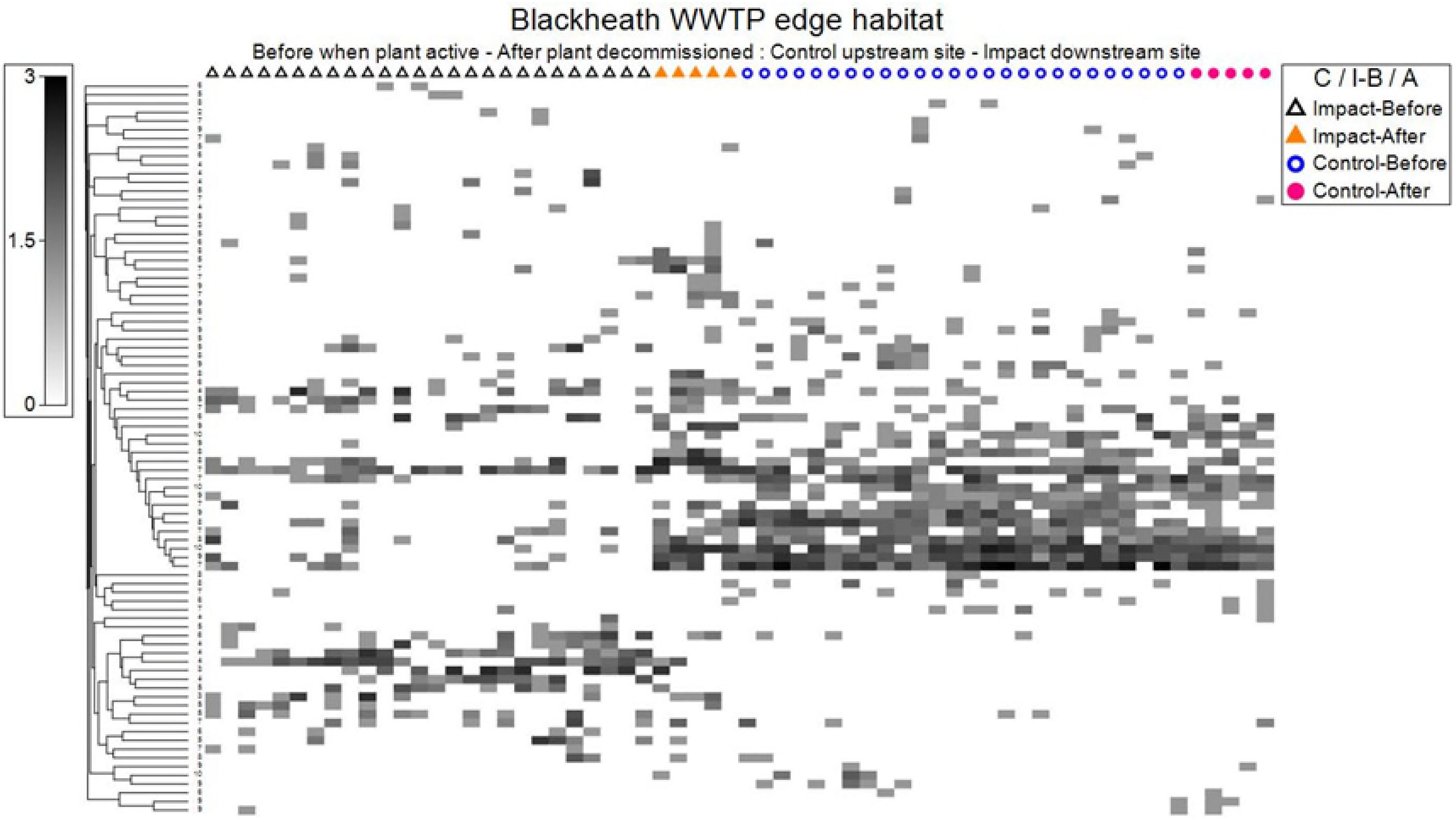
ANOSIM provides an absolute measure of how separated groups of samples are on a scale of – 1 to 1 (Clarke 1993). As the R-value approaches 1, this indicates all temporal samples from a site were more similar to each other than they were to temporal samples from another site; that is, groups are clearly different. When the R-value approaches 0, temporal samples within and between sites are equally similar; that is, no differences between groups. If the R-value approaches –1, then pairs consisting of one temporal sample from each site are more similar to each other than pairs of temporal samples from the same site (Clarke 1993).

Under the ANOSIM pairwise tests autumn and spring samples from 2022 and 2023 calendar years were used, with the autumn 2023 sample from each site as a test group. Under this analysis approach, four or five measurements became available from each of the four WRRFs upstream or downstream sites. This sample grouping made 3% level tests possible when four measurements were available in each of the historical to recent period comparisons. While 1% level tests were then possible when five measurements were available in each of these two site sample groups.

As stated above, habitat presence through time was influenced by broad climate conditions and stream reach specific characteristics. Under drought conditions we would generally see macrophytes dominate, covering pool edge and pool rock habitats. Riffle habitats would also diminish in area. After floods the opposite pattern was generally observed. If habitats formed less than 10% of the nominal site area on a sample occasion, then those habitats would not be sampled (Chessman 1995). These constraints saw inconsistent collection of some habitat samples through time as outlined in Table 3-8. This habitat presence governed how many of the more recent sample occasions were required to obtain four of five samples to achieve sensible level tests under the above ANOSIM pairwise comparisons.

Note: White represents zero counts, while black rectangles represent maximum abundance after dispersion weighting and square root transformation. Increasing grey shading represents increasing abundance

Figure 3-7 Shade plot of square root transformed count data



Note: Classification on genera was based on square root transformed data that were standardised by total followed by construction of a data matrix based on Whittaker's (1952) Index of Association resemblance measure. SIGNAL-SG grades of each genus level taxon were also annotated onto these plots

Figure 3-8 Shade plot of square root transformed count data serially reordered based on classification of genera

3.2.3 Other urban rivers and reference sites - Ecosystem health

A number of control sites around greater Sydney were monitored to define the level of natural variation of macroinvertebrate communities in streams of bushland areas without urban or rural influences on water quality. This information was and continues to be used to calibrate the stream health SIGNAL-SG biotic index assessment tool (Chessman et al. 2007). The range of scores for natural water quality status and pollution categories is shown below. The control sites were Lynch's Creek (N451) a tributary of Hawkesbury-Nepean River, Hacking River at McKell Avenue in Royal National Park (PH22), and in the upper Georges River system at O'Hares Creek (GE510) and Georges River at Ingleburn Reserve (GR24).

Impact sites monitored for the macroinvertebrate indicator in freshwater streams assessed the general condition of stream health downstream of urban areas. Three out of four impact sites are situated in urban areas just upstream of estuarine limits of the Parramatta River (PJPR), Lane Cove River (PJLC) and Georges River (GR22). The fourth urban site is situated about 5 km further up in the Georges River (GR23). Sites were visually assessed against criteria in Table 3-9, SIGNAL-SG scores back to 1995 were plotted by financial year (Appendix C-2).

Table 3-9 SIGNAL-SG inferred pollution categories

Impairment rating	Criteria
Natural water quality	SIGNAL-SG score > 6.5
Mild water pollution	SIGNAL-SG score < 6.5 to 5.1
Moderate water pollution	SIGNAL-SG score < 5.1

3.2.4 Nearshore marine ecosystem health

Results from the shoreline outfall program for the Shellharbour WRRF are presented in Appendix D- 5.

The Bray-Curtis resemblance measure is focused on compositional changes in taxa identities (Anderson and Walsh 2013). This is an appropriate choice since we understand the former measurable impact from nearshore wastewater discharge at Shellharbour caused a change in the composition of the intertidal rock platform community.

Multivariate data analyses were performed using statistical routines of the PRIMER Version 7.0.13 software package (Clarke et al. 2014) and the add-on module PERMANOVA+ (Anderson et al. 2008).

The PERMANOVA routine is designed to test whether it is reasonable to consider the existence of pre-defined groups given overall variability (Anderson et al. 2008).

An asymmetrical permutational analysis of variance test (PERMANOVA) was conducted with 'Control' and 'Impact' locations treated as a fixed factor. Sites were nested within 'Control' and 'Impact' and treated as a random factor. The outfall site was the only site under the 'Impact' location and the other 2 sites formed the 'Control' locations. A quadratic root transformation was applied to the data before a Bray-Curtis dissimilarity matrix was constructed. This matrix was the basis for

PERMANOVA testing with 9999 permutations run under a reduced model, with conservative Type III sums of squares inspected to base hypothesis decisions upon.

To further explore site differences, hypothesis testing was conducted with PERMANOVA of a single fixed factor ‘Site’.

SIMPER analysis reflected a community structure dominated by invertebrates with a lesser contribution of macroalgae at all three locations including the outfall location.

Inclusion of yearly replicate samples from 2008-09 to 2022-23 allowed the factor ‘Time’ to be included in the above PERMANOVA. Time was comprised of 2008-09, 2009-10, 2010-11, 2011-12, 2012-13, 2013-14, 2014-15, 2015-16, 2016-17, 2017-18, 2018-19, 2019-20, 2020-21, 21-22 and 2022-23 surveys, which were conducted at varying times through late winter to late spring each year.

Ordination plots were raised to visualise data patterns. The non-metric multidimensional scaling (nMDS) ordination routine of PRIMER was used to produce 2- and 3-dimensional ordination plots. In these plots, the relative distance between samples is proportional to the relative similarity in taxonomic composition and abundance – the closer the points on the graph the more similar the community (Clarke 1993). That is, site samples with similar taxa lay closer together and site samples with a differing taxon composition lie farther apart. An unconstrained ordination procedure such as nMDS inevitably introduces distortion when trying to simultaneously represent the similarities between large numbers of samples in a few dimensions. The success of the procedure is measured by a stress value, which indicates the degree of distortion imposed. In the PRIMER software package, a stress value of below 0.2 indicates an acceptable representation of the original data, although lower values are desirable. Where stress values are just above 0.2, the patterns displayed should be confirmed with other techniques such as PERMANOVA.

To understand the context of 2022-23 site data to that from previous years (2008-09 to 2021-22), site sample data were colour coded.

Under the nMDS routine, due to rank ordering of dissimilarities, some detail can be hidden. This detail may be seen using a Principal Coordinates Analysis (PCO) routine as PCO is based upon original dissimilarities being projected onto axes in the space of the chosen resemblance measure (Anderson et al. 2008). As a check for any additional dimensionality in the multivariate data cloud a PCO ordination plot was produced based on a quadratic transformation of the data and a Bray-Curtis resemblance measure.

A Canonical Analysis of Principal Coordinates (CAP) ordination plot was also produced. The CAP routine is designed to ascertain if axes exist in the multivariate space that separate groups. CAP is designed to purposely seek out and find groups even if differences occur in obscure directions and may not have been apparent from nMDS or PCO plots that provide views of the multivariate data cloud as a whole (Anderson et al. 2008).

3.2.5 Ocean receiving water quality

Data from the effluent monitoring point of the three major ocean outfall WRRFs (North Head, Bondi and Malabar) were collated and averaged for the 2022-23 monitoring year. Modelled dilution factors from the PLOOM3 modelling outcomes are then applied to the average effluent concentration data, at 98% and 10% probability of exceedance thresholds. These results are then compared with known ANZG (2018) guideline values for 95% protection of marine species. Results from the ocean receiving water quality program are presented in Appendix E-5.

3.2.6 Ocean sediment quality and ecosystem health

In surveillance years, grain size and Total Organic Carbon (TOC) analyses are conducted for the two sites of each of the three deepwater outfall locations. While benthic community samples are only collected and analysed for the Malabar 0 km location.

Particle size analyses were done with results for sediment fractions obtained for three categories: < 0.063 mm (%); > 0.063 mm (%); and > 2.0 mm (%). A table of mean and standard deviations of the mean were raised for each of the six sites. Mean particle size for the three size classes was also plotted by year over the period 2000 to 2023 to look for signs of build-up in fines size class (< 0.063 mm).

Results from the analysis of TOC obtained from Malabar 0 km (Site 1) were compared with the 99th percentile value of 1.2% specified in EPA (1998). No set trigger values were defined for Bondi or North Head outfall locations. A table was also presented of TOC samples with values equal to or greater than 1% TOC content across the nine locations of the broader study program from 2001 to 2022 to look for increasing trends of TOC.

The higher taxonomic level composition of benthic community samples collected from the Malabar 0 km location was plotted at the Polychaeta, Crustacea, Mollusca and Echinodermata taxonomic levels for both the number of taxa and number of individuals of each these four broader taxonomic groups.

In addition to the above check of the higher taxonomic structure, a finer comparison of the taxonomic structure at the Malabar 0 km location to assessment years was performed at the family taxonomic level as a check that taxonomic structure was typical of that seen in these past interpretive years. This was done by placing the 2022-23 sample results from the Malabar outfall location onto the canonical axes of a Canonical Analysis of Principal coordinates (CAP) model of assessment year data (2002, 2005, 2008, 2011, 2014, 2016, 2020) with the outputted sample allocations inspected for fit of the 2022-23 samples to historical samples.

The most recent scheduled assessment year was 2020. For 2020, we analysed all assessment year data extensively (2002, 2005, 2008, 2011, 2014, 2016 and 2020). Under STSIMP 2020 reporting, a separate report (*Ocean Sediment Program 2020 Assessment Year Report*) contains these outcomes (Sydney Water 2020).

3.2.7 Wastewater overflows

Wastewater overflows can occur under dry or wet weather conditions. Each year wastewater overflows are reported extensively to the EPA in two separate reports:

- *Annual Sewage Treatment System Performance Report – Wet Weather Overflow, 2022-23* (Sydney Water, 2022c)
- *Annual Sewage Treatment System Performance Report 2022-23 – Environment Protection Licences Condition R5.5 b) and c) Reticulation System Dry Weather Overflows and Cronulla EPL U3.6, North Head EPL U9.6*. (Sydney Water, 2023b).

This *STSIMP Data Report* is mainly based upon these two reports and provides a condensed summary on wastewater overflows over the last 10 years.

3.2.8 Dry weather leakage detection program

The wastewater network has been divided into 232 SCAMPs, with 226 SCAMPs requiring routine monitoring. When monitoring results from a SCAMP exceed the EPA set trigger threshold value, that SCAMP is investigated to determine the source of the faecal contamination. Investigations may result in multiple sampling events and exceedances for that SCAMP, as these investigations remain open until a source is identified, rectified and verification samples are below the threshold. If resamples (of the routine sample) under these investigations return values below threshold, the investigation is closed, as the leak is not persistent. The findings and rectification work from these in vestigations are recorded and documented for the current financial year in Section 6.1.3.

The dry weather wastewater leakage data presented in this report is based on faecal coliform concentrations recorded over the last 10 years (2013 to 2023). Exceedances were compared against the EPA's >10,000 cfu/100 mL trigger threshold. Dry sites and sites without flowing water at the time of sampling are considered to have passed, as a dry site or no flow indicates no possibility of wastewater contamination.

Historically, two replicate grab samples collected 5 minutes apart were analysed for faecal coliforms up to and including the first quarter of the 2015-16 year (July to September 2015). From October 2015, the sample methodology changed with analysis completed on a composited sample, made up of two equally portioned grab samples collected 5 minutes apart. For consistency, only the highest r ecorded faecal coliform concentration from the paired duplicate samples (pre-October 2015) was us ed to generate the exceedance data represented in the Dry Weather Wastewater Leakage results in Section 6.1.3.

The repeat visits outlined above can result in multiple sampling events and exceedances. For consistency, all information presented in the exceedance chart was based on the site exhibiting at least one exceedance within the corresponding financial period. The percentage of exceedance and pass values for the project were derived by dividing by the number of SCAMPS measured each year.

Alternately, exceedance percentage data presented in the 3-year and 10-year SCAMP performance is derived from the total number of exceedances / number of times the site was sampled. These percentages were overlaid on the existing SCAMP catchment map and categorised into percentage exceedance ranges to highlight problematic SCAMPs with respect to temporal variation.

3.2.9 Chlorophyll-a in estuarine sites

Data availability

All monthly sampling runs for 16 estuarine monitoring sites were conducted by Sydney Water during 2022-23.

Data analysis and presentation

Chlorophyll-a data from the latest year (2022-23) were compared with recent years (previous nine years, 2013-14 to 2021-22). Statistical analysis was performed using PROC GLM in SAS 9.4 to determine significant difference. The trend was considered significantly downward or upward when the p-value was less than 0.05. Data were presented as box plots (as shown earlier in Figure 3-4) for each site to visualise the trends and comparisons over time. Instances when the 2022-23 data were significantly different from previous years and instances when guideline limits (Table 3-10) were exceeded are identified as exceptions and presented in the main body of this report (Volume 1). All box plots for chlorophyll-a in tidal urban rivers and estuaries are presented in Appendix G (Volume 2).

3.2.10 Water quality trends in lagoons

Data availability

Data from all seven lagoon monitoring sites were available for 12 out of scheduled 12 sampling events during 2022-23. The reference site at Wattamolla Lagoon (WL83) was inaccessible for one sampling event due to unsafe access.

Data analysis and presentation

Lagoon chlorophyll-*a*, conductivity and *Enterococci* data were analysed using the same method as outlined above (Section 3.2.10). The exception plots with a trend or guideline exceedance are presented in the main body of the report (Volume 1) and all plots are in Appendix G (Volume 2).

Table 3-10 Water quality guideline for the estuarine and lagoon monitoring sites used in box plots

Water quality	Freshwater sites: (PJLC, PJPRA and GR22)	Estuarine or saline site	Guideline references
Chlorophyll-a (µg/L)	<3.0[a]	<4.0[b]	ANZG 2018
Enterococci (cfu/100 mL)	35[c]		ANZECC 2000
	230[d]		ANZECC 2000

a: Default trigger value for NSW and VIC east flowing coastal rivers.
b: Default trigger value for estuaries.
c: Primary contact recreation.
d: Secondary contact recreation.

3.2.11 Intertidal communities – Sydney estuaries

Sites were grouped based on relatively higher or lower salinity to avoid possible salinity influences. This approach was also used for the intertidal assemblage data and the settlement panel data.

As a check of potential change in community structure of intertidal rock platforms at test sites, a comparison was made to control sites and other sites situated below urban catchments. This check was conducted using PCO. PCO is an ordination technique that is a projection of points onto axes that minimise the residual variation in the space of a chosen dissimilarity measure (Anderson et al. 2008). The user chooses the number of axes to include in the output, but usually the first 2 or 3 axes contain most of the percent variation. In the analysis presented here, PCO was based on a matrix from a distance among centroids analysis, which was calculated from a Bray-Curtis distance measure matrix of either quadratic root (for higher salinity sites) or square root transformed data (for lower salinity sites) for site by year. The Bray-Curtis resemblance measure is focused on compositional changes in taxa identities (Anderson and Walsh 2013). The choice of this resemblance measure is considered appropriate as we understand sites in wave-sheltered areas had measurable impacts after remediation, showing a change in taxonomic composition (Sydney Water 2012). A separate analysis was conducted for each salinity zone. This testing was conducted in PERMANOVA+ (Anderson et al. 2008).

The subsequent PCO output allowed control chart style visualisation of these centroids in Bray-Curtis space for each site by plotting output for PCO axis 1 against year.

Settlement panels were used to supplement intertidal rock platform measurements and provide a focus on colonisation of intertidal larvae at the swimming juvenile life stage. Previous analysis by Sydney Water (2012) showed reductions in barnacle cover (for example Rushcutters Bay PJ33) following sewer remediation, suggesting higher levels of barnacle cover to be a possible indicator of wastewater overflows in wave-sheltered areas of the estuaries around Sydney. As such, analysis of 2022-23 data focused on this single taxon.

A one-way analysis of variance (ANOVA) of barnacle cover with a single factor ‘site’ was conducted on each dataset. Where site differences were indicated by a significant test outcome, a multiple mean (SNK) comparison test was then performed, and SNK test results presented in tables. This testing was conducted in SAS Version 9.4.

3.2.12 Recreational water quality – Harbour and beaches

The Beachwatch data analysis and assessment for this report focused on dry weather *Enterococci* data. Overflows or leakage reaching the waterways during dry weather conditions pose a greater risk to public health. The wet weather public health risk for recreational activities in waterways (harbour and beaches) are a known fact and people are generally aware of this.

Trends in *Enterococci*: Bubble plots

The temporal trends in health of Sydney beaches, harbours and estuaries were first explored by plotting *Enterococci* results for each site with the respective conductivity (Volume 2: Appendix G-4). These bubble plots highlighted the dry weather elevated *Enterococci* densities (as shown by larger bubbles). Assumptions behind these plots were:

- *Enterococci* results without a respective conductivity value were excluded.
- Only dry weather results were included in these plots. *Enterococci* results collected when conductivity was below 30,000 µS/cm were considered extreme wet weather and not included in these plots.
- Data labels: Maximum *Enterococci* values for each financial year were labelled where *Enterococci* values ≥ 230 cfu/100mL, which is the secondary contact recreation guideline (ANZECC 2000, Table 3-10).

Dry weather overflows or leakage would be represented by higher value bubbles that corresponded to the upper conductivity level. Sites identified by this assessment might inform catchments in which to undertake non-routine investigations under the dry weather leakage program.

Site-specific investigations

Site-specific investigations were carried out on all Beachwatch data with *Enterococci* values higher than the primary contact recreational guideline (35 cfu/100 mL) during 2022-23. Firstly, these exceptions were merged with the site-specific rainfall data (BOM). Any *Enterococci* data collected following 2 mm or more rainfall in the previous 72 hours of sampling time were excluded considering wet weather conditions and other catchments impacts (Volume 2: Appendix G, Table G-1).

These short-listed extreme dry weather *Enterococci* exceptions were cross-checked against wastewater network overflow records and relevant environmental response data to determine if the elevated levels were potentially associated with known surcharges. Sites that could not be explained by known network issues represented unexplained dry weather events. If those unexplained events are persistent, there is an opportunity to complete non-routine catchment investigations under the Dry Weather Leakage Detection Program to locate the potential source.

4 Results and discussion – WRRF discharges

4.1 Hawkesbury-Nepean River

This chapter presents the monitoring results for the Hawkesbury-Nepean River catchment that are directly linked with the assessment of WRRF impact. WRRFs discharging into this catchment are ordered from upstream (Picton) to downstream (Brooklyn). Under each WRRF, results are presented following the **Pressure**, **Stressor** and **Ecosystem Receptor** (**P-S-ER**) causal pathway elements.

The volume of treated wastewater discharged from the Hawkesbury-Nepean River WRRFs in 2022-23 and the population serviced by these WRRFs are shown in Table 4-1.

This section contains a summary of exceptions for each of the Hawkesbury-Nepean River discharging WRRFs.

Trend plots of discharge volume and catchment specific rainfall are presented first, then reuse volume where applicable. This is followed by load limit plots where there was an exceedance during the 2022-23 monitoring period.

Trend plots showing the concentration of analytes in the discharge were only presented where they exceeded the respective EPL limit for a WRRF during the 2022-23 monitoring period, or there was a significant analyte concentration increase/decrease in 2022-23 with comparison to earlier years.

Trend plots on nutrients, physico-chemical water quality and phytoplankton analytes for the upstream/downstream sites were only presented where the 2022-23 median concentrations exceeded the respective ANZG (2018) or NHMRC (2008) guideline limits, or there was a significant analyte concentration increase/decrease in 2022-23 compared to earlier years.

Trend plots on macroinvertebrate biotic index SIGNAL-SG were only presented where a statistical test was significant between upstream and downstream SIGNAL-SG scores for 2022-23.

All trend plots showing the analyte concentration and load data for Hawkesbury-Nepean River WRRFs, including applicable concentration and load limits, can be found in Volume 2 (Appendix A-1 to A-15)

All trend plots on nutrients, physico-chemical water quality and phytoplankton analytes of the Hawkesbury-Nepean River are also included in Volume 2 (Appendix A-1 to A-14).

Multiple electronic appendix files are also provided on raw data and summary of results for all Hawkesbury-Nepean River WRRFs, receiving water quality by year.

All trend plots, univariate statistical analysis, multivariate analysis and interpretation on macroinvertebrate data are included in Volume 2 (Appendix A-1 to A-14, Ecosystem receptor – macroinvertebrate sections). Raw data of macroinvertebrate taxa and counts is also included in the electronic appendices.

Table 4-1 Hawkesbury-Nepean River WRRFs operated by Sydney Water

WRRFs	Treatment level	Discharge 2022-23 (ML/year)[a]	Projected population 2022-23[b]	Discharge location
Picton	Tertiary and disinfection	1,091	17,970	Re-used for on-site agricultural irrigation with wet-weather discharge to Stonequarry Creek
West Camden	Tertiary and disinfection	9,173	97,760	Matahil Creek to the Hawkesbury-Nepean River
Wallacia	Tertiary and disinfection	439	5,450	Warragamba River to the Hawkesbury-Nepean River
Penrith	Tertiary and disinfection	5,225	119,880	Boundary Creek to the Hawkesbury-Nepean River
Winmalee	Tertiary and disinfection	8,572	59,330	Unnamed creek to the Hawkesbury-Nepean River
North Richmond	Tertiary and disinfection	468	6,500	Redbank Creek to the Hawkesbury River
Richmond	Tertiary and disinfection	823	14,890	Re-used for irrigation at the University of Western Sydney Richmond campus and Richmond Golf Club; excess discharged to an unnamed creek that flows to Rickabys Creek
St Marys	Tertiary and disinfection	10,003	173,880	Unnamed creek to South Creek
Quakers Hill	Tertiary and disinfection	17,231	167,790	Breakfast Creek to Eastern Creek
Riverstone	Tertiary and disinfection	5,368	81,400	Eastern Creek to South Creek
Rouse Hill	Tertiary and disinfection	8,712	125,970	Second Ponds Creek to Cattai Creek; also re-used for local recycling scheme
Castle Hill	Tertiary and disinfection	2,864	33,560	Cattai Creek
West Hornsby	Tertiary and disinfection	5,980	58,150	Waitara Creek to Berowra Creek
Hornsby Heights	Tertiary and disinfection	3,146	32,500	Calna Creek to Berowra Creek
Brooklyn	Tertiary and disinfection	96	1,460	Hawkesbury River at 14 m depth on the second pylon of the old road bridge adjacent to Kangaroo Point

[a] Discharge volume excludes onsite and offsite reuse.

[b] Projected populations (at 30 June 2023) are based on forecasts by the Australian Bureau of Statistics and the DPE.

4.1.1 Picton WRRF

- Total phosphorus and total suspended solid discharge load in the precautionary discharge and faecal coliforms 80th percentile in the Western Dam irrigation exceeded the EPL limits. These exceedances were largely influenced by extreme wet weather events in the first half of the 2022-23 reporting period. All other discharge parameters were within EPL limits. There was an increasing trend in ammonia nitrogen and total phosphorus concentration in the discharge, while total nitrogen concentration showed a decreasing trend.
- Filterable total phosphorus decreased significantly at the upstream Stonequarry Creek site while the total phosphorus concentration increased significantly at the downstream Nepean River site.
- Trends in phytoplankton as chlorophyll-a or biovolume or species counts were steady at all creek/river monitoring sites in 2022-23. However, phytoplankton blooms were observed at the Stonequarry Creek site downstream of Picton discharges where potentially toxic blue-green taxa (*Microcystis)* reached NHMRC (2008) Red Alert level twice during May 2023.
- No stream health impacts (as indicated by macroinvertebrates) were identified for the Hawkesbury-Nepean River downstream of where Picton WRRF discharges.

Pressure – Wastewater discharge

Table 4-2 Gate 1 Analysis outcome summary – Picton WRRF

Analytes / Picton WRRF	Nutrients			Conventional analytes				
	Ammonia Nitrogen	Total Nitrogen	Total Phosphorus	Biochemical Oxygen Demand	Faecal Coliforms	Oil and Grease	pH	Total Suspended Solids
Concentration EPA ID 1 (Precautionary discharge)	↗	↘	↗	→	→			→
Load EPA ID 1 (Precautionary discharge)								
Concentration EPA ID 11 (Eastern Dam to Irrigation Farm)	→	↘	→	→	→		↗	→
Concentration EPA ID 13 (Western Dam to Irrigation Farm	↗	→	↗	→	→		→	→

↗	Upward trend	↘	Downward trend	→	No trend, p>0.05

(green)	Within the Environment Protection Licence limit
(yellow)	Environment Protection Licence limit exceedance
(grey)	Analytes not required in the EPL or no concentration limit

The load limits for total phosphorus and total suspended solids were exceeded in the precautionary discharge from Picton WRRF (EPA ID 1, PI0001) during the 2022-23 reporting period. Additionally, the 80th percentile concentration limit for faecal coliforms (EPA ID Point 13, PI0013 Western irrigation dam) was also exceeded.

The 50th percentile value for pH at the Eastern Dam irrigation sample point was outside the prescribed EPL limit (6.5 – 9.5 pH units). Under EPL condition L3.10, when the pH of the effluent discharged at Point 11 and Point 13 is elevated due to excessive algae in the irrigation dam, exceedance of the upper value of the 50th percentile concentration limit for pH is permitted. The elevated 50th percentile value (9.67 pH) was due to algae in the dam being the sole cause of the exceedances recorded on 16/12/2022 (9.97 pH), 28/12/2022 (10.23 pH), 03/01/2023 (10.08 pH) and 09/01/2023 (10.13 pH). Excluding these data points, the revised 50th percentile value for pH from the Eastern Dam is 9.02 pH, within the EPL limit range.

All other concentration and load limits in the precautionary discharge and irrigation storage dams were within EPL limits.

Statistical analysis identified significant increasing trends in ammonia nitrogen and total phosphorus concentrations within the precautionary discharge from Picton WRRF in 2022-23 compared to the previous nine years. A significant decreasing trend was observed in total nitrogen. Increasing trends in ammonia nitrogen and total phosphorus concentrations were also observed in the Western irrigation dam (EPA ID 13), whilst an increasing trend in pH and a decreasing trend in total nitrogen were recorded in the secondary treated Eastern irrigation dam (EPA ID 11).

The load EPL annual limit non compliances for total suspended solids and total phosphorus were exceeded during the 2022-23 reporting period due to the following factors:

- During the extreme weather events during the first half of the reporting period, Picton WRRF received elevated wet weather flows. To minimise uncontrolled discharge of water from the Eastern Dam, effluent which was not fully treated was transferred into the Western Dam, impacting water quality.
- Increasing inflows being received by the facility and treated volume exceeding the irrigation capacity of Picton Farm. Higher than average rainfall for the first half of the reporting period resulted in increased inflow and reduced opportunities to irrigate.

Subsequently, this led to higher volumes of treated effluent being discharged to the environment through the Emergency Operating Protocol resulting in these load limits being exceeded.

The 80th percentile concentration limit for faecal coliforms was exceeded at Picton WRRF EPL Point 13 (Western Dam irrigation sample point) was as a result from the wet weather events in the first half of the 2022-23 reporting period. Picton WRRF received elevated wet weather flows into the facility during this period. To reduce the risk of Eastern Dam overflowing into the adjoining environment, dam transfers from the Eastern Dam to Western Dam containing effluent not fully treated were carried out, impacting water quality.

The increasing trends in ammonia nitrogen and total phosphorus can also be linked to the above mentioned factors. The increasing trend in pH within the Eastern irrigation dam was due to algal growth.

In February 2023, Sydney Water applied to the EPA to vary the Picton EPL to allow for more flexibility in discharges to Stonequarry Creek. Changes to pollutant concentrations and load limits were also proposed. The EPA issued an amended 10555 EPL to Sydney Water on 24 May 2023, allowing for greater flexibility in discharges to Stonequarry Creek when preparing for anticipated extreme wet weather events. In response to the pollution studies and reduction programs added to the amended EPL, Sydney Water is planning the delivery of various projects to improve effluent quality and increase reuse from Picton WRRF.

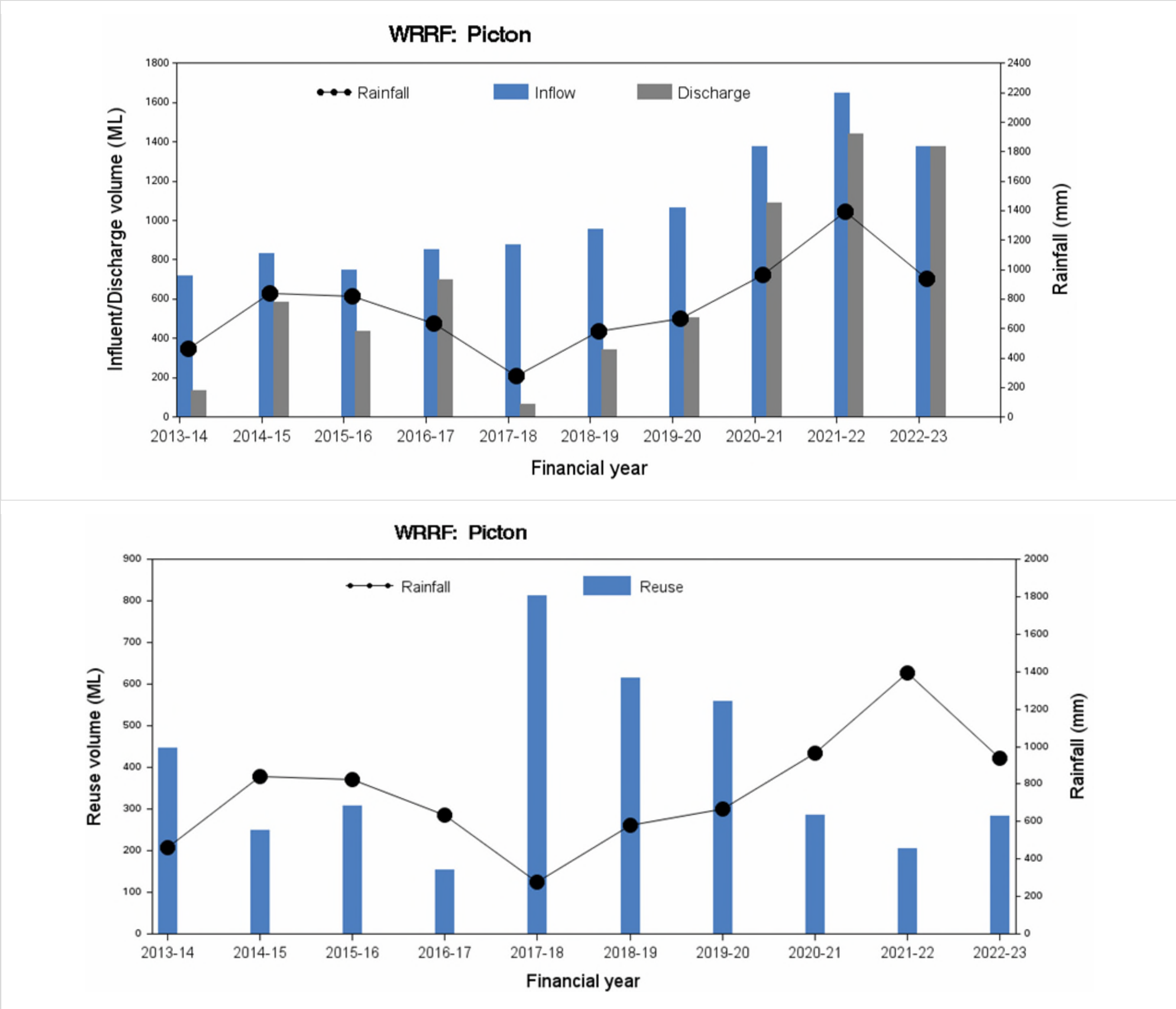
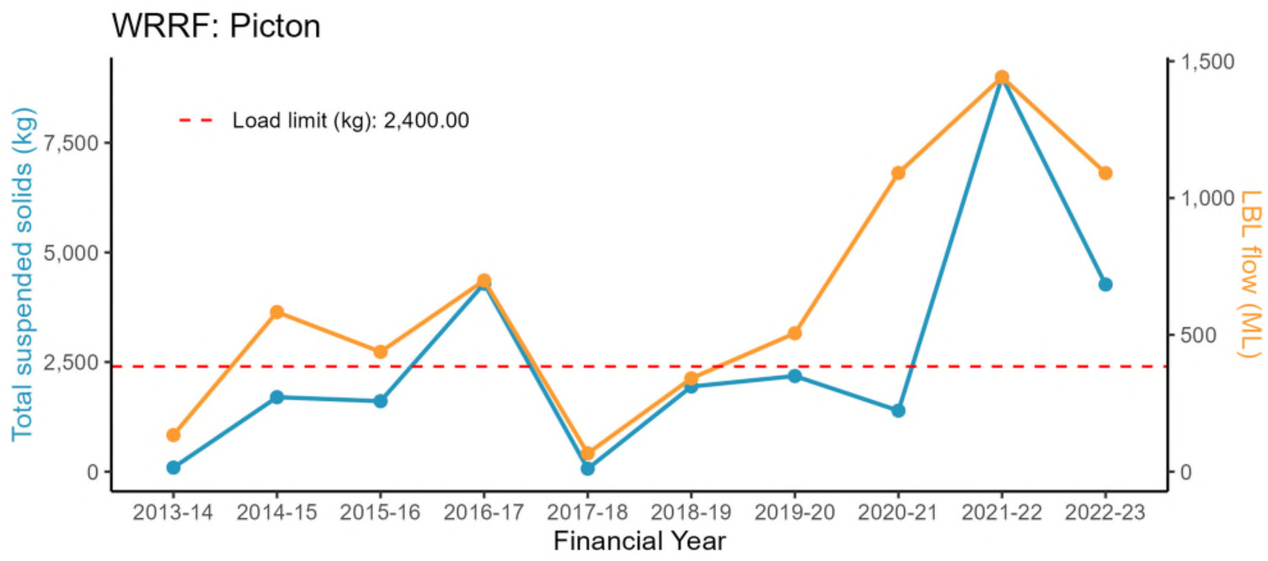
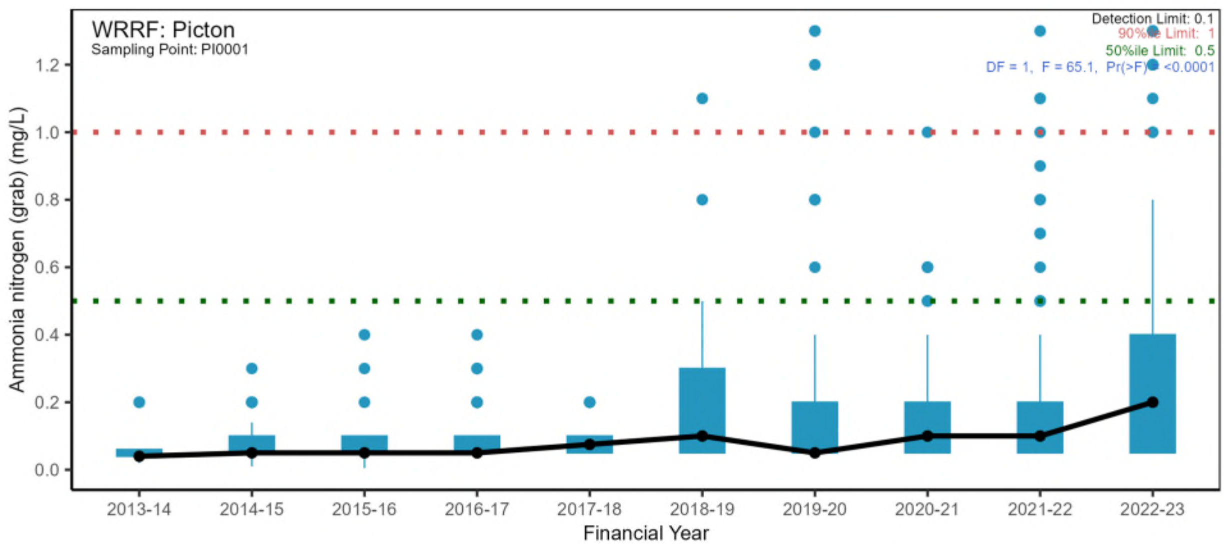


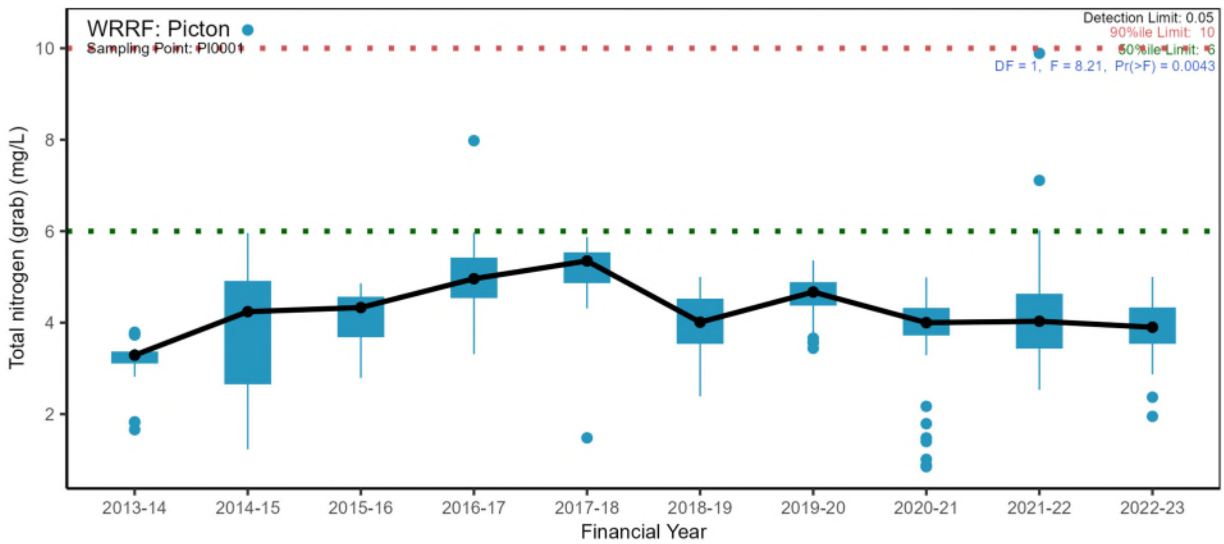
Figure 4-1 Picton WRRF inflow, discharge and reuse volume with catchment rainfall plots



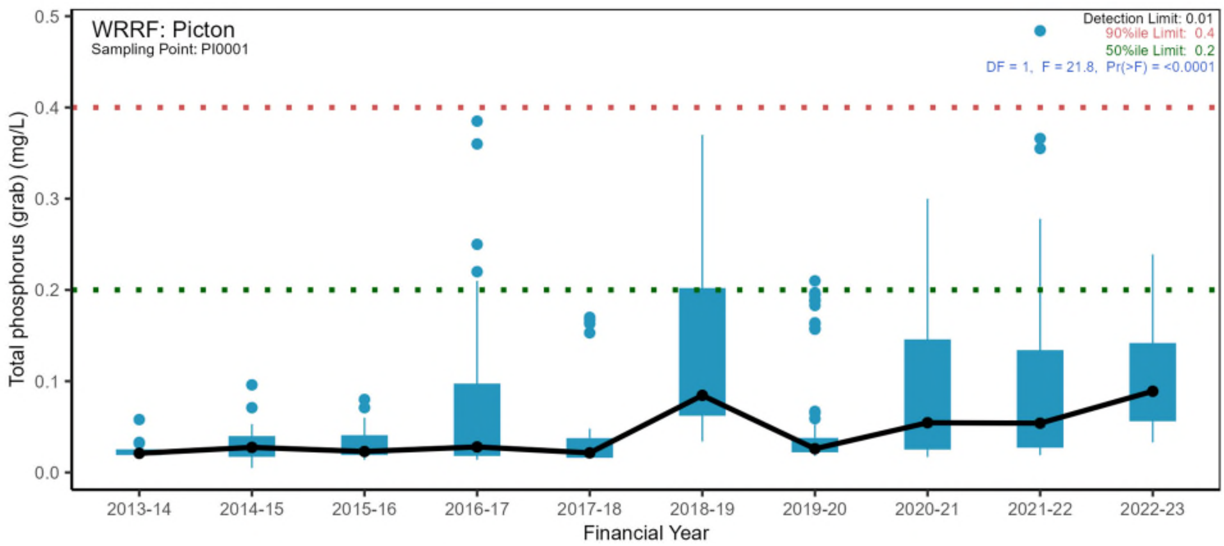
WRRF: Picton
Load limit (kg): 2,400.00
Total suspended solids (kg)
LBL flow (ML)
Financial Year

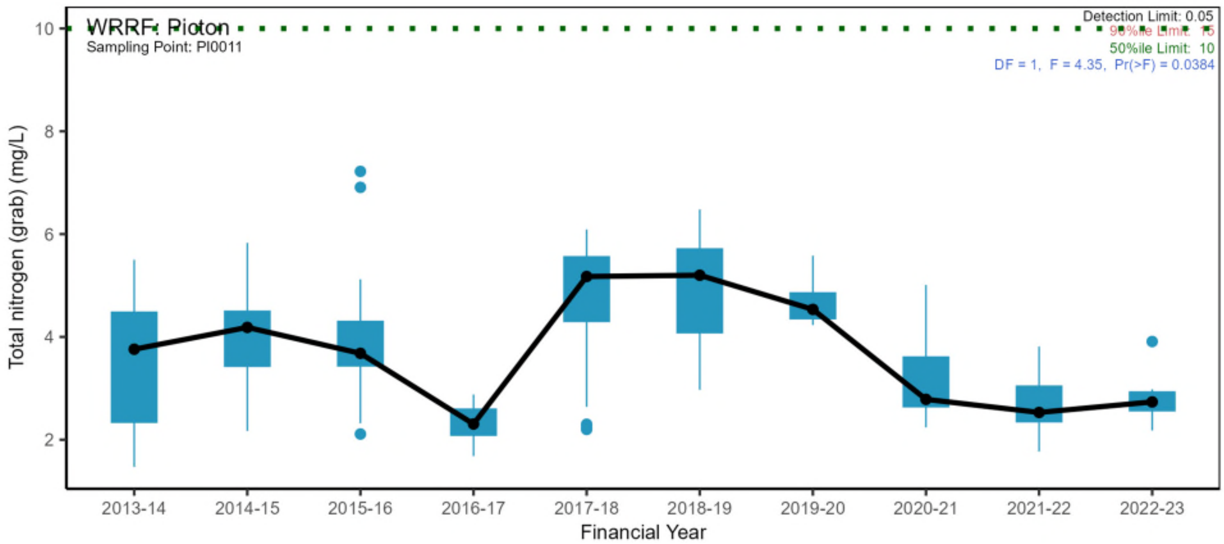


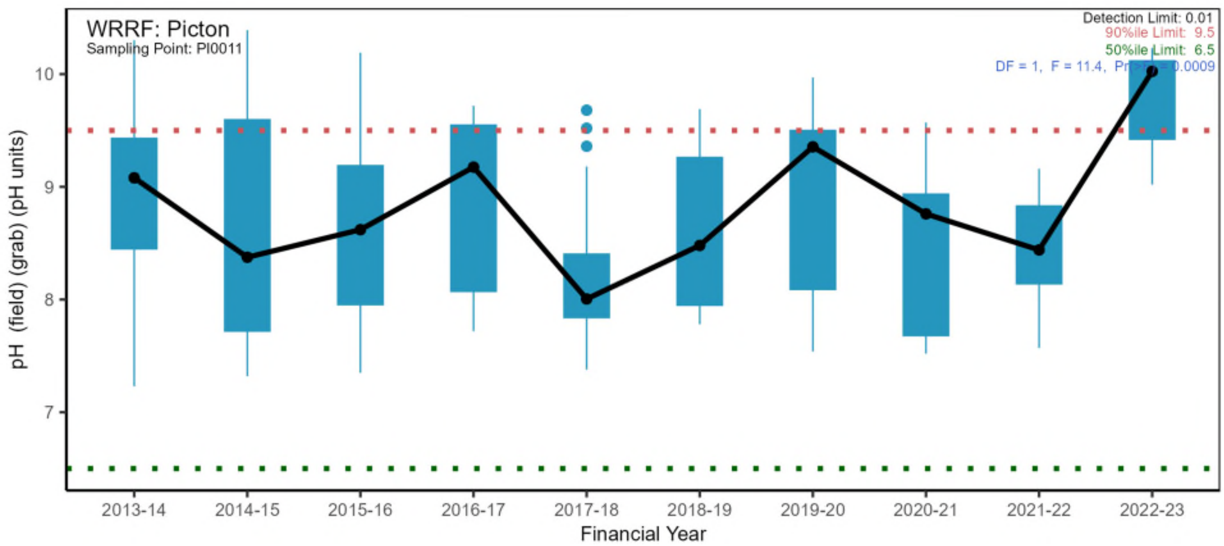
WRRF: Picton
Sampling Point: PI0001
Detection Limit: 0.1
90%ile Limit: 1
50%ile Limit: 0.5
DF = 1, F = 65.1, Pr(>F) = <0.0001
Ammonia nitrogen (grab) (mg/L)
Financial Year



WRRF: Picton
Sampling Point: PI0001
Detection Limit: 0.05
90%ile Limit: 10
50%ile Limit: 6
DF = 1, F = 8.21, Pr(>F) = 0.0043
Total nitrogen (grab) (mg/L)
Financial Year


WRRF: Picton
Sampling Point: PI0001
Detection Limit: 0.01
90%ile Limit: 0.4
50%ile Limit: 0.2
DF = 1, F = 21.8, Pr(>F) = <0.0001
Total phosphorus (grab) (mg/L)
Financial Year
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
2020-21
2021-22
2022-23


WRRF: Picton
Sampling Point: PI0011
Detection Limit: 0.05
50%ile Limit: 10
DF = 1, F = 4.35, Pr(>F) = 0.0384
Total nitrogen (grab) (mg/L)
Financial Year
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
2020-21
2021-22
2022-23


WRRF: Picton
Sampling Point: PI0011
Detection Limit: 0.01
90%ile Limit: 9.5
50%ile Limit: 6.5
pH (field) (grab) (pH units)
Financial Year
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
2020-21
2021-22
2022-23

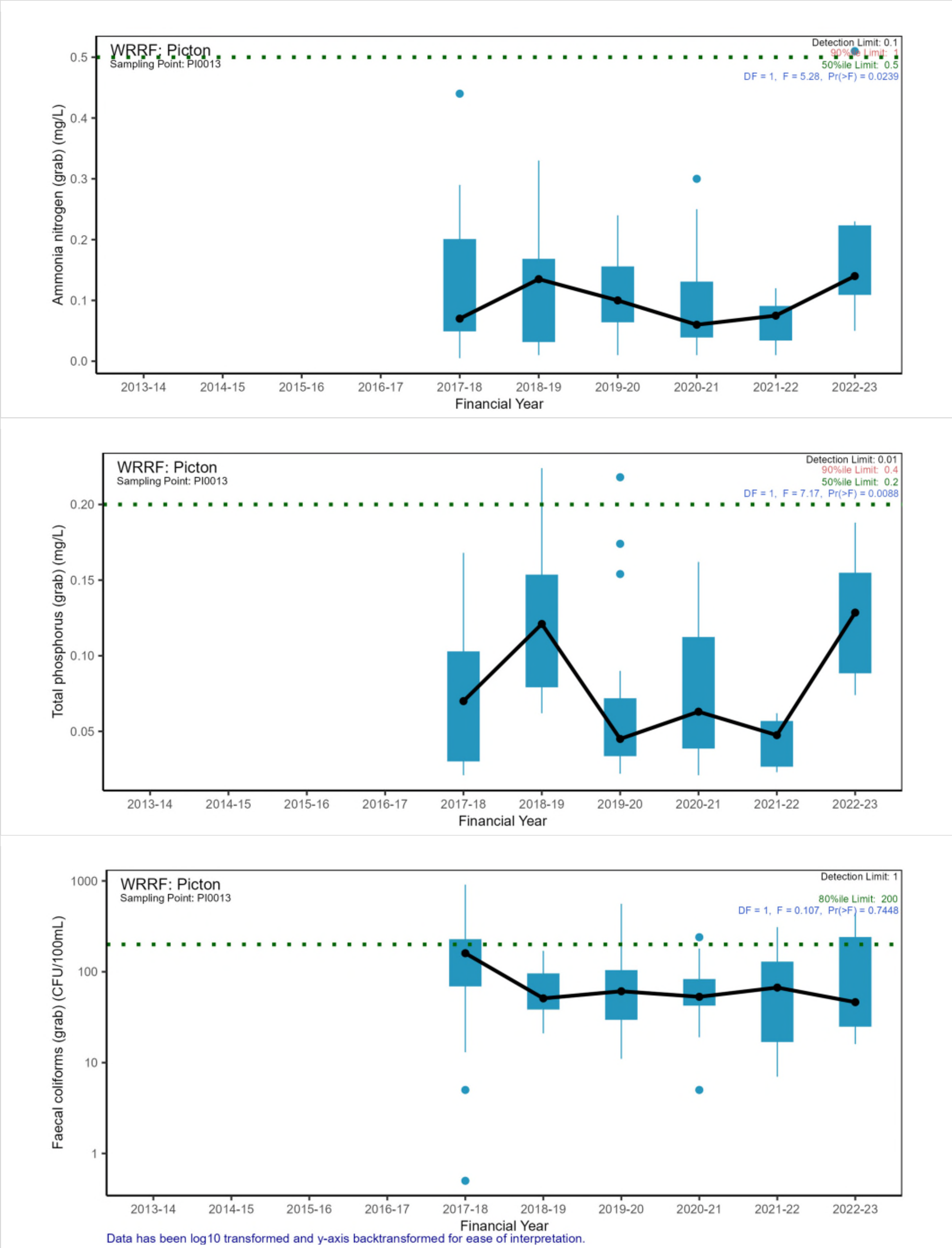


Figure 4-2 Picton WRRF discharge and reuse quality exception plots

Stressor – Water quality

Table 4-3 Gate 1 Analysis outcome summary – water quality upstream and downstream of Picton WRRF discharge

Monitoring sites	Nutrient analytes					Physico-chemical analytes					
	Ammonia nitrogen	Oxidised nitrogen	Total nitrogen	Filterable total phosphorus	Total phosphorus	Conductivity	Dissolved oxygen	Dissolved oxygen saturation	pH	Temperature	Turbidity
Upstream tributary (N911B)	→	→	→	↘	→	→	→	→	→	→	→
Downstream tributary (N911)	→	→	→	→	→	→	→	→	→	→	→
Upstream River (N92)	→	→	→	→	→	↘	→	→	↘	→	↗
Downstream River (N91)	→	→	→	→	↗	→	→	↗	↘	→	↗

↗	Upward trend	↘	Downward trend	→	no trend, p>0.05

(green)	2022-23 Median value within the guideline limit	(white)	No guideline applicable
(yellow)	2022-23 Median value outside the guideline limit	(grey)	Insufficient data

Picton WRRF discharges into Stonequarry Creek joining with the Nepean River downstream of Maldon Weir. The control site for Stonequarry Creek is located immediately upstream of the Picton WRRF discharge point at Picton Farm (N911B). The water quality of this site is also influenced by upstream catchment run-off with mixed land uses including low density rural residential areas and township of Picton and Thirlmere (partly). For the Nepean River, N92 is the control site at Maldon Weir upstream of Stonequarry Creek. The water quality at Maldon Weir is influenced by upstream rural catchment factors, Tahmoor colliery and environmental flows released from the upstream water storage dams (Nepean, Avon and Cordeaux).

Statistical analysis confirmed that ammonia nitrogen, oxidised nitrogen and total nitrogen concentrations were steady in 2022-23 in comparison to previous periods at all four monitoring sites in Stonequarry Creek and the Nepean River. However, the trend plots of oxidised and total nitrogen analytes indicated that concentrations of these analytes have eased further at the downstream river site (N91) in 2022-23 compared to peaks in 2018-20. Downstream Stonequarry Creek data also showed a decreasing trend in these analytes although not statistically significant.

Filterable total phosphorus in the upstream Stonequarry Creek site (N911B) was significantly lower in 2022-23 compared to 2021-22 results. Total phosphorus concentrations were significantly higher at the downstream Nepean River site (N91) during 2022-23 in comparison to 2015-22. Concentrations of phosphorus analytes were steady at the other three monitoring sites. There is no link between the increased phosphorus concentrations at downstream Nepean River site (N91) with the elevated phosphorus concentrations in Picton WRRF discharges (as mentioned above in Pressure indicators).

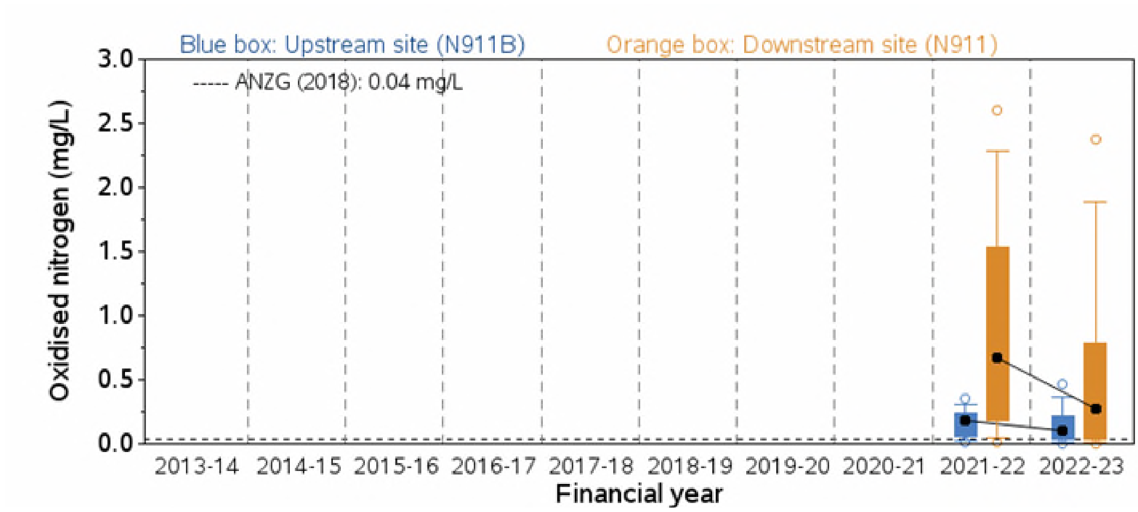
The trends in key nutrient concentrations in the downstream Stonequarry Creek site (N911) are not aligned with the increasing or decreasing trends in respective nutrients concentrations in Picton

WRRF discharges. Statistical analysis will be included in SWAM reports from 2023-24 to further validate the trend.

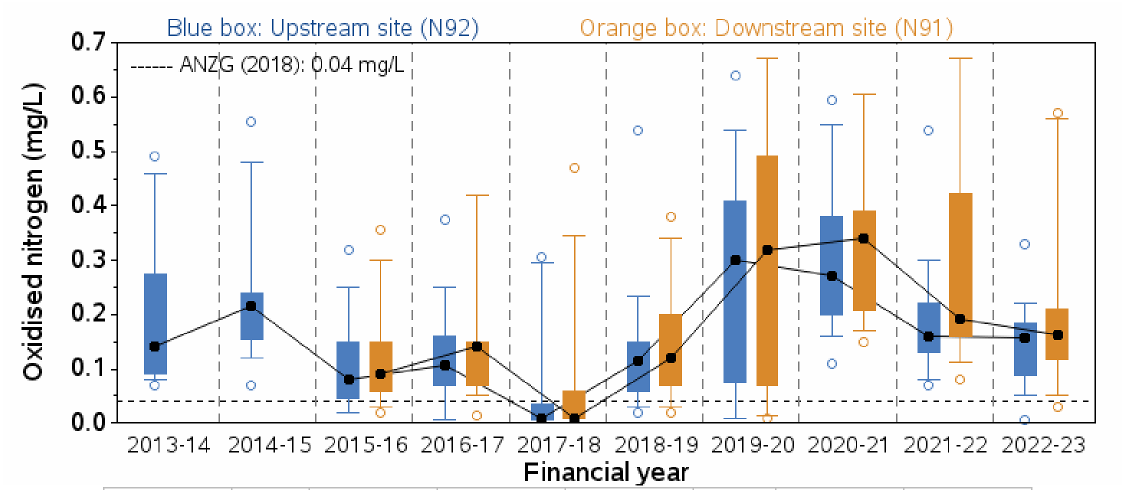
Conductivity and pH values were significantly lower at the upstream Nepean River site (N92) in 2022-23 in comparison to the previous nine years, whereas turbidity was significantly higher at this site. This may be attributed to increased rainfall events in 2022-23.

Dissolved oxygen saturation and turbidity was significantly higher, and pH significantly lower in 2022-23 at downstream Nepean River site (N91) compared to 2015-22 results.

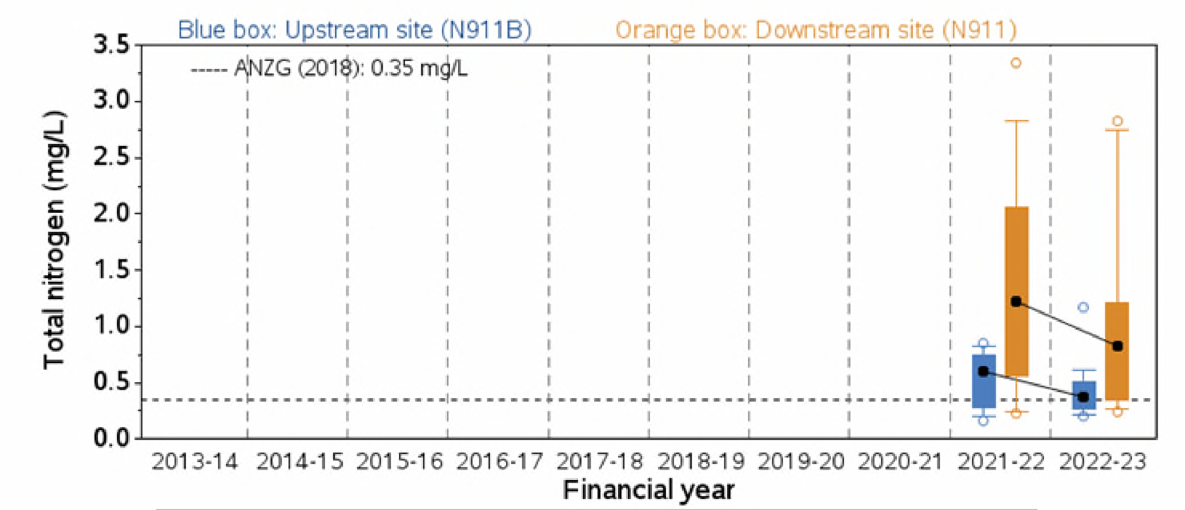
The median ammonia nitrogen at both Stonequarry Creek and Nepean River sites were within the guideline limits during the 2022-23 reporting year. The median oxidised nitrogen concentrations at all four upstream and downstream monitoring sites for Picton WRRF were higher than the guideline value. Total nitrogen concentrations also exceeded at three of the sites, the exception was upstream Nepean River at Maldon Weir (N92). The median turbidity level at N92 was below the lower guideline value.



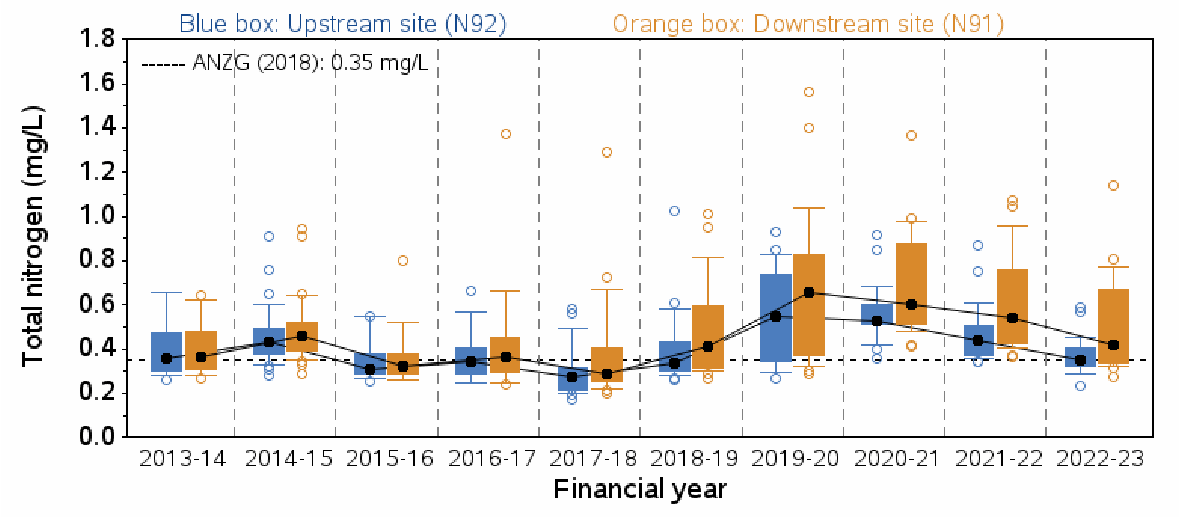
Site	DF	F Value	Pr>F	Site	DF	F Value	Pr>F
N911B	1	0.28	0.6031	N911	1	0.78	0.3831



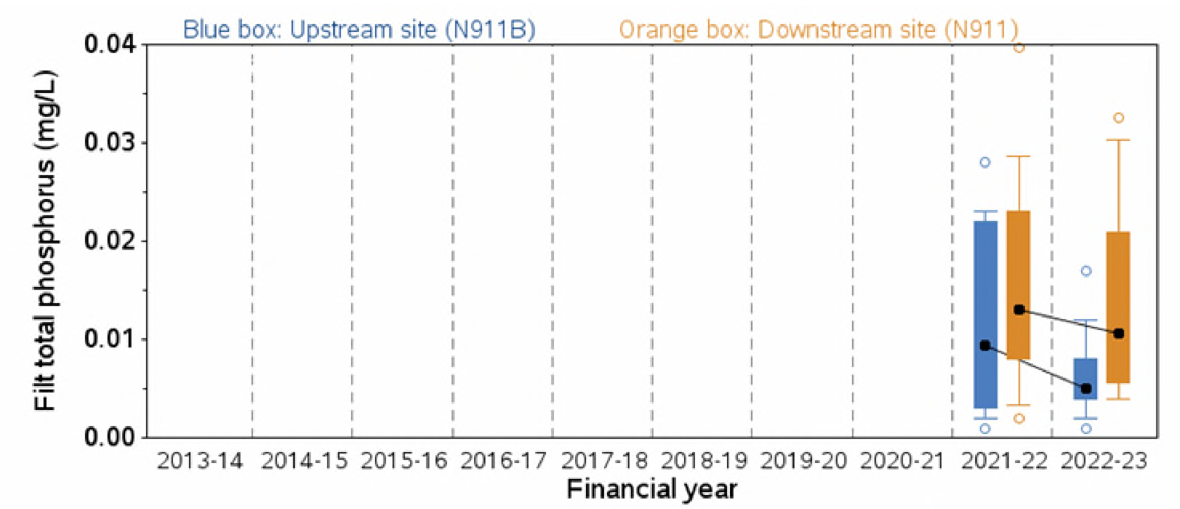
site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N92	1	0.86	0.3543	N91	1	0	0.989



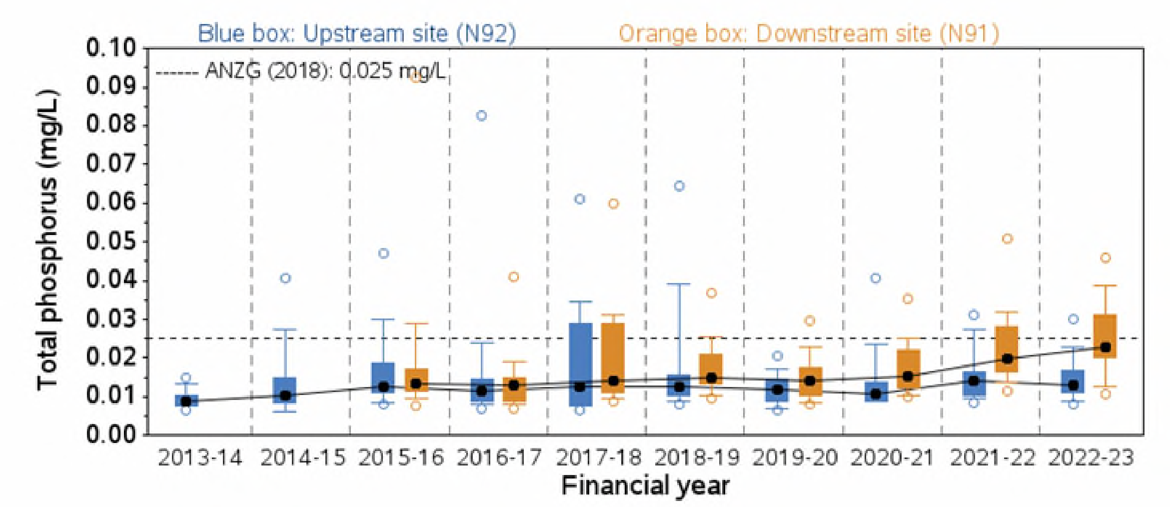
Site	DF	F Value	Pr>F	Site	DF	F Value	Pr>F
N911B	1	1.88	0.1801	N911	1	1.02	0.3206



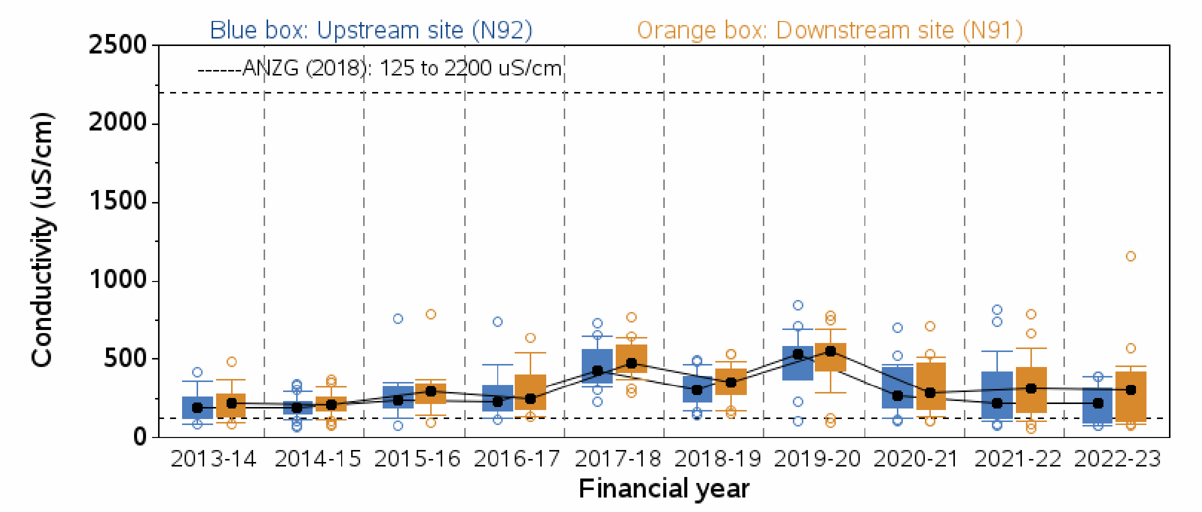
site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N92	1	2.91	0.09	N91	1	0.11	0.7411



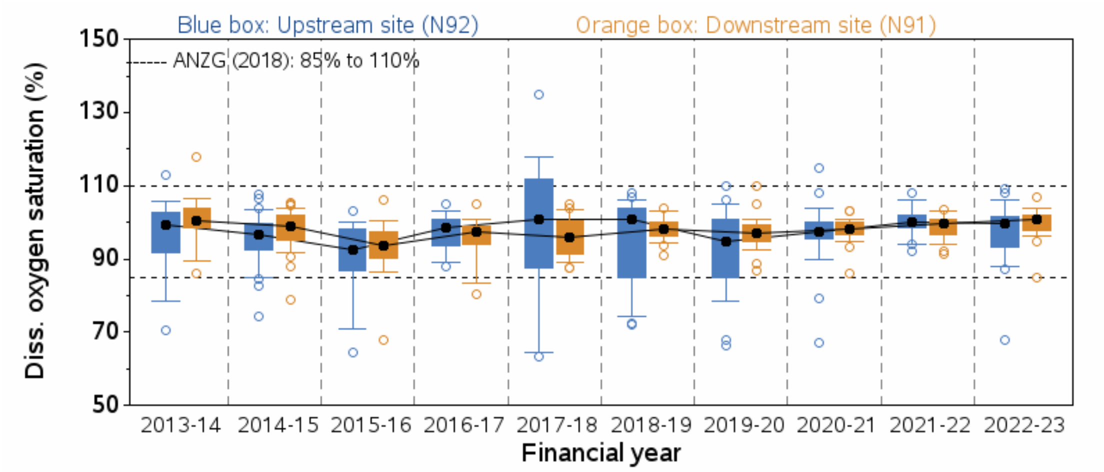
site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N911B	1	5.38	0.0267	N911	1	0.39	0.5362



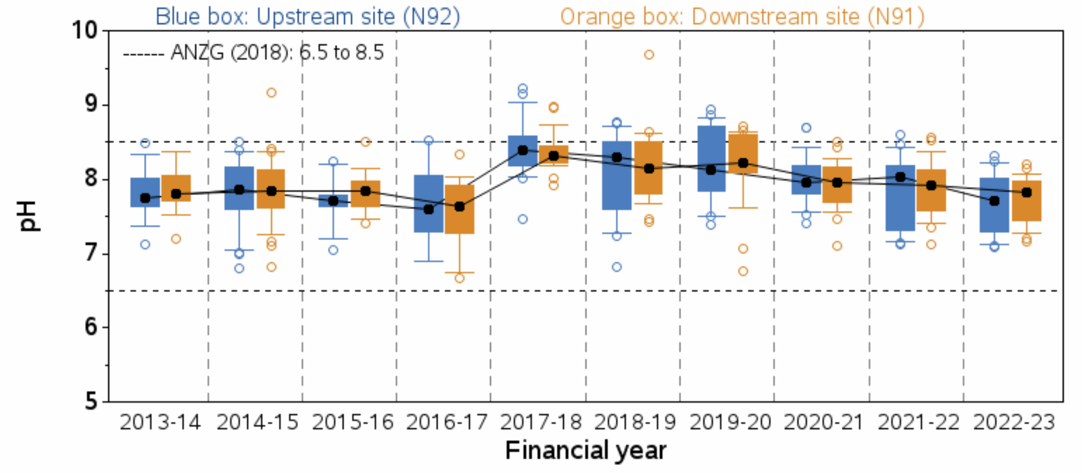
site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N92	1	0	0.9447	N91	1	6.82	0.01



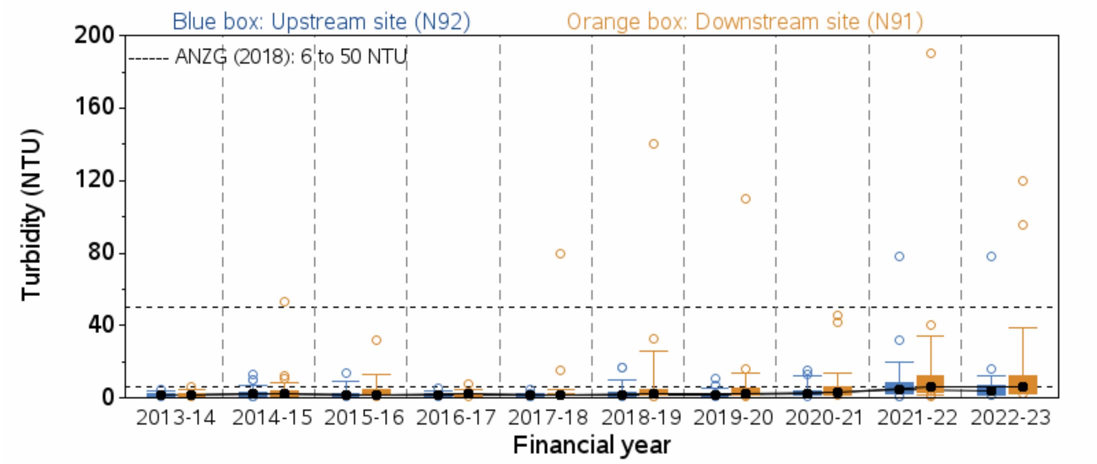
site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N92	1	4.2	0.042	N91	1	1.48	0.2262



site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N92	1	0.08	0.7758	N91	1	8.53	0.0041



site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N92	1	6.68	0.0106	N91	1	7.24	0.008



site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N92	1	4.31	0.0394	N91	1	4.52	0.0353

Figure 4-3 Nutrients and physico-chemical water quality exception plots, upstream and downstream of Picton WRRF

Ecosystem Receptor – Phytoplankton

Table 4-4 Gate 1 Analysis outcome summary – phytoplankton as chlorophyll-a, biovolume and species counts, upstream and downstream of Picton WRRF discharge

Monitoring sites	Phytoplankton analytes			
	Chlorophyll-a	Total phytoplankton biovolume	Blue-green biovolume	Toxic blue-green count
Upstream tributary (N911B)	→			
Downstream tributary (N911)	→	→	→	→
Upstream River (N92)	→	→	→	→
Downstream River (N91)	→	→	→	→

↗	Upward trend	↘	Downward trend	→	no trend, p>0.05

(green)	2022-23 Median value within the guideline limit	(white)	No guideline applicable
(yellow)	2022-23 Median value outside the guideline limit	(grey)	Insufficient data

No significant statistical trend was found in chlorophyll-a or other phytoplankton analytes at any Stonequarry Creek or Nepean River sites.

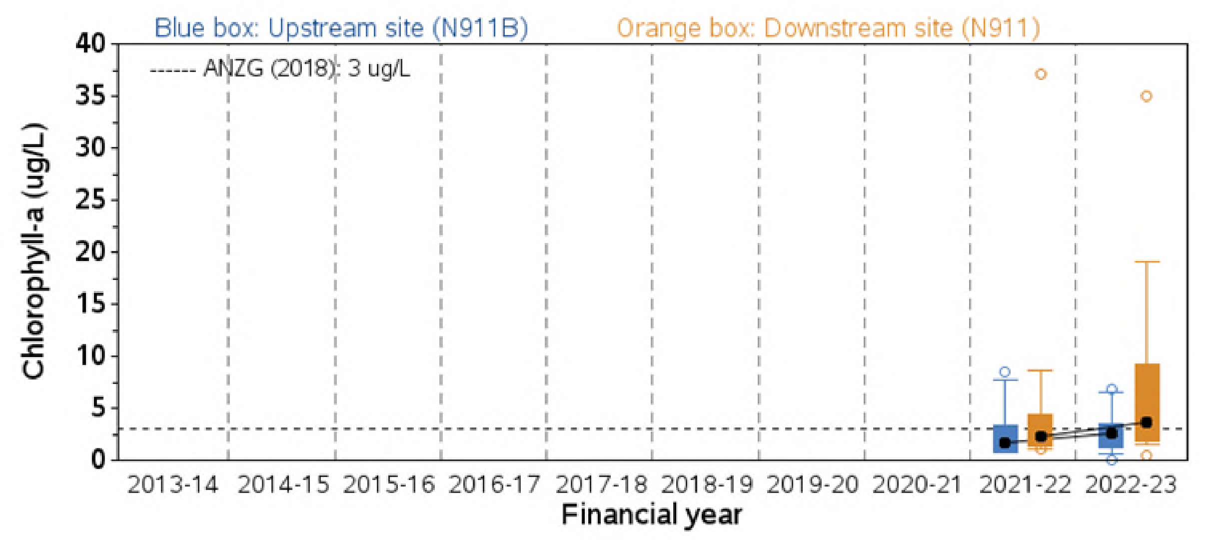
The median chlorophyll-a concentration was higher than the ANZG (2018) guideline at downstream Stonequarry Creek site (N911) in 2022-23.

There were insufficient phytoplankton data for the upstream creek site (N911B), where none of the samples qualified for phytoplankton biovolume and species count (ie chlorophyll-a was lower than 7 µg/L).

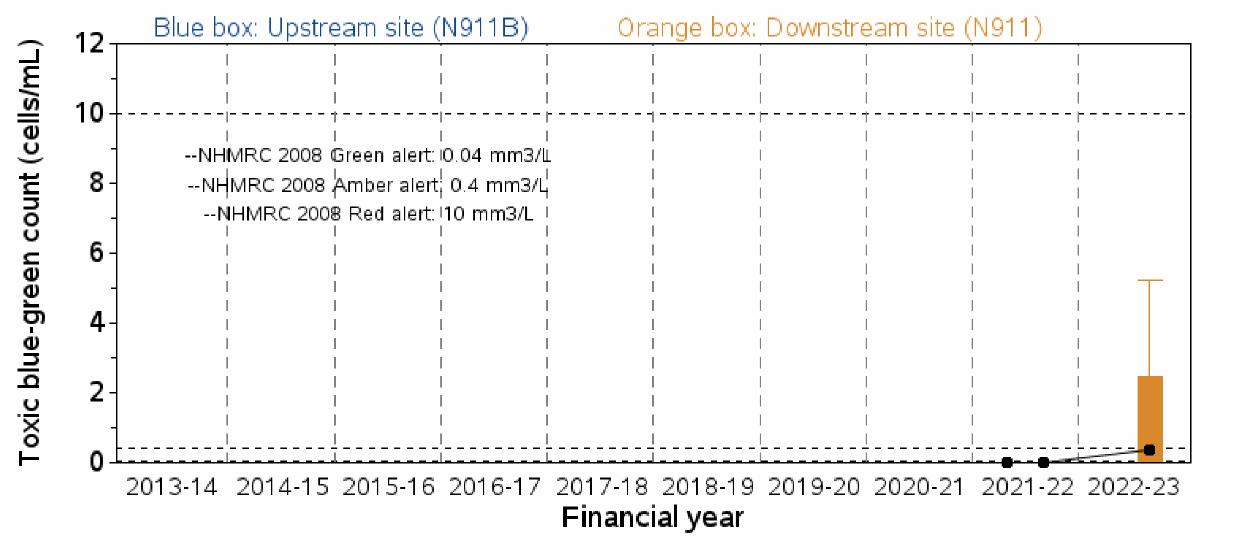
Six of the 17 samples collected from N911 qualified for a phytoplankton biovolume and species count as chlorophyll-a were higher than 7.0 µg/L. The median toxic blue-green count for these samples was higher than the NHRMC (2008) Amber Alert. The toxic blue-green counts for this site reached NHMRC (2008) Red Alert levels (>50,000 cells) on two sampling days in May 2023. Potentially toxic blue-green taxa *Microcystis sp.* And *Microcystis aeruginosa* were found in these samples, maximum of 161,300 cell/mL on 30 May 2023.

Three of the 16 samples collected from N92 qualified for a phytoplankton biovolume and species count as chlorophyll-a were higher than 7.0 µg/L. No potentially toxic blue-green species were found in these samples.

Four of the 17 samples collected from N91 qualified for a phytoplankton biovolume and species count as chlorophyll-a were higher than 7.0 µg/L. Potentially toxic taxa *Microcystis* was found in one of the samples on 20 June 2023 (484 cells/mL).



Site	DF	F Value	Pr>F	Site	DF	F Value	Pr>F
N911B	1	0.09	0.7653	N911	1	0.66	0.4214



Site	DF	F Value	Pr>F	Site	DF	F Value	Pr>F
N911B	No data for analysis.			N911	1	1.81	0.2151

Figure 4-4 Phytoplankton as chlorophyll-a, biovolume and species counts exception plots, upstream and downstream of Picton WRRF

Ecosystem Receptor – Macroinvertebrates

No stream health impacts (as indicated by macroinvertebrates) were identified in the Nepean River downstream of where Picton WRRF discharges (Volume 2 Appendix A-1).

4.1.2 West Camden WRRF

- Ammonia nitrogen and total nitrogen 50th and 90th percentiles as well as the annual total nitrogen load limit were exceeded during 2022-23. All other parameters (concentrations and loads) monitored in the discharge from West Camden WRRF were within EPL limits. There were increasing trends in ammonia nitrogen, total nitrogen and faecal coliform concentrations within the discharge, while copper and zinc concentrations showed a decreasing trend.
- Oxidised nitrogen and total nitrogen concentrations increased significantly during 2022-23 at the downstream Matahil Creek site. Concentrations of all three nitrogen analytes (including ammonia nitrogen) also increased significantly at the downstream Nepean River site. Nitrogen enrichment at these downstream sites indicate a link with the elevated nitrogen concentrations/ loads in West Camden WRRF discharge.
- Chlorophyll-a remained elevated at the upstream Matahil Creek site although 2022-23 results data were not significantly different from the earlier data. Total phytoplankton biovolume increased significantly at this site in 2022-23. Chlorophyll-a and total phytoplankton biovolume increased significantly at the downstream Nepean River site in 2022-23.
- Stream health results (as indicated by macroinvertebrates) suggested localised ecosystem impacts in Matahil Creek, downstream of West Camden WRRF. There was no evidence these impacts had any effect on the Hawkesbury-Nepean River system to which this creek flows.

Pressure – Wastewater discharge

Table 4-5 Gate 1 Analysis outcome summary – West Camden WRRF

Analytes / West Camden WRRF	Nutrients			Conventional analytes					EC_{50} Toxicity	Trace Metals				Other chemicals / organics	
	Ammonia Nitrogen	Total Nitrogen	Total Phosphorus	Biochemical Oxygen Demand	Total Residual Chlorine	Faecal Coliforms	Oil and Grease	Total Suspended Solids		Aluminium	Copper	Iron	Zinc	Diazinon	Hydrogen sulfide (un-ionised)
Concentration	↗	↗	→	→	→	↗		→	→	→	↘	→	↘	→	→
Load															

↗	Upward trend	↘	Downward trend	→	No trend, p>0.05

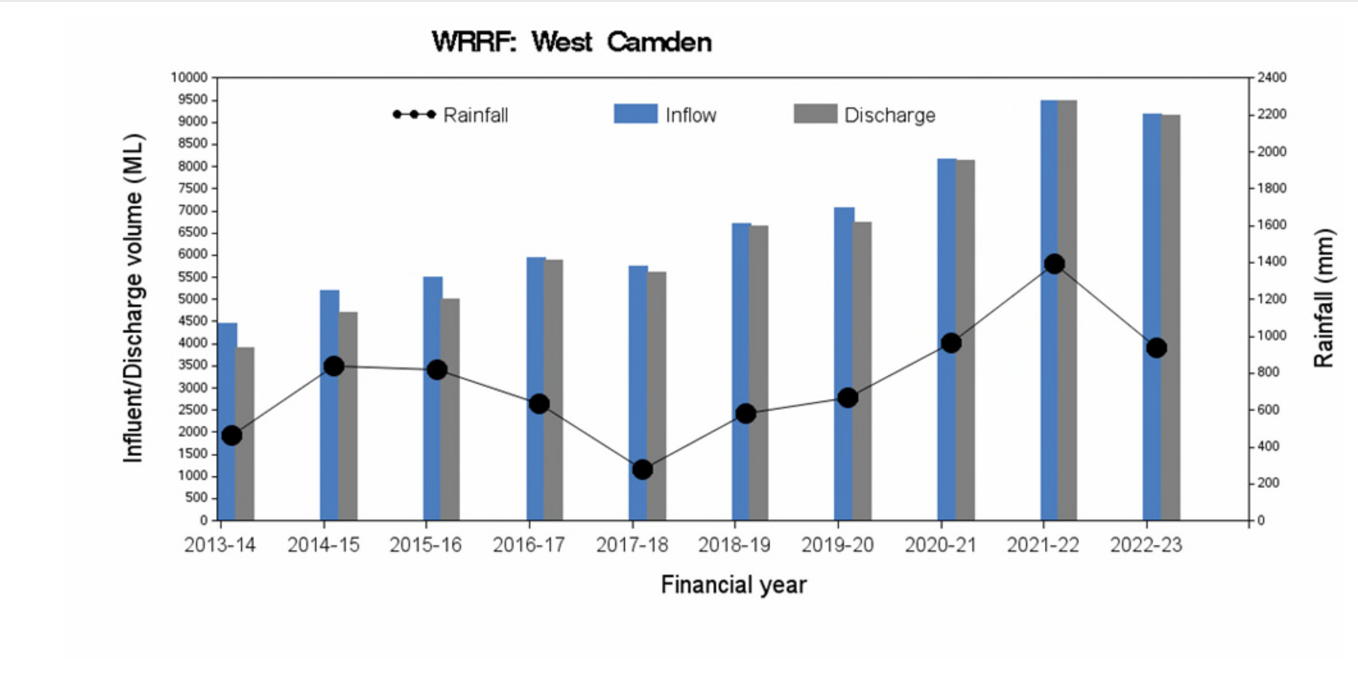
	Within the Environment Protection Licence limit
	Environment Protection Licence limit exceedance
	Analytes not required in the EPL or no concentration limit

West Camden WRRF ammonia nitrogen and total nitrogen 50th and 90th percentile concentration limits were exceeded in the 2022-23 reporting period. The annual load limit for total nitrogen was also exceeded in 2022-23. All other concentration and load values in the West Camden WRRF discharge were within the EPL limits.

Statistical analysis identified significantly increasing trends in ammonia nitrogen, total nitrogen and faecal coliform concentrations and significantly decreasing trends for copper and zinc concentrations in the discharge from West Camden WRRF in 2022-23 compared to the previous nine years.

Ammonia nitrogen and total nitrogen exceedances were largely influenced by catchment growth and subsequent increasing inflows to West Camden WRRF exceeding the treatment capacity of the biological processes. Ammonia removal was prioritised during the current amplification project, which subsequently impacted the total nitrogen performance. The upward trend in faecal coliforms can be linked to non-compliant tertiary clarification and filtration bypasses during the first half of the 2022-23 reporting period caused by Intermittently Decanted Aerated Lagoon (IDAL) boot failures.

West Camden WRRF is currently progressing a major $220M amplification, including the construction of a new Membrane Bioreactor (MBR) plant. This amplification will increase the treatment capacity to cater for population growth in the Camden district. The MBR is expected to be operational by September 2024. An additional $1.1M investment in interim capacity upgrades are being undertaken at the facility, scheduled for completion in April 2024. These interim upgrades are necessary to manage compliance until completion of the major upgrade, expected early 2025.



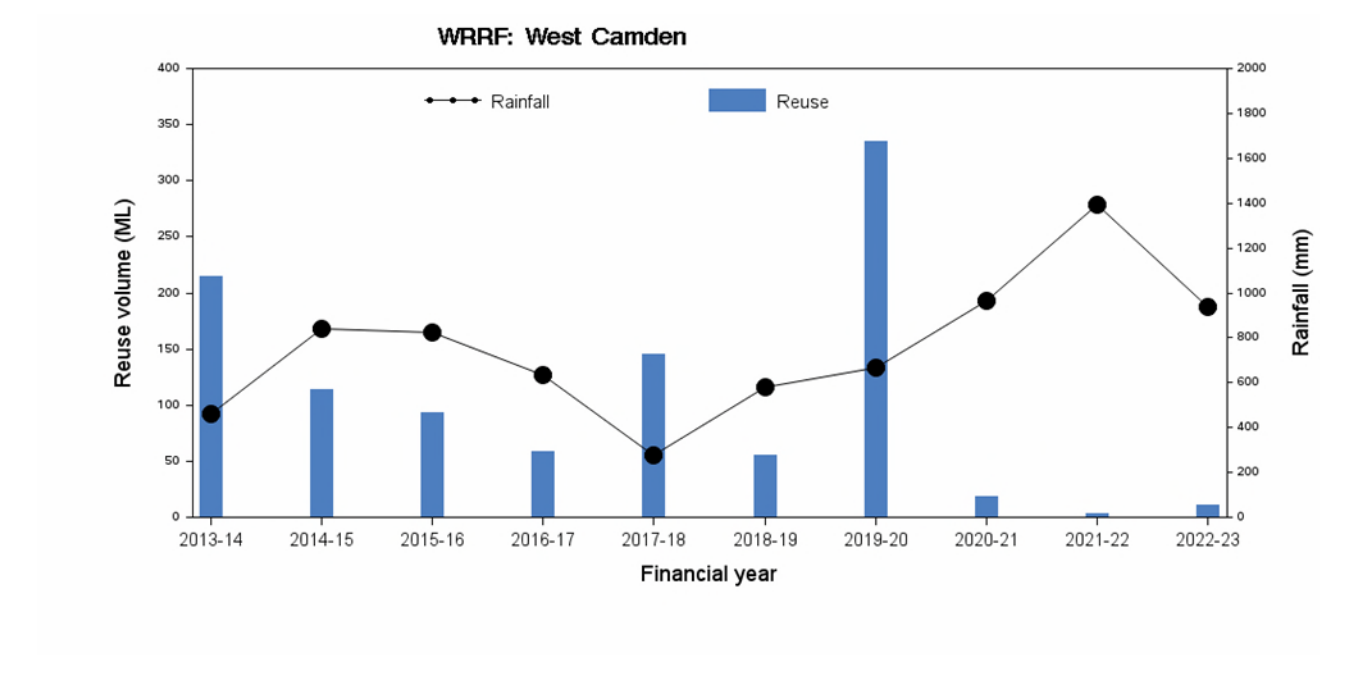
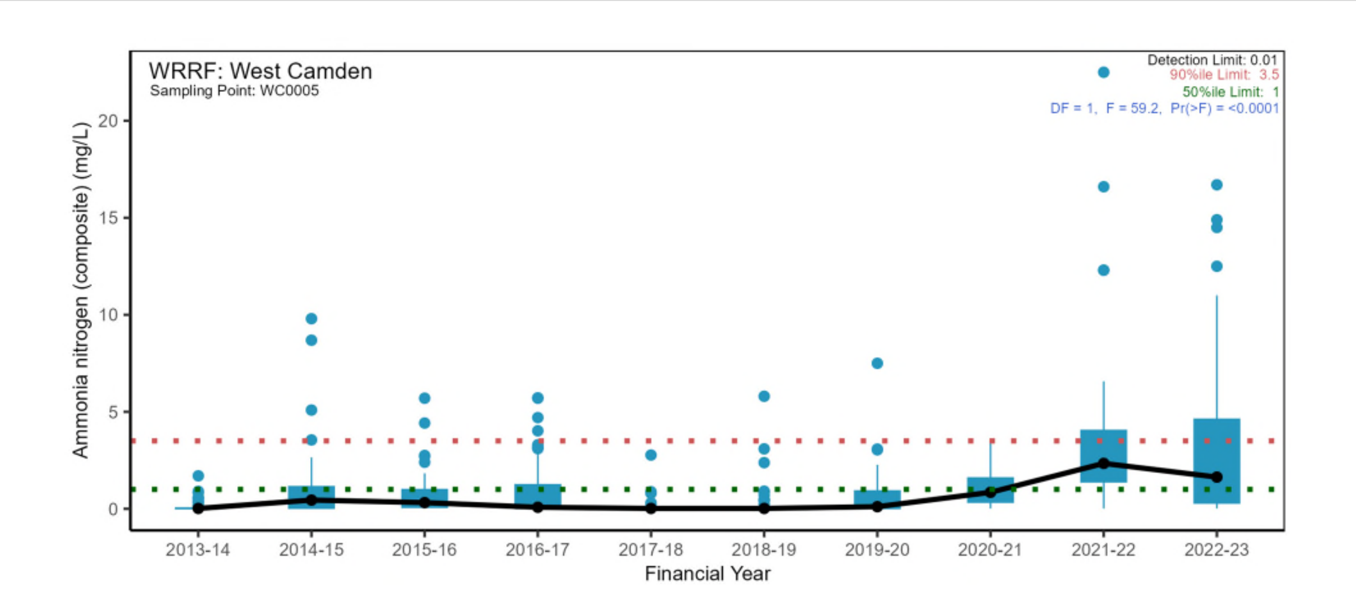
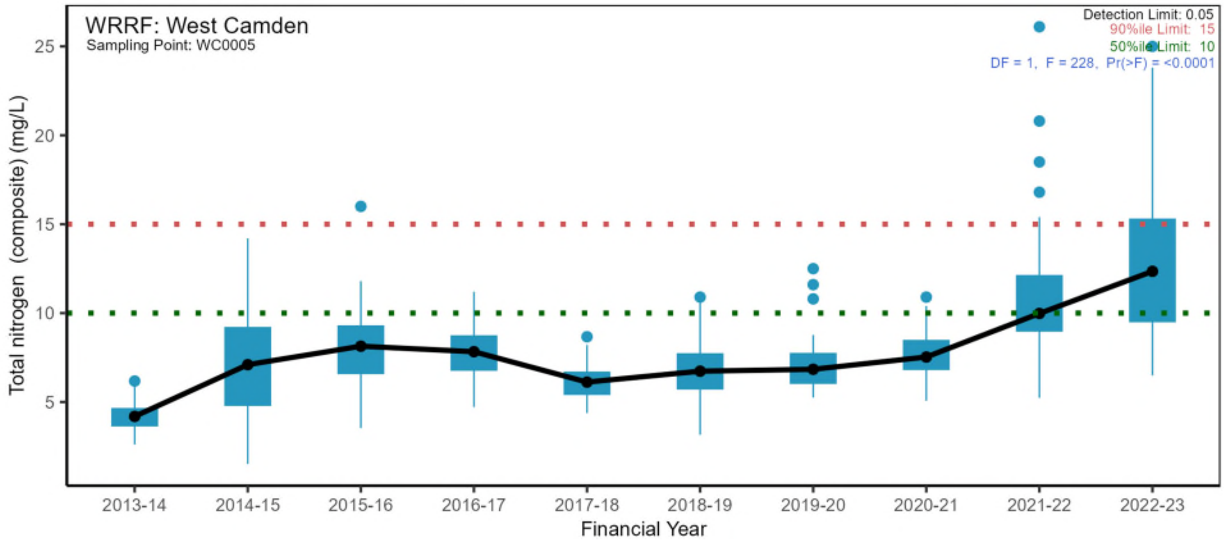
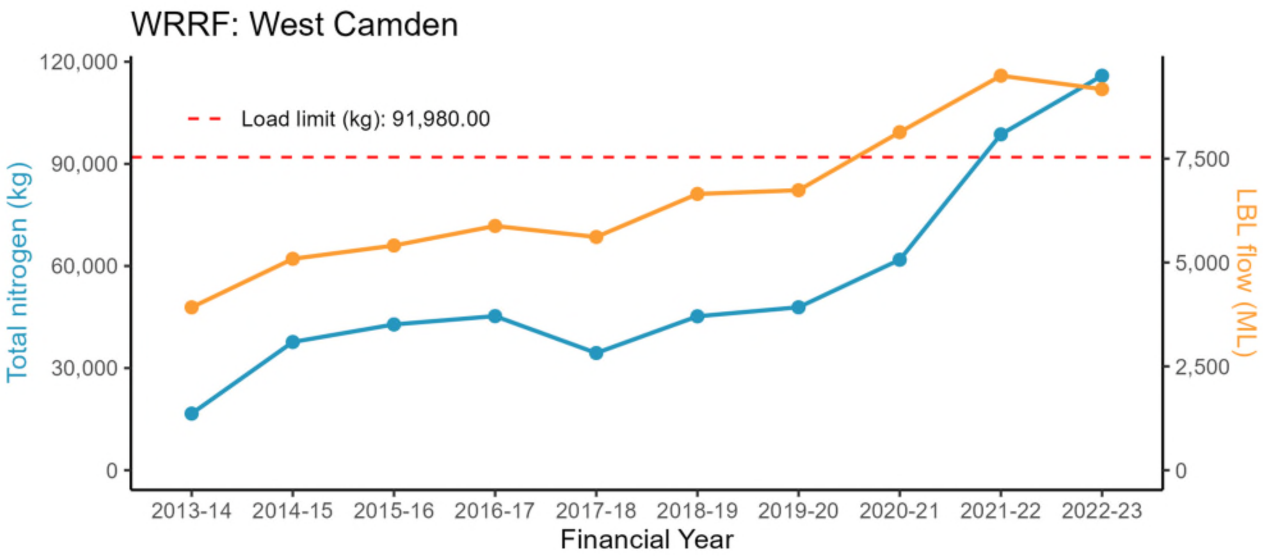


Figure 4-5 West Camden WRRF inflow, discharge and reuse volume with catchment rainfall plots

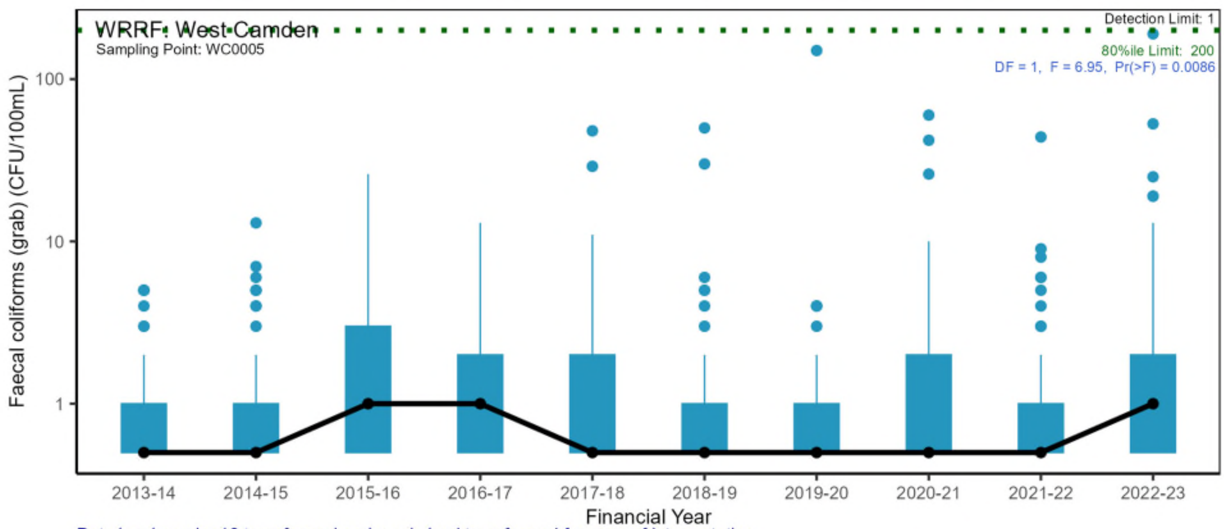




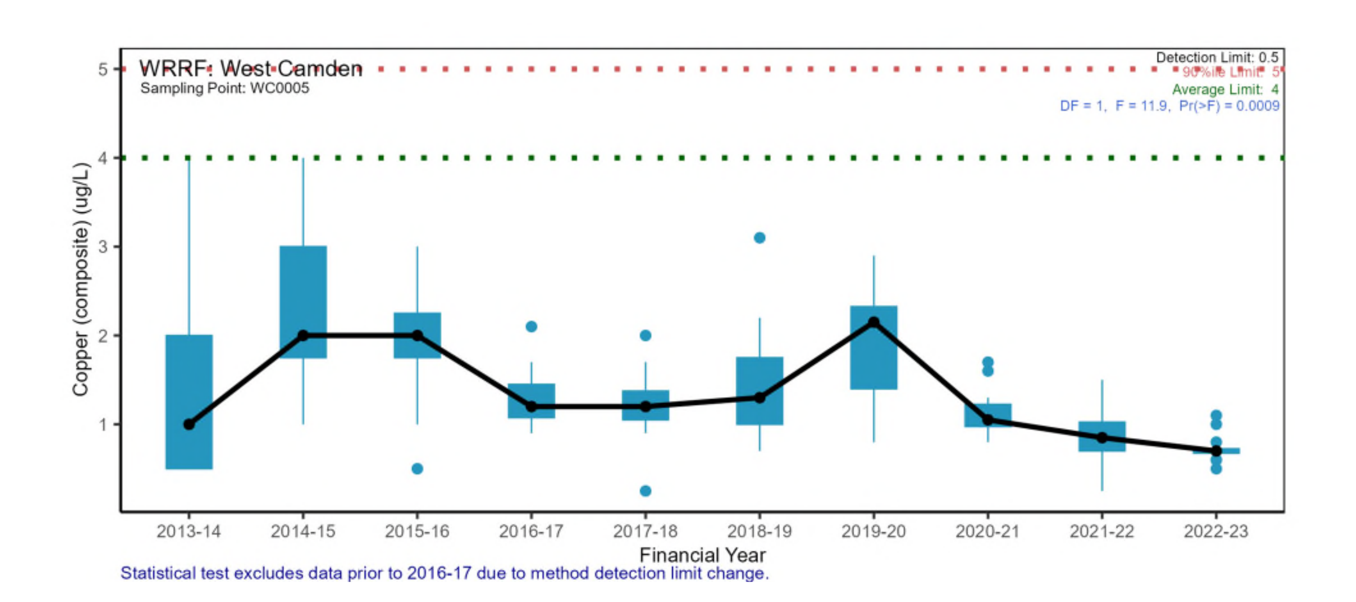
WRRF: West Camden
Sampling Point: WC0005
Detection Limit: 0.05
90%ile Limit: 15
50%ile Limit: 10
DF = 1, F = 228, Pr(>F) = <0.0001
Total nitrogen (composite) (mg/L)
Financial Year



WRRF: West Camden
Load limit (kg): 91,980.00
Total nitrogen (kg)
LBL flow (ML)
Financial Year



WRRF: West Camden
Sampling Point: WC0005
Detection Limit: 1
80%ile Limit: 200
DF = 1, F = 6.95, Pr(>F) = 0.0086
Faecal coliforms (grab) (CFU/100mL)
Financial Year
Data has been log10 transformed and y-axis backtransformed for ease of interpretation.



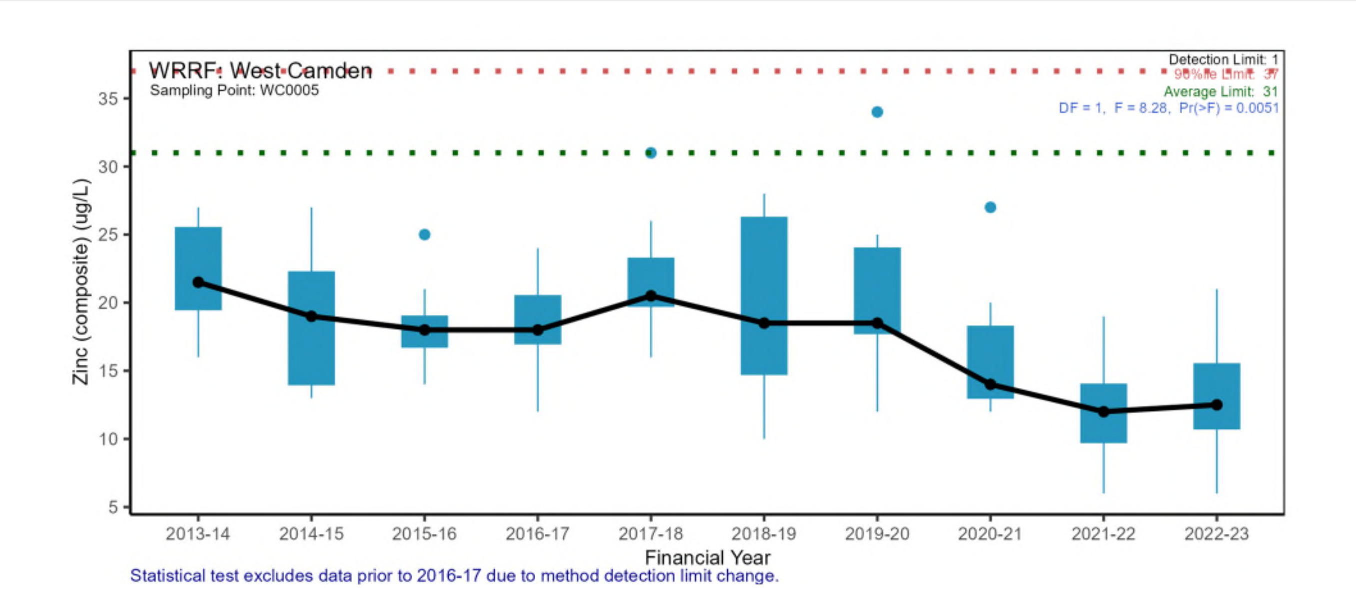


Figure 4-6 West Camden WRRF discharge quality and toxicity exception plots

Stressor – Water quality

Table 4-6 Gate 1 Analysis outcome summary – water quality upstream and downstream of West Camden WRRF discharge

Monitoring sites	Nutrient analytes					Physico-chemical analytes					
	Ammonia nitrogen	Oxidised nitrogen	Total nitrogen	Filterable total phosphorus	Total phosphorus	Conductivity	Dissolved oxygen	Dissolved oxygen saturation	pH	Temperature	Turbidity
Upstream tributary (N7824A)	→	→	→	↘	→	→	→	→	→	→	→
Downstream tributary (N7824)	→	↗	↗	→	→	→	→	→	↘	→	→
Upstream River (N78)	→	→	→	→	→	→	→	↗	→	→	→
Downstream River (N75)	↗	↗	↗	→	→	→	→	→	→	→	→

↗	Upward trend	↘	Downward trend	→	no trend, p>0.05

(green)	2022-23 Median value within the guideline limit	(white)	No guideline applicable
(yellow)	2022-23 Median value outside the guideline limit	(grey)	Insufficient data

West Camden WRRF discharges into an unnamed tributary that joins with Matahil Creek and flows about 1 km before joining with the Nepean River. The water quality of the control site at Matahil Creek (N7824A) is influenced by the upstream catchment with mixed land uses including agricultural run-off and increased urbanisation. For the Nepean River, N78 is the control site at Macquarie Grove Road upstream of Matahil Creek. The water quality at this site is influenced by mixed upstream catchment factors including Picton WWRF (about 39 km upstream) which discharges predominantly in wet weather.

Statistical analysis confirmed that filterable total phosphorus in 2022-23 was significantly lower at upstream Matahil Creek site (N7824A), consistent with the trend seen in the Picton WRRF tributary site. At the downstream Matahill Creek site (N7824), oxidised nitrogen and total nitrogen concentrations were significantly higher in 2022-23.

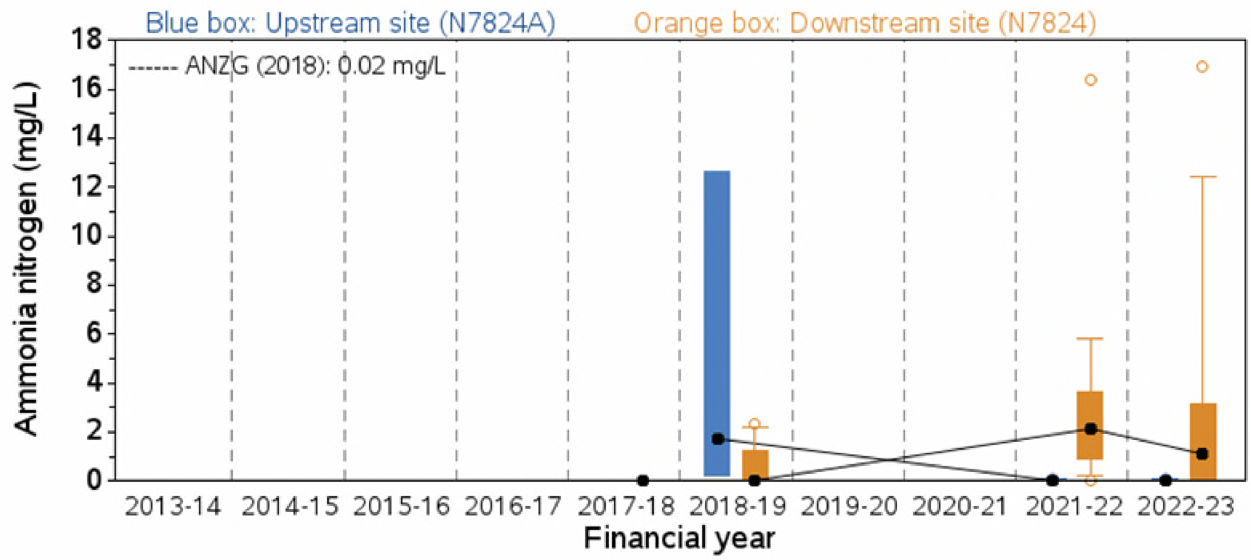
Ammonia nitrogen, oxidised nitrogen and total nitrogen concentrations were also significantly higher at the downstream Nepean River site (N75) in 2022-23 in comparison to the previous nine years. These increasing trends in the concentrations of nitrogen analytes are possibly related with the increasing discharge concentration trends from West Camden WRRF (see Pressure indicator section above).

Concentrations of nitrogen analytes at the downstream impact sites in both Matahil Creek and the Nepean River (N7824 or N75) were notably higher in comparison to upstream concentrations indicating an impact from nitrogen-rich discharges of West Camden WRRF. Statistical analysis of upstream-downstream pairs will be included in SWAM reports from 2023-24 to further validate the trend.

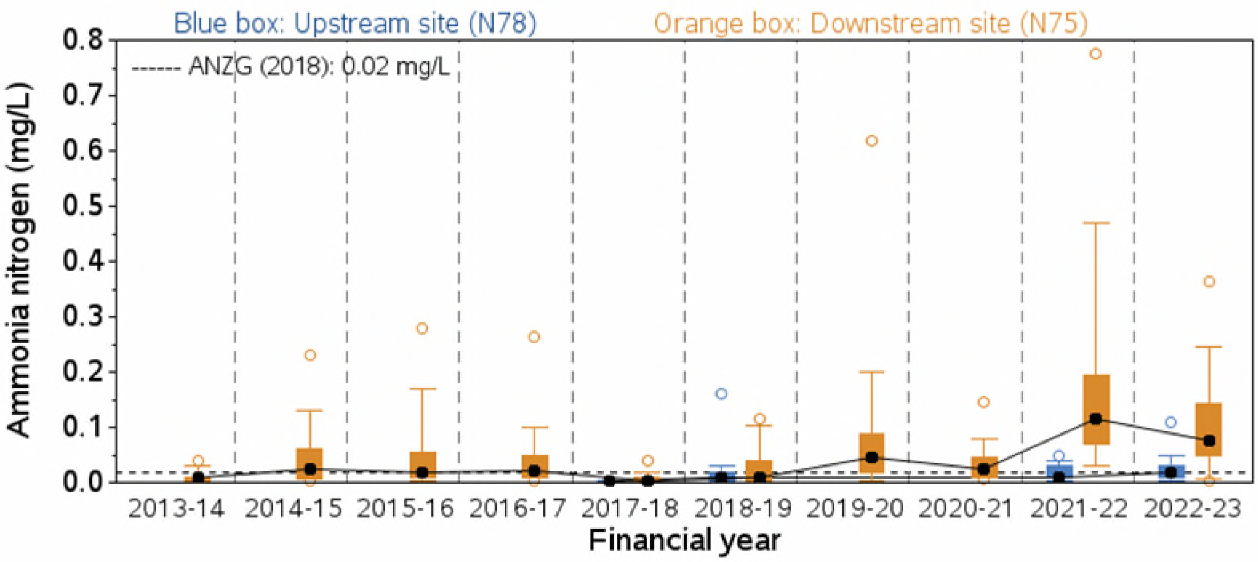
pH decreased significantly in 2022-23 at the downstream Matahil Creek site (N7824). Concentration of other physico-chemical water quality analytes were steady at both upstream downstream creek sites.

Dissolved oxygen saturation levels significantly increased at the upstream control site of Nepean River (N78). Concentration of other physico-chemical water quality analytes were steady at both upstream and downstream river sites.

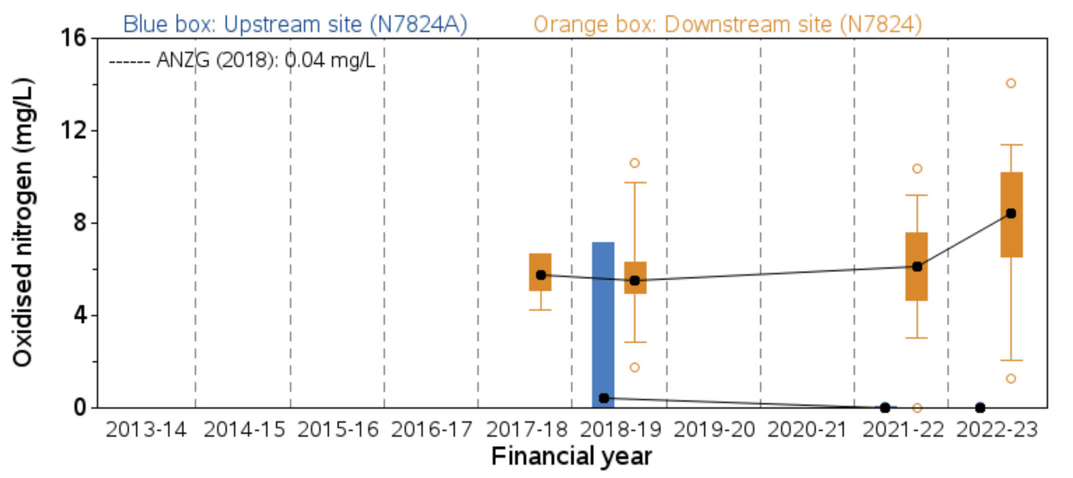
The median concentrations of nitrogen analytes were generally higher than the respective guideline values during the 2022-23 reporting period. The exception was at the upstream Matahil Creek site (N7824A), where the median ammonia nitrogen and oxidised nitrogen concentrations were lower than the guideline. The median total phosphorus concentrations at both the upstream (N7824A) and downstream (N7824) Matahil Creek sites were higher than the guideline value. The median turbidity level at N7824 was below the lower guideline value.



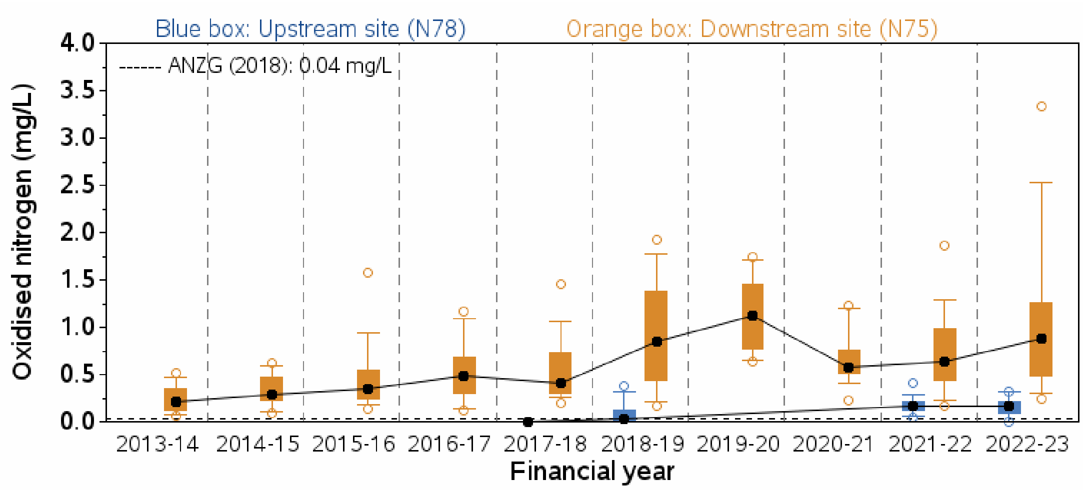
site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N7824A	1	1.08	0.3054	N7824	1	2.37	0.1294



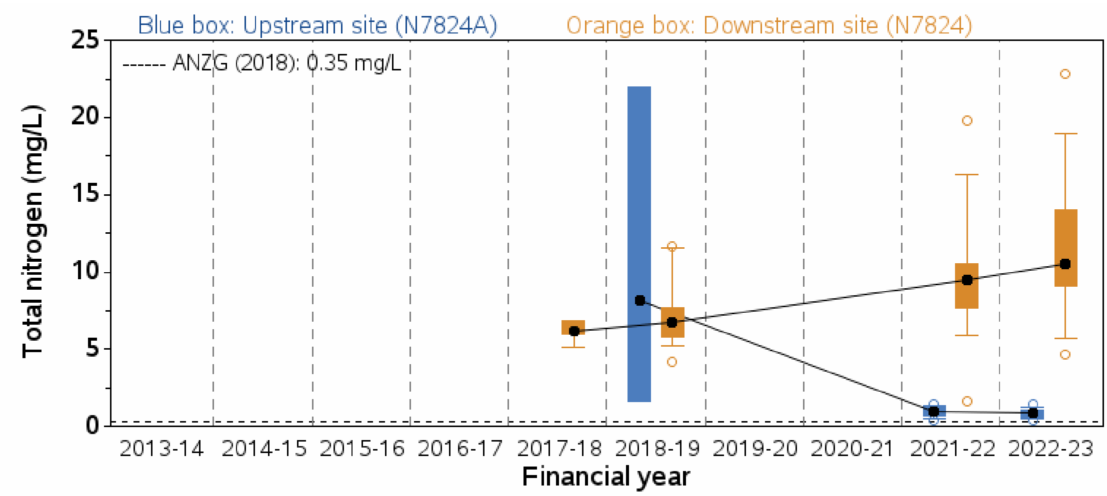
site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N78	1	0.89	0.3498	N75	1	4.33	0.0391



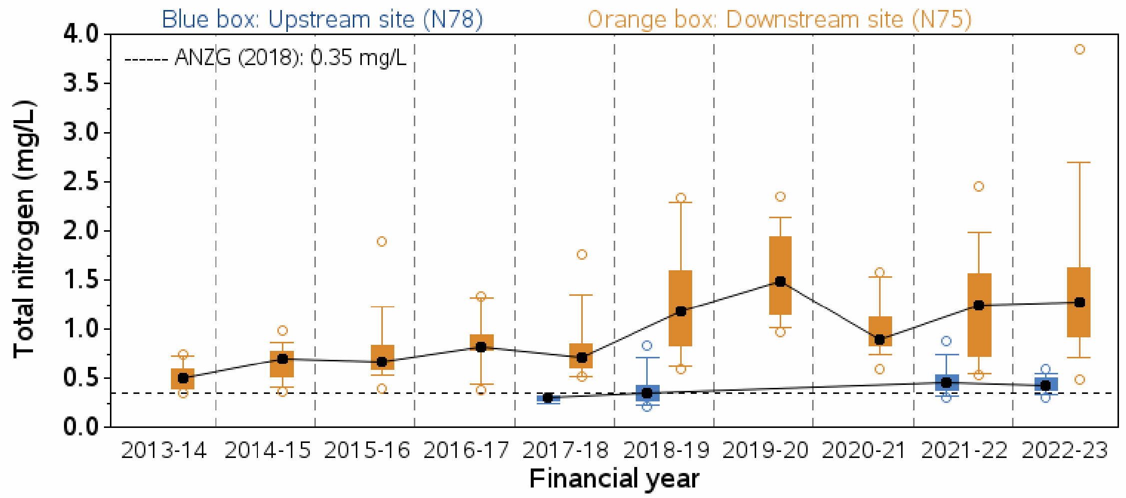
site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N7824A	1	0.92	0.3438	N7824	1	7.06	0.0103



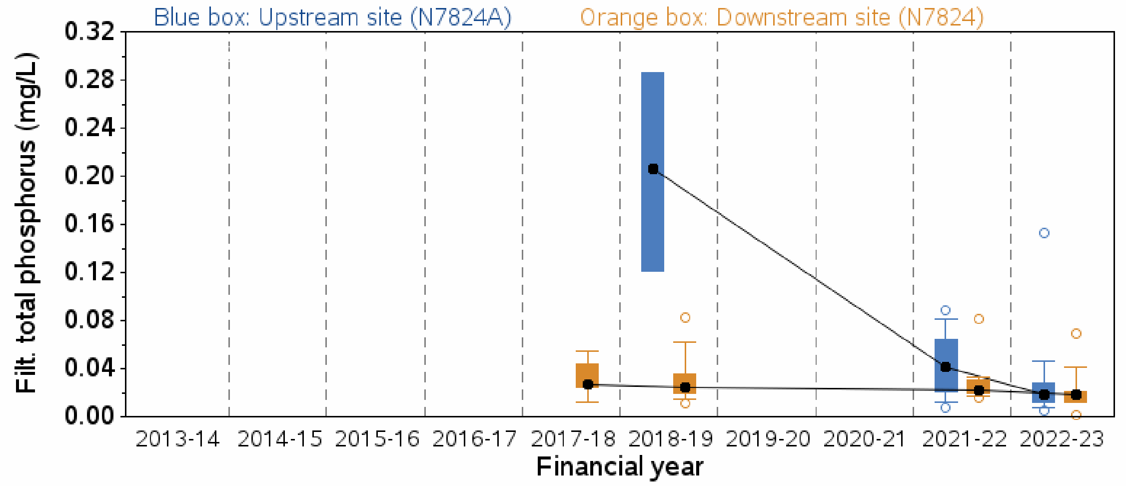
site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N78	1	1.12	0.2935	N75	1	13.53	0.0003



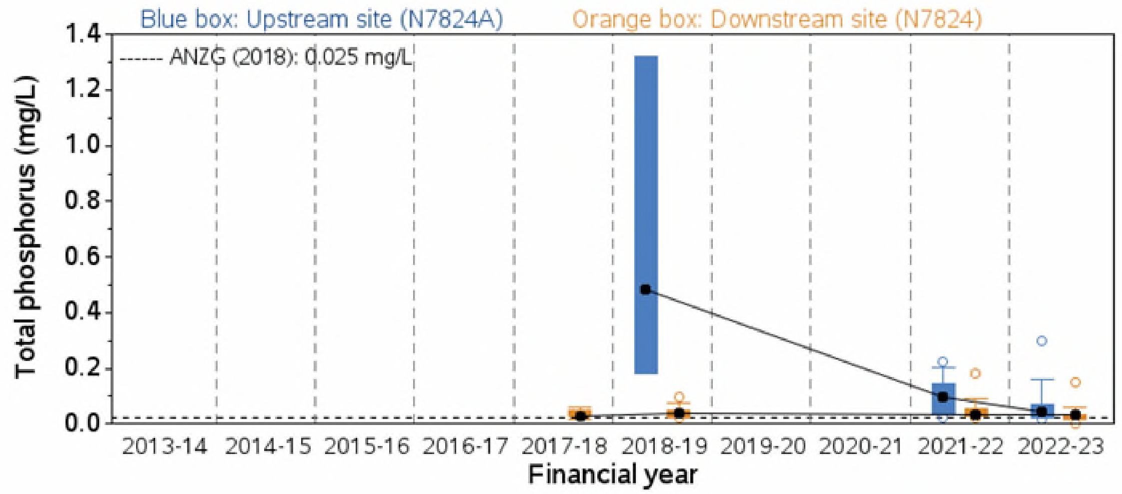
site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N7824A	1	1.59	0.2156	N7824	1	10.79	0.0018



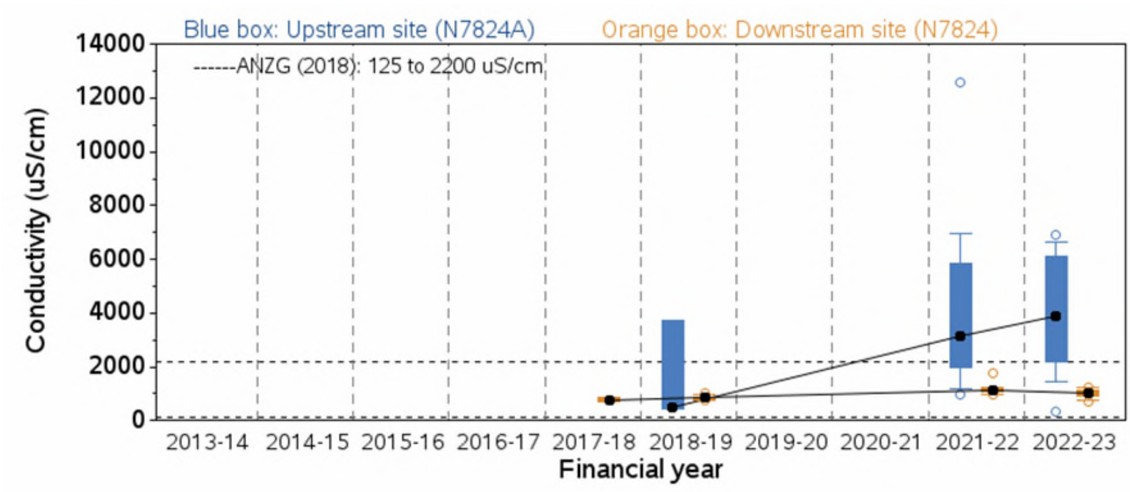
site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N78	1	0.16	0.6908	N75	1	16.36	<.0001



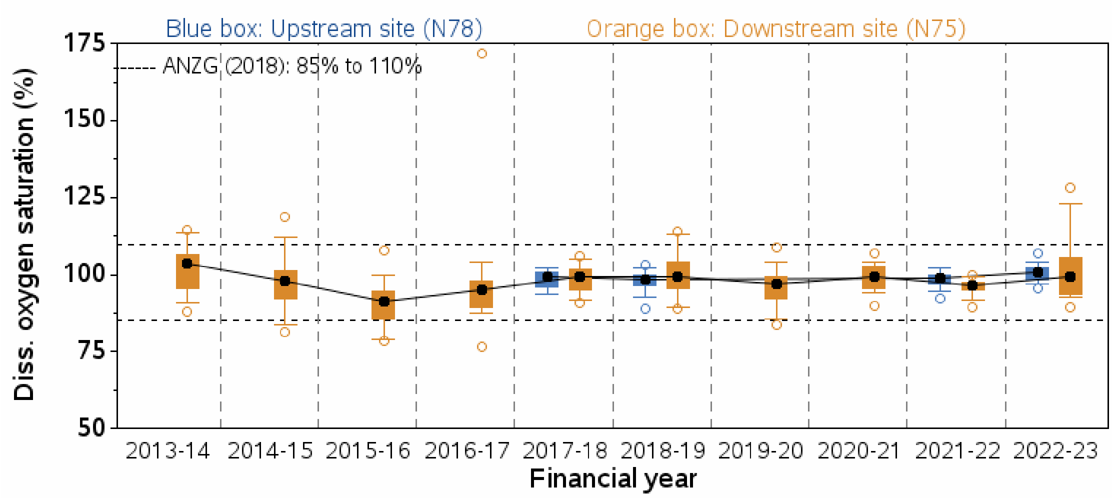
site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N7824A	1	4.57	0.0395	N7824	1	3.26	0.0766



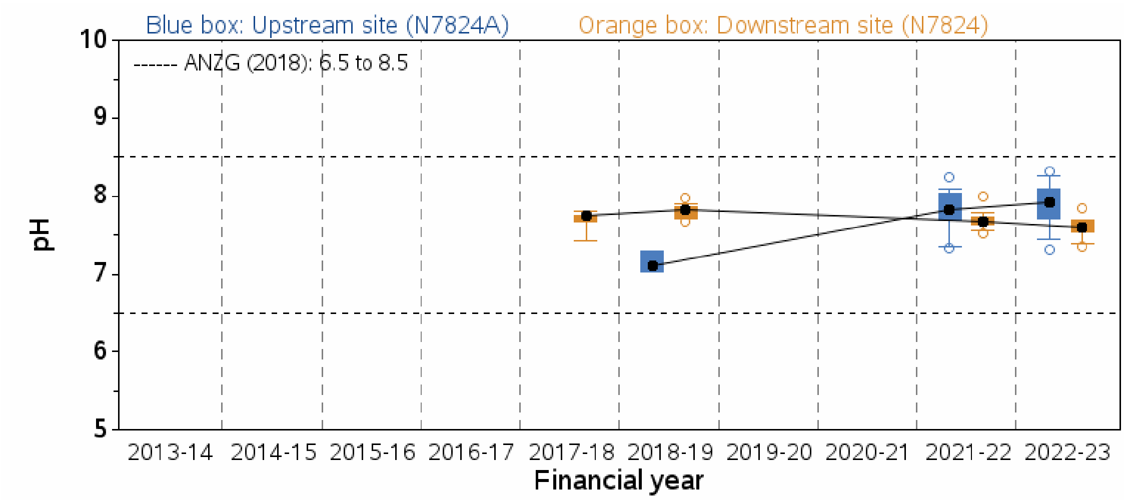
site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N7824A	1	2.73	0.1073	N7824	1	0.68	0.4119



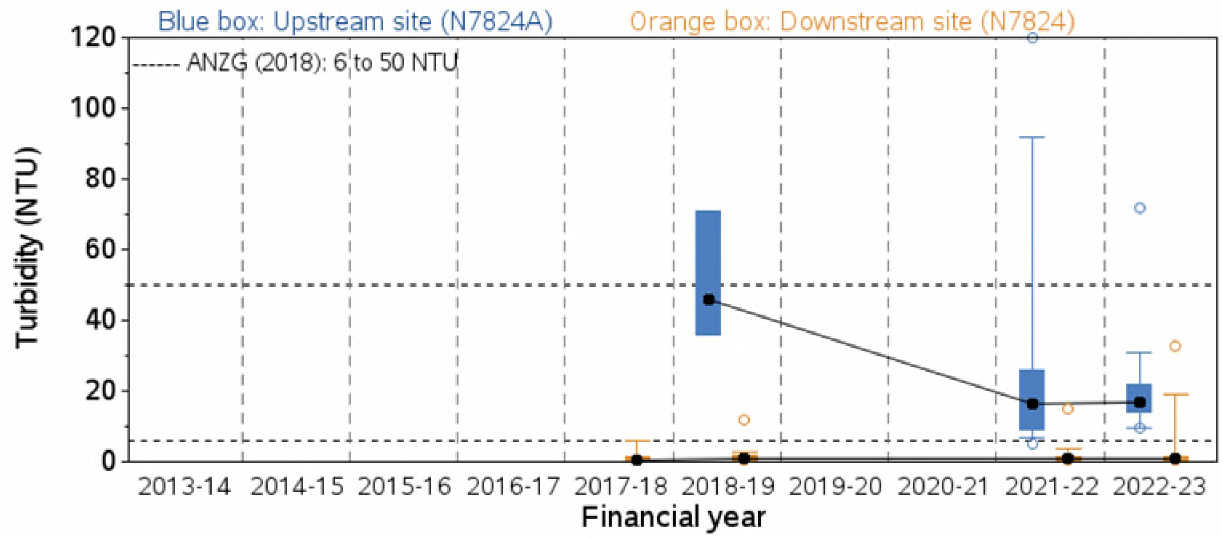
site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N7824A	1	0.19	0.6658	N7824	1	0.62	0.4343



site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N78	1	5.84	0.019	N75	1	2.25	0.1357



site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N7824A	1	2.79	0.1036	N7824	1	19.89	<.0001



site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N7824A	1	1.17	0.2861	N7824	1	2.05	0.1578

Figure 4-7 Nutrients and physico-chemical water quality exception plots, upstream and downstream of West Camden WRRF

Ecosystem Receptor – Phytoplankton

Table 4-7 Gate 1 Analysis outcome summary – phytoplankton as chlorophyll-a, biovolume and species counts, upstream and downstream of West Camden WRRF discharge

Monitoring sites	Phytoplankton analytes			
	Chlorophyll-a	Total phytoplankton biovolume	Blue-green biovolume	Toxic blue-green count
Upstream tributary (N7824A)	→	↗	→	→
Downstream tributary (N7824)	→			
Upstream River (N78)	→	→	→	→
Downstream River (N75)	↗	↗	→	

↗	Upward trend	↘	Downward trend	→	no trend, p>0.05

(green)	2022-23 Median value within the guideline limit	(white)	No guideline applicable
(yellow)	2022-23 Median value outside the guideline limit	(grey)	Insufficient data

Statistical analysis confirmed that the 2022-23 total phytoplankton biovolume was significantly higher at the upstream Matahil Creek site (N7824A) in comparison to 2021-22 results. Significantly increasing trends in chlorophyll-a and total phytoplankton biovolume were found at downstream Nepean River site (N75).

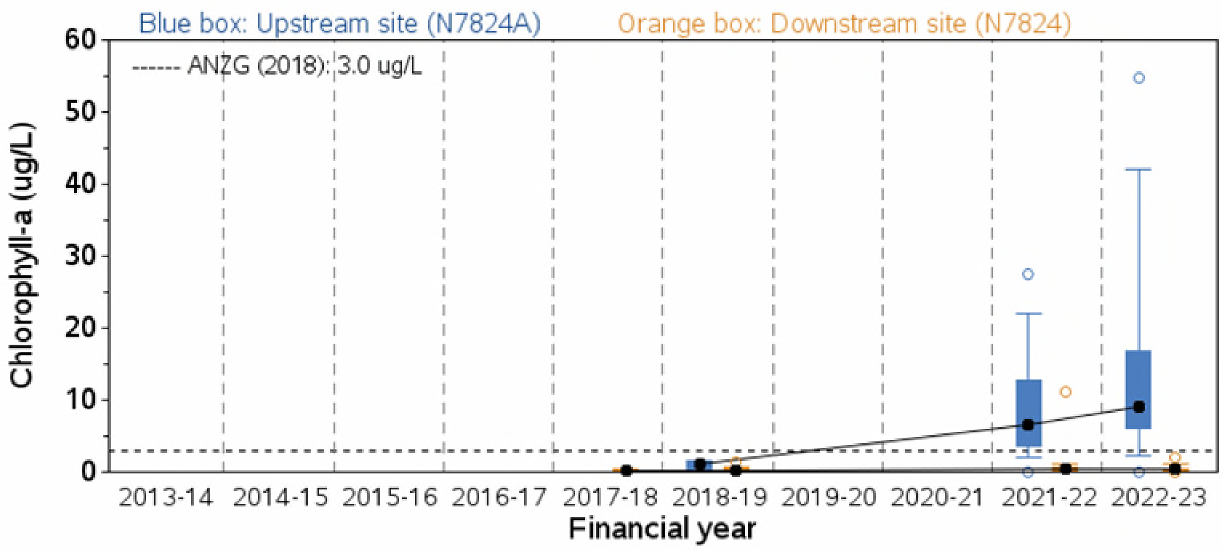
The median chlorophyll-a concentration was higher than the ANZG (2018) guideline at the upstream Matahil Creek (N7824A) and both upstream/downstream Nepean River sites in 2022-23. Blue-green biovolume or toxic blue-green species counts were generally low, with the median within the NHMRC (2008) Amber Alert level.

Thirteen of the 17 samples collected from N7824A qualified for a phytoplankton biovolume and species count as chlorophyll-a were higher than 7.0 µg/L. Potentially toxic phytoplankton taxa *Anabaenopsis* reached 17,358 cell/mL on 24 January 2023. Statistical analysis identified significant increasing trends in total phytoplankton biovolume at this site. Only one of the 17 samples was qualified for phytoplankton count from the downstream Matahil Creek site (N7824).

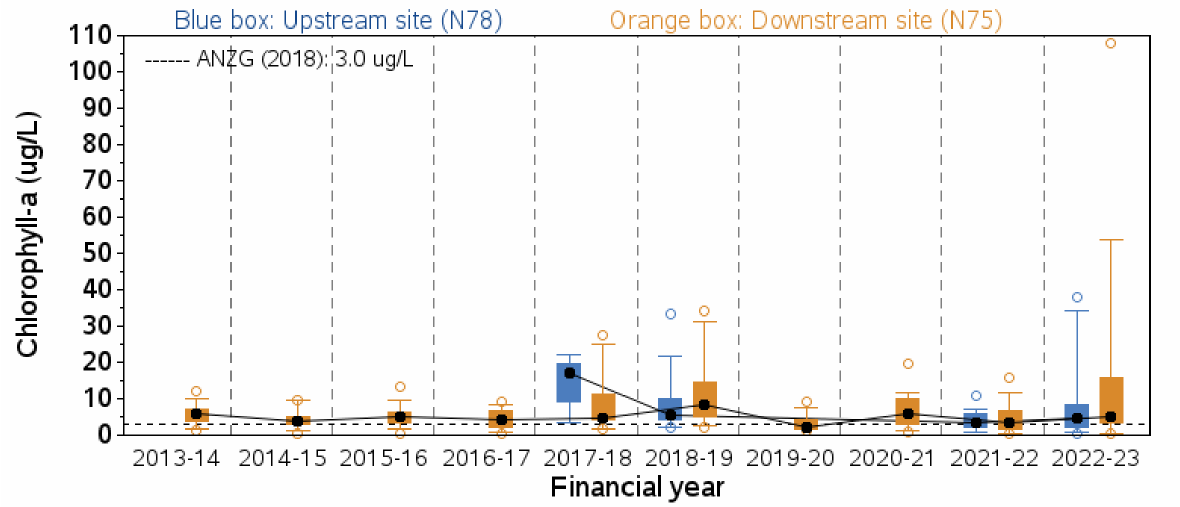
Only one sample, from downstream N7824, qualified for a phytoplankton count. No toxic blue-greens were found in this sample.

Six of the 17 samples were qualified for phytoplankton count from the upstream Nepean River site (N78). No potentially toxic blue-greens were found in any of the samples.

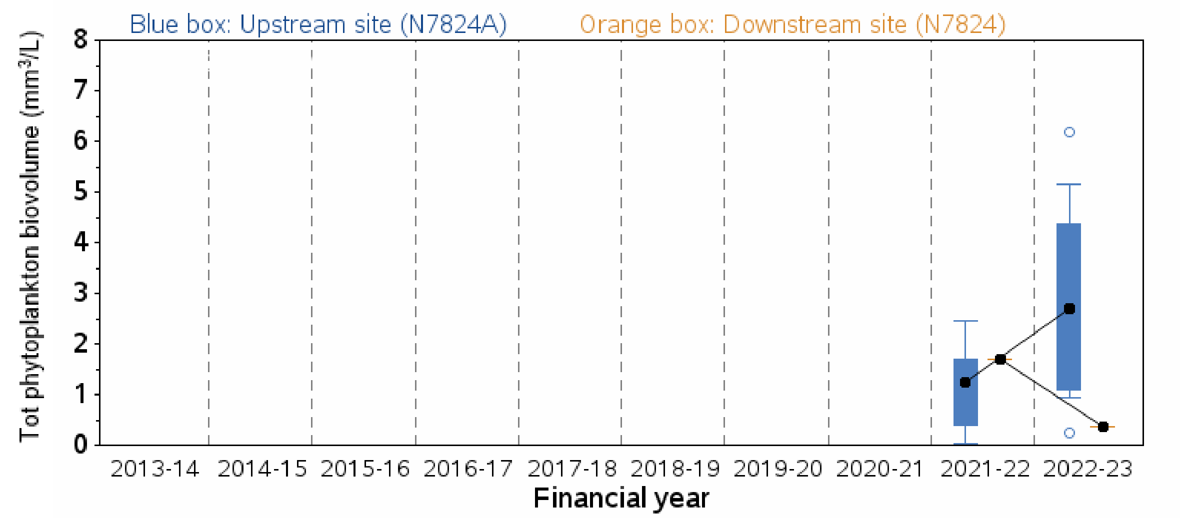
Six of the 17 samples were qualified for phytoplankton count from the downstream Nepean River site (N75). Potentially toxic blue-green was found in one sample in low number (*Phormidium* 451 cells/mL).



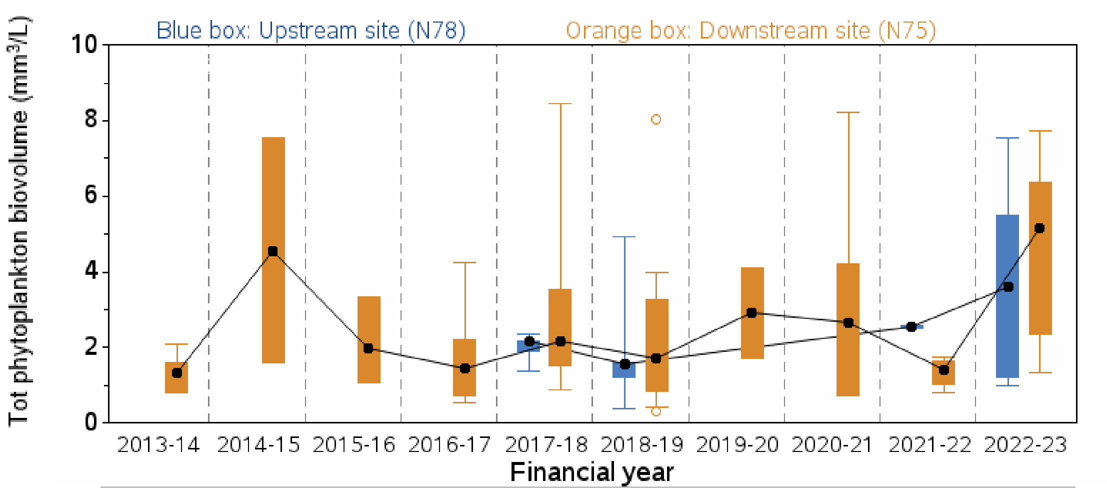
site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N7824A	1	2.61	0.1146	N7824	1	0.22	0.6388



site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N78	1	0.26	0.6107	N75	1	14.11	0.0002



site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N7824A	1	4.88	0.0396	N7824	Insufficient data		



site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N78	1	4.08	0.0593	N75	1	6.4	0.0146

Figure 4-8 Phytoplankton as chlorophyll-a, biovolume and species counts exception plots, upstream and downstream of West Camden WRRF

Ecosystem Receptor – Macroinvertebrates

The 2022-23 macroinvertebrate results suggested a localised ecosystem impact in Matahil Creek, downstream of West Camden WRRF. There was no evidence these impacts had any effect on the Nepean River system to which this creek flows (Volume 2 Appendix A-2).

Table 4-8 t-test of upstream-downstream SIGNAL-SG scores of 2022-23 samples from the Matahil Creek and Nepean River waterways near West Camden WRRF

Waterway	Method	Statistic	DF	P value
Matahil Creek	Welch Two Sample t-test	3.80	8.8	0.004
Nepean River	Welch Two Sample t-test	-0.06	6.2	0.951

A relatively persistent impact in stream health was suggested by the SIGNAL-SG scores and multivariate testing of macroinvertebrate data from Matahil Creek which receives treated wastewater from West Camden WRRF, but this impact did not extend to the Nepean River.

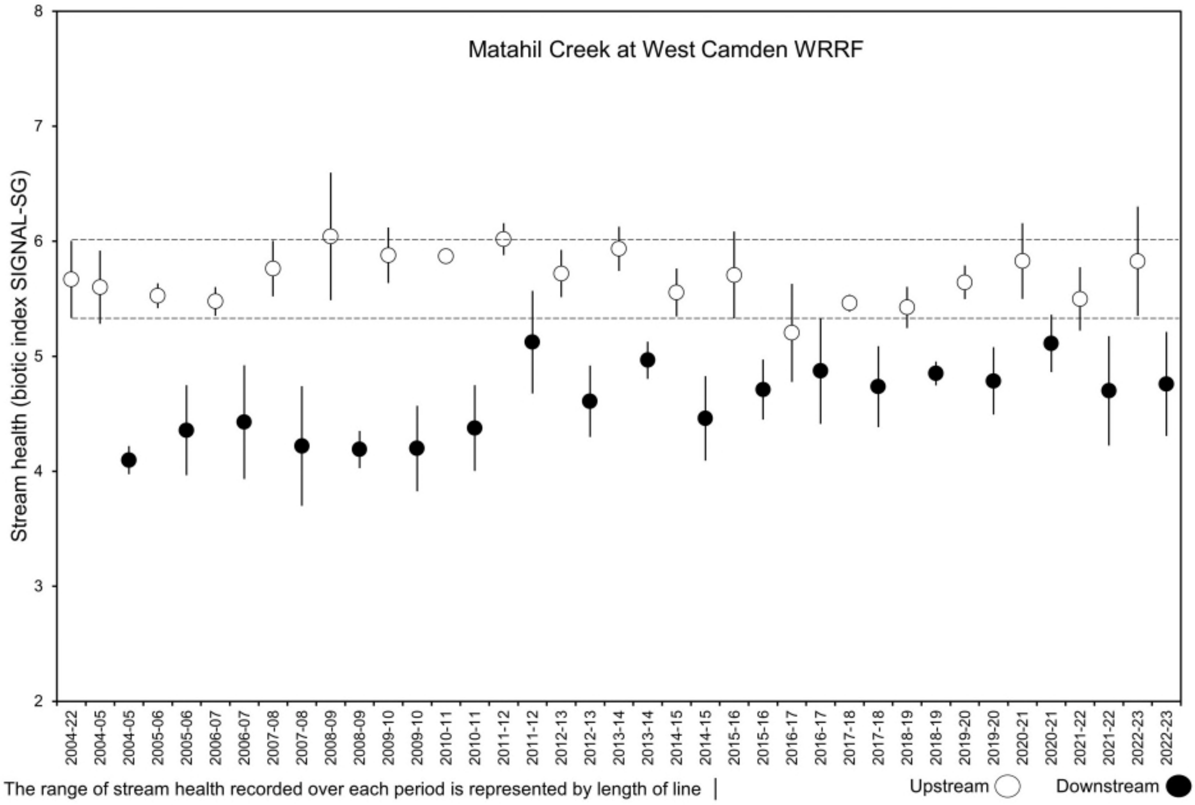


Figure 4-9 Stream health of Matahil Creek near West Camden WRRF

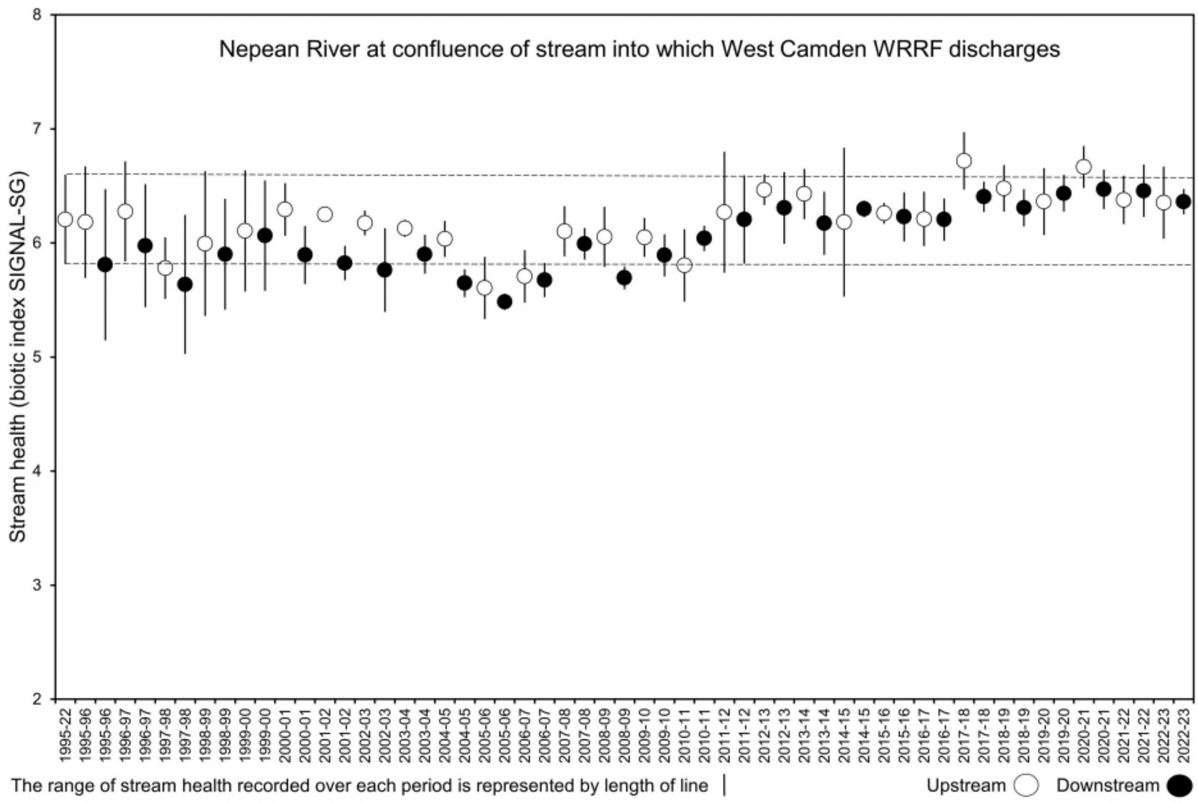


Figure 4-10 Stream health of the Nepean River near West Camden WRRF

4.1.3 Wallacia WRRF

- All parameters (concentrations and loads) monitored in the discharge from Wallacia WRRF were within EPL limits in 2022-23. There were increasing trends in ammonia nitrogen, total nitrogen and total phosphorus concentrations in the discharge.
- Filterable total phosphorus and total phosphorus concentrations increased significantly at the upstream Warragamba River site in 2022-23. At the downstream site, oxidised nitrogen, total nitrogen and total phosphorus increased significantly in 2022-23, possibly linked with the increasing trend of these analytes in the Wallacia discharge.
- Trends in phytoplankton as chlorophyll-a, biovolume or species counts were steady at both upstream/downstream Warragamba River sites in 2022-23. Blue-green biovolume or toxic blue-green species counts were low and always within the NHMRC (2008) Amber Alert level.
- Stream health results (as indicated by macroinvertebrates) suggested a decline in stream health at the site downstream of Wallacia WRRF compared to previous years. However, a definitive impact of wastewater discharge from Wallacia WRRF cannot be determined as the upstream macroinvertebrate site was not accessible on both sampling occasions in 2022-23 due to persistent high flows. A nearby SoE site (N67) on the Nepean River was used as a proxy. The decline in stream health at the downstream site is likely attributed to scouring of the downstream habitat during wet weather flows.

Pressure – Wastewater discharge

Table 4-9 Gate 1 Analysis outcome summary – Wallacia WRRF

Analytes / Wallacia WRRF	Nutrients			Conventional analytes					EC_{50} Toxicity	Trace Metals			Other chemicals / organics	
	Ammonia Nitrogen	Total Nitrogen	Total Phosphorus	Biochemical Oxygen Demand	Total Residual Chlorine	Faecal Coliforms	Oil and Grease	Total Suspended Solids		Aluminium	Copper	Zinc	Hydrogen sulfide (un-ionised)	Nonylphenol ethoxylates
Concentration	↗	↗	↗	→	→	→		→	→	→	→	→	→	→
Load														

↗	Upward trend	↘	Downward trend	→	no trend, p>0.05

	Within the Environment Protection Licence limit
	Environment Protection Licence limit exceedance
	Analytes not required in the EPL or no concentration limit

All concentration and load limits in the discharge from Wallacia WRRF were within the EPL limits in 2022-23. Statistical analysis identified significant increasing trends in ammonia nitrogen, total nitrogen and total phosphorus in the 2022-23 reporting period compared to the past nine years.

The increasing ammonia nitrogen and total nitrogen trends can be linked to one of two Intermittently Decanted Aerated Lagoons (IDAL) being offline for major periodic maintenance. Works were completed and the IDAL was brought back online in March 2023.

The increasing total phosphorus trend can be linked to the extreme wet weather events and subsequent elevated inflows in the first half of the 2022-23 reporting period. The low alkalinity and pH of wastewater during wet weather resulted in the need to reduce the ferric dosing, which increased the total phosphorus in the final effluent.

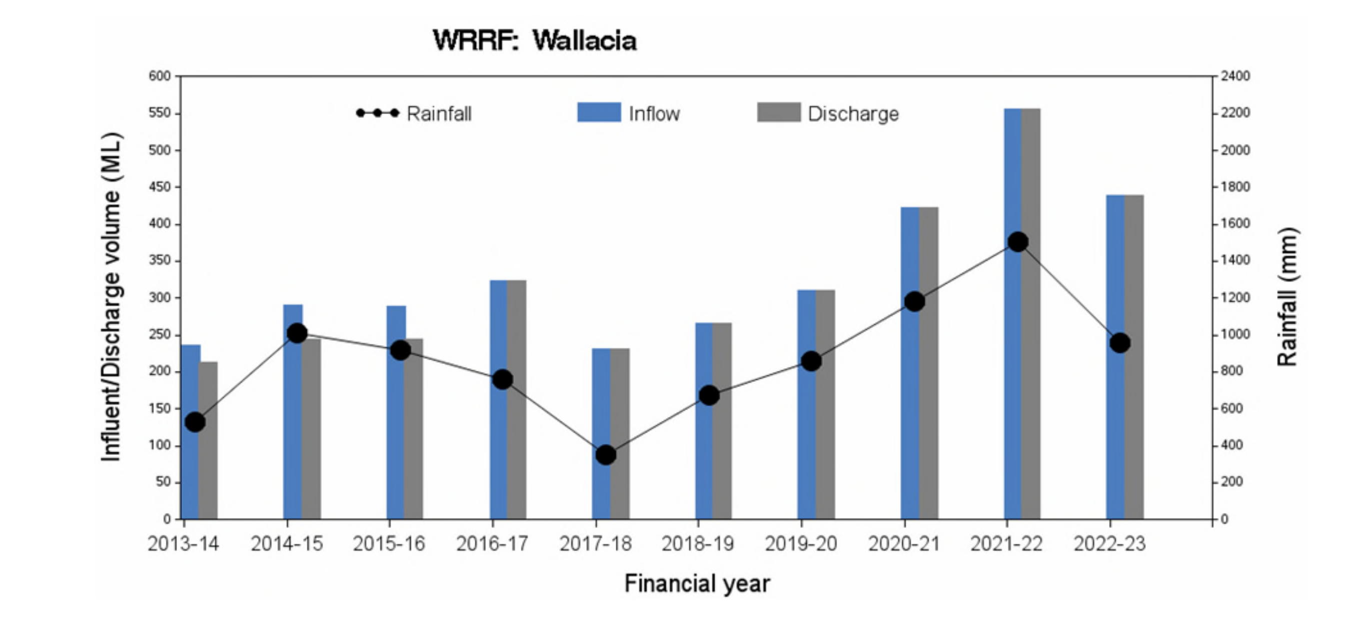
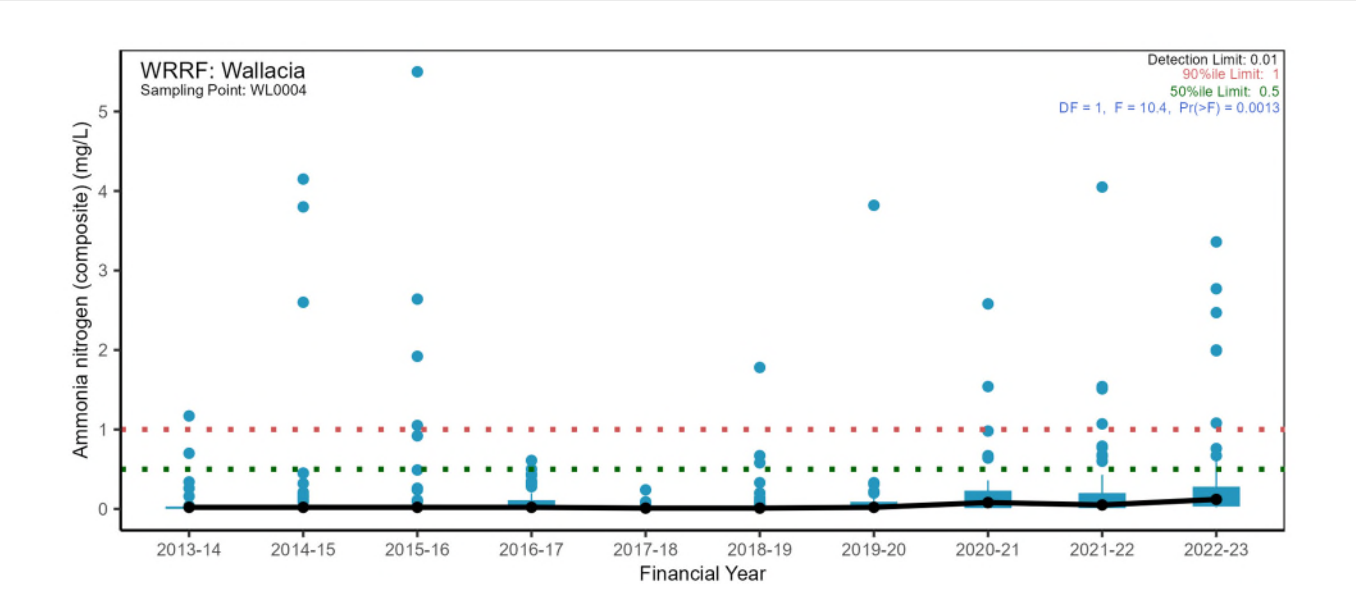
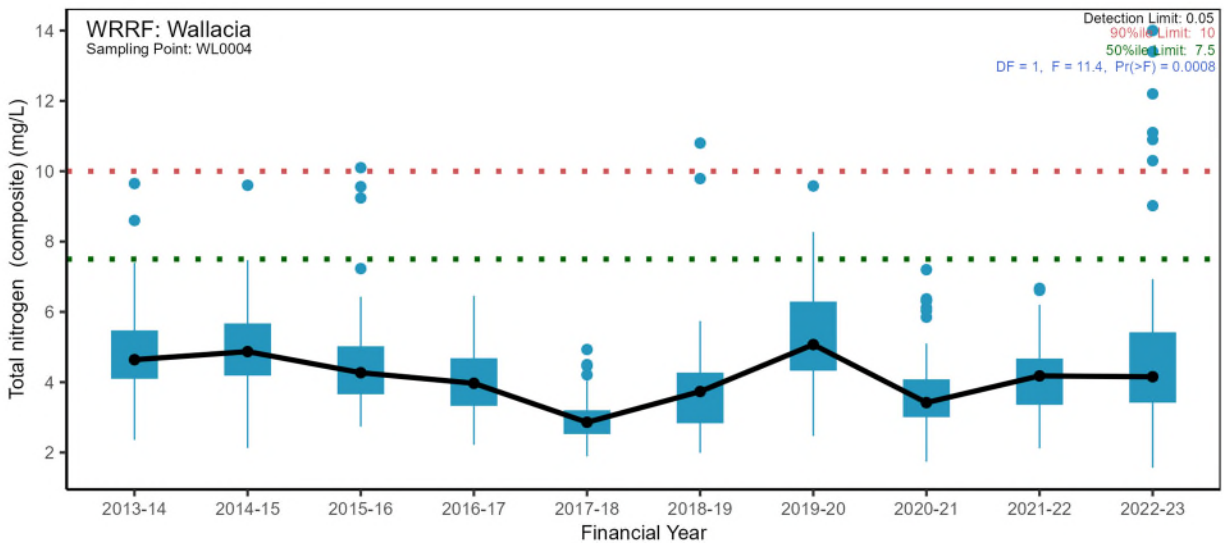


Figure 4-11 Wallacia WRRF inflow and discharge volume with catchment rainfall





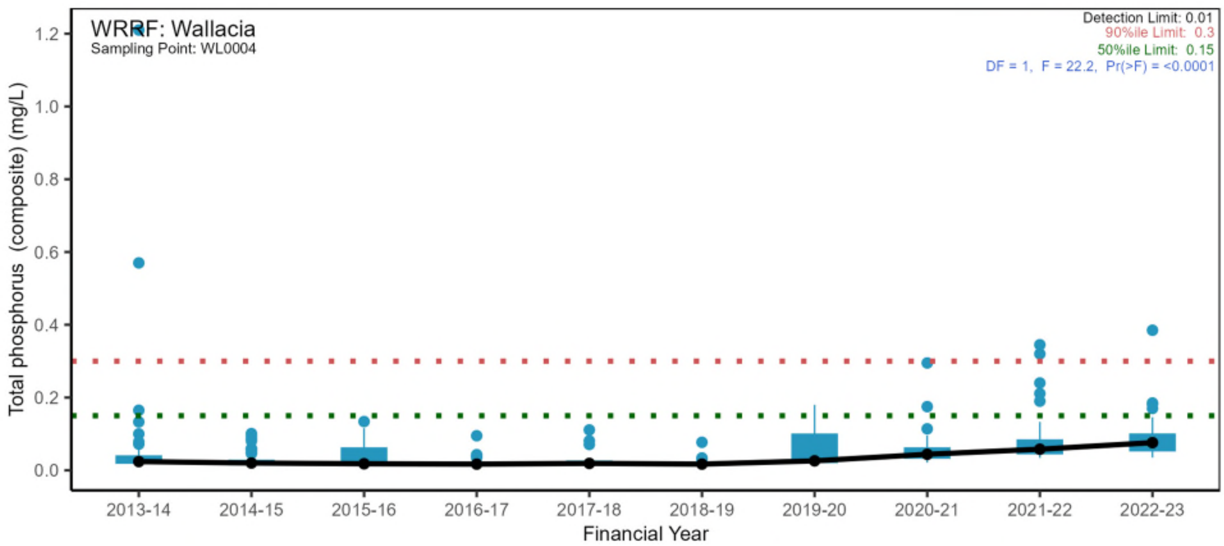


Figure 4-12 Wallacia WRRF discharge quality and toxicity exception plots

Stressor – Water quality

Table 4-10 Gate 1 Analysis outcome summary – water quality upstream and downstream of Wallacia WRRF discharge

Monitoring sites	Nutrient analytes					Physico-chemical analytes					
	Ammonia nitrogen	Oxidised nitrogen	Total nitrogen	Filterable total phosphorus	Total phosphorus	Conductivity	Dissolved oxygen	Dissolved oxygen saturation	pH	Temperature	Turbidity
Upstream tributary (N642A)	→	→	→	↗	↗	→	→	→	→	→	→
Downstream tributary (N641)	→	↗	↗	→	↗	→	→	→	→	→	→

↗	Upward trend	↘	Downward trend	→	no trend, p>0.05

(green)	2022-23 Median value within the guideline limit	(white)	No guideline applicable
(yellow)	2022-23 Median value outside the guideline limit	(grey)	Insufficient data

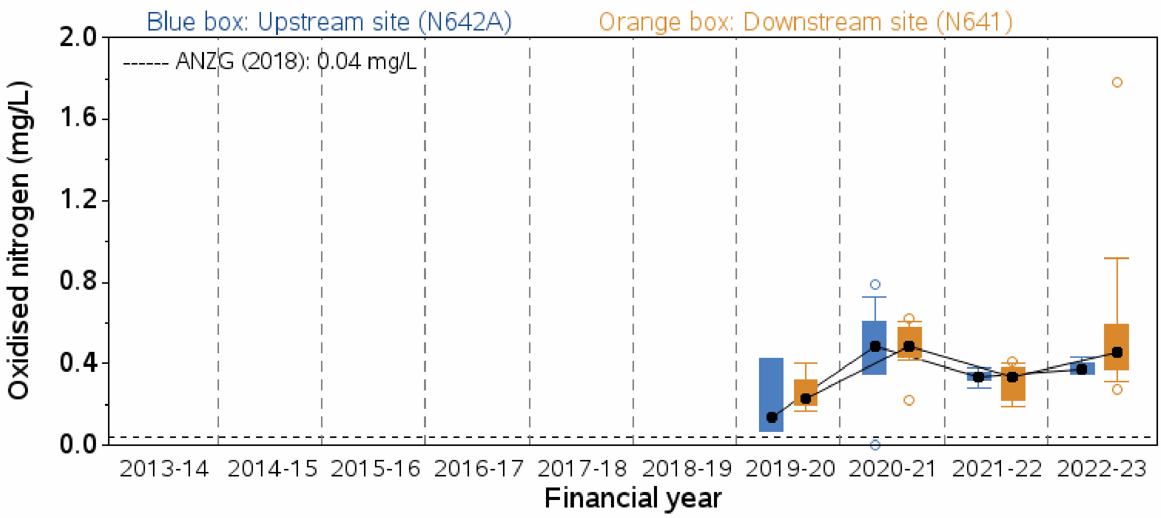
Wallacia WRRF discharges directly into Warragamba River which joins with the Nepean River. The control site for the Warragamba River is located downstream of Megarritys Creek. The water quality of this site is also influenced by environmental water releases from Warragamba Dam and urban run-off from Warragamba township draining via Megarritys creek.

The water quality data set for the upstream control site (N642A) is limited (six samples only) due to safety issues accessing the site preventing sample collection, especially during wet weather or Warragamba Dam releases.

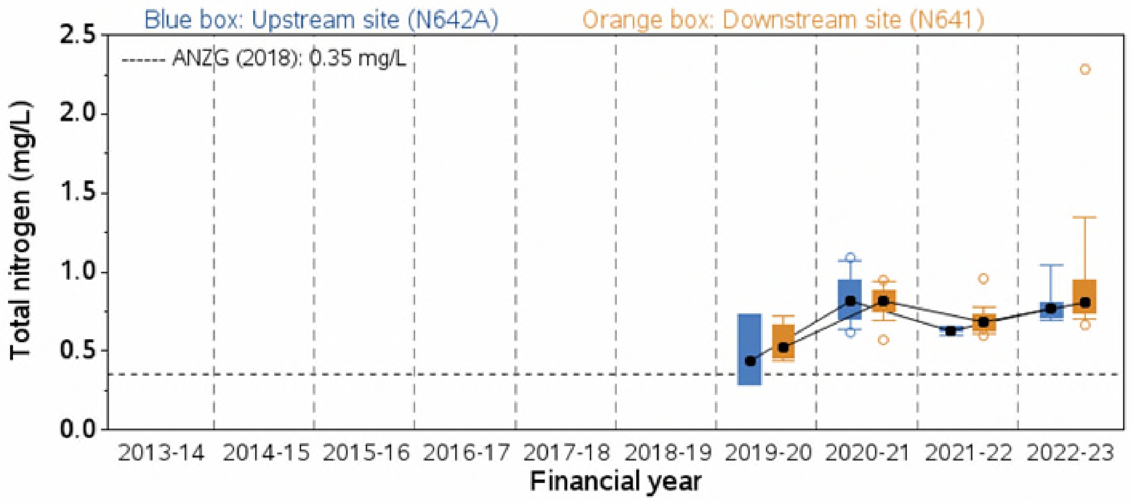
Statistical analysis confirmed that the 2022-23 filterable total phosphorus and total phosphorus concentrations increased significantly at the upstream Warragamba River site (N642A) in comparison to previous years. Upstream catchment factors via Megarritys Creek may have influenced this. At the downstream river site (N641), oxidised nitrogen, total nitrogen and total phosphorus increased significantly in 2022-23, possibly linked with the increasing trend of these analytes in Wallacia discharges.

Filterable total phosphorus and total phosphorus concentrations at the upstream control sites were notably higher during 2022-23 in comparison to downstream concentrations indicating an influence from other catchment sources. The increasing concentrations of oxidised nitrogen and total nitrogen at downstream sites were probably linked with the increasing concentrations of these analytes in Wallacia WRRF discharge. Statistical analysis will be included in SWAM reports from 2023-24 to further validate the trend.

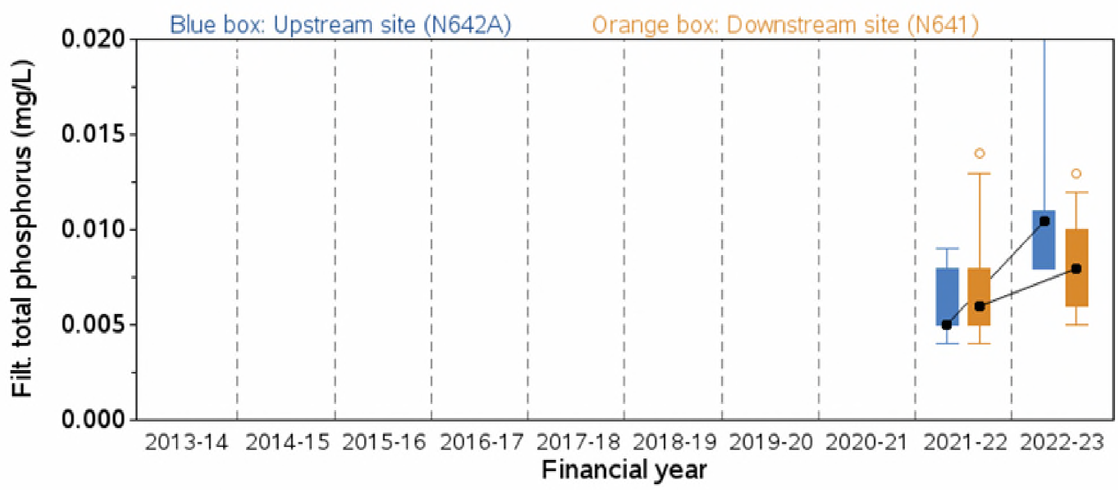
In the 2022-23 period, the median oxidised nitrogen and total nitrogen concentrations exceeded the respective ANZG (2018) guideline at both sites.



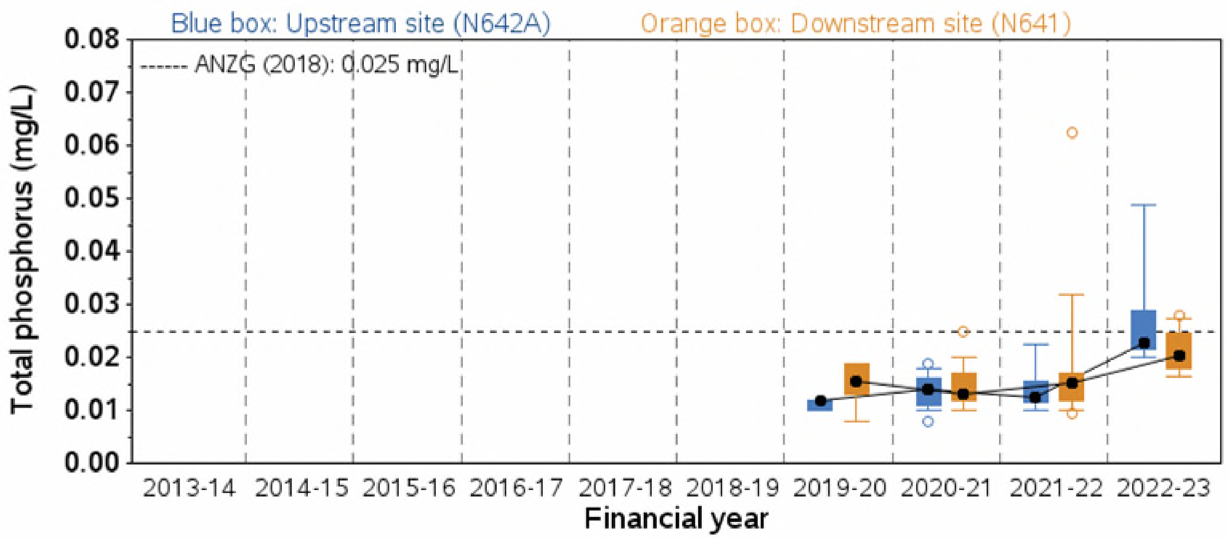
site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N642A	1	0.14	0.7155	N641	1	6.58	0.0133



site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N642A	1	0.46	0.5042	N641	1	9.21	0.0038



site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N642A	1	5.48	0.044	N641	1	1.42	0.2431



site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N642A	1	28.03	<.0001	N641	1	5.06	0.0289

Figure 4-13 Nutrients and physico-chemical water quality exception plots, upstream and downstream of Wallacia WRRF

Ecosystem Receptor – Phytoplankton

Table 4-11 Gate 1 Analysis outcome summary – phytoplankton as chlorophyll-a, biovolume and species counts, upstream and downstream of Wallacia WRRF discharge

Monitoring sites	Phytoplankton analytes			
	Chlorophyll-a	Total phytoplankton biovolume	Blue-green biovolume	Toxic blue-green count
Upstream tributary (N642A)	→			
Downstream tributary (N641)	→	→	→	

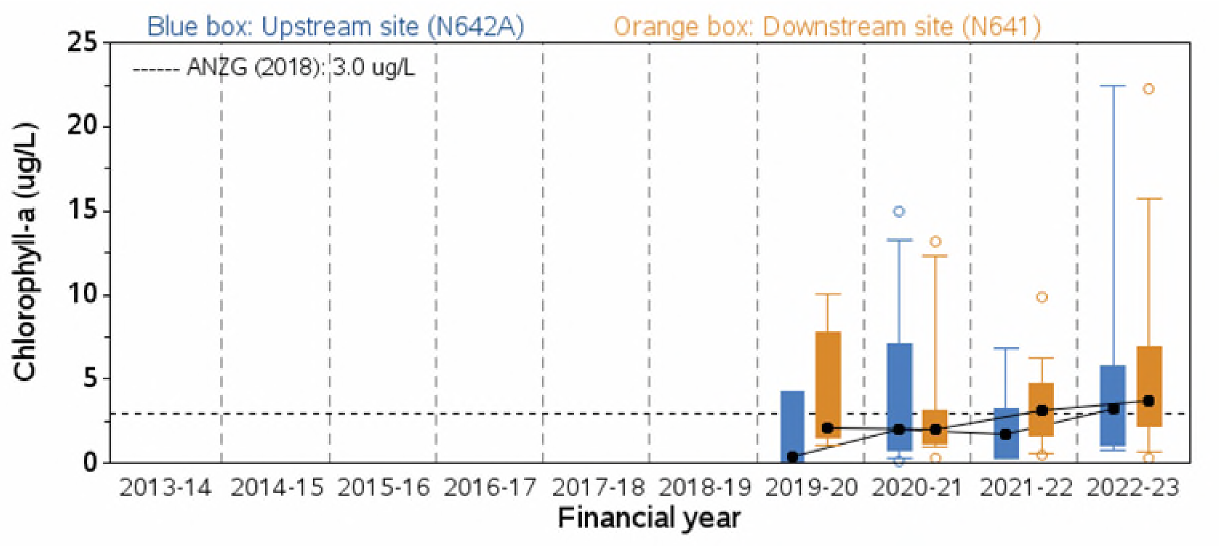
↗	Upward trend	↘	Downward trend	→	no trend, p>0.05

	2022-23 Median value within the guideline limit		No guideline applicable
	2022-23 Median value outside the guideline limit		Insufficient data

In 2022-23 period, there was no significantly increasing or decreasing trends identified in chlorophyll-a or any of the phytoplankton analytes at both the upstream and downstream Warragamba River sites.

In the 2022-23 period, the median chlorophyll-a concentrations exceeded the ANZG (2018) guideline at both upstream/downstream site. Blue-green biovolume or toxic blue-green species counts were low and always within the NHMRC (2008) Amber Alert level at downstream site.

Two of the six samples collected from the upstream Warragamba River site (N642A) qualified for phytoplankton species counts during 2022-23. No potentially toxic blue-green taxa were found in these samples. At the downstream river site (N641), five of the 17 samples were counted for phytoplankton species and biovolumes.



site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N642A	1	1.26	0.272	N641	1	2.66	0.1088

Figure 4-14 Phytoplankton as chlorophyll-a, biovolume and species counts exception plots, upstream and downstream of Wallacia WRRF

Ecosystem Receptor – Macroinvertebrates

The 2022-23 macroinvertebrate results suggested a decline in stream health at the site downstream of Wallacia WRRF. As the site upstream was not accessible due to persistent high flows, the nearby upstream/SoE site (N67) along the Nepean River was used as a proxy. There was no evidence that the downstream Warragamba site differed in community assemblage relative to the proxy site on the Nepean River. A definitive impact from wastewater discharge of Wallacia WRRF could therefore not be determined, and the decline in stream health at the downstream site may be attributed to scouring of the downstream habitat as a result of wet weather flows in 2022-23. (Volume 2 Appendix A-3).

Table 4-12 t-test of upstream-downstream SIGNAL-SG scores of 2022-23 samples from waterways near Wallacia WRRF

Waterway	Method	Statistic	DF	P value
Nepean / Warragamba River	Welch Two Sample t-test	3.92	12.5	0.002

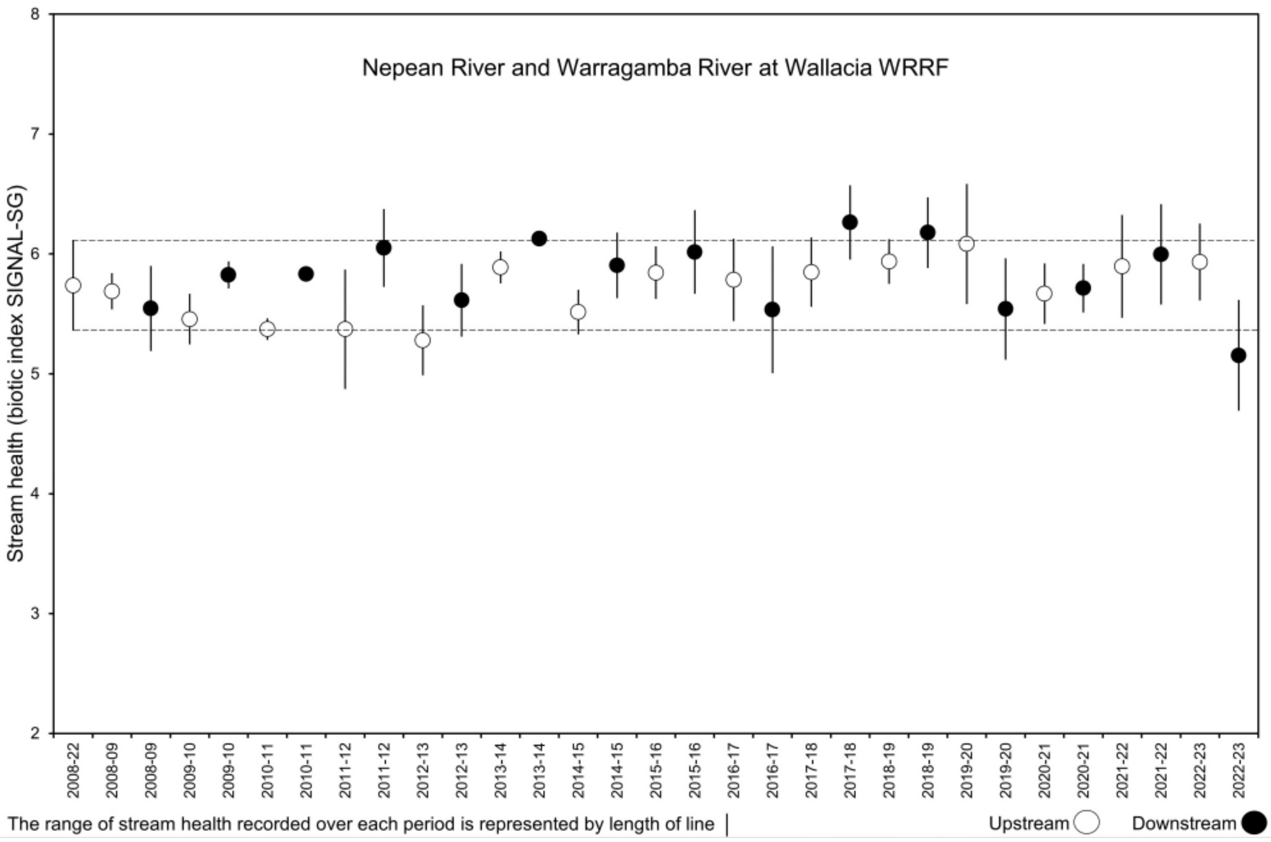


Figure 4-15 Stream health of waterways near Wallacia WRRF

4.1.4 Penrith WRRF

- All parameters (concentrations and loads) monitored in the discharge from Penrith WRRF were within EPL limits. There were increasing trends in total phosphorus and iron concentrations in the discharge, with decreasing trends in total nitrogen, aluminium and copper concentrations.
- Oxidised nitrogen concentrations decreased significantly at the upstream control site in Boundary Creek, with the exception of an elevated result on 17 February 2023 due to a localised sewer overflow from Sydney Water's networks.
- Nutrient concentrations increased significantly at the upstream Nepean River site in 2022-23 in terms of oxidised nitrogen, total nitrogen and filterable total phosphorus. At the downstream Nepean River site, oxidised nitrogen concentrations were elevated or significantly increased in 2022-23.
- Trends in phytoplankton as chlorophyll-a were steady at both upstream/downstream creek and river sites. Analysis on limited phytoplankton monitoring data identified increasing total phytoplankton biovolume at both upstream control sites (creek/river). Phytoplankton blooms were more intensified at the upstream creek site where potentially toxic blue-green taxa reached NHMRC (2008) Amber Alert level four times during 2022-23.
- No stream health impacts (as indicated by macroinvertebrates) were identified for the waterways downstream Penrith WRRF discharge

Pressure – Wastewater discharge

Table 4-13 Gate 1 Analysis outcome summary – Penrith WRRF

Analytes / Penrith WRRF	Nutrients			Conventional analytes				
	Ammonia Nitrogen	Total Nitrogen	Total Phosphorus	Biochemical Oxygen Demand	Faecal Coliforms	Oil and Grease	Total Suspended Solids	EC_{50} Toxicity
Concentration	→	↘	↗	→	→		→	→
Load								

Analytes / Penrith WRRF	Trace Metals									Other chemicals / organics	
	Aluminium	Cadmium	Chromium	Copper	Iron	Lead	Mercury	Selenium	Zinc	Hydrogen sulfide (un-ionised)	Pesticides and PCBs
Concentration	↘	→		↘	↗				→	→	
Load											

↗	Upward trend	↘	Downward trend	→	no trend, p>0.05

	Within the Environment Protection Licence limit
	Environment Protection Licence limit exceedance
	Analytes not required in the EPL or no concentration limit

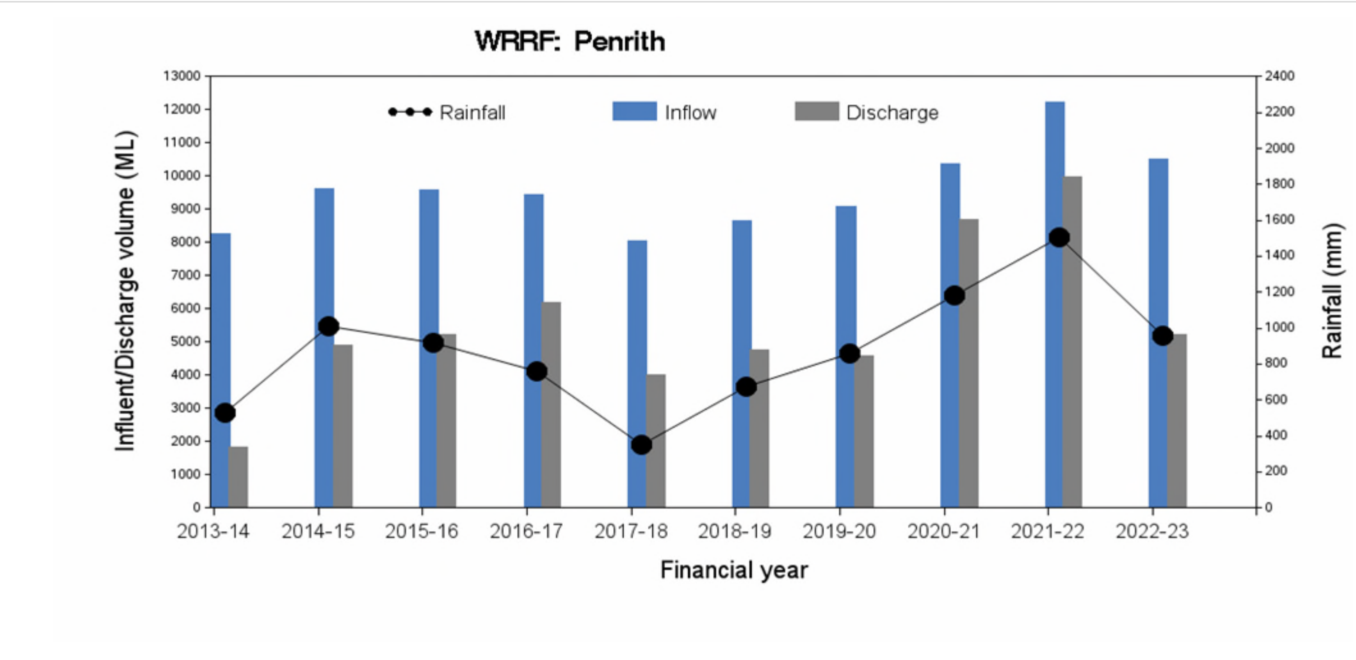
All concentration and load values in the discharge from Penrith WRRF were within the EPL limits in the 2022-23 reporting period.

Statistical analysis identified a significantly increasing trend in total phosphorus and iron concentrations, and significantly decreasing trends in total nitrogen, aluminium and copper concentrations in the discharge compared to the previous nine years.

The increasing total phosphorus trend is linked to extreme wet weather events over the past two reporting periods as well as one of the IDALs being offline for major periodic maintenance during the 2022-23 reporting period.

The increasing trend in iron can also be linked to one of the IDALs being offline for maintenance as operational requirements to increase ferric/ferrous dosing was required to manage phosphorus levels.

Approximately half of the total tertiary treated effluent flow from Penrith WRRF during the 2022-23 reporting period was transferred to St Marys AWTP for additional treatment (including ultra filtration and reverse osmosis) before being discharged into Boundary Creek. Similar to 2021-22, there was minimal offsite reuse during the 2022-23 reporting period due to the continuation of wet weather patterns that reduced the demand from the community for irrigation water.



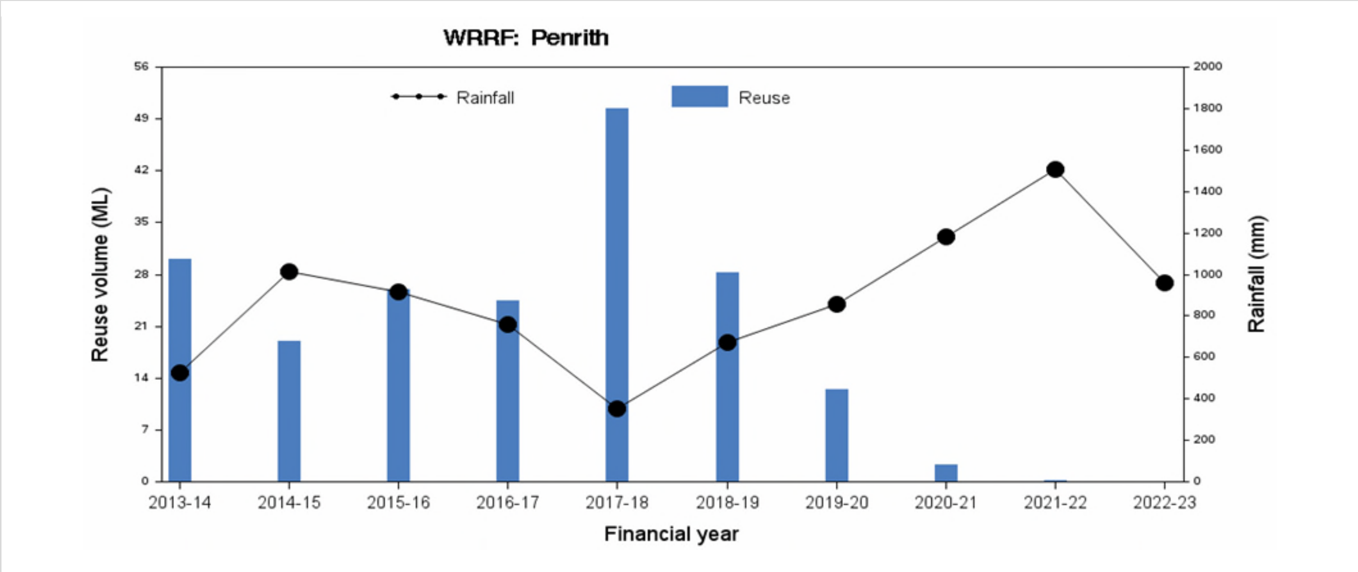
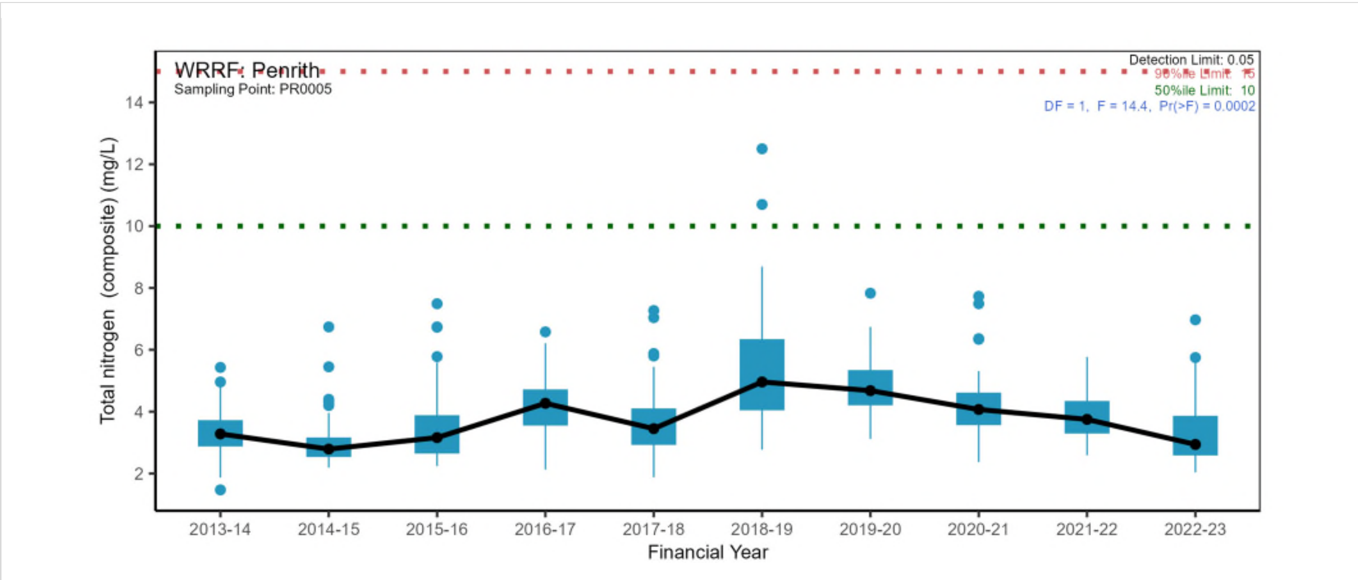
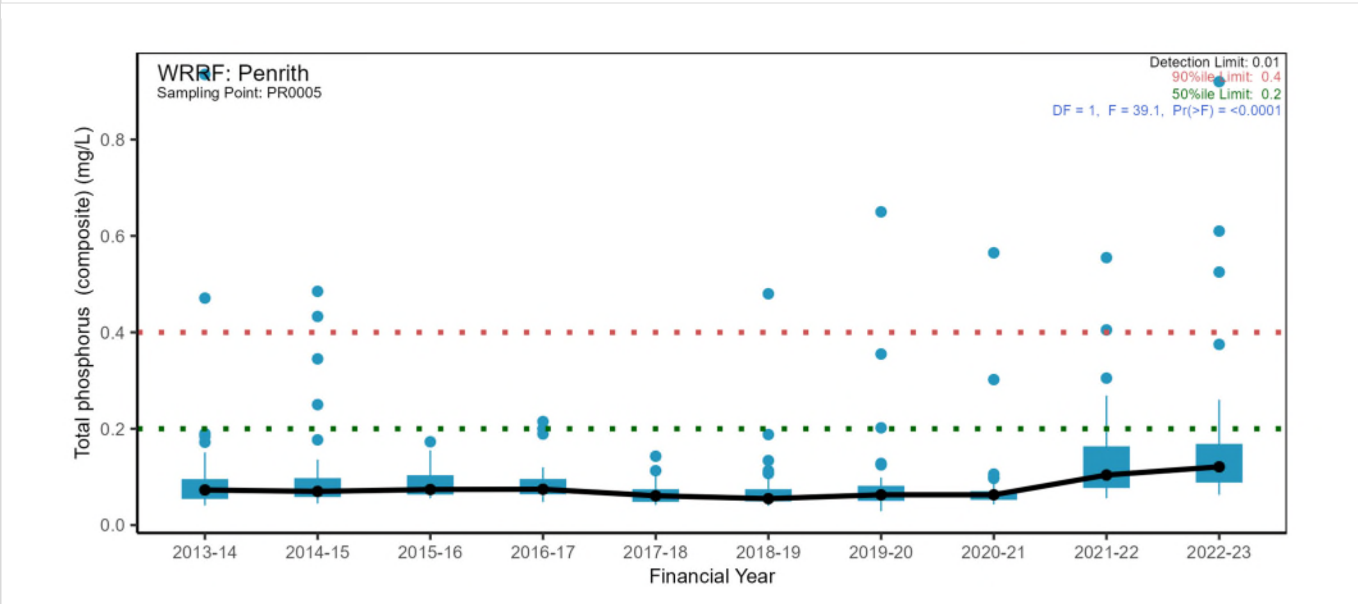


Figure 4-16 Penrith WRRF inflow, discharge and reuse volume with catchment rainfall plots





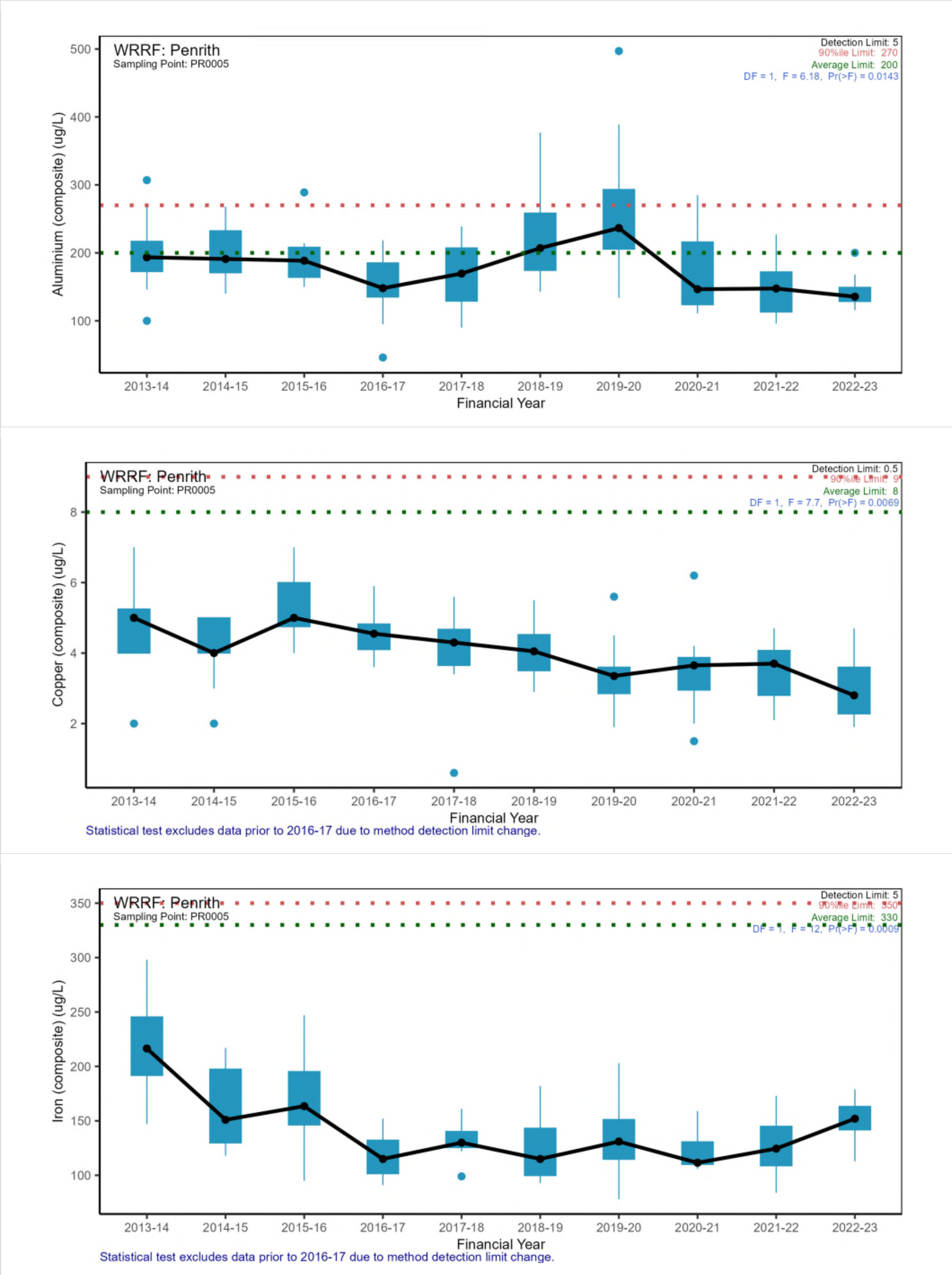


Figure 4-17 Penrith WRRF discharge quality and toxicity exception plots

Stressor – Water quality

Table 4-14 Gate 1 Analysis outcome summary – water quality upstream and downstream of Penrith WRRF discharge

Monitoring sites	Nutrient analytes					Physico-chemical analytes					
	Ammonia nitrogen	Oxidised nitrogen	Total nitrogen	Filterable total phosphorus	Total phosphorus	Conductivity	Dissolved oxygen	Dissolved oxygen saturation	pH	Temperature	Turbidity
Upstream tributary (N542)	→	↘	→	→	→	↗	→	→	→	→	→
Downstream tributary (N541)	→	↘	↘	→	→	→	→	→	→	→	→
Upstream River (N57)	→	↗	↗	↗	→	→	→	↗	→	→	→
Downstream River (N53)	→	↗	→	→	→	→	→	↗	→	→	↗

↗	Upward trend	↘	Downward trend	→	no trend, p>0.05

(green)	2022-23 Median value within the guideline limit	(white)	No guideline applicable
(yellow)	2022-23 Median value outside the guideline limit	(grey)	Insufficient data

Penrith WRRF discharges into Boundary Creek that drains directly to Nepean River downstream of Penrith Weir. Water quality at the upstream control site in Boundary Creek (N542) is influenced by urban run-off and also had a history of impact from uncontrolled sewer overflows in the past. The upstream Nepean River control site at Penrith Weir (N57) is largely undeveloped with a mix of rural, agricultural, protected catchment/national park. The Warragamba River joins the Nepean River about 18 km upstream of Penrith Weir. The Warragamba River receives discharges from Wallacia WRRF and environmental flow releases from Warragamba Dam.

In 2022-23, oxidised nitrogen concentrations decreased significantly, and conductivity increased significantly at the upstream control site in Boundary Creek (N542) compared to previous years. At the downstream creek site (N541), oxidised nitrogen and total nitrogen concentration decreased significantly in 2022-23.

There was a significant increase in oxidised nitrogen, total nitrogen and filterable total phosphorus at Penrith Weir (N57; upstream control site in the Nepean River) in 2022-23 compared to earlier years. Dissolved oxygen saturation also increased or improved significantly at this site.

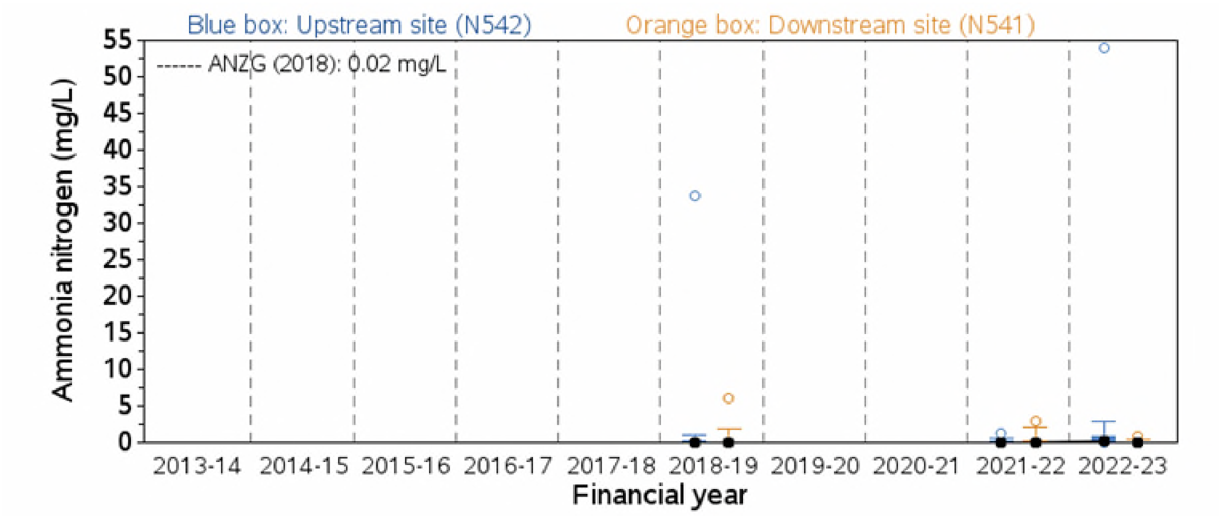
Data for the downstream Nepean River site (N53) was limited to the period from 2017-2023. Oxidised nitrogen, dissolved oxygen saturation and turbidity values/concentrations at this site were significantly higher in 2022-23 compared to 2017-22 data.

Oxidised nitrogen concentrations at the upstream control site of Boundary Creek were notably lower during 2022-23 in comparison to downstream concentration indicating an impact from nitrogen-rich discharges of Penrith WRRF. Whereas conductivity and turbidity values are much higher at the upstream site related with the upstream catchment factors. Statistical analysis will be included in SWAM reports from 2023-24 to further validate the trend.

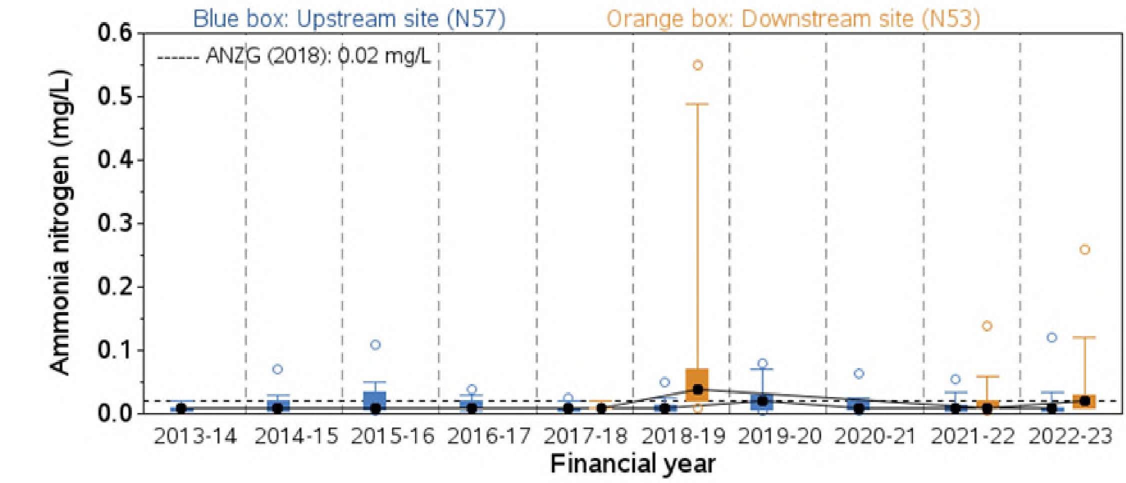
In 2022-23, the median concentrations/values of all nutrients and other physico-chemical analytes exceeded the respective ANZG (2018) guideline values at the upstream Boundary Creek site (N542). The only exceptions were turbidity and pH where the median values were within the guideline. At the downstream Boundary Creek site (N541), the median ammonia nitrogen, oxidised nitrogen, total nitrogen and turbidity concentrations were outside the respective ANZG (2018) guideline values.

The median oxidised nitrogen and total nitrogen concentrations exceeded the respective ANZG (2018) guideline at both upstream/downstream Nepean River sites. At downstream Nepean River site (N53), the median ammonia nitrogen concentration also exceeded the guideline.

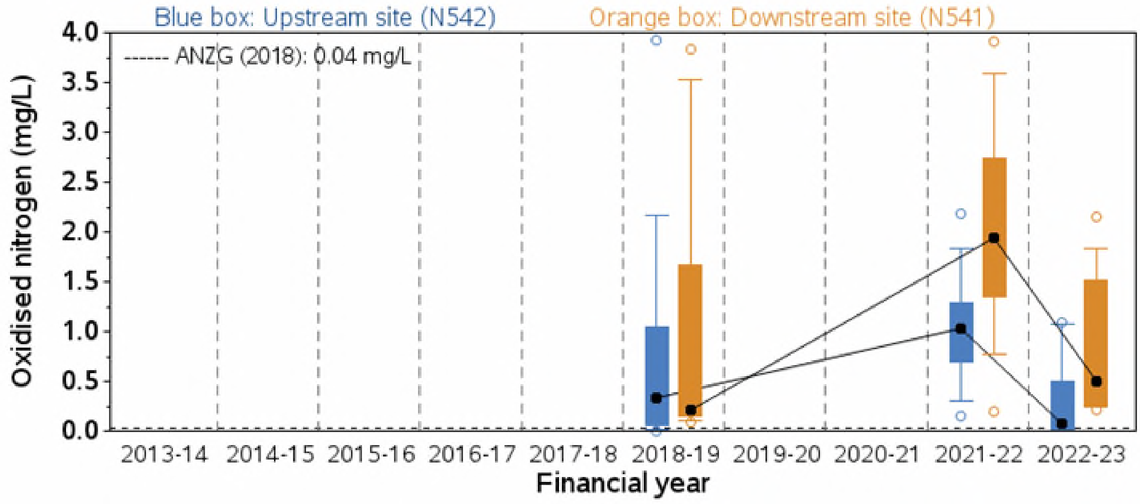
On 17 February 2023, nutrient concentrations at the upstream Boundary Creek site (N542) were highly elevated (ammonia nitrogen 53.9 mg/L, total nitrogen 63.8 mg/L and total phosphorus 7 mg/L). Further investigation found a link between a sewer overflow at upstream Hickeys Lane, Penrith on the same day. The impact of this incident did not extend to the downstream Boundary Creek site (N541) or Nepean River (N53) because of dilution from low nutrient discharges from Penrith WRRF and St Marys AWTP.



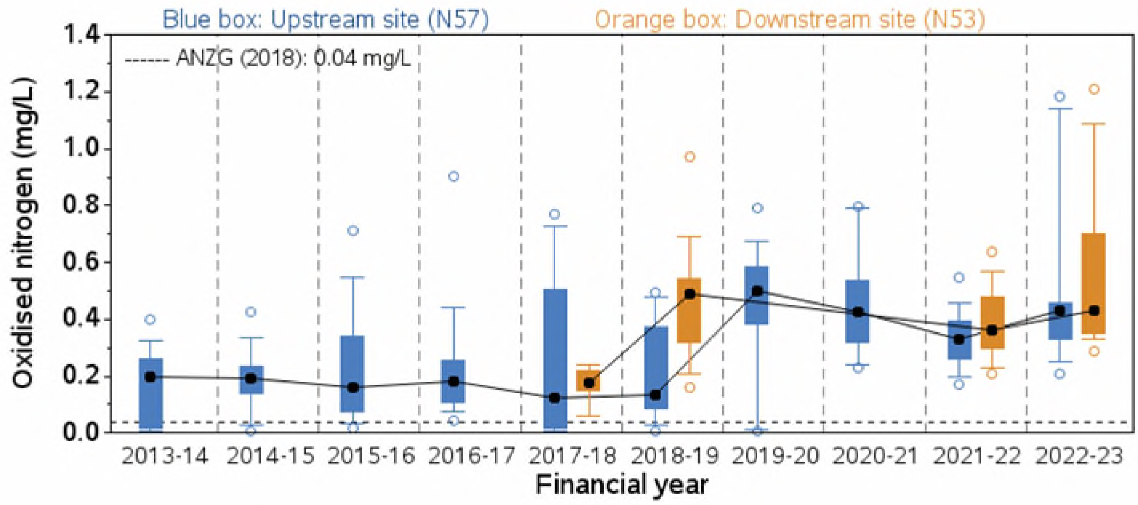
site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N542	1	0.92	0.3409	N541	1	1.26	0.2677



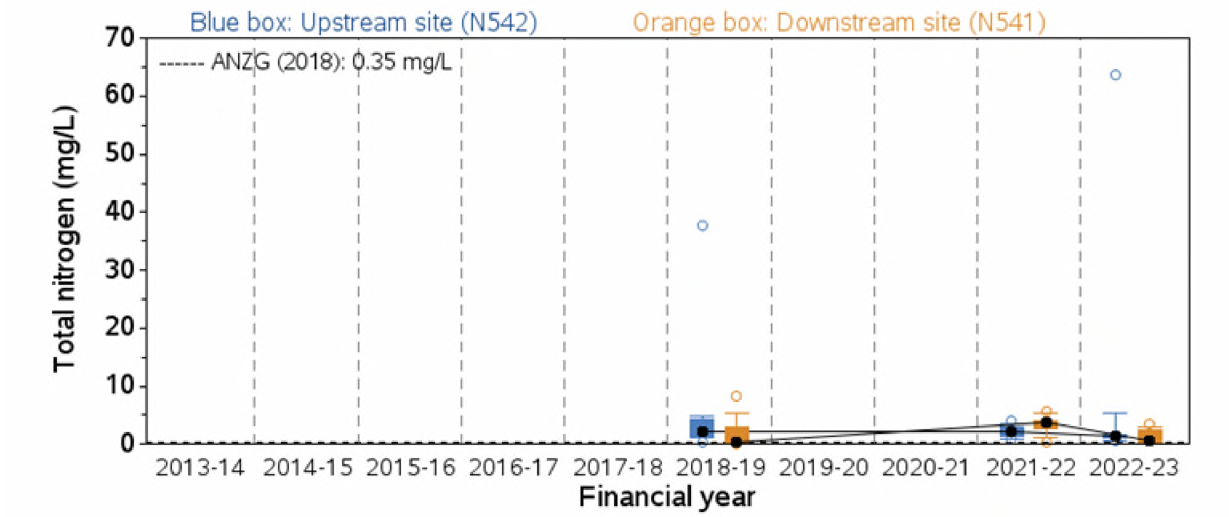
site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N57	1	0.11	0.7458	N53	1	0.38	0.542



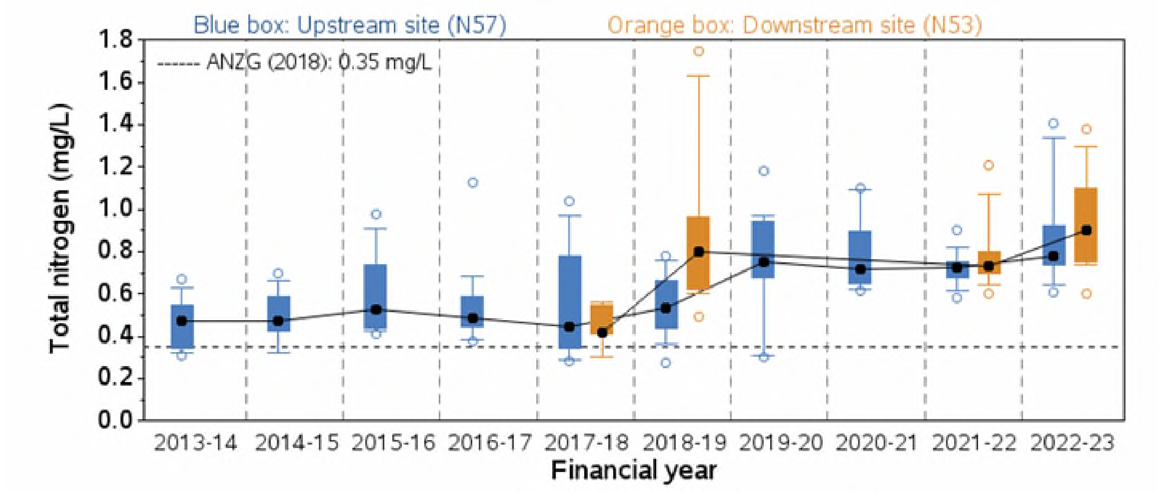
site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N542	1	9.26	0.0037	N541	1	4.84	0.0324



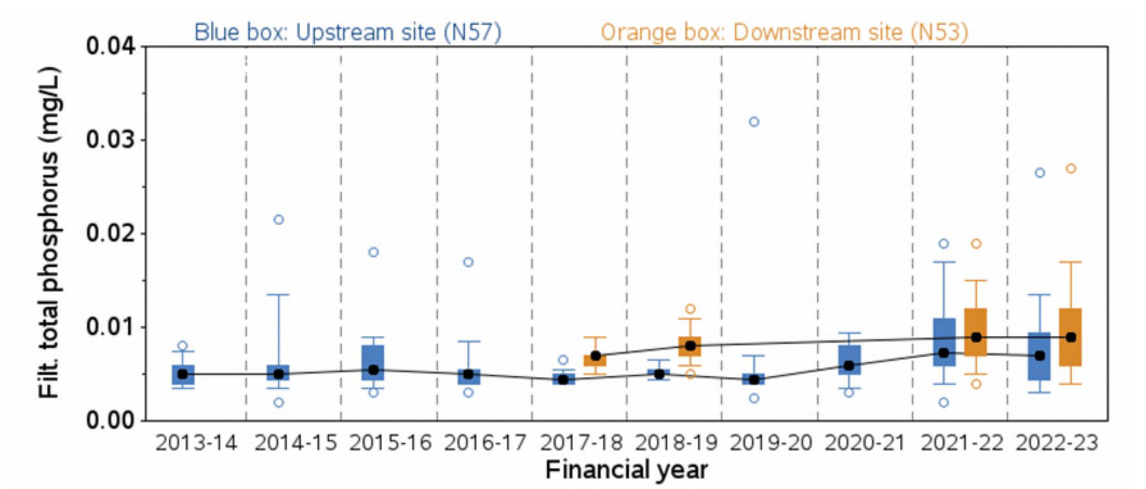
site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N57	1	17.88	<.0001	N53	1	6	0.0177



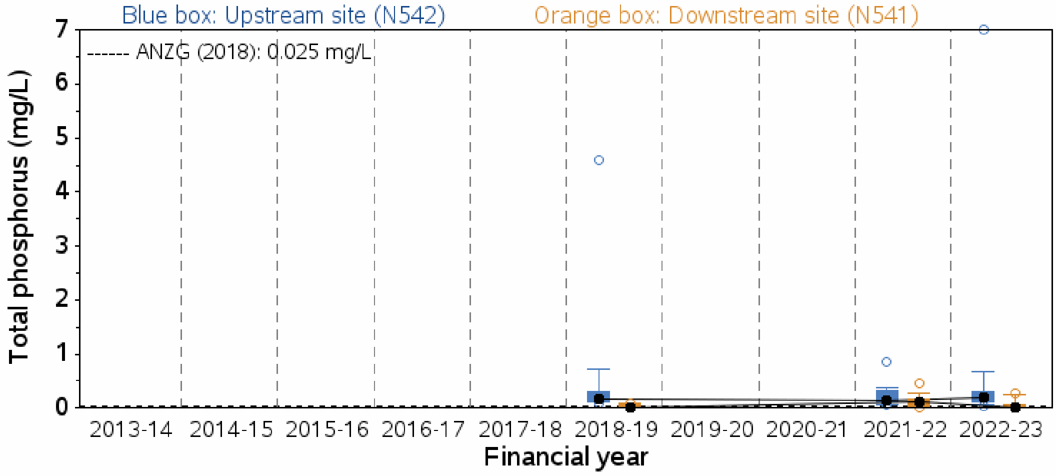
site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N542	1	0.44	0.5099	N541	1	5.26	0.0261



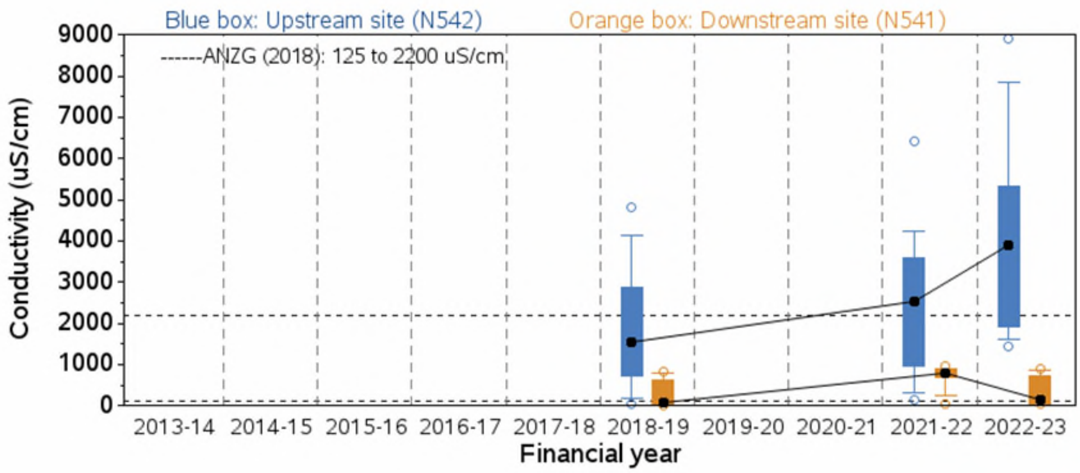
site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N57	1	26.74	<.0001	N53	1	3.28	0.0756



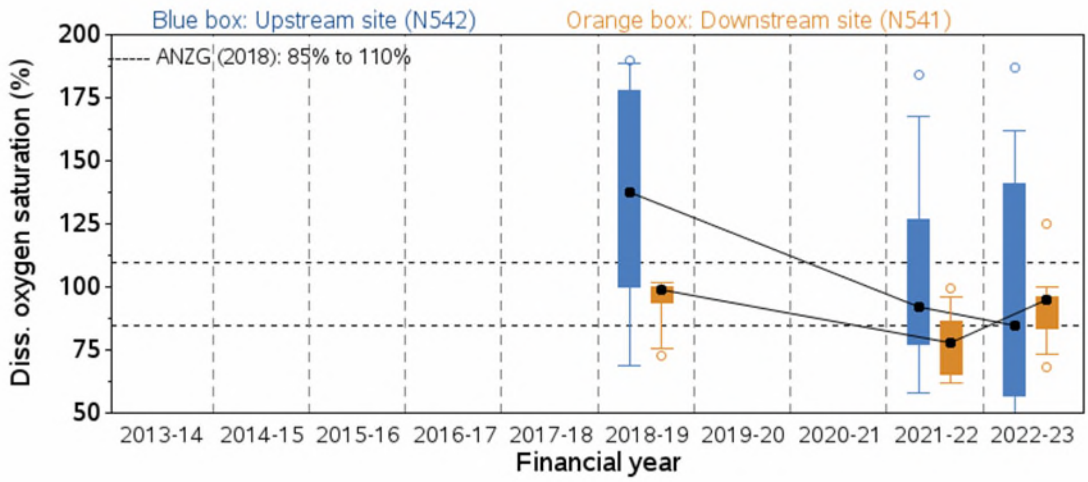
site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N57	1	4.16	0.0429	N53	1	1.6	0.2119



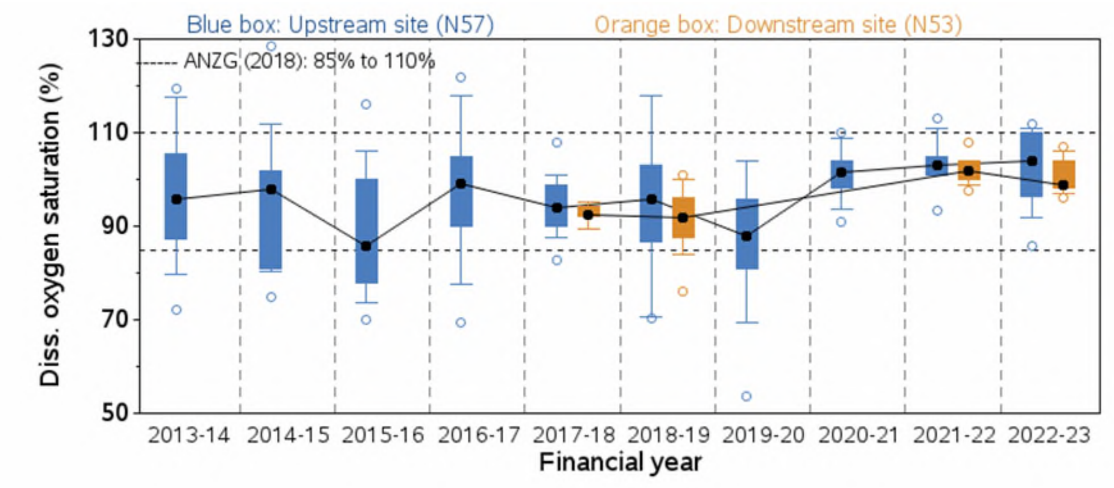
site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N542	1	0.57	0.4536	N541	1	0.75	0.3895



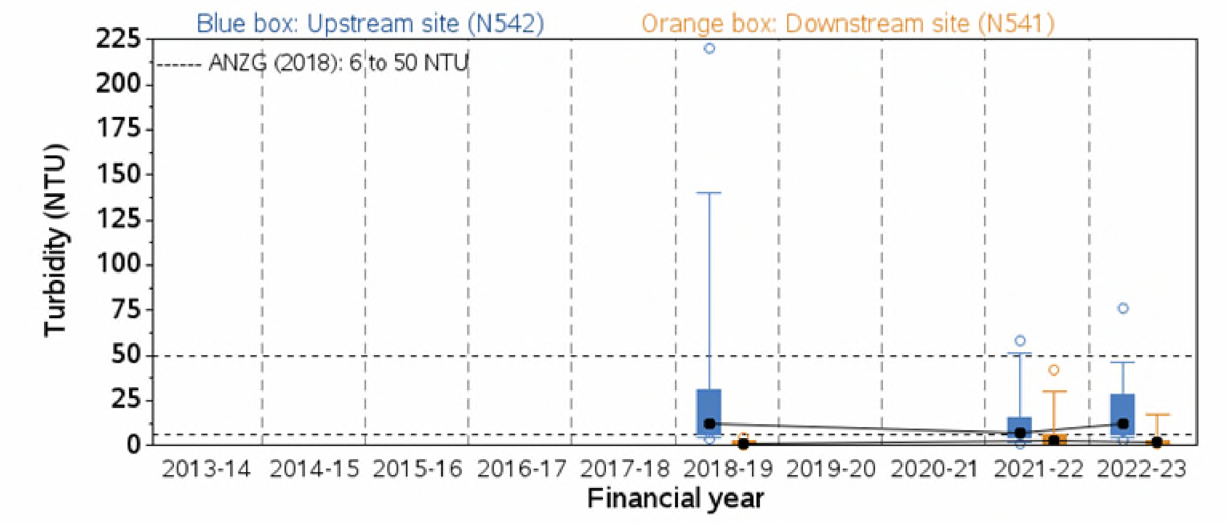
site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N542	1	13.31	0.0006	N541	1	2.76	0.1028



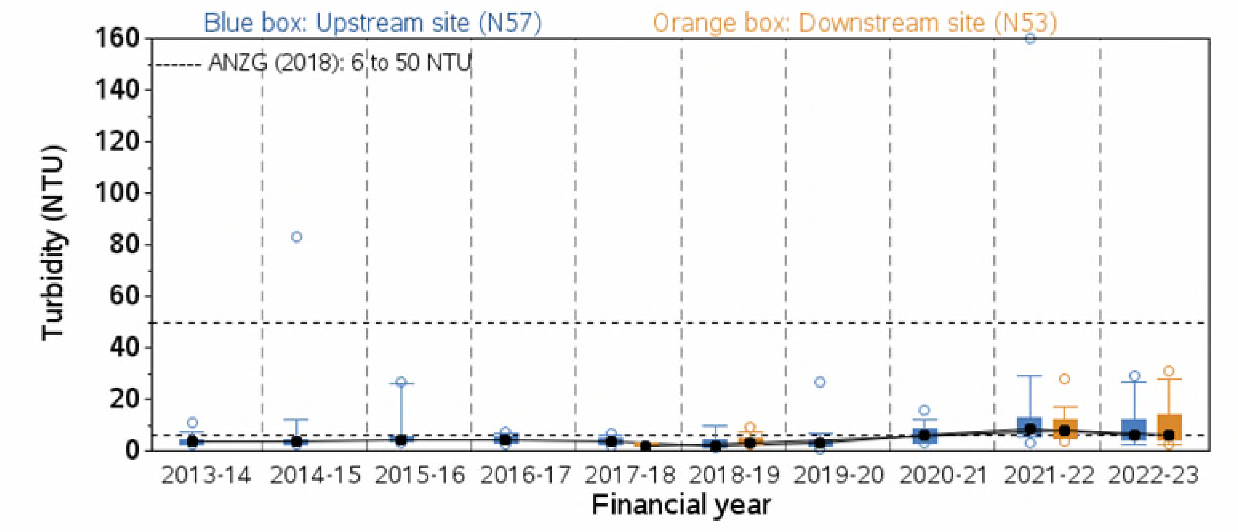
site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N542	1	3.06	0.0865	N541	1	1.62	0.2094



site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N57	1	5.04	0.026	N53	1	7.79	0.0073



site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N542	1	0.29	0.5904	N541	1	0.01	0.9033



site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N57	1	0.63	0.4267	N53	1	6.48	0.0138

Figure 4-18 Nutrients and physico-chemical water quality exception plots, upstream and downstream of Penrith WRRF

Ecosystem Receptor – Phytoplankton

Table 4-15 Gate 1 Analysis outcome summary – phytoplankton as chlorophyll-a, biovolume and species counts, upstream and downstream of Penrith WRRF discharge

Monitoring sites	Phytoplankton analytes			
	Chlorophyll-a	Total phytoplankton biovolume	Blue-green biovolume	Toxic blue-green count
Upstream tributary (N542)	→	↗	→	→
Downstream tributary (N541)	→			
Upstream River (N57)	→	↗	→	→
Downstream River (N53)	→	→	→	

↗	Upward trend	↘	Downward trend	→	no trend, p>0.05

	2022-23 Median value within the guideline limit		No guideline applicable
	2022-23 Median value outside the guideline limit		Insufficient data

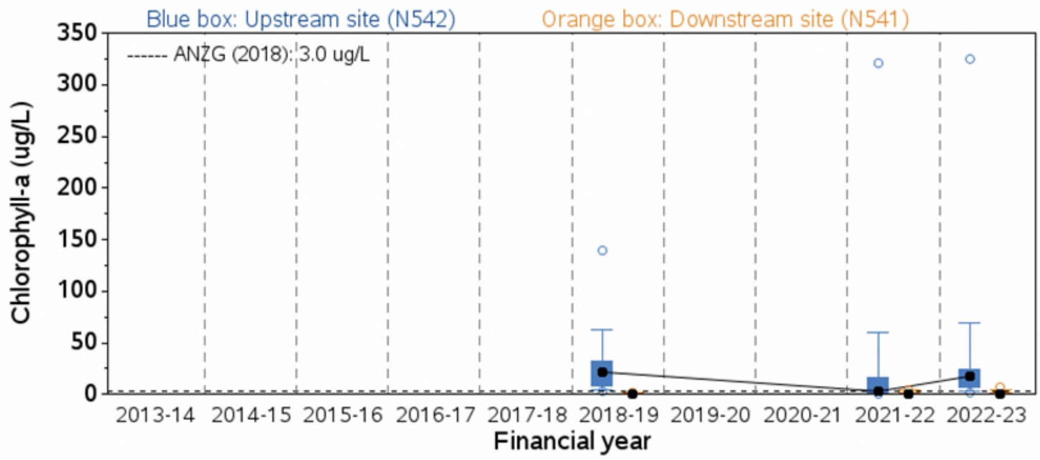
Chlorophyll-a concentrations were steady at both upstream/downstream monitoring sites in Boundary Creek and Nepean River. However, statistical analysis on the limited phytoplankton monitoring data found a significantly increasing trend in total phytoplankton biovolume at the upstream Boundary Creek (N542) and upstream Penrith Weir (N57).

In the 2022-23 period, the median chlorophyll-a concentrations exceeded the ANZG (2018) guidelines at upstream control site of Boundary Creek (N542) and downstream impact site of Nepean River (N53).

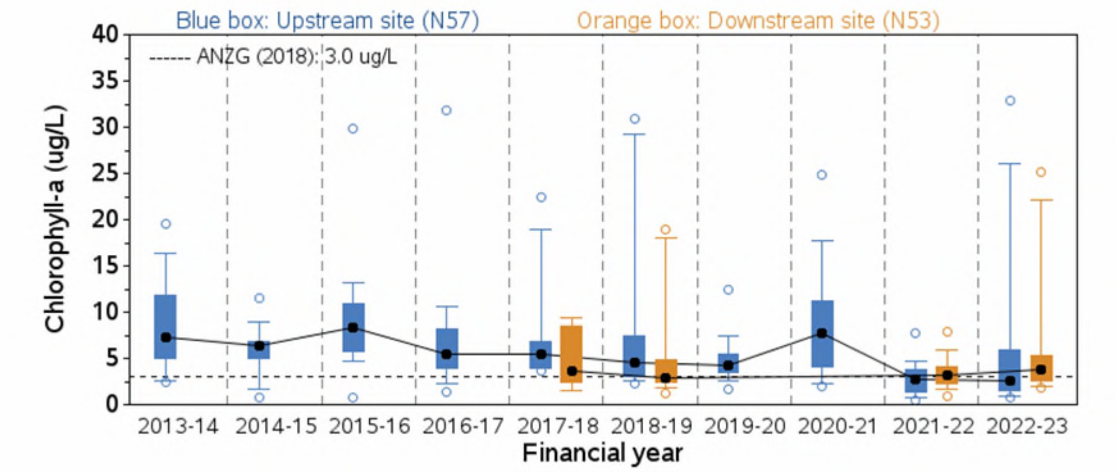
Twelve of the 17 phytoplankton samples were qualified for species count for the upstream control site of Boundary Creek (N542). Blue-green biovolume and species counts were elevated including potentially toxic taxa that reached a maximum of 24,000 cells/mL on 19 September 2022-23 (*Microcystis* 20,121 cells/mL and *Phormidium* 278 cells/mL*).* Potentially toxic blue-green taxa counts reached NHMRC (2008) Amber Alert level at this site four times during 2022-23.

Only one sample qualified for species count for the downstream Boundary Creek site (N541). No blue-greens or potentially toxic blue-green species was found in this sample.

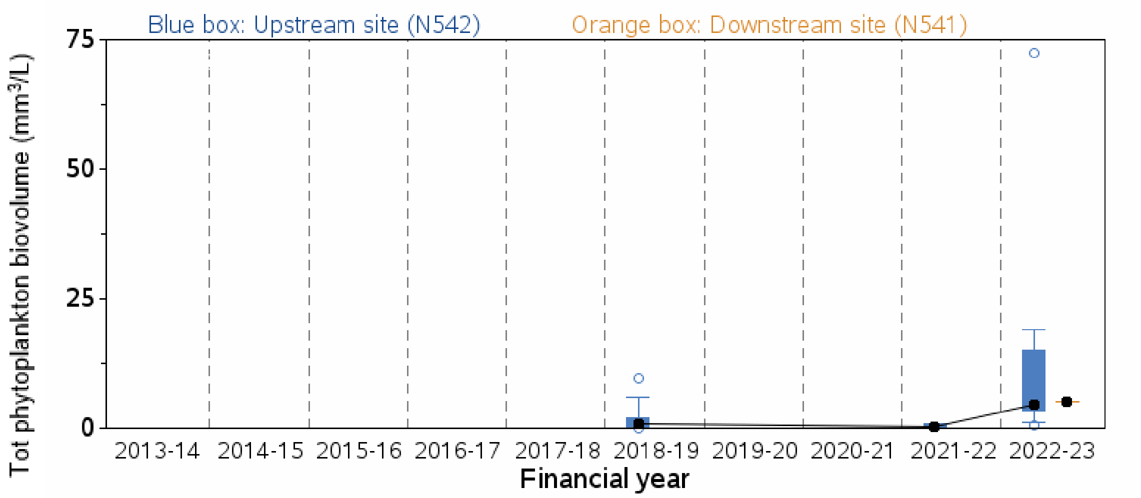
Three of the 17 samples collected from both upstream and downstream Nepean River site qualified for species counts during January-February 2023. At Penrith Weir (N57, upstream control site), potentially toxic blue-green species counts reached 1,700 cells/mL on 17 February 2023 (*Aphanizomenonaceae* and *Microcystis*) which is within the NHMRC (2008) Amber Alert. No potentially toxic blue green species were found at downstream site (N53).



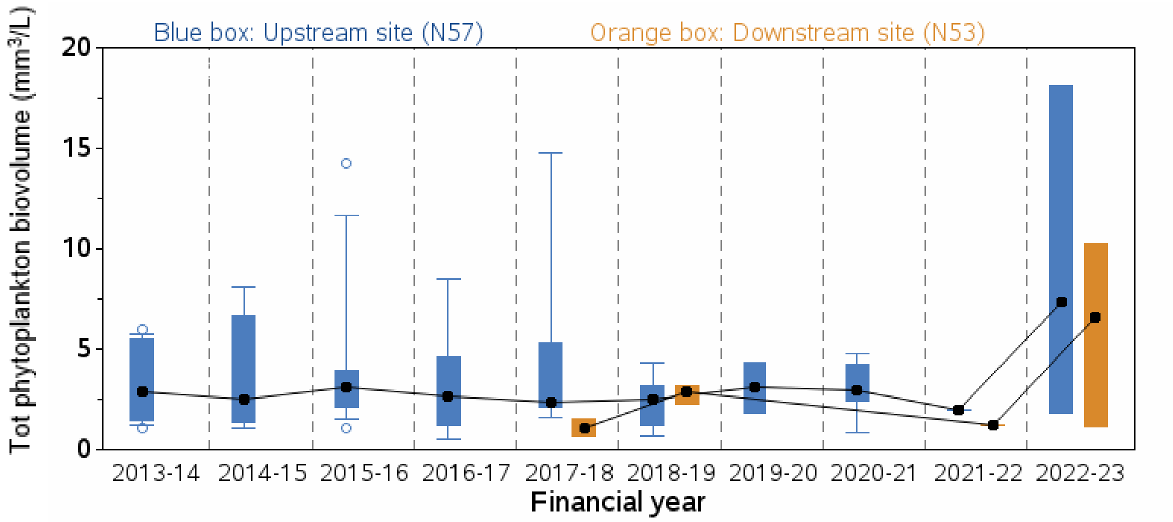
site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N542	1	0.18	0.6717	N541	1	2.33	0.1335



site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N57	1	0	0.9781	N53	1	1.69	0.1993



site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N542	1	5.78	0.0229	N541	Insufficient data		



site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N57	1	8.36	0.0054	N53	1	4.9	0.0625

Figure 4-19 Phytoplankton as chlorophyll-a, biovolume and species counts exception plots, upstream and downstream of Penrith WRRF

Ecosystem Receptor – Macroinvertebrates

No macroinvertebrate stream health impacts were identified for the waterways downstream of where Penrith WRRF discharges, including the Nepean River (Volume 2 Appendix A-4).

4.1.5 Winmalee WRRF

- All parameters (concentrations and loads) monitored in the discharge from Winmalee WRRF were within EPL limits. There was an increasing trend in total nitrogen and total phosphorus concentrations in the discharge, and a decreasing trend in iron concentration.
- Nutrient concentrations increased significantly at the upstream Nepean River site in 2022-23 in terms of oxidised nitrogen and total nitrogen. At the downstream site no significant trend was observed in nutrient analytes.
- The chlorophyll-a and phytoplankton biovolume or toxic species counts were steady at both upstream/downstream sites in 2022-23. Toxic blue-green species counts were low and always within the NHMRC (2008) Amber Alert level.
- Stream health analysis (as indicated by macroinvertebrates) suggested a localised ecosystem impact in the unnamed creek into which Winmalee WRRF discharges. There was no evidence these impacts had any effect on the Nepean River system to which this creek flows.

Pressure – Wastewater discharge

Table 4-16 Gate 1 Analysis outcome summary – Winmalee WRRF

Analytes / Winmalee WRRF	Nutrients			Conventional analytes						Trace Metals				Other
	Ammonia Nitrogen	Total Nitrogen	Total Phosphorus	Biochemical Oxygen Demand	Total Residual Chlorine	Faecal Coliforms	Oil and Grease	Total Suspended Solids	EC_{50} Toxicity	Aluminium	Copper	Iron	Zinc	Diazinon
Concentration	→	↗	↗	→	→	→		→	→	→	→	↘	→	→
Load														

↗	Upward trend	↘	Downward trend	→	no trend, p>0.05

(green)	Within the Environment Protection Licence limit
(yellow)	Environment Protection Licence limit exceedance
(grey)	Analytes not required in the EPL or no concentration limit

All concentration and load values in the discharge from Winmalee WRRF were within the EPL limits. Statistical analysis identified significantly increasing trends in total nitrogen and total phosphorus concentration and a significant decreasing trend in iron concentration during the 2022-23 reporting period compared to the previous nine years.

The increasing total nitrogen and total phosphorus trends can be attributed to increasing inflows as well as extreme wet weather events at Winmalee WRRF exceeding the treatment capacity of the biological processes.

Winmalee WRRF is undergoing a $50M upgrade to fulfill the requirements of the Pollution Reduction Program (PRP) 800 under Environment Protection Licence (EPL) 1963. The upgrade includes the construction of a membrane bioreactor which will increase biological process capability and facilitate a reduction in nutrient concentrations being discharged from Winmalee WRRF. The membrane bioreactor was completed in October 2023 and currently in post commissioning phase. Upgrades to the Winmalee WRRF are due to be completed by September 2024.

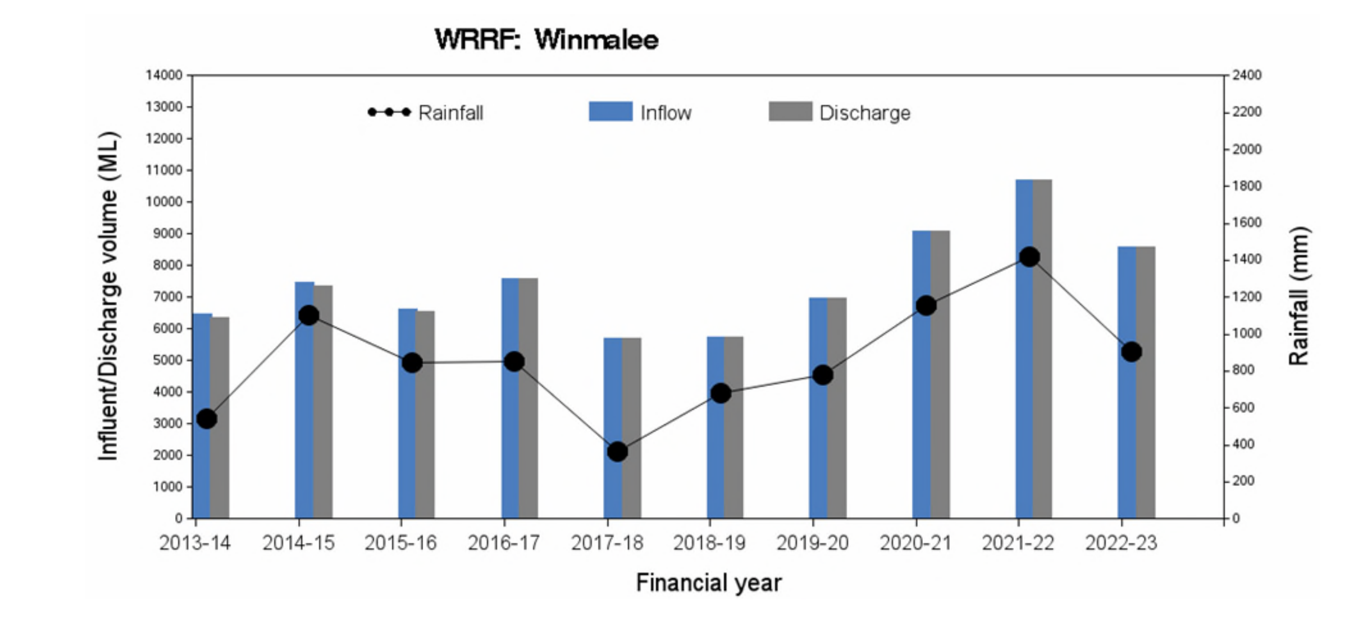
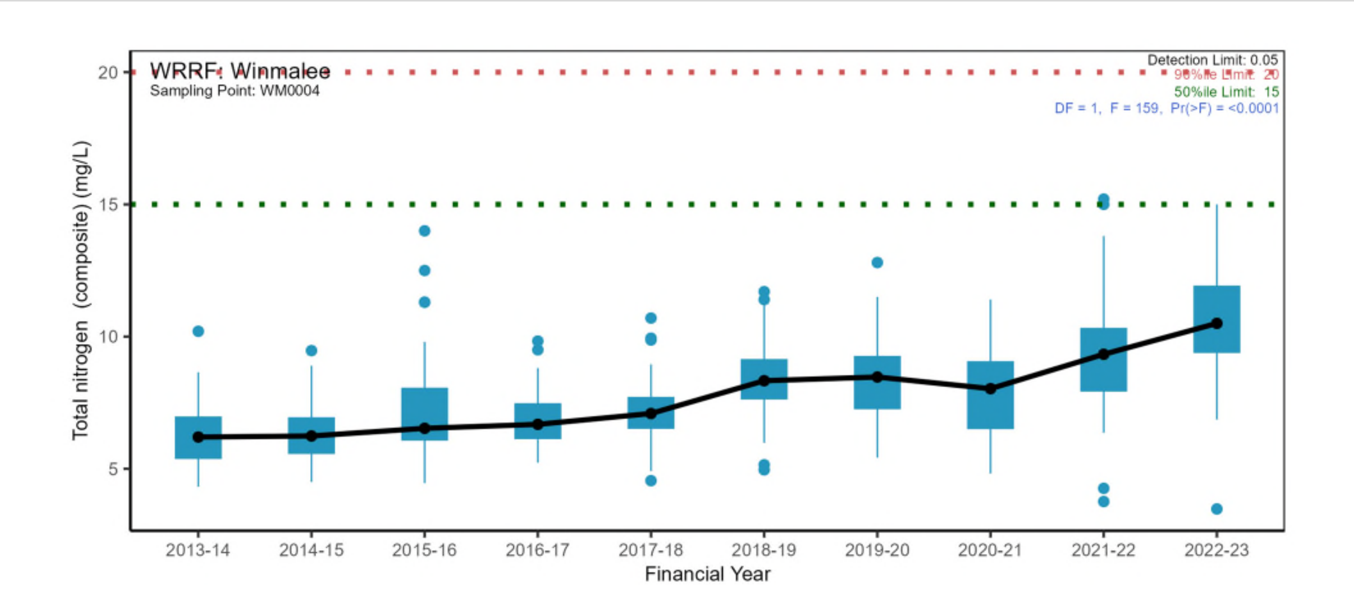


Figure 4-20 Winmalee WRRF inflow and discharge volume with catchment rainfall



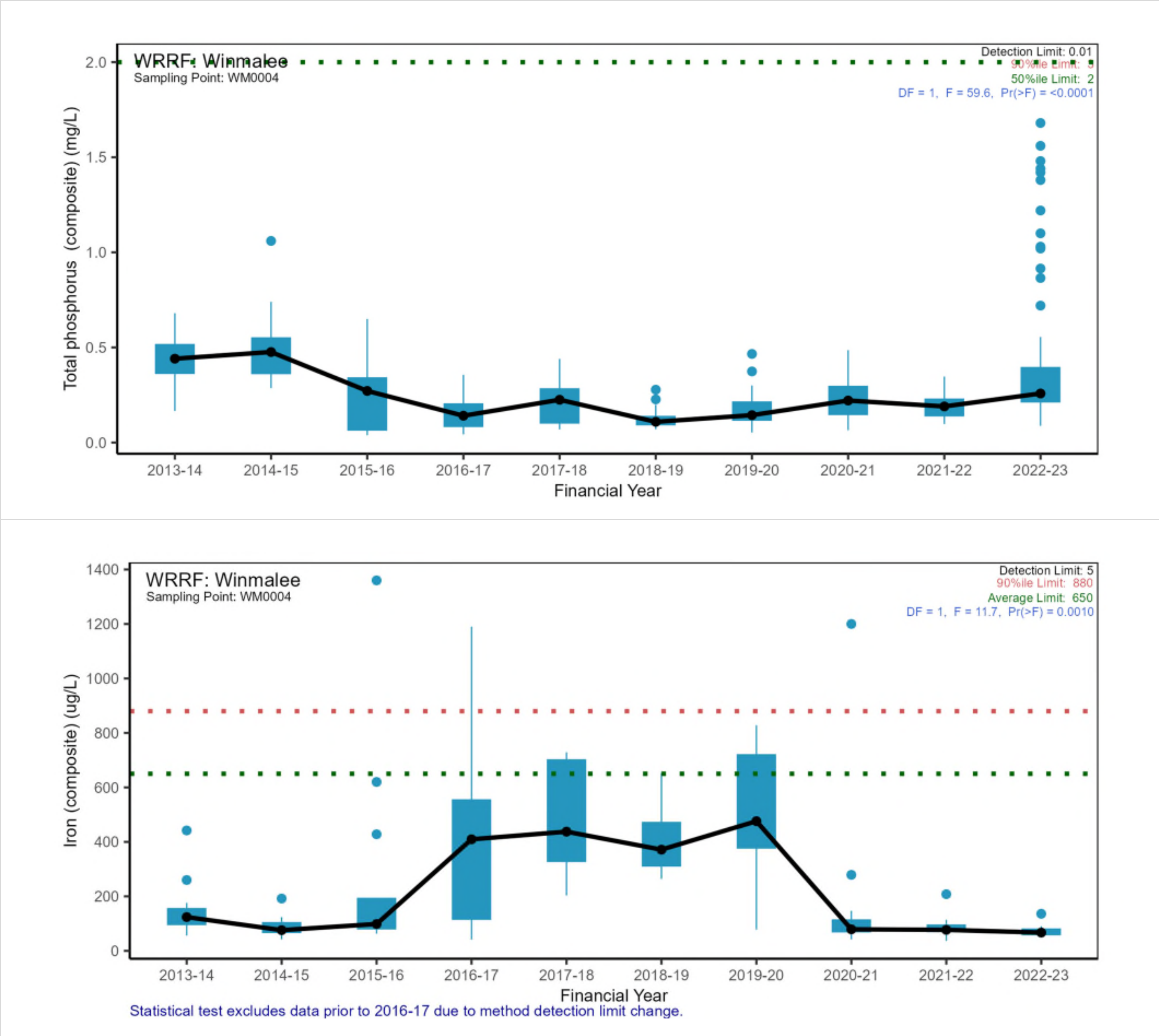


Figure 4-21 Winmalee WRRF discharge quality and toxicity exception plots

Stressor – Water quality

Table 4-17 Gate 1 Analysis outcome summary – water quality upstream and downstream of Winmalee WRRF discharge

Monitoring sites	Nutrient analytes					Physico-chemical analytes					
	Ammonia nitrogen	Oxidised nitrogen	Total nitrogen	Filterable total phosphorus	Total phosphorus	Conductivity	Dissolved oxygen	Dissolved oxygen saturation	pH	Temperature	Turbidity
Upstream River (N48A)	→	↗	↗	→	→	→	→	→	→	→	→
Downstream River (N464)	→	→	→	→	→	→	→	→	→	→	↗

↗	Upward trend	↘	Downward trend	→	no trend, p>0.05

(green)	2022-23 Median value within the guideline limit	(white)	No guideline applicable
(yellow)	2022-23 Median value outside the guideline limit	(grey)	Insufficient data

An unnamed creek starts at the Winmalee WRRF discharge point and therefore no feasible upstream tributary monitoring site exists for the Winmalee WRRF. Data for the downstream creek site (N461) was very limited or not suitable for analysis.

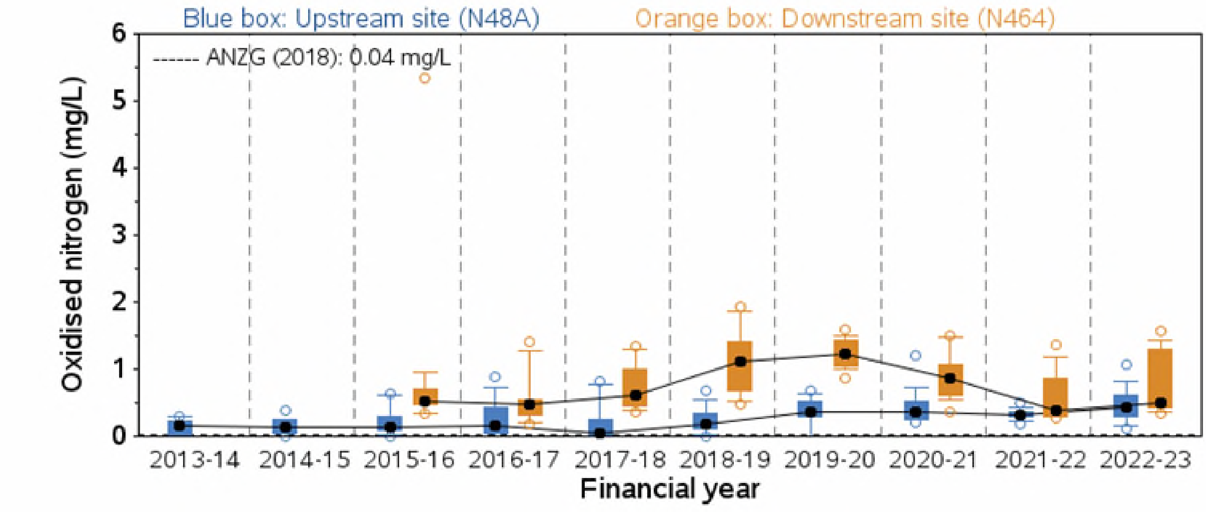
The Nepean River site at Smith Road (N48A) is about 7 km downstream from Boundary Creek where Penrith WRRF discharges. The water quality at this control site for the Winmalee WRRF is also influenced by local agricultural and upstream mining activities. This site often contains submerged macrophyte beds with the occasional floating macrophyte species.

The water quality for the upstream control site (N48A) deteriorated significantly in terms of oxidised nitrogen and total nitrogen concentrations in 2022-23 compared to the previous nine years.

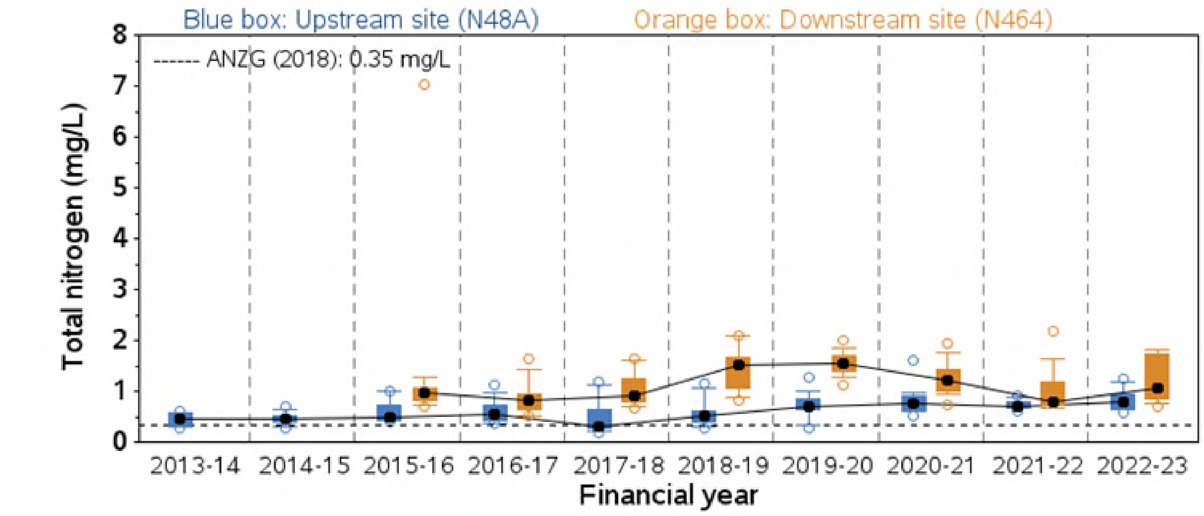
The downstream river site is located at Winmalee lagoon (N464), at the main branch of Nepean River draining downstream. None of the nutrient analytes exhibited a significant trend in 2022-23 at this site. Among other water quality analytes, turbidity increased significantly in 2022-23.

Concentrations of key nutrient analytes (oxidised nitrogen, total nitrogen and total phosphorus) at the downstream impact sites were notably higher in comparison to upstream concentrations indicating a possible impact from nutrient rich discharges from Winmalee WRRF. Statistical analysis will be included in SWAM reports from 2023-24 to further validate the trend.

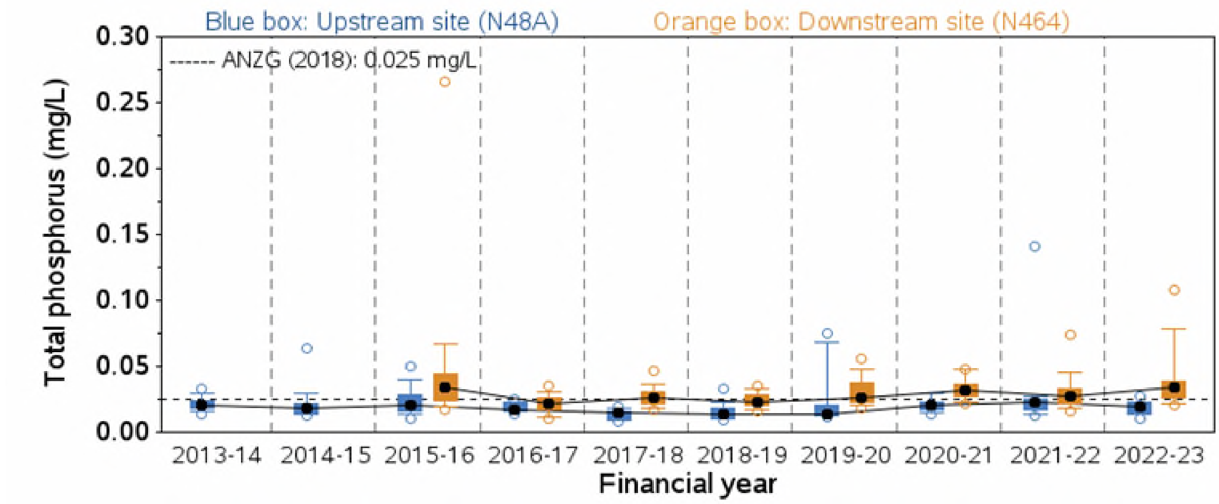
In the 2022-23 period, the median oxidised nitrogen and total nitrogen concentrations exceeded the respective ANZG (2018) guideline at both upstream and downstream sites. The total phosphorus concentration also exceeded the guideline at downstream site (N464).



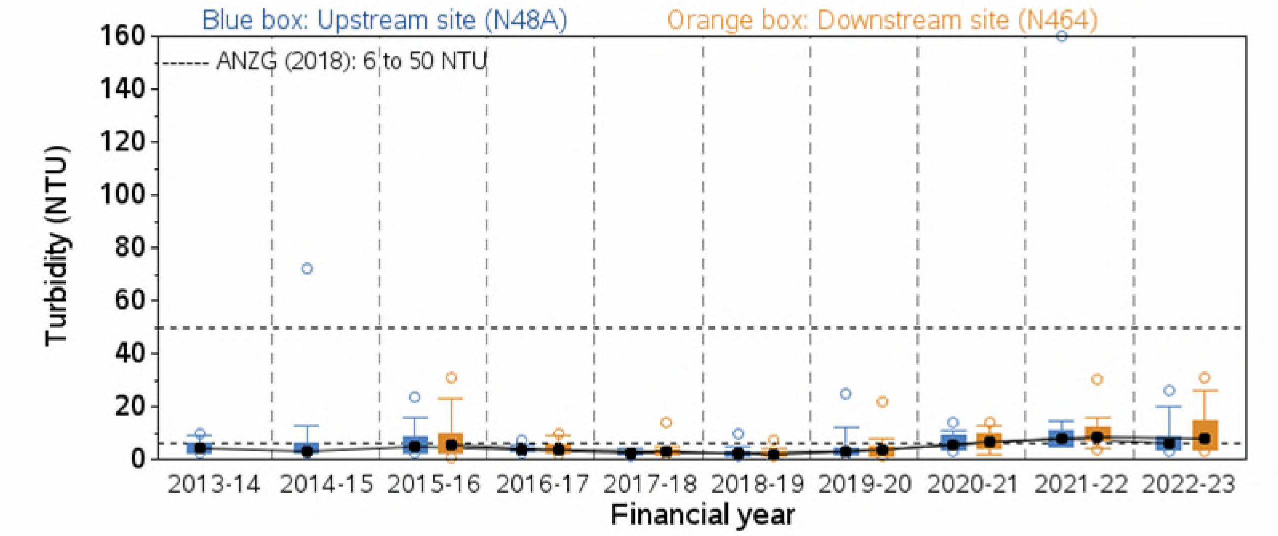
site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N48A	1	9.42	0.0025	N464	1	0	0.9514



site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N48A	1	12.35	0.0006	N464	1	0.07	0.7956



site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N48A	1	0.2	0.652	N464	1	3.14	0.0786



site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N48A	1	0.15	0.6972	N464	1	13.28	0.0004

Figure 4-22 Nutrients and physico-chemical water quality exception plots, upstream and downstream of Winmalee WRRF

Ecosystem Receptor – Phytoplankton

Table 4-18 Gate 1 Analysis outcome summary – phytoplankton as chlorophyll-a, biovolume and species counts, upstream and downstream of Winmalee WRRF discharge

Monitoring sites	Phytoplankton analytes			
	Chlorophyll-a	Total phytoplankton biovolume	Blue-green biovolume	Toxic blue-green count
Upstream River (N48A)	→	→	↗	→
Downstream River (N464)	→	→	→	→

↗	Upward trend	↘	Downward trend	→	no trend, p>0.05

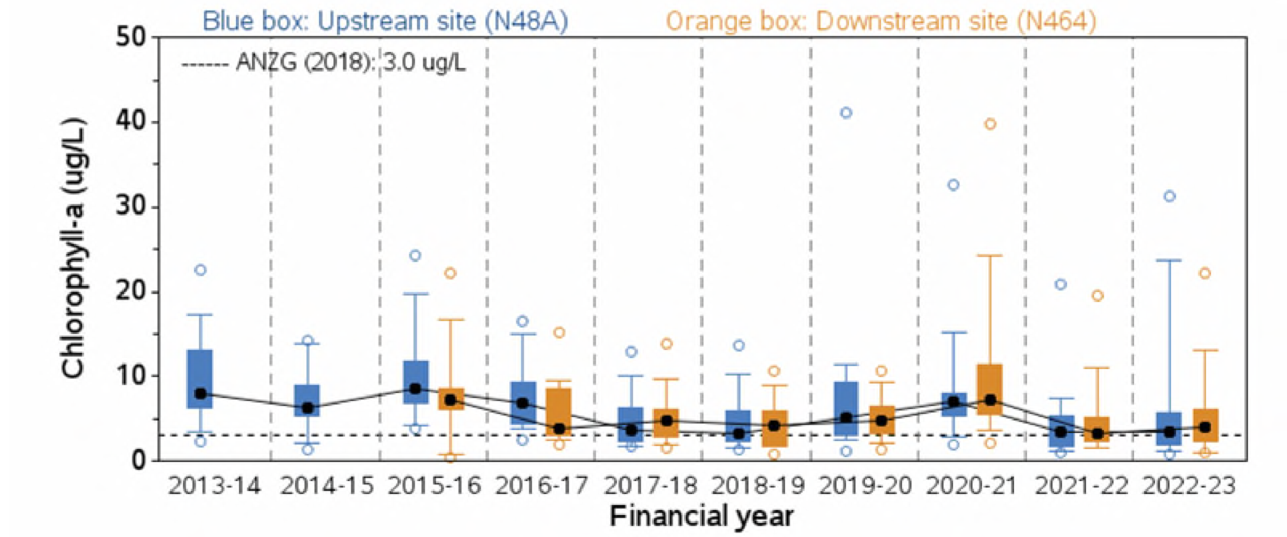
	2022-23 Median value within the guideline limit		No guideline applicable
	2022-23 Median value outside the guideline limit		Insufficient data

The chlorophyll-a, phytoplankton biovolume and toxic species counts were steady at both the upstream and downstream sites in 2022-23. However, the blue-green biovolume increased significantly at the upstream site.

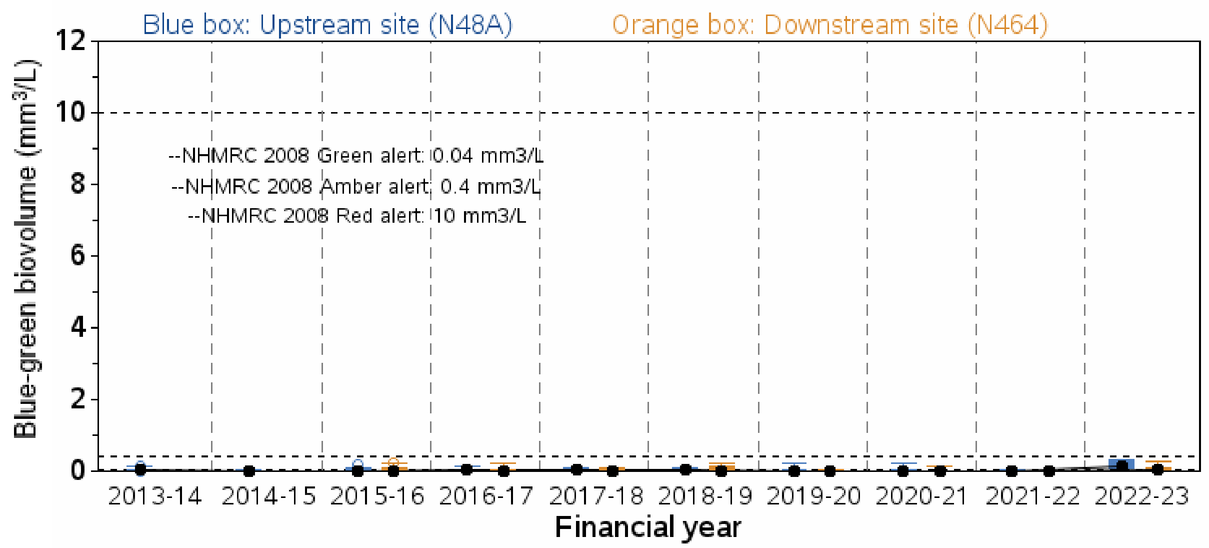
The median chlorophyll-a concentrations exceeded the ANZG (2018) guideline at both sites. Blue-green biovolume or toxic blue-green species counts were low and always within the NHMRC (2008) Amber Alert level.

Three out of 15 phytoplankton samples collected from the upstream site (N48A) were qualified for counting with chlorophyll-a concentrations higher than 7 µg/L. Chlorophyll-a concentrations reached a maximum of 36.2 µg/L on 25 January 2023, when toxigenic blue-green taxa *Dolichospermum* was found in low number (295 cell/mL).

For the downstream lagoon site (N464), six of the 17 samples qualified for species counts. Four of these samples contained toxic blue-green taxa (*Aphanizomenonaceae* and *Microcystis*), maximum of 589 cells/mL on 6 March 2023.



site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N48A	1	0.04	0.8448	N464	1	0.26	0.6084



site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N48A	1	14.38	0.0003	N464	1	1.57	0.216

Figure 4-23 Phytoplankton as chlorophyll-a, biovolume and species counts exception plots, upstream and downstream of Winmalee WRRF

Ecosystem Receptor – Macroinvertebrates

The 2022-23 macroinvertebrate results suggested localised ecosystem impacts in the unnamed creek into which Winmalee WRRF discharges. There was no evidence these impacts had any effect on the Nepean River system to which this creek flows (Volume 2 Appendix A-5).

Table 4-19 t-test of both downstream sites SIGNAL-SG scores from 2022-23 for unnamed creek below Winmalee WRRF and upstream-downstream SIGNAL-SG scores of 2022-23 samples from Nepean River near Winmalee WRRF

Waterway	Method	Statistic	DF	P value
Unnamed Creek	Welch Two Sample t-test	7.63	8.9	<0.001
Nepean River	Welch Two Sample t-test	2.43	3.3	0.085

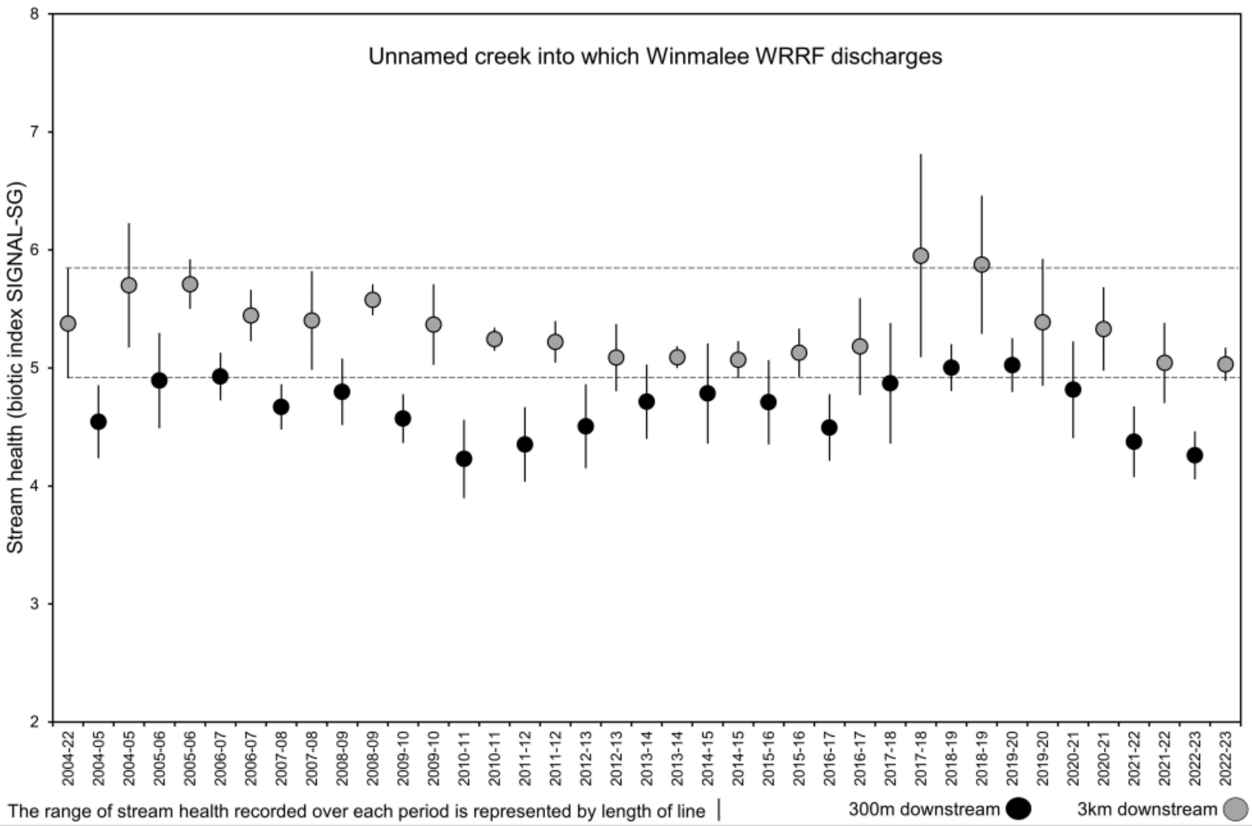


Figure 4-24 Stream health of unnamed creek below Winmalee WRRF for two downstream sites

These results suggested community structure in the unnamed creek near the WRRF was altered by wastewater discharge from Winmalee WRRF but this impact did not extend as far as the Nepean River.

4.1.6 North Richmond WRRF

- Ammonia nitrogen 50th and 90th percentile concentrations were exceeded in the discharge from North Richmond WRRF during 2022-23. All other parameters (concentrations and loads) monitored in the discharge were within EPL limits. There were increasing trends in ammonia nitrogen, total nitrogen, total phosphorus, faecal coliforms and total suspended solids concentrations in the discharge.
- Filterable total phosphorus and total phosphorus concentrations improved/decreased significantly in 2022-23 at the upstream control site of Redbank Creek. At the downstream site these parameters also improved including significant decreases in oxidised nitrogen and total nitrogen concentrations. For the Hawkesbury River, the opposite occurred with significant increases in oxidised nitrogen, total nitrogen and filterable total phosphorus concentrations at both the upstream and downstream river sites.
- Among phytoplankton analytes, chlorophyll-a and total phytoplankton biovolume were significantly lower in 2022-23 at the upstream river site. However, the blue-green biovolume increased significantly at this site in 2022-23. Blue-green biovolume and toxic blue-green species counts were low and the median levels within the NHMRC (2008) Amber Alert level at all sites.
- No stream health impacts (as indicated by macroinvertebrates) were identified for the waterways downstream of where North Richmond WRRF discharges

Pressure – Wastewater discharge

Table 4-20 Gate 1 Analysis outcome summary – North Richmond WRRF

Analytes / Penrith WRRF	Nutrients			Conventional analytes					Trace metals				Other	
	Ammonia Nitrogen	Total Nitrogen	Total Phosphorus	Biochemical Oxygen Demand	Faecal Coliforms	Oil and Grease	Total Suspended Solids	EC_{50} Toxicity	Aluminium	Copper	Iron	Zinc	Hydrogen sulfide (un-ionised)	Diazinon
Concentration	↗	↗	↗	→	↗		↗	→	→	→	→	→	→	→
Load														

↗	Upward trend	↘	Downward trend	→	no trend, p>0.05

	Within the Environment Protection Licence limit
	Environment Protection Licence limit exceedance
	Analytes not required in the EPL or no concentration limit

The 50th and 90th concentration limits for ammonia nitrogen in the discharge from North Richmond WRRF were exceeded during the 2022-23 reporting period. The annual total nitrogen load was also exceeded during this period. All other concentration and load limits in the discharge were within the EPL limits.

Statistical analysis identified a significantly increasing trend in the concentrations of ammonia nitrogen, total nitrogen, total phosphorus, faecal coliforms and total suspended solids in 2022-23 compared to the previous nine years.

The concentration and load non compliances, as well as the increasing trends in key nutrient and conventional analytes were largely influenced by increased inflows to North Richmond WRRF due to catchment growth and limitations of the existing biological treatment technology to meet the EPL concentration limits. This has been particularly relevant during the extended periods of extreme wet weather events, that have been more frequent over the past three reporting periods.

North Richmond WRRF uses outdated technology that is not capable of treating wastewater to the current standard that is required under EPL limits, which were reduced in June 2020. The revised concentration limits don't reflect the capability of the treatment assets at North Richmond, especially alongside the growth in the catchment area.

To restore compliance, Sydney Water is initiating the option to upgrade Richmond WRRF treatment capacity and decommission North Richmond WRRF, with flows from the North Richmond catchment transferred to Richmond WRRF for treatment via construction of a transfer pipeline.

The Richmond WRRF upgrade has faced delays due to:

- Complications with confirming the road alignment of a new bridge over the Hawkesbury River by Transport for NSW. The delay in confirming the road alignment impacted the design timeframe, re-designs of the alignment, and delays in environmental approvals for the project.
- Market capacity across the infrastructure construction sector in Sydney is constrained. As a result, Sydney Water had difficulty acquiring a suitable service provider which prolonged the tender period and delayed the design process.

The project is expected to be completed in late 2026.

In the interim, Sydney Water is involved in further collaborative work with the EPA to address the heightened compliance risk at North Richmond WRRF. A Licence Variation Application was submitted in May 2023 to relax the concentration limits until the North Richmond WRRF is decommissioned, Richmond WRRF is amplified and a transfer pipeline between North Richmond and Richmond WRRFs is constructed.

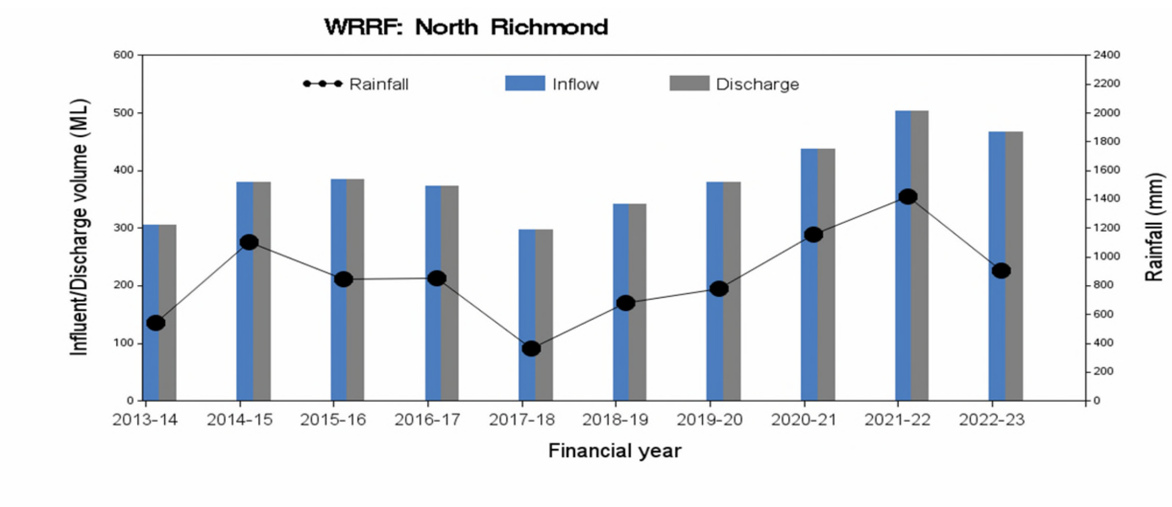
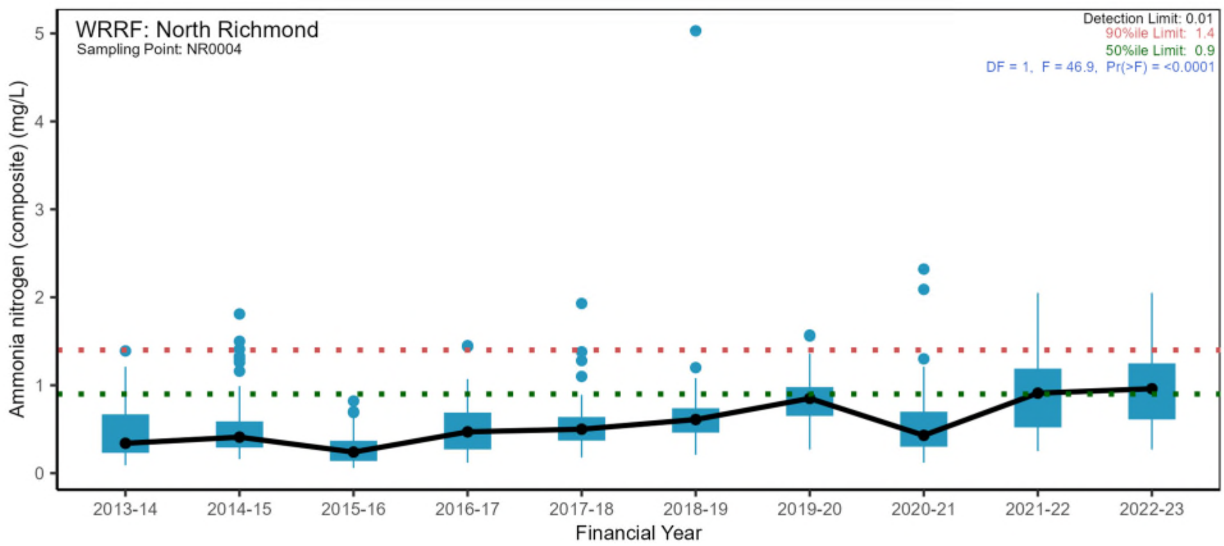
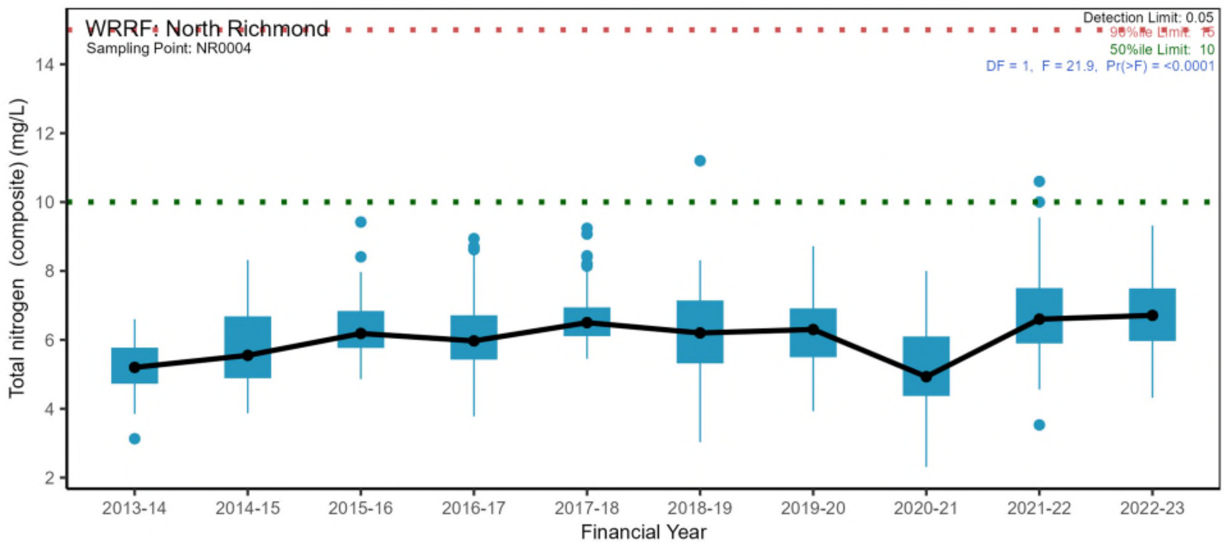
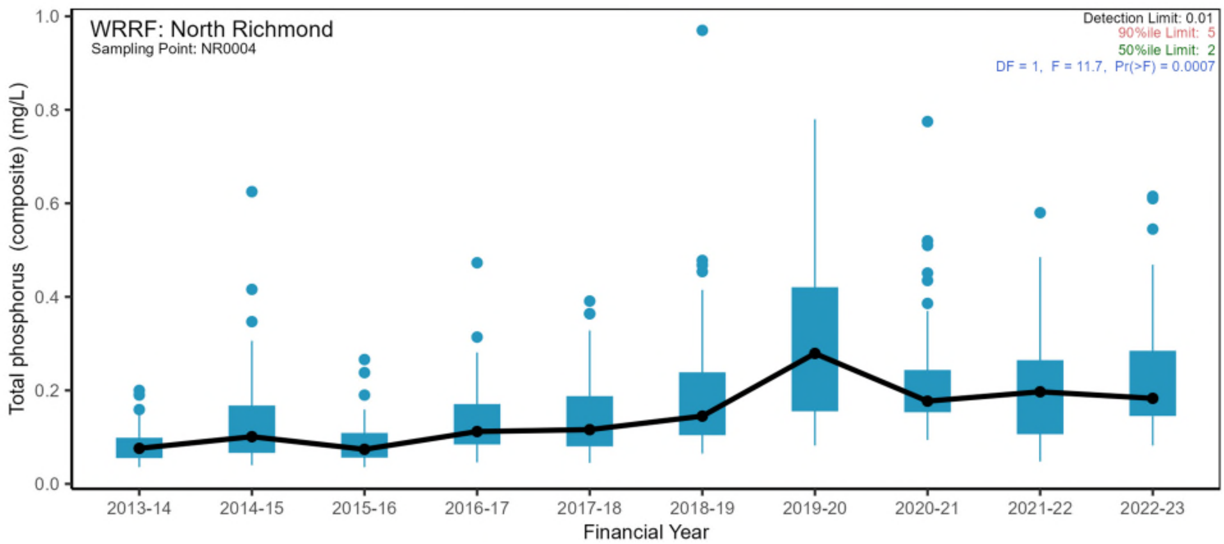


Figure 4-25 North Richmond WRRF inflow and discharge volume with catchment rainfall


WRRF: North Richmond
Sampling Point: NR0004
Detection Limit: 0.01
90%ile Limit: 1.4
50%ile Limit: 0.9
DF = 1, F = 46.9, Pr(>F) = <0.0001
Ammonia nitrogen (composite) (mg/L)
Financial Year
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
2020-21
2021-22
2022-23


WRRF: North Richmond
Sampling Point: NR0004
Detection Limit: 0.05
90%ile Limit: 15
50%ile Limit: 10
DF = 1, F = 21.9, Pr(>F) = <0.0001
Total nitrogen (composite) (mg/L)
Financial Year
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
2020-21
2021-22
2022-23


WRRF: North Richmond
Sampling Point: NR0004
Detection Limit: 0.01
90%ile Limit: 5
50%ile Limit: 2
DF = 1, F = 11.7, Pr(>F) = 0.0007
Total phosphorus (composite) (mg/L)
Financial Year
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
2020-21
2021-22
2022-23

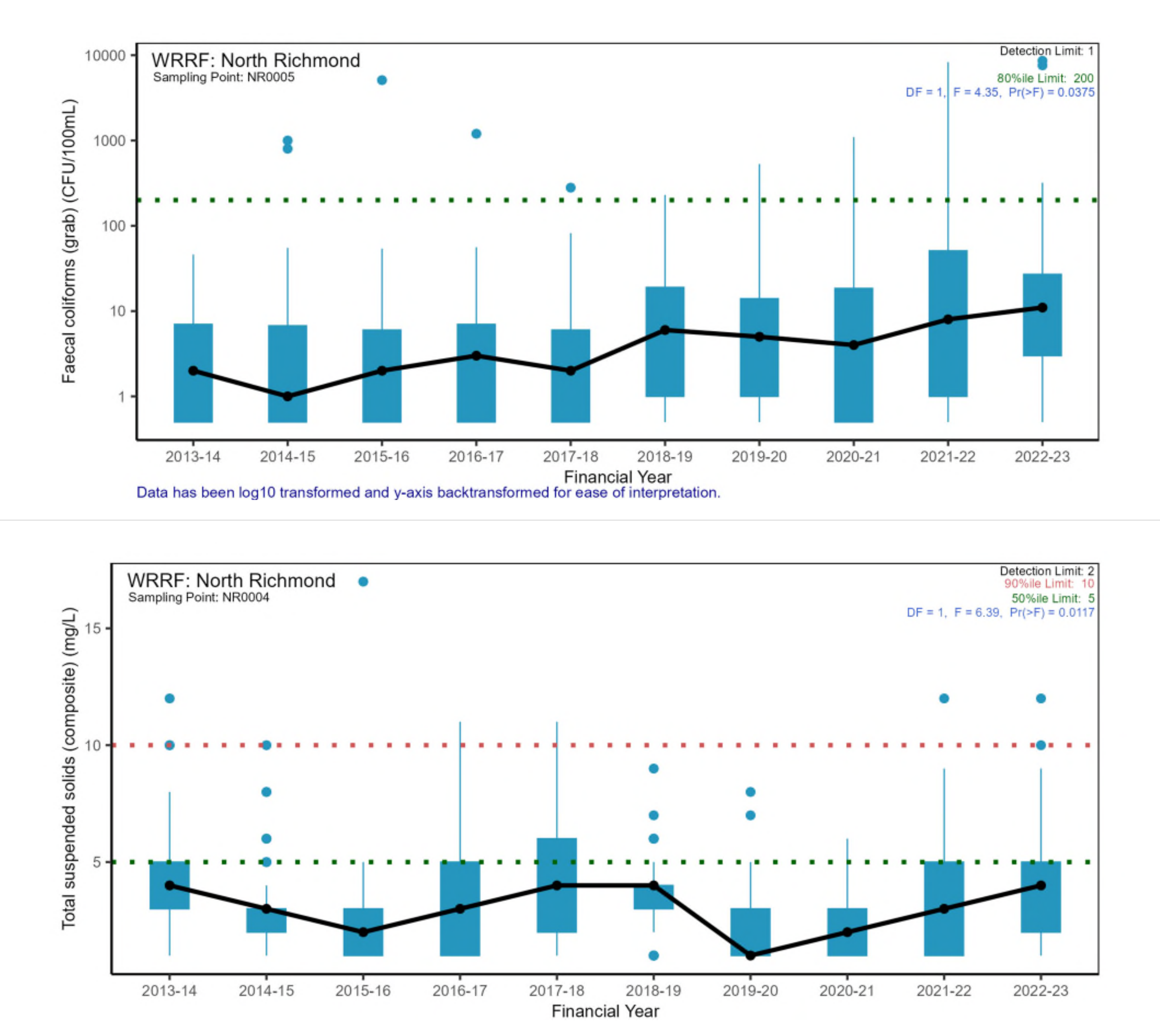


Figure 4-26 North Richmond WRRF discharge quality and toxicity exception plots

Stressor – Water quality

Table 4-21 Gate 1 Analysis outcome summary – water quality upstream and downstream of North Richmond WRRF discharge

Monitoring sites	Nutrient analytes					Physico-chemical analytes					
	Ammonia nitrogen	Oxidised nitrogen	Total nitrogen	Filterable total phosphorus	Total phosphorus	Conductivity	Dissolved oxygen	Dissolved oxygen saturation	pH	Temperature	Turbidity
Upstream tributary (N412)	→	→	→	↘	↘	→	↗	↗	↗	→	→
Downstream tributary (N411)	→	↘	↘	↘	↘	↘	→	→	→	→	→
Upstream River (N42)	→	↗	↗	↗	→	→	↗	→	→	→	→
Downstream River (N39)	→	↗	↗	↗	→	→	→	→	→	→	↗

↗	Upward trend	↘	Downward trend	→	no trend, p>0.05

	2022-23 Median value within the guideline limit		No guideline applicable
	2022-23 Median value outside the guideline limit		Insufficient data

North Richmond WRRF discharges to an unnamed watercourse flowing to Redbank Creek and then Nepean River. The upstream control site of Redbank Creek (N412) is influenced by a semi-rural residential and agricultural catchment, and further upstream catchment is predominantly Blue-Mountains National Park.

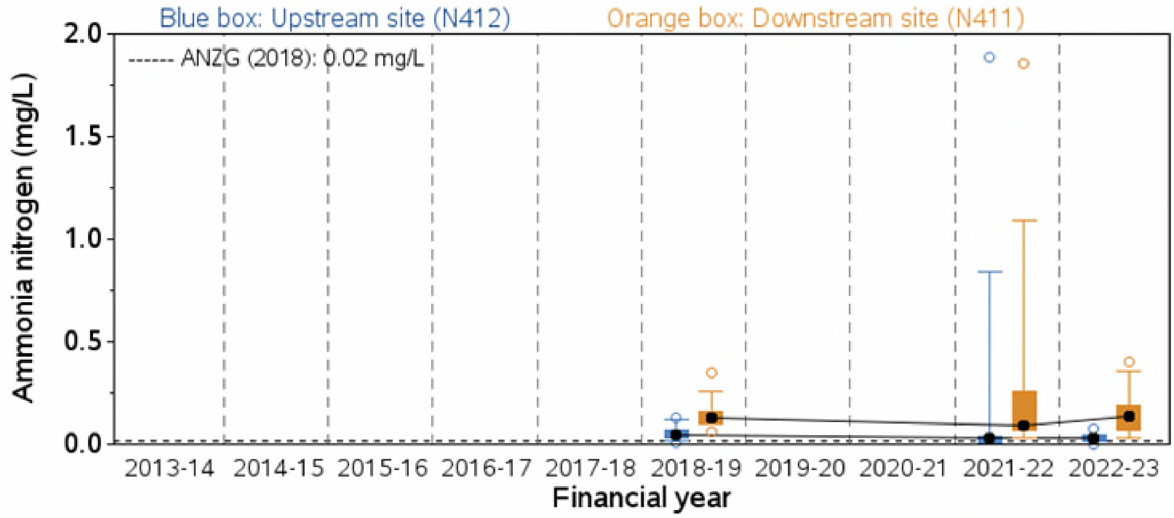
The Hawkesbury River at North Richmond (N42) is the control site for the North Richmond WRRF and located downstream of the confluence with the Grose River. The river widens and deepens from this point.

Filterable total phosphorus and total phosphorus concentrations decreased significantly in 2022-23 at the upstream control site of Redbank Creek (N412). Dissolved oxygen (concentration and saturation) and pH increased significantly at this site in 2022-23 compared to earlier years. At the downstream Redbank Creek site (N411), water quality improved with a significantly decreasing trend in oxidised nitrogen, total nitrogen, filterable total phosphorus, total phosphorus and conductivity in 2022-23. The decreasing trends in nutrient concentrations at this site are in contrast to increasing trends in nutrient concentrations in the North Richmond WRRF discharge.

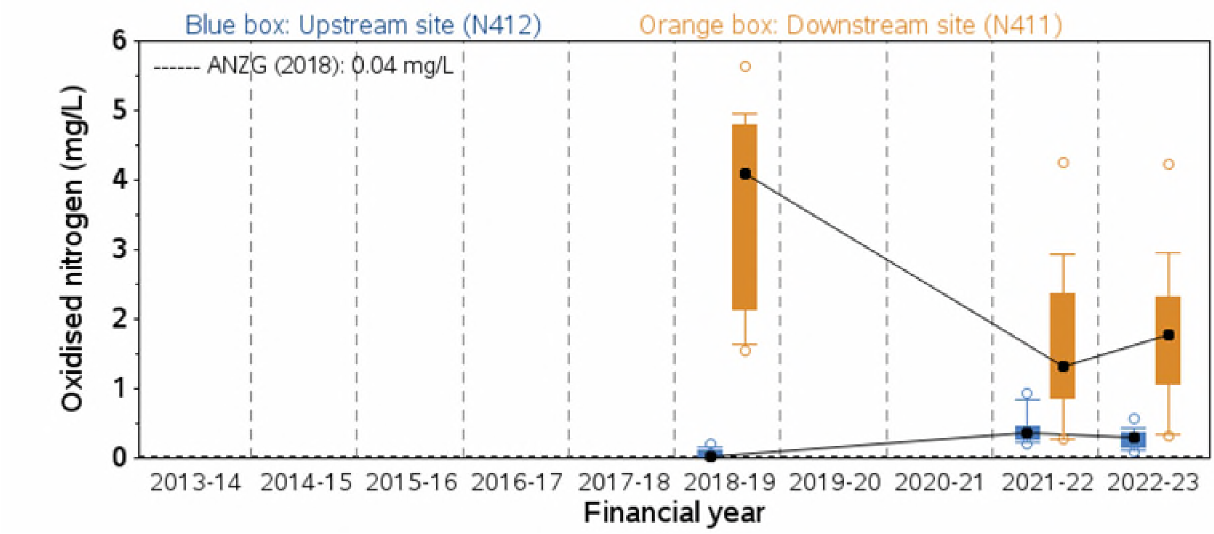
In the Hawkesbury River, oxidised nitrogen, total nitrogen and filterable total phosphorus concentrations increased significantly in 2022-23 at both upstream/downstream sites (N42/N39). Dissolved oxygen saturation significantly increased at the upstream North Richmond site (N42) and turbidity significantly increased at the downstream Freemans Reach site (N39).

Concentrations of key nutrient analytes (ammonia nitrogen, oxidised nitrogen, total nitrogen and filterable total phosphorus) concentrations at the downstream tributary sites were notably higher in comparison to upstream concentrations indicating a possible impact from North Richmond WRRF. Statistical analysis will be included in SWAM reports from 2023-24 to further validate the trend.

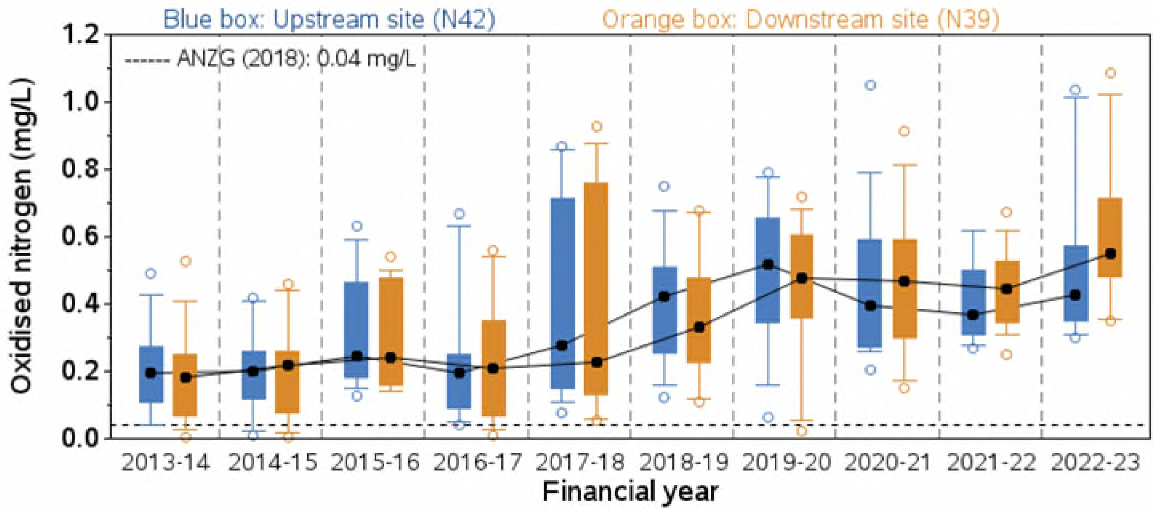
The median oxidised nitrogen and total nitrogen concentrations exceeded the respective ANZG (2018) guidelines in 2022-23 at all four upstream/downstream creek/river sites. The median ammonia nitrogen and turbidity levels/concentrations exceeded the respective guideline at both creek sites, whilst the median total phosphorus concentration also exceeded at downstream creek site (N411).



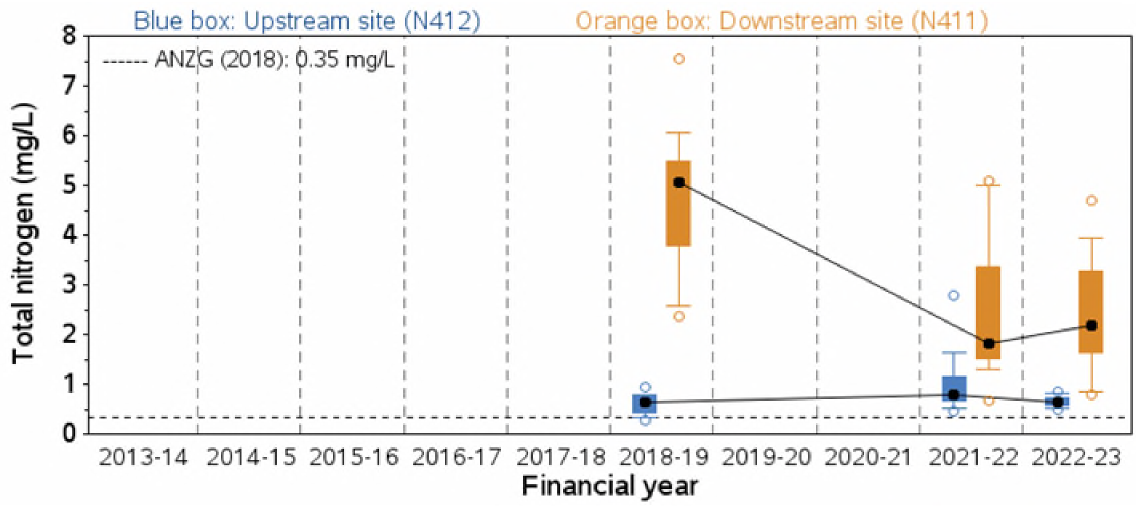
site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N412	1	1.57	0.2168	N411	1	1.08	0.3049



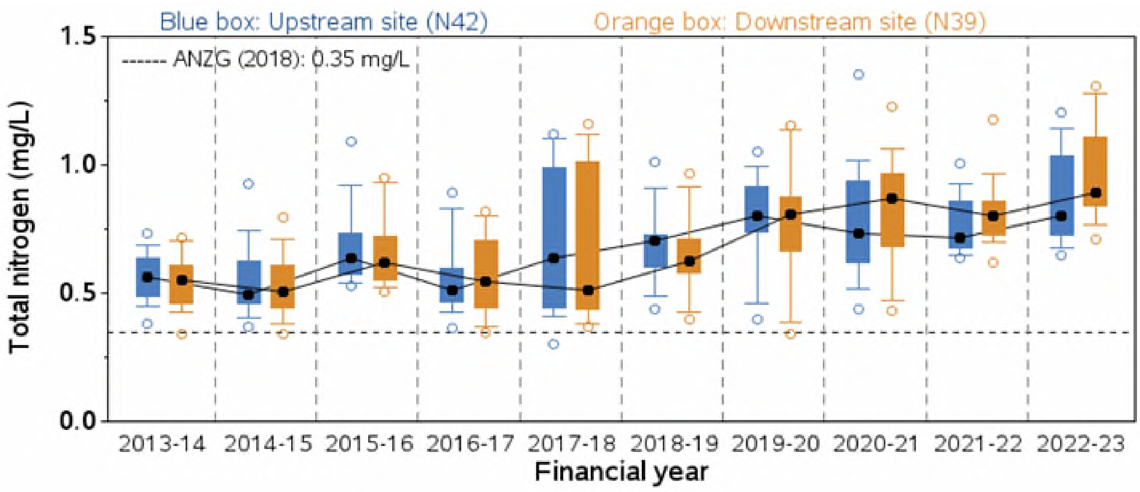
site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N412	1	0.33	0.5672	N411	1	4.05	0.0498



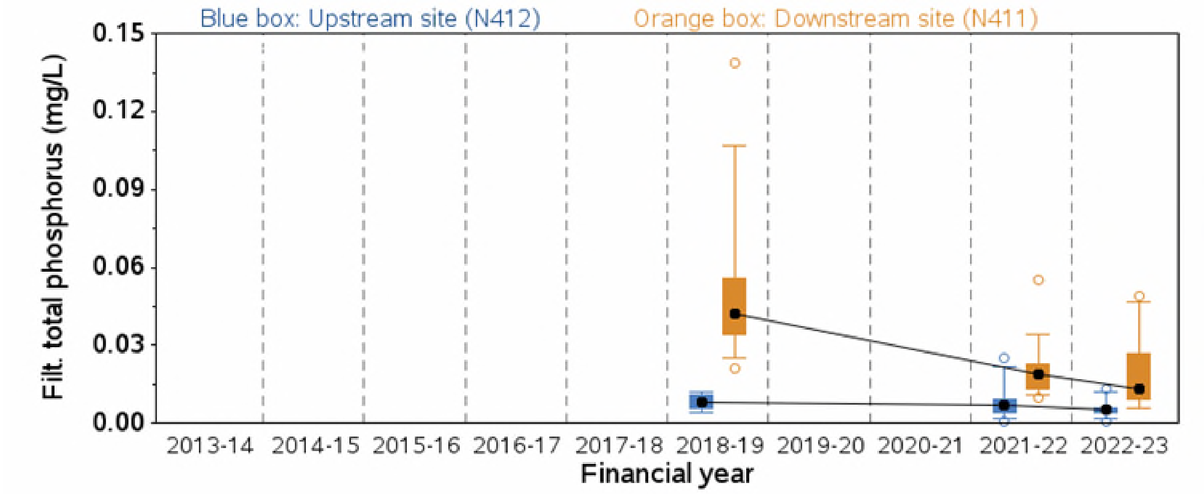
site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N42	1	9.69	0.0022	N39	1	25.21	<.0001



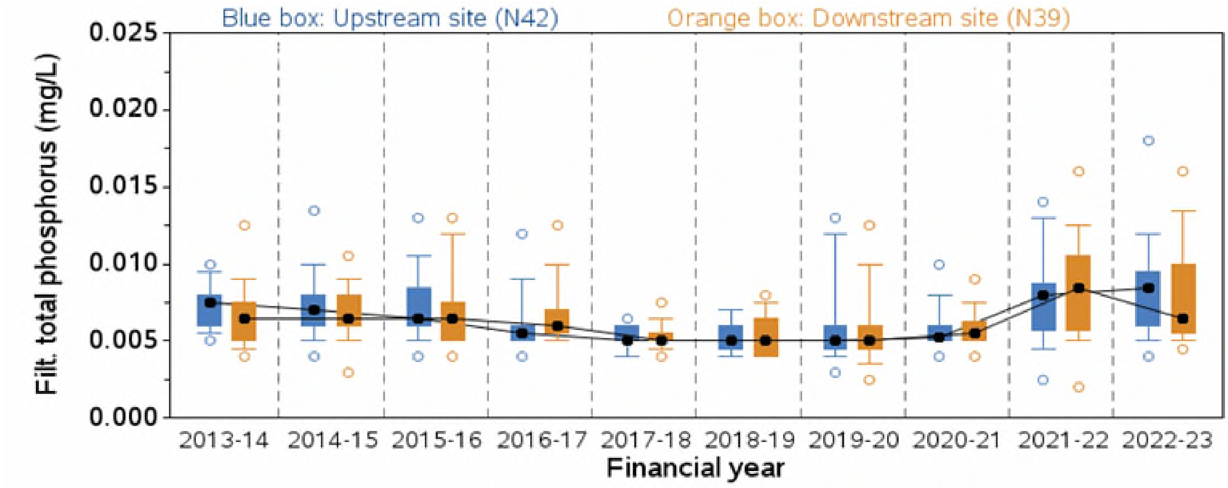
site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N412	1	1.84	0.1815	N411	1	5.56	0.0225



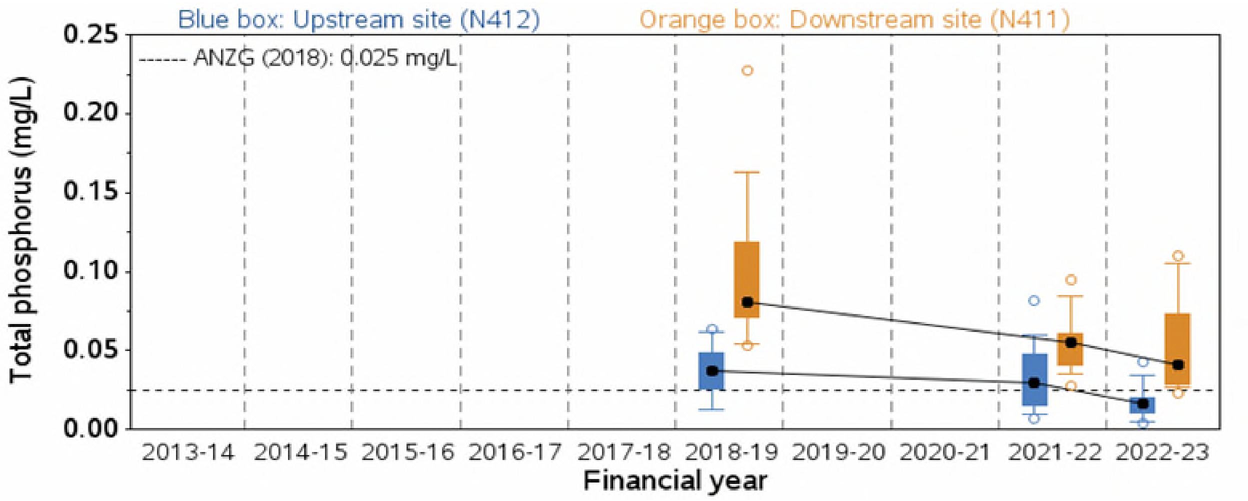
site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N42	1	14.8	0.0002	N39	1	35.2	<.0001



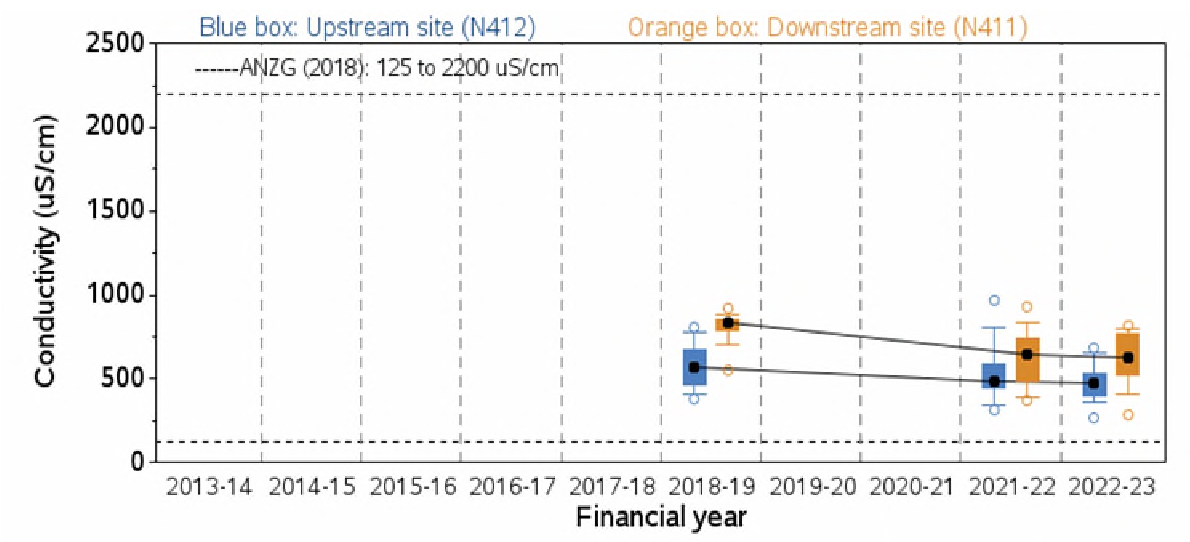
site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N412	1	4.29	0.0437	N411	1	5.27	0.0261



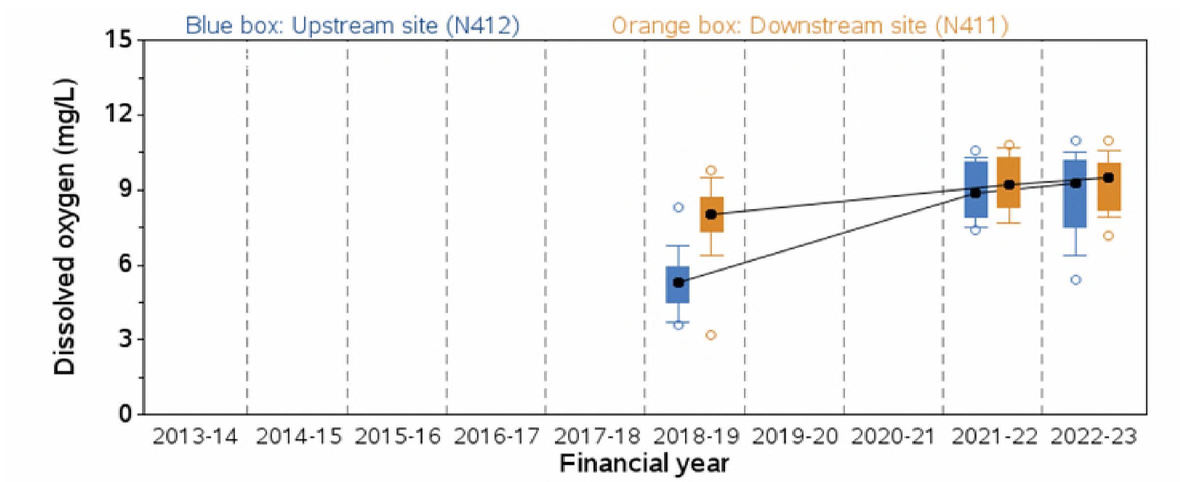
site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N42	1	9.79	0.0021	N39	1	5.76	0.0175



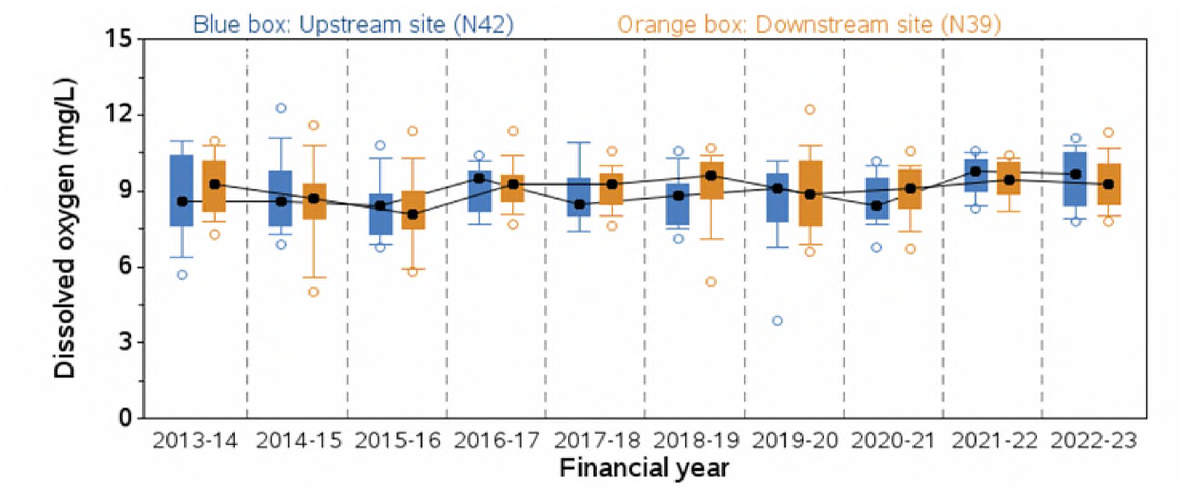
site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N412	1	12.8	0.0008	N411	1	4.84	0.0326



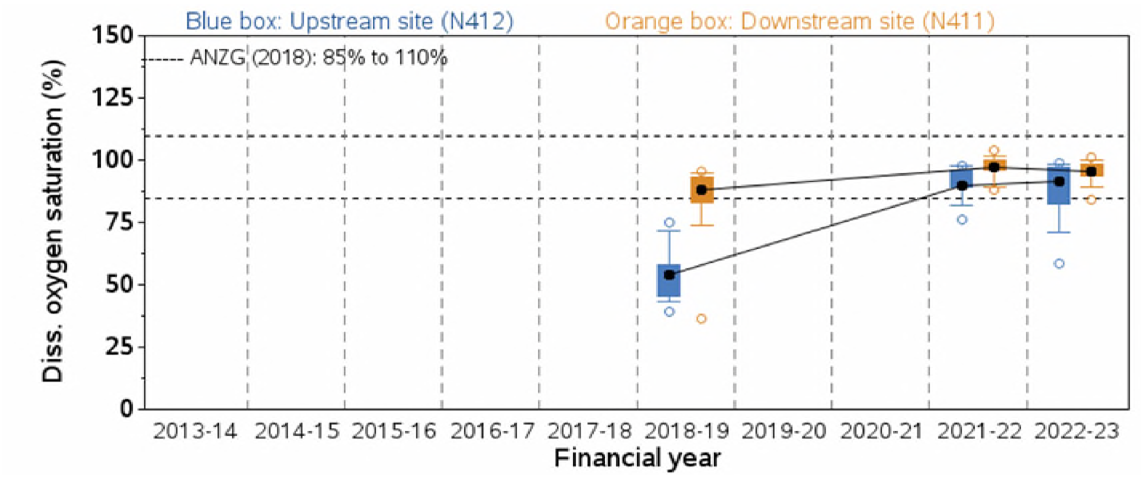
site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N412	1	2.69	0.1078	N411	1	4.12	0.0478



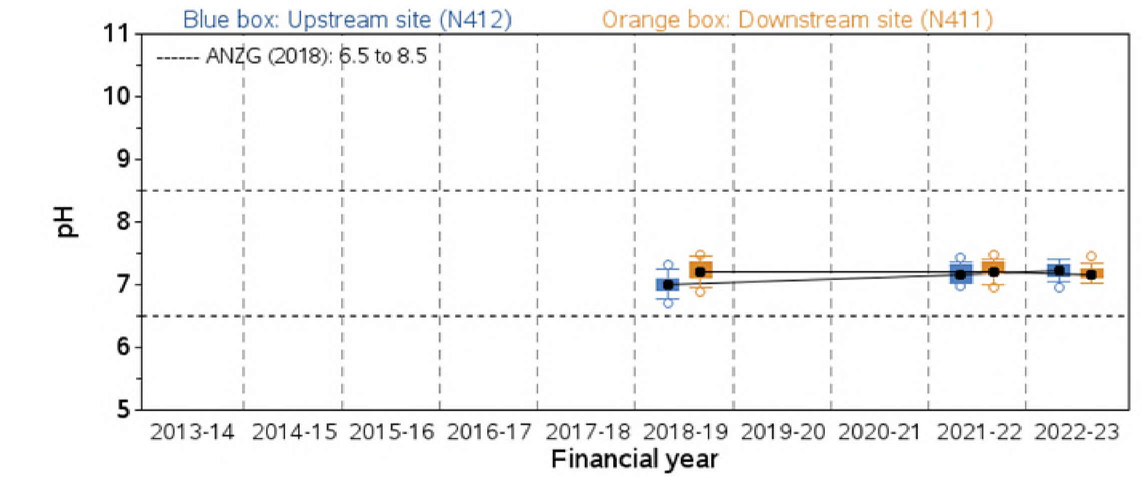
site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N412	1	6.59	0.0135	N411	1	2.44	0.1252



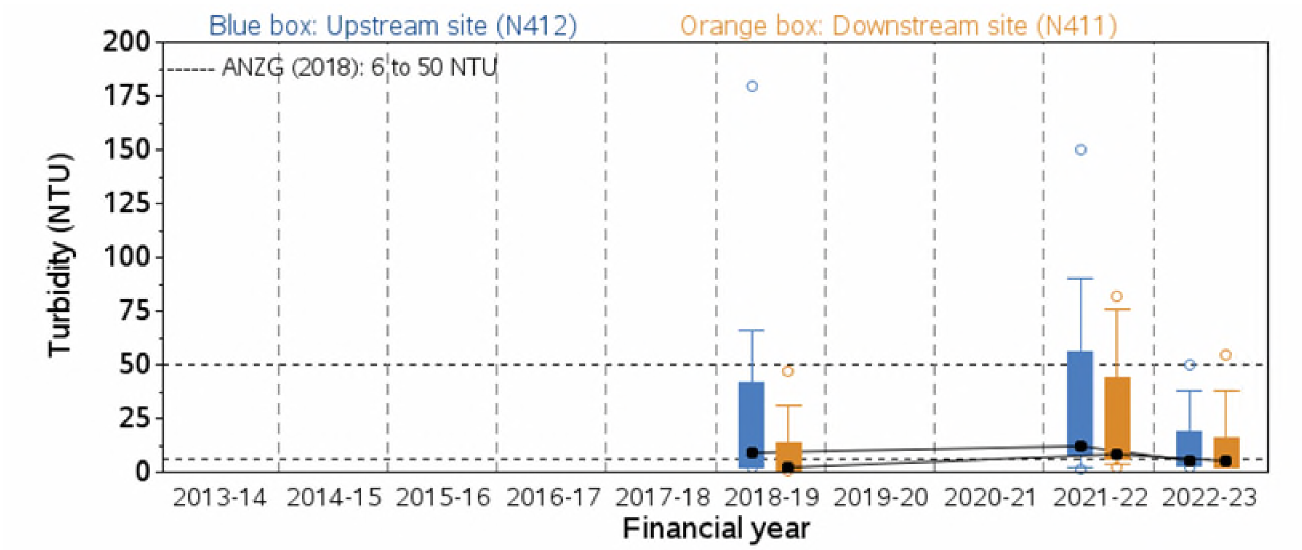
site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N42	1	4.35	0.0385	N39	1	1.27	0.2612



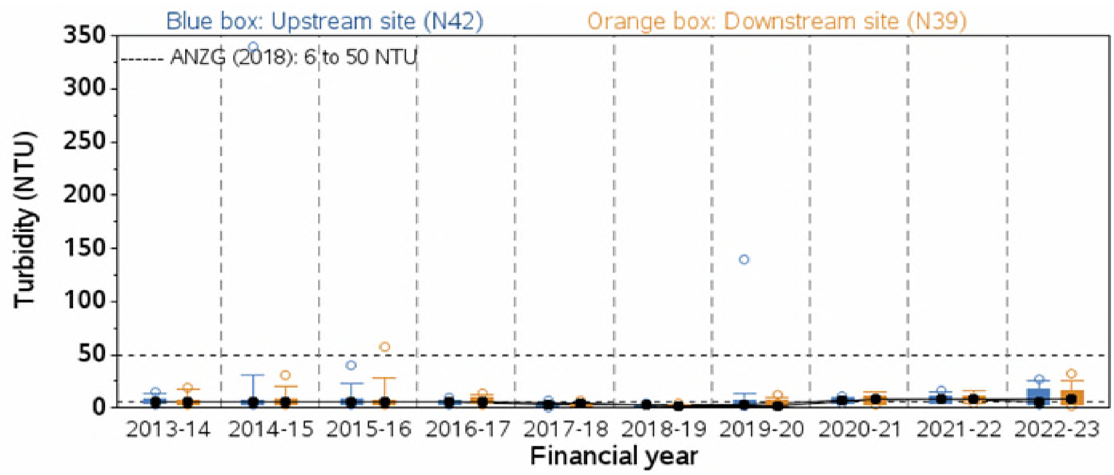
site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N412	1	7.54	0.0085	N411	1	1.61	0.2104



site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N412	1	7.67	0.0081	N411	1	1.09	0.3007



site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N412	1	3.4	0.0714	N411	1	1.12	0.2944



site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N42	1	0.02	0.8962	N39	1	6.52	0.0116

Figure 4-27 Nutrients and physico-chemical water quality exception plots, upstream and downstream of North Richmond WRRF

Ecosystem Receptor – Phytoplankton

Table 4-22 Gate 1 Analysis outcome summary – phytoplankton as chlorophyll-a, biovolume and species counts, upstream and downstream of North Richmond WRRF discharge

Monitoring sites	Phytoplankton analytes			
	Chlorophyll-a	Total phytoplankton biovolume	Blue-green biovolume	Toxic blue-green count
Upstream tributary (N412)	→	→	→	
Downstream tributary (N411)	→			
Upstream River (N42)	↘	→	↗	→
Downstream River (N39)	→	→	→	→

↗	Upward trend	↘	Downward trend	→	no trend, p>0.05

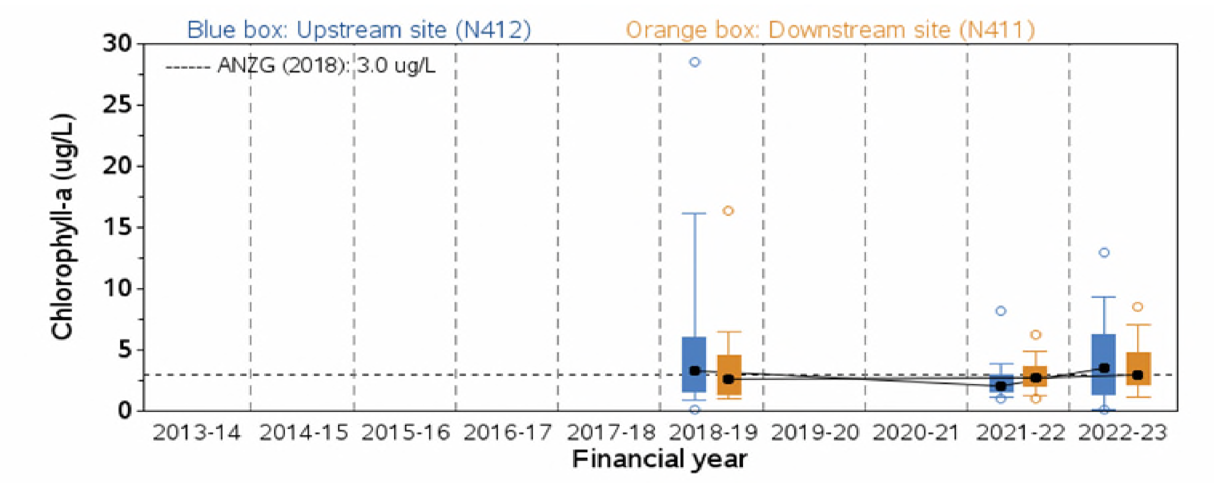
	2022-23 Median value within the guideline limit		No guideline applicable
	2022-23 Median value outside the guideline limit		Insufficient data

Chlorophyll-a was significantly lower at upstream control site of the Hawkesbury River (N42) in 2022-23 compared to earlier years, while blue-green biovolume increased significantly at this site.

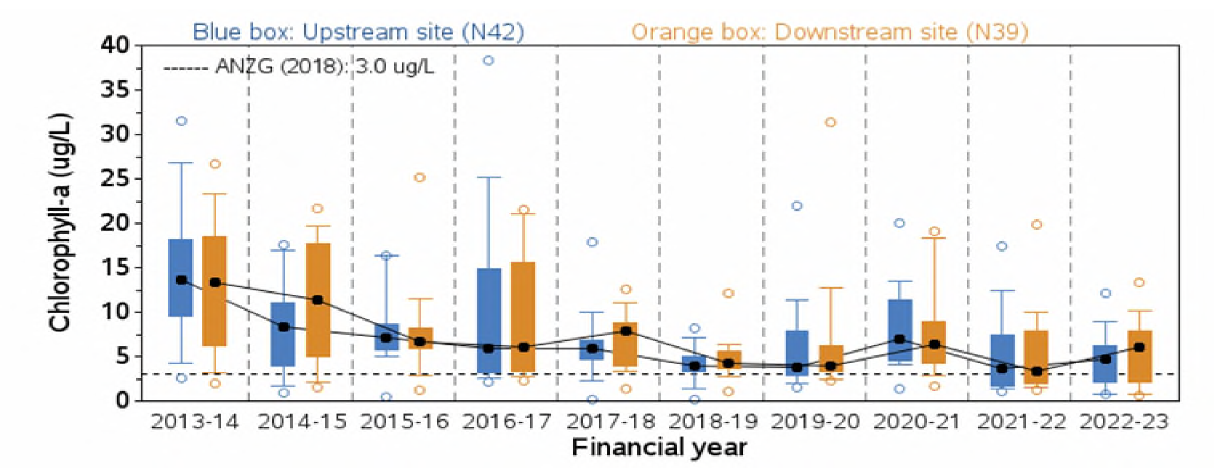
In the 2022-23 period, the median chlorophyll-a concentrations exceeded the ANZG (2018) guidelines at all four upstream/downstream creek/river sites. Blue-green biovolume and toxic blue-green species counts were low and the median levels within the NHMRC (2008) Amber Alert level at all sites.

Phytoplankton count data was very limited for the Redbank Creek sites, with only two and three samples for the upstream and downstream sites respectively qualifying for a species count. No toxic blue-green species was found in any of the samples.

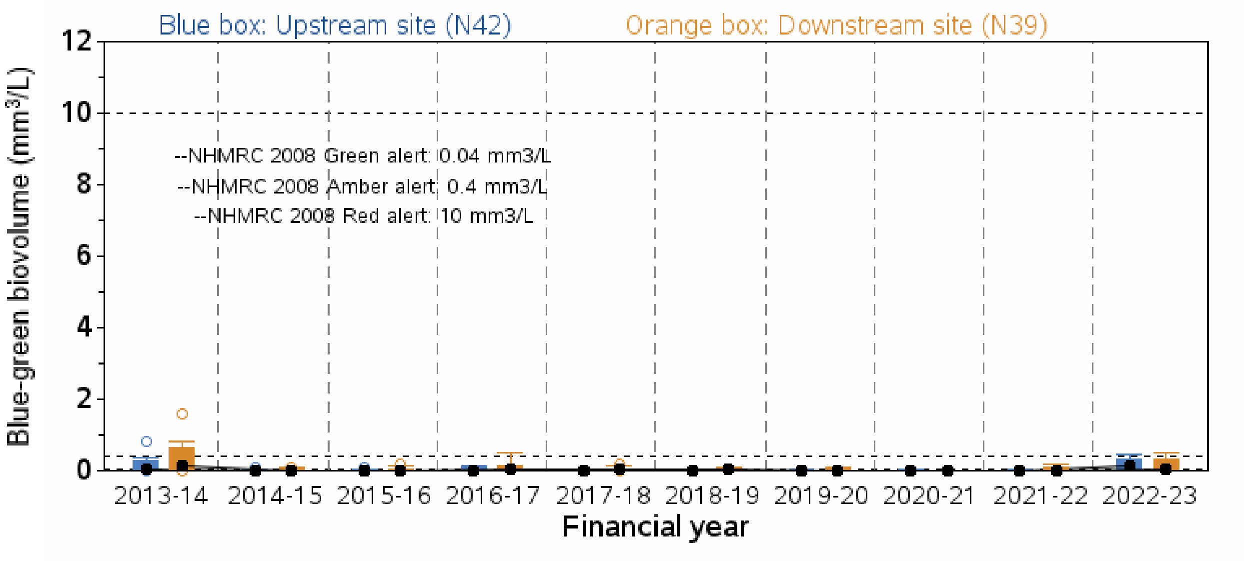
For the river sites, phytoplankton data was also limited with four and six of the 17 samples qualifying for analysis in 2022-23 for the upstream and downstream sites respectively. Potentially toxic blue-green taxa was found in low numbers in both upstream (N42, *Microcystis* 332 cells/mL, 17 February 2023) and downstream site (N39, *Dolichospermum* 330 cells/mL, 10 March 2023).



site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N412	1	0	0.9967	N411	1	0.27	0.6062



site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N42	1	3.98	0.0477	N39	1	2.62	0.1075



site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N42	1	4.53	0.0368	N39	1	0.18	0.6704

Figure 4-28 Phytoplankton as chlorophyll-a, biovolume and species counts exception plots, upstream and downstream of North Richmond WRRF

Ecosystem Receptor – Macroinvertebrates

No macroinvertebrate stream health impacts were identified for the waterways downstream of where North Richmond WRRF discharges, including the Hawkesbury River (Volume 2 Appendix A- 6).

4.1.7 Richmond WRRF

- All parameters (concentrations and loads) monitored in the discharge from Richmond WRRF were within the EPL limits. No significant trends were identified in the discharge.
- Filterable total phosphorus and total phosphorus concentrations improved/decreased significantly in 2022-23 at both the upstream and downstream sites on Rickabys Creek.
- Trends in phytoplankton as chlorophyll-a, blue-green biovolume or toxic blue-green species counts were steady at both upstream/downstream sites. However, at the downstream site the blue-green biovolume reached the Red Alert level once but potentially toxic blue-green numbers were low (*Microcystis* 270 cells/mL).

Pressure – Wastewater discharges

Table 4-23 Gate 1 Analysis outcome summary – Richmond WRRF

Analytes / Richmond WRRF	Nutrients			Conventional analytes					
	Ammonia Nitrogen	Total Nitrogen	Total Phosphorus	Biochemical Oxygen Demand	Total Residual Chlorine	Faecal Coliforms	Oil and Grease	Total Suspended Solids	EC_{50} Toxicity
Concentration EPA ID 16 (discharge)	→	→	→	→	→	→		→	→
Load EPA ID 16 (discharge)									
Concentration EPA ID 17 (reuse)	→	→	→	→	↗	→		→	

↗	Upward trend	↘	Downward trend	→	no trend, p>0.05

(green)	Within the Environment Protection Licence limit
(yellow)	Environment Protection Licence limit exceedance
(grey)	Analytes not required in the EPL or no concentration limit

All concentration and load limits in the discharge (EPA ID 16) and reuse (EPA ID 17) from Richmond WRRF were within the EPL limits during the 2022-23 period. Statistical analysis did not identify any significant trends in the discharge. An increasing trend in total residual chlorine was observed at the reuse monitoring point (EPA ID 17). The increase in total residual chlorine can be linked to chloramines during high flows, resulting in increased dosing to ensure recycled water supply to customers.

Like the previous two reporting periods, there was reduced offsite reuse during the 2022-23 reporting period compared to earlier years due to the continuation of wet weather patterns that reduced the demand from the community for irrigation water. Subsequently, elevated volumes of treated effluent were discharged to the receiving waterway (unnamed creek that flows into Rickabys Creek).

Sydney Water is planning to upgrade the Richmond WRRF treatment capacity and decommission North Richmond WRRF, with flows from the North Richmond catchment to be transferred to Richmond WRRF for treatment.

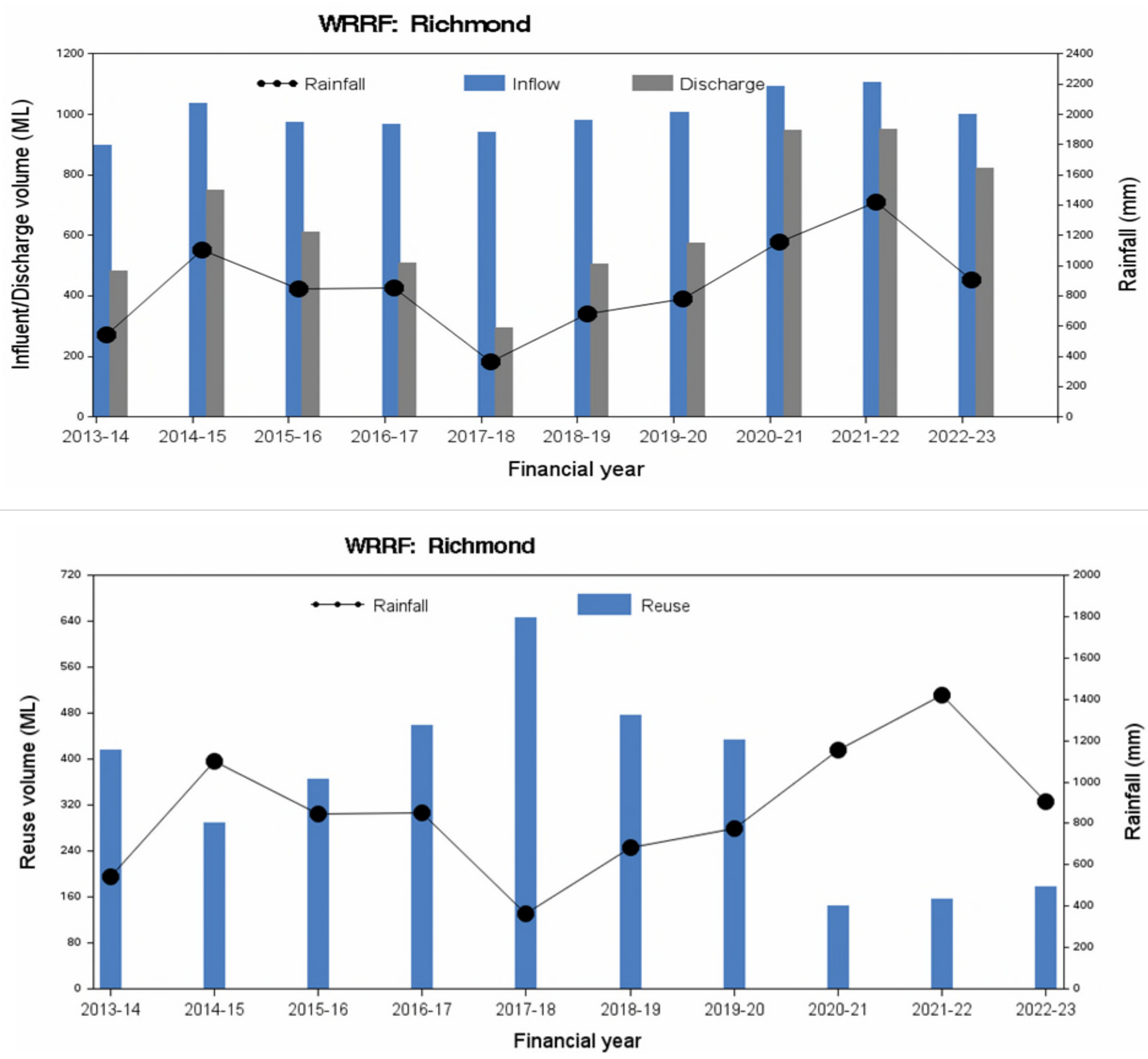


Figure 4-29 Richmond WRRF inflow, discharge and reuse volume with catchment rainfall plots

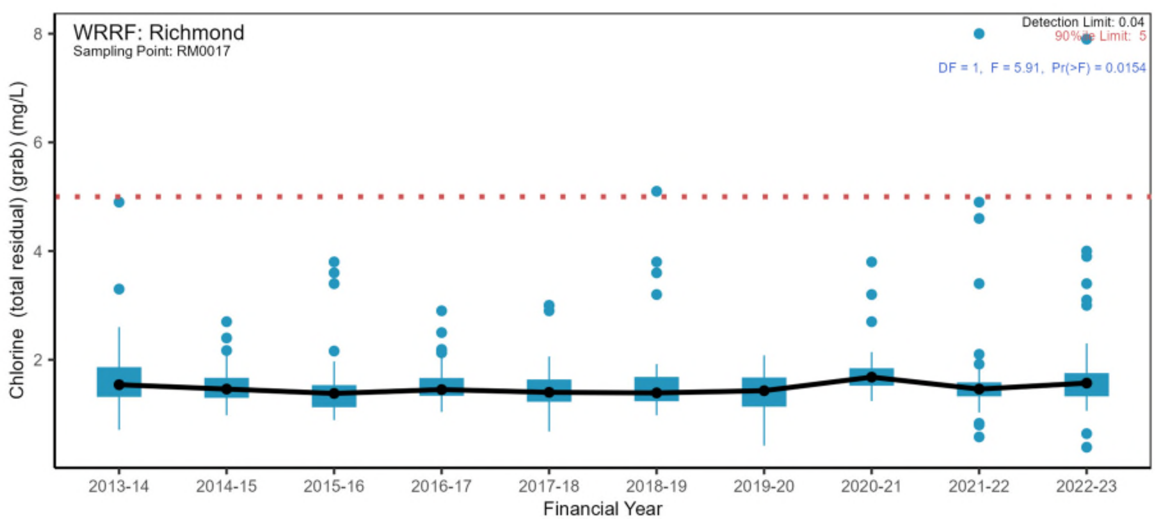


Figure 4-30 Richmond WRRF discharge quality and toxicity exception plot

Stressor – Water quality

Table 4-24 Gate 1 Analysis outcome summary – water quality upstream and downstream of Richmond WRRF discharge

Monitoring sites	Nutrient analytes					Physico-chemical analytes					
	Ammonia nitrogen	Oxidised nitrogen	Total nitrogen	Filterable total phosphorus	Total phosphorus	Conductivity	Dissolved oxygen	Dissolved oxygen saturation	pH	Temperature	Turbidity
Upstream tributary (N389)	→	→	→	↘	↘	→	→	→	→	→	→
Downstream tributary (N388)	→	→	→	↘	↘	↗	→	→	→	→	→

↗	Upward trend	↘	Downward trend	→	no trend, p>0.05

	2022-23 Median value within the guideline limit		No guideline applicable
	2022-23 Median value outside the guideline limit		Insufficient data

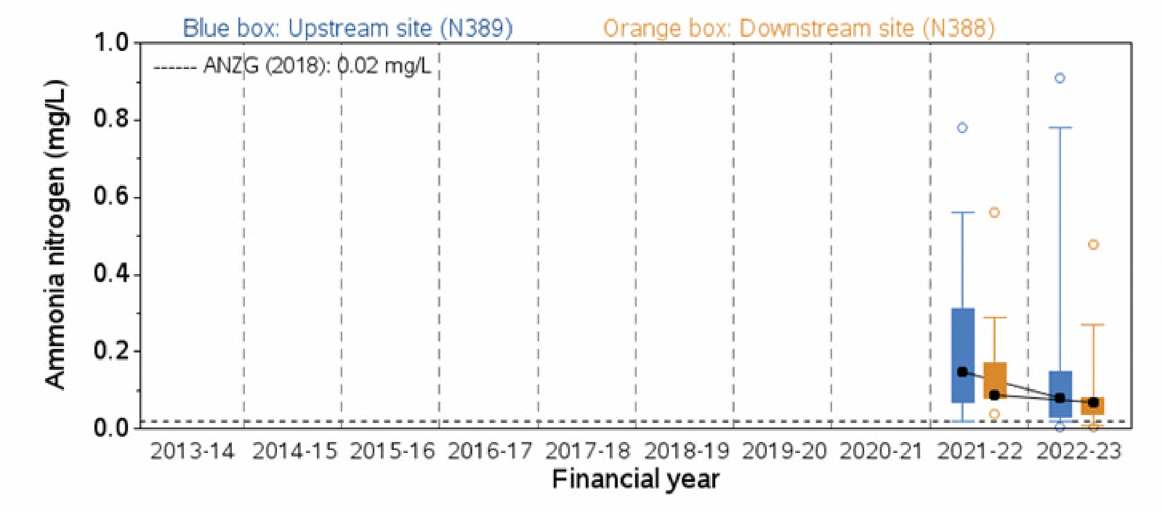
The Richmond WRRF discharges a small volume of treated effluent in an unnamed tributary that flows into Rickabys creek (823 ML in 2022-23). The upstream catchment of Rickabys Creek is predominantly agricultural and semi-rural housing.

The water quality data set for the upstream/downstream Rickabys Creek sites were collected only for a limited period (2021-23).

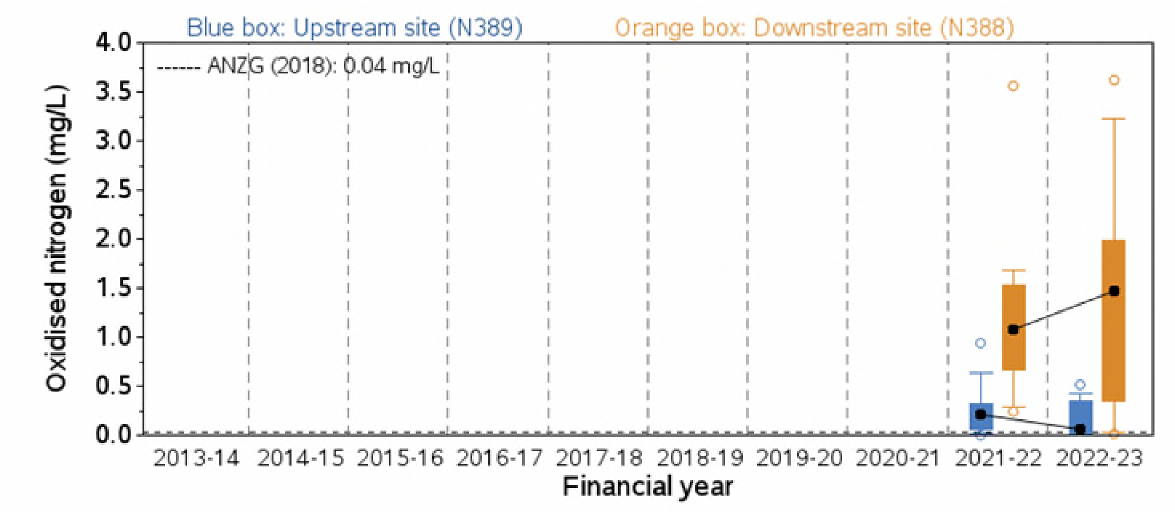
There was a significant decrease in filterable total phosphorus and total phosphorus in 2022-23 compared to 2021-22 results at both upstream/downstream sites. Conductivity significantly increased at the downstream site (N388) in 2022-23.

Concentrations of key nutrient analytes (except ammonia nitrogen) at the downstream site were notably higher in comparison to upstream concentrations indicating a possible impact from Richmond WRRF. Statistical analysis will be included in SWAM reports from 2023-24 to further validate the trend.

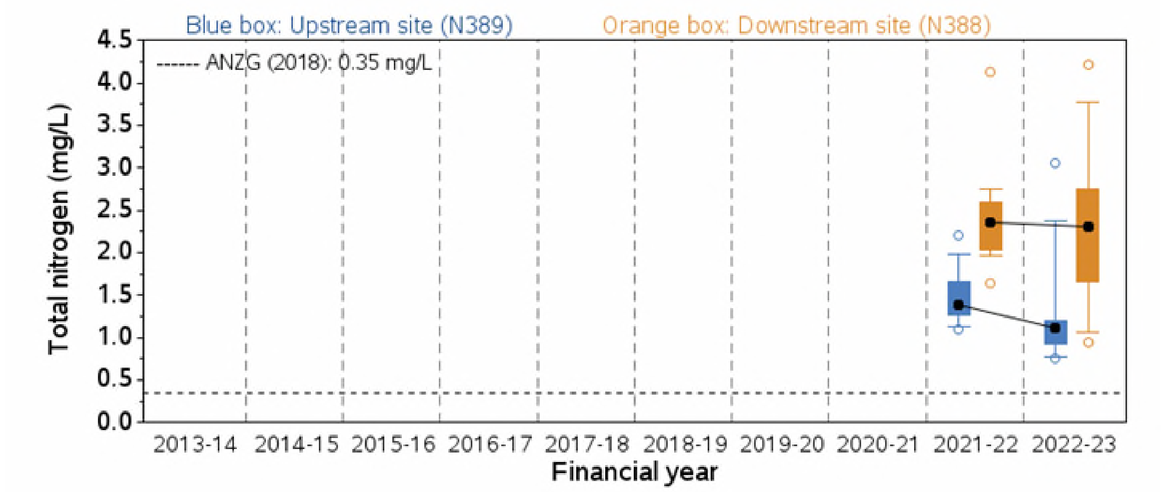
In the 2022-23 period, the median concentrations of ammonia nitrogen, oxidised nitrogen, total nitrogen and total phosphorus exceeded the respective ANZG (2018) guidelines at both upstream and downstream sites. Dissolved oxygen saturation was low at the upstream site (N389) and the median level was lower than the ANZG (2018) guideline value.



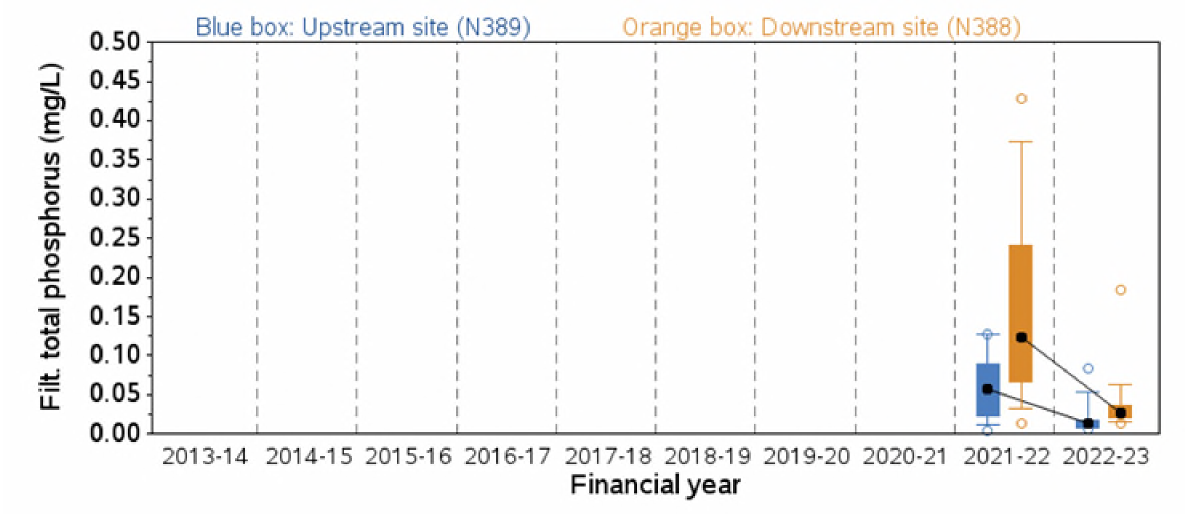
site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N389	1	0.21	0.6488	N388	1	1.15	0.2936



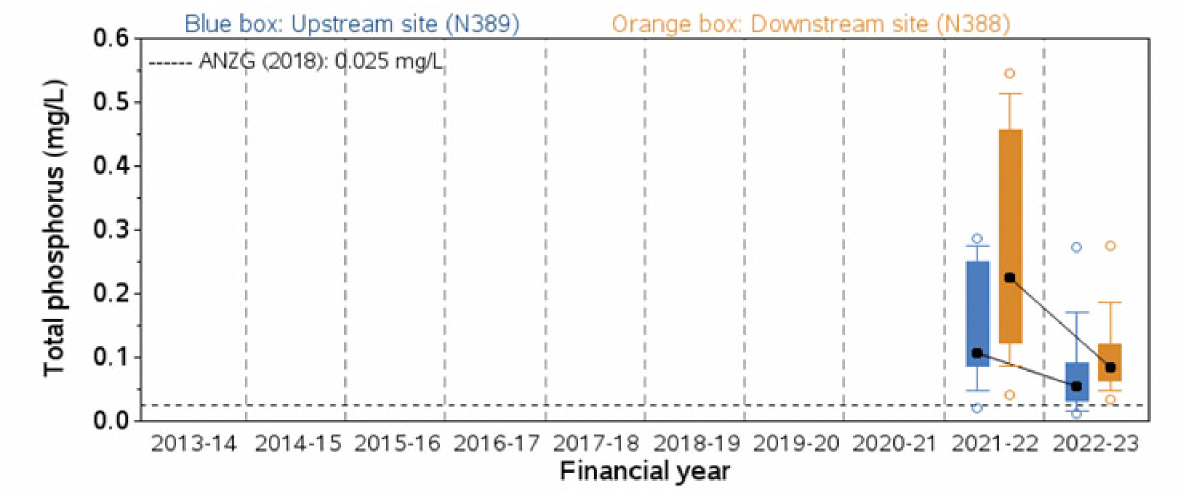
site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N389	1	1.02	0.3217	N388	1	0.07	0.7976



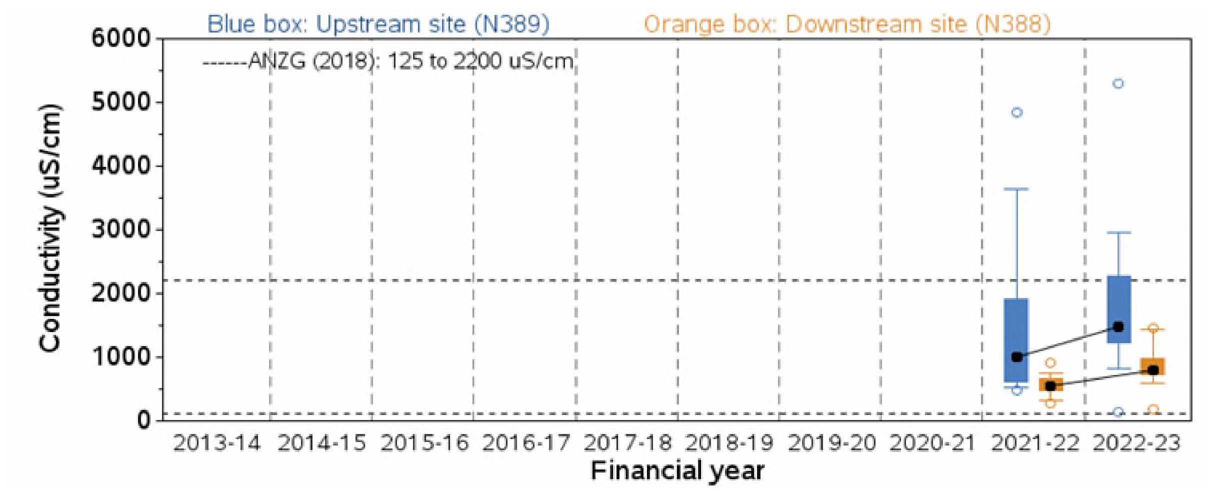
site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N389	1	1.44	0.2416	N388	1	0.17	0.6833



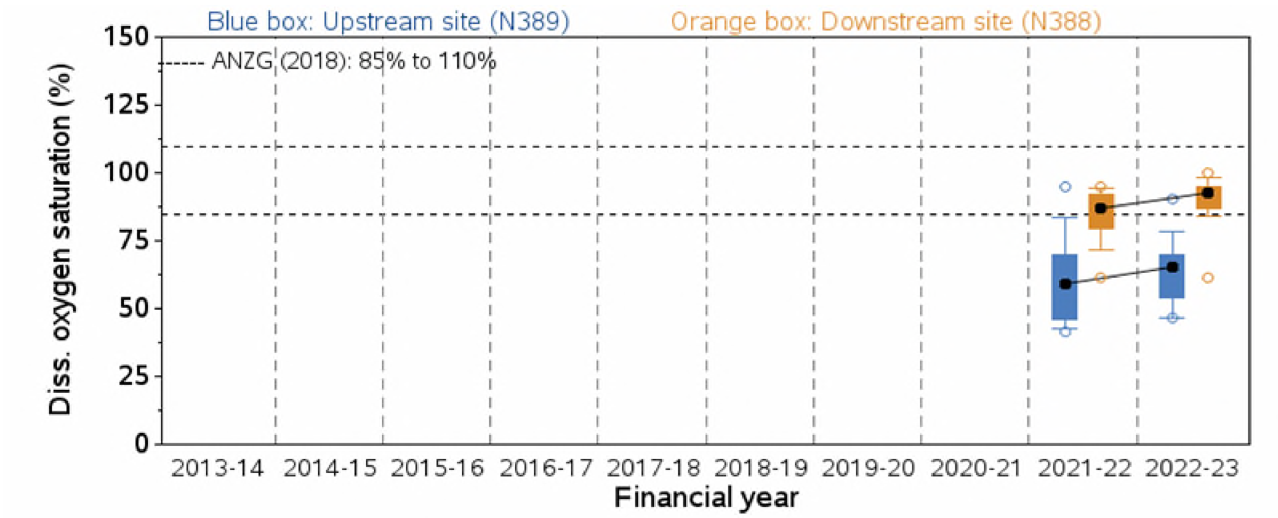
site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N389	1	11.23	0.0026	N388	1	11.67	0.0021



site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N389	1	5.77	0.0241	N388	1	13.07	0.0013



site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N389	1	0.5	0.4877	N388	1	9.18	0.0055



site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N389	1	0.35	0.5601	N388	1	2.95	0.0979

Figure 4-31 Nutrients and physico-chemical water quality exception plots, upstream and downstream of Richmond WRRF

Ecosystem Receptor – Phytoplankton

Table 4-25 Gate 1 Analysis outcome summary – phytoplankton as chlorophyll-a, biovolume and species counts, upstream and downstream of Richmond WRRF discharge

Monitoring sites	Phytoplankton analytes			
	Chlorophyll-a	Total phytoplankton biovolume	Blue-green biovolume	Toxic blue-green count
Upstream tributary (N389)	→	→	→	→
Downstream tributary (N388)	→	→	→	→

↗	Upward trend	↘	Downward trend	→	no trend, p>0.05

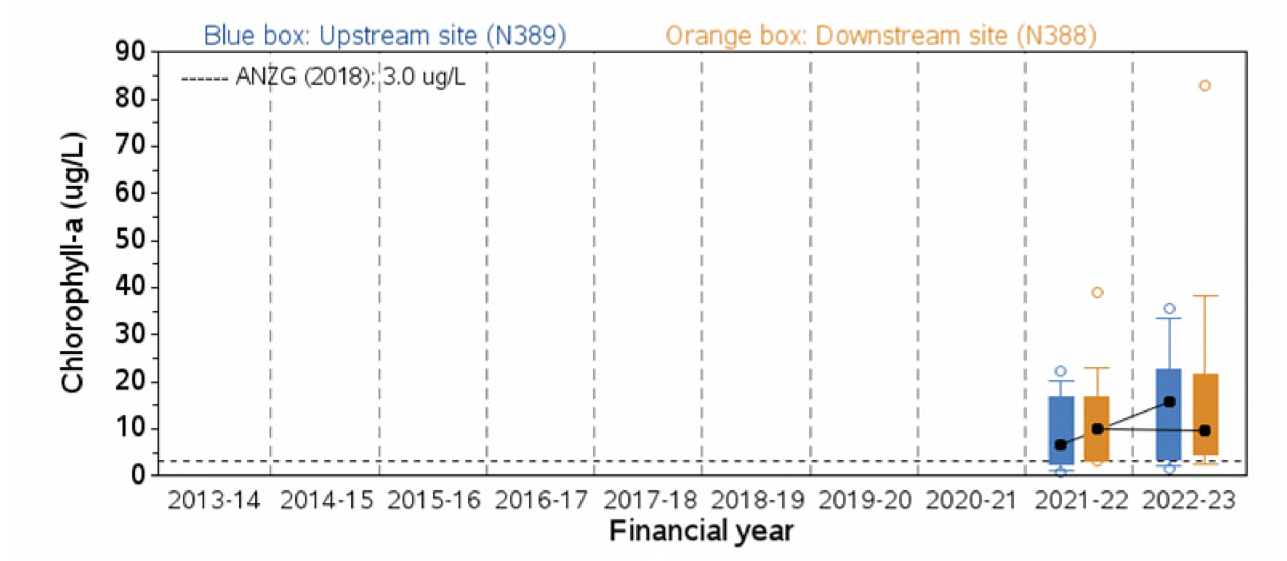
	2022-23 Median value within the guideline limit		No guideline applicable
	2022-23 Median value outside the guideline limit		Insufficient data

In 2022-23, there was no significantly increasing/decreasing trend identified in any of the phytoplankton analytes at the upstream or downstream Rickabys Creek sites.

In the 2022-23 period, the median chlorophyll-a concentrations exceeded the respective ANZG (2018) guidelines at both sites. Blue-green biovolume or toxic blue-green species counts were low and the median levels within the NHMRC (2008) Amber Alert level at both sites. However, the blue-green biovolume reached Red Alert level once at the downstream river site in 2022-23 period.

Chlorophyll-a concentrations were generally elevated in 2022-23 and majority of the phytoplankton samples qualified for species counts from both monitoring sites. Chlorophyll-a reached a peak of 35.7 µg/L at upstream site (N389) on 4 November 2022 when no toxic blue-green species was detected. However, on 17 April 2023, toxic species *Phormidium* was found at this site in low numbers (728 cells/mL).

At the downstream site (N388), the 2022-23 chlorophyll-a maxima was 35.4 µg/L on 27 January 2023, when the blue-green biovolume reached Red Alert level, but potentially toxic blue-green taxa *Microcystis* was found in low numbers (270 cells/mL).



site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
N389	1	2.34	0.1383	N388	1	0.37	0.5472

Figure 4-32 Phytoplankton as chlorophyll-a, biovolume and species counts exception plots, upstream and downstream of Richmond WRRF

Ecosystem Receptor – Macroinvertebrates

Monitoring macroinvertebrates upstream and downstream of Richmond WRRF began in 2021-22 as part of the Richmond upgrade baseline monitoring. Initial outcomes of SIGNAL-SG scores and t-tests can be performed from 2023-24 onwards, and multivariate analysis will commence once >4 years of continuous data is generated.

4.1.8 St Marys WRRF

- The 90th percentile and average concentration limits for copper were exceeded in the discharge from St Marys WRRF during 2022-23. The South Creek bubble load limit for total phosphorus (combined St Marys, Quakers Hill and Riverstone WRRF discharge load) was also exceeded. All other parameters (concentrations and loads) were within EPL limits. There were increasing trends in copper, iron, nickel and zinc concentrations in the discharge.
- Nutrient concentrations were steady at both upstream and downstream South Creek sites during 2022-23.
- No significant trend was identified in chlorophyll-a concentrations at the upstream or downstream site. However, the blue-green biovolume increased significantly in 2022-23 at the upstream site but did not reach the NHMRC (2008) Amber Alert level during 2022-23.
- No stream health impacts (as indicated by macroinvertebrates) were identified for the waterways downstream of where St Marys WRRF discharges

Pressure – Wastewater discharge

Table 4-26 Gate 1 Analysis outcome summary – St Marys WRRF

Analytes / St Marys WRRF	Nutrients			Conventional analytes					
	Ammonia Nitrogen	Total Nitrogen	Total Phosphorus	Biochemical Oxygen Demand	Total Residual Chlorine	Faecal Coliforms	Oil and Grease	Total Suspended Solids	EC_{50} Toxicity
Concentration	→	→	→	→	→	→		→	→
Load									

Analytes / St Marys WRRF	Trace Metals										Other chemicals / organics		
	Aluminium	Cadmium	Chromium	Copper	Iron	Lead	Mercury	Nickel	Selenium	Zinc	Diazinon	Hydrogen sulfide (un-ionised)	Pesticides and PCBs
Concentration	→			↗	↗			↗		↗	→	→	
Load													

↗	Upward trend	↘	Downward trend	→	no trend, p>0.05

	Within the Environment Protection Licence limit
	Environment Protection Licence limit exceedance
	Analytes not required in the EPL or no concentration limit

The 90th percentile and average concentration limits for copper in the discharge from St Marys WRRF were exceeded during the 2022-23 reporting period. All other concentration values in the St Marys WRRF discharge were within the EPL limits. The South Creek bubble load limit (combined St Marys, Quakers Hill and Riverstone WRRF discharge load) for total phosphorus was also exceeded during the 2022-23 reporting period. All other load values in the St Marys WRRF discharge were within the EPL limits.

Statistical analysis identified significantly increasing trends in the concentrations of copper, iron, nickel and zinc during 2022-23 compared to the previous nine years.

The St Marys WRRF has been going through an amplification and upgrade that has been progressively commissioned over the past two years. This has resulted in improvements in several key pollutant effluent parameters including ammonia and total nitrogen. More recently, significant technology changes in biosolids treatment has included the commissioning of a Thermal Hydrolysis Process (THP) yielding significant benefits in terms of greater biosolids optimisation, reduced infrastructure footprint, potential to act on more chemical contaminants and ability to generate renewable energy.

Due to the significant changes in the biosolids process, the movement and incidental capture of metals across St Marys WRRF has changed resulting in a transfer of mass from the biosolids stream to the liquid effluent stream. This has resulted in St Marys WRRF exceeding the 90th percentile and average concentration limits for copper and can also be linked to the increasing trends in iron, nickel and zinc concentrations within the final effluent.

Following the significant technology changes in biosolids treatment at St Marys WRRF, it has become evident that current limits are unable to be achieved. Sydney Water are working with the EPA to review these limits in response to technological process changes.

The cause of the South Creek Bubble total phosphorus load limit exceedance was largely due to the extreme wet weather events experienced within the catchment area between 2 – 11 July and 28 September – 10 October 2022 with all three facilities within the South Creek Bubble operating under wet weather conditions.

St Marys WRRF contributed 32.5% of the total phosphorus load from 30.7% of the total flow from the three South Creek facilities.

Sydney Water is engaging with the EPA on wet weather load calculations under extreme weather events due to a skewing effect of calculated loads in extreme wet weather. Further collaboration between Sydney Water and EPA is required to progress this.

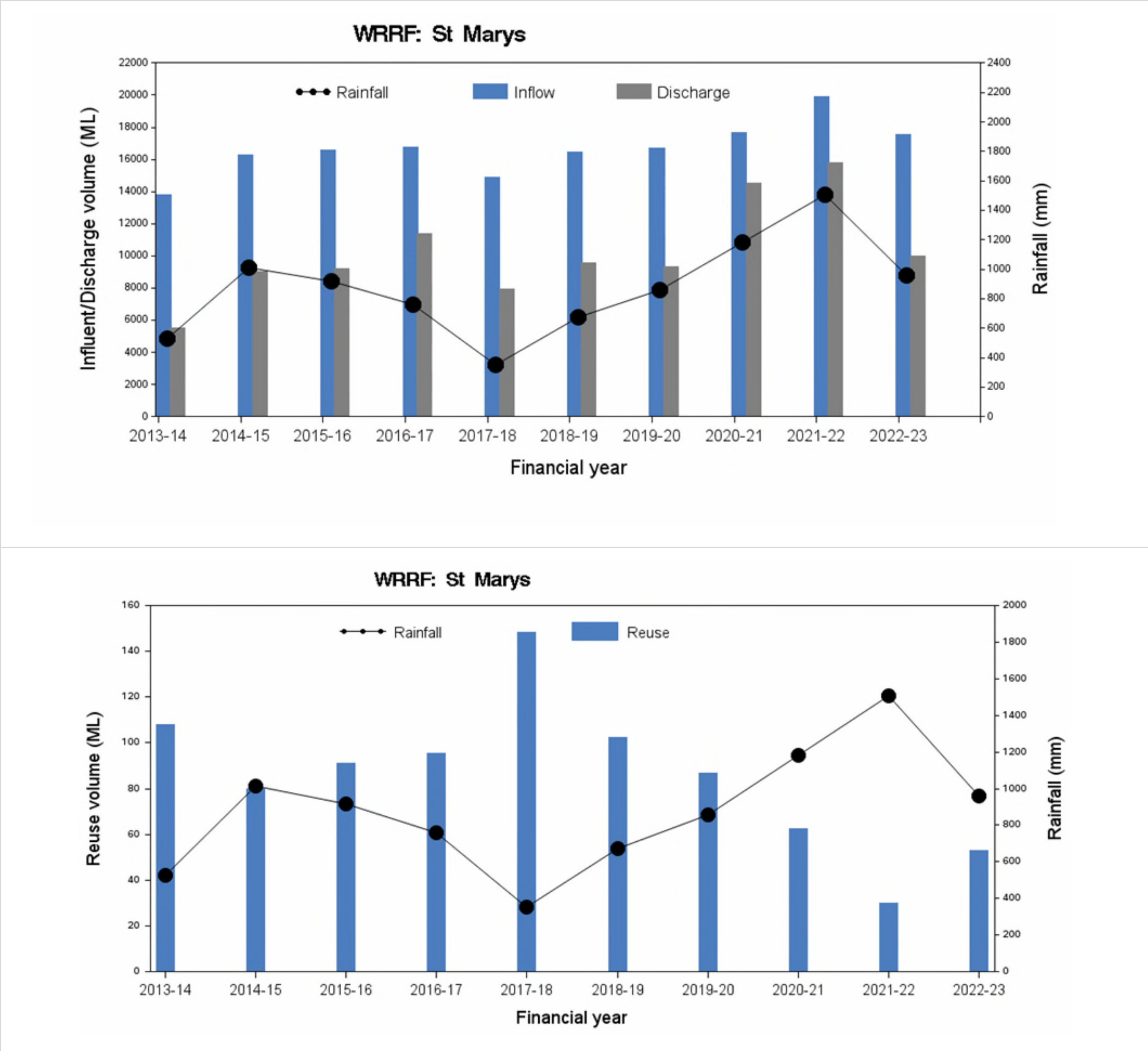
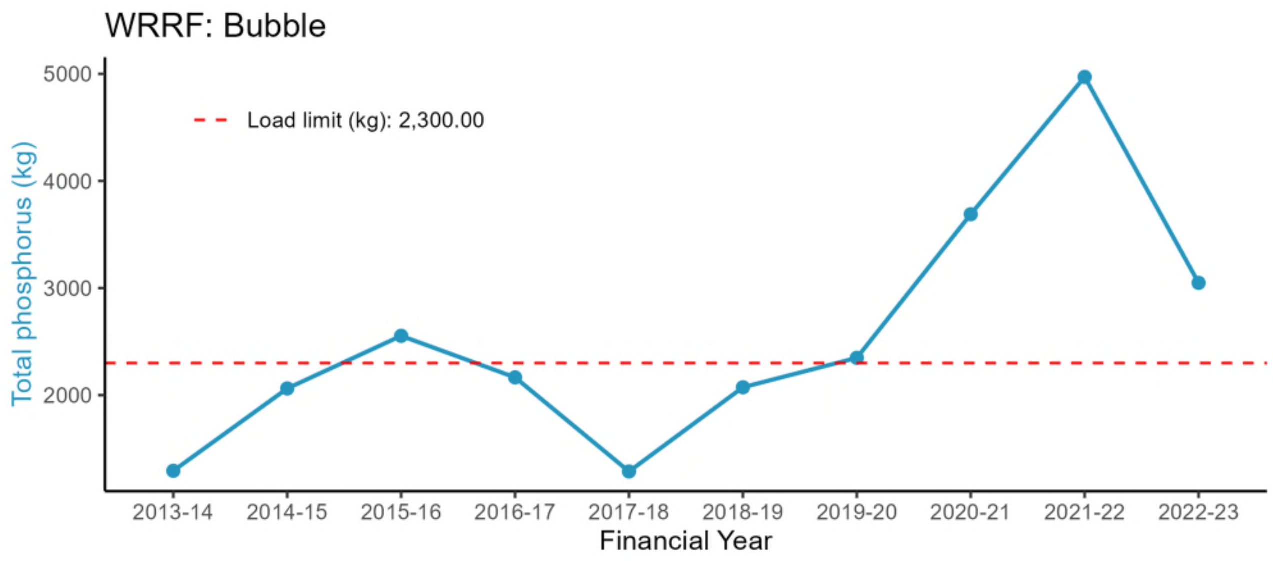
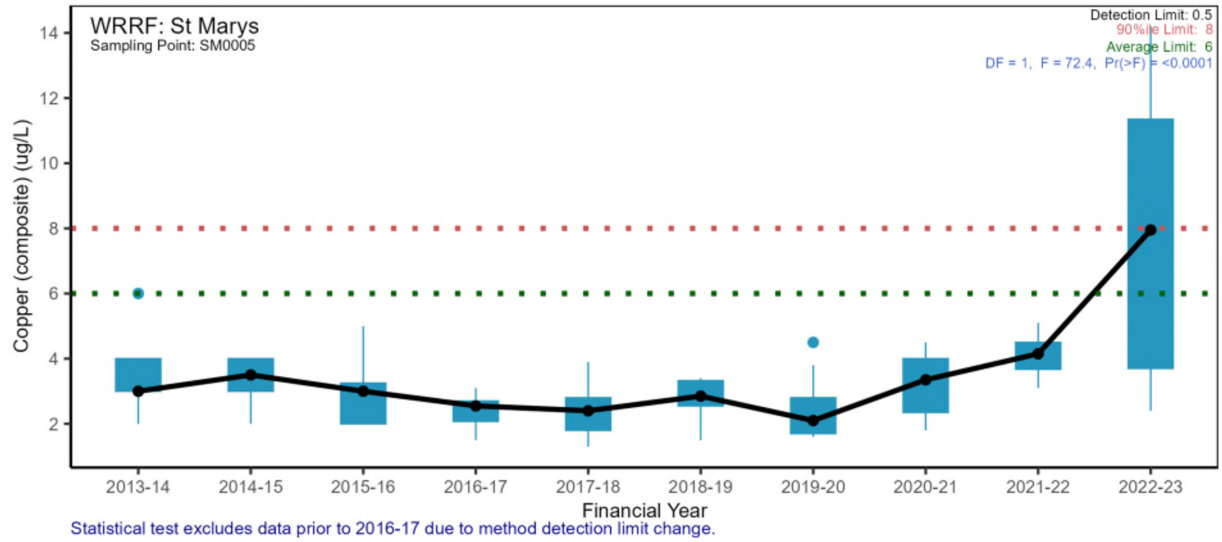
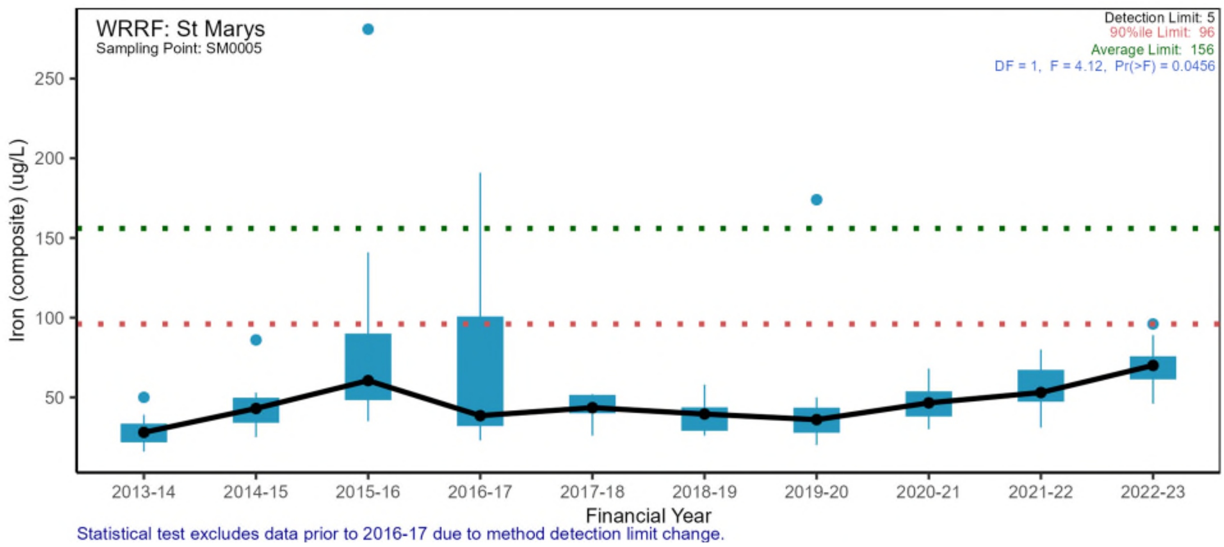
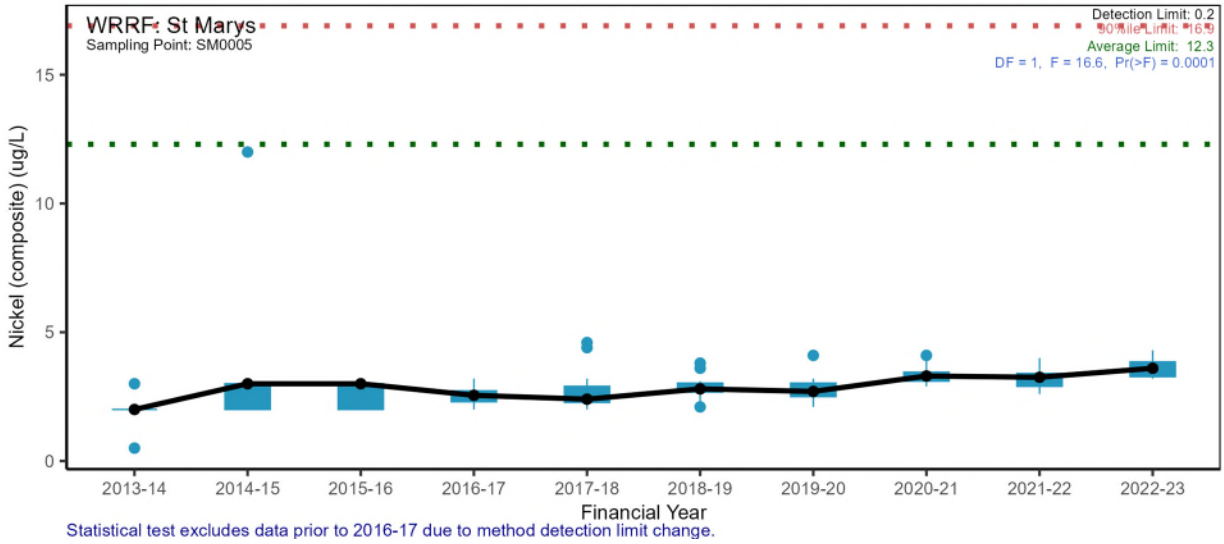


Figure 4-33 St Marys WRRF inflow, discharge, and reuse volume with catchment rainfall plots


WRRF: Bubble
Load limit (kg): 2,300.00
Total phosphorus (kg)
5000
4000
3000
2000
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
2020-21
2021-22
2022-23
Financial Year


WRRF: St Marys
Sampling Point: SM0005
Detection Limit: 0.5
90%ile Limit: 8
Average Limit: 6
DF = 1, F = 72.4, Pr(>F) = <0.0001
Copper (composite) (ug/L)
14
12
10
8
6
4
2
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
2020-21
2021-22
2022-23
Financial Year
Statistical test excludes data prior to 2016-17 due to method detection limit change.


WRRF: St Marys
Sampling Point: SM0005
Detection Limit: 5
90%ile Limit: 96
Average Limit: 156
DF = 1, F = 4.12, Pr(>F) = 0.0456
Iron (composite) (ug/L)
250
200
150
100
50
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
2020-21
2021-22
2022-23
Financial Year
Statistical test excludes data prior to 2016-17 due to method detection limit change.



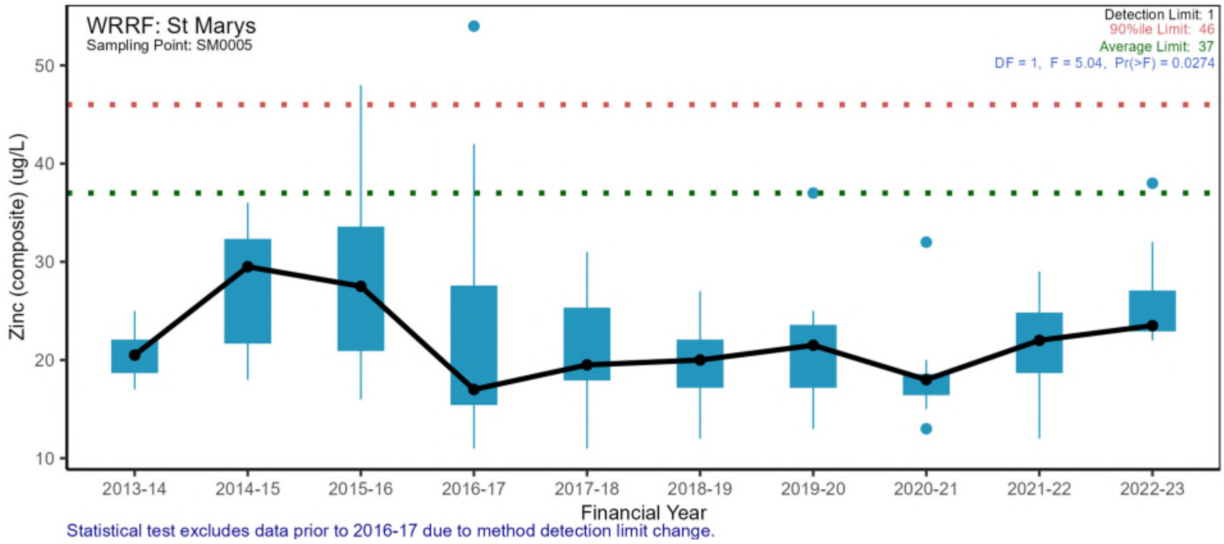


Figure 4-34 St Marys WRRF discharge quality and toxicity exception plots

Stressor – Water quality

Table 4-27 Gate 1 Analysis outcome summary – water quality upstream and downstream of St Marys WRRF discharge

Monitoring sites	Nutrient analytes					Physico-chemical analytes					
	Ammonia nitrogen	Oxidised nitrogen	Total nitrogen	Filterable total phosphorus	Total phosphorus	Conductivity	Dissolved oxygen	Dissolved oxygen saturation	pH	Temperature	Turbidity
Upstream tributary (NS26)	→	→	→	→	→	→	→	↗	→	→	→
Downstream tributary (NS23A)	→	→	→	→	→	→	→	→	→	→	→

↗	Upward trend	↘	Downward trend	→	no trend, p>0.05

	2022-23 Median value within the guideline limit		No guideline applicable
	2022-23 Median value outside the guideline limit		Insufficient data

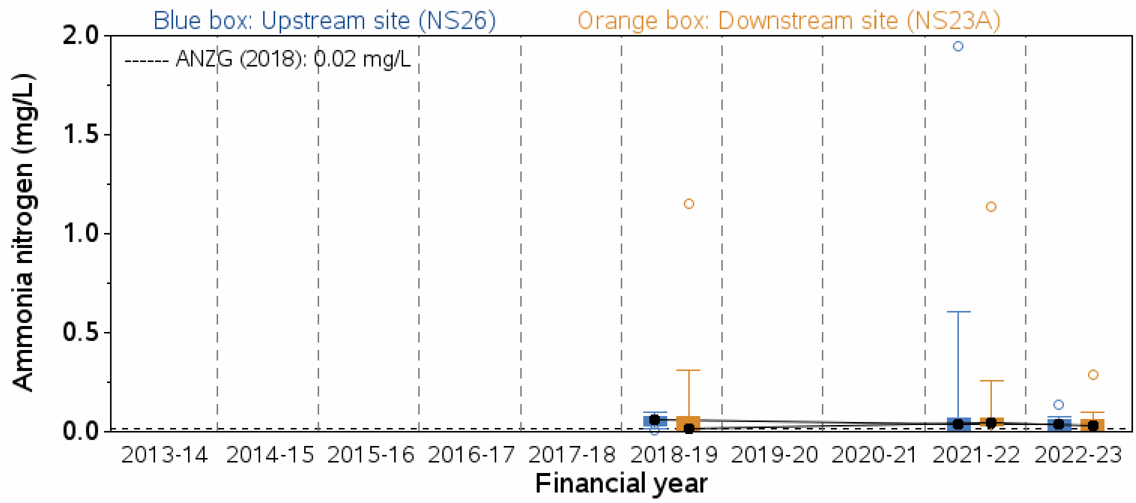
St Marys WRRF discharges into an unnamed tributary before joining South Creek and then the Hawkesbury River. The land along upstream South Creek is predominantly rural including grazing, market gardening and other intensive agriculture such as poultry farming. It also has both residential and industrial land uses that have increased in recent years.

Nutrient concentrations were steady during 2022-23 at both upstream and downstream South Creek sites. Dissolved oxygen saturation increased significantly at the upstream site (NS26). No other significant statistical trends were found in any other water quality analytes at this site or at downstream site (NS23A).

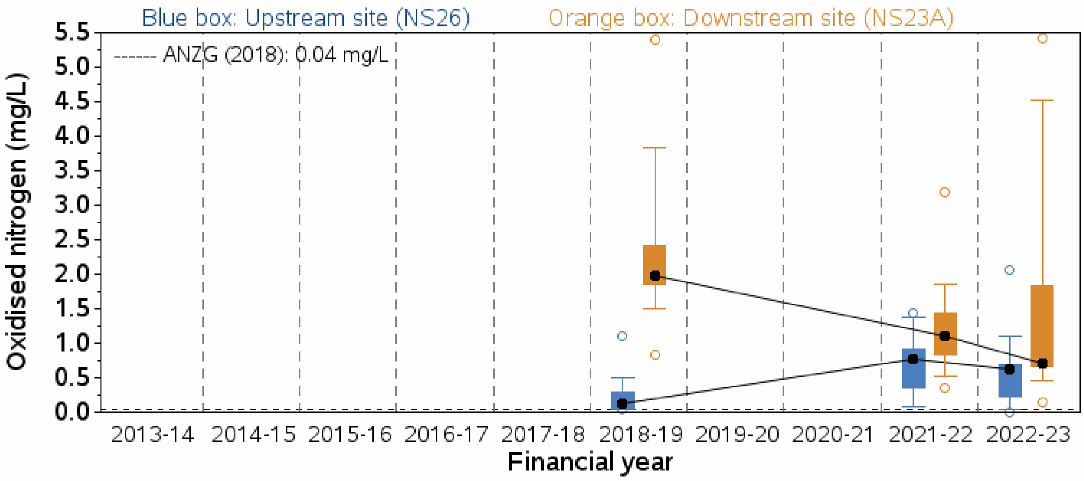
Concentrations of key nitrogen analytes (oxidised nitrogen and total nitrogen) at the downstream South Creek site were notably higher in comparison to upstream concentrations indicating a possible impact from St Marys WRRF. Statistical analysis will be included in SWAM reports from 2023-24 to further validate the trend.

In the 2022-23 period, the median nutrient concentrations of all four analytes (ammonia nitrogen, oxidised nitrogen, total nitrogen and total phosphorus) exceeded their respective ANZG (2018) guidelines at both upstream and downstream sites. Dissolved oxygen saturation was low at the upstream site (NS26) and the median level was lower than the ANZG (2018) guideline value. The upstream South Creek (NS26) water quality was turbid with a median result of 64 NTU in 2022-23.

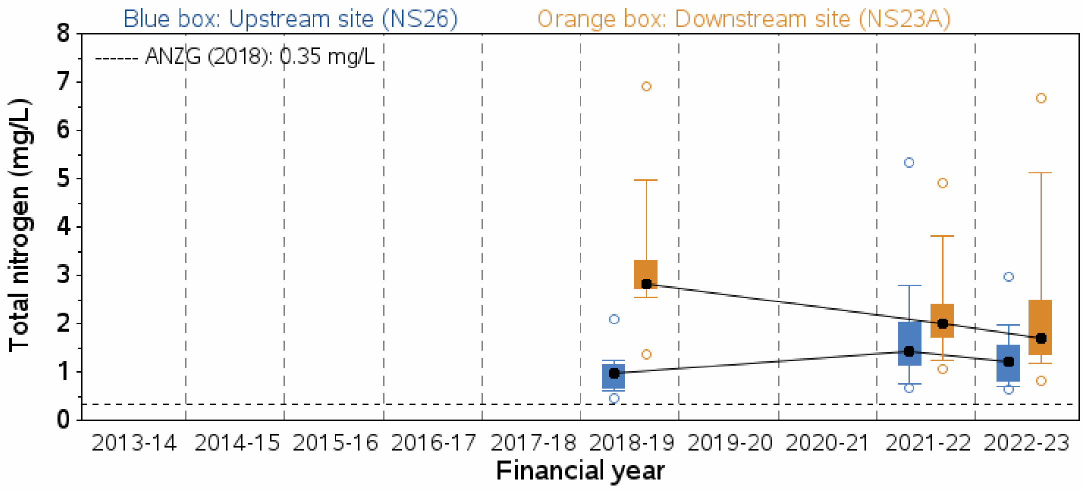
The median turbidity at downstream site was 41 NTU (2022-23), being diluted by discharges from the St Marys WRRF.



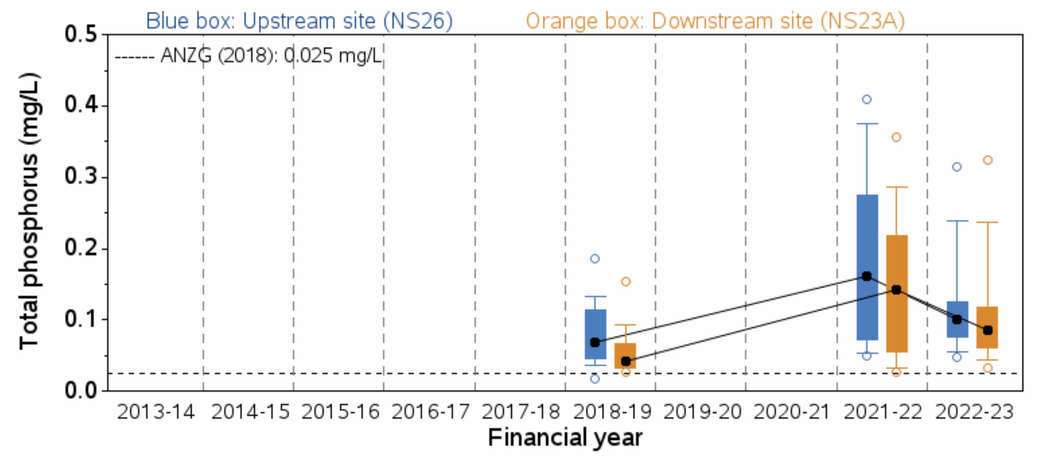
site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
NS26	1	0.78	0.3808	NS23A	1	1.47	0.2318



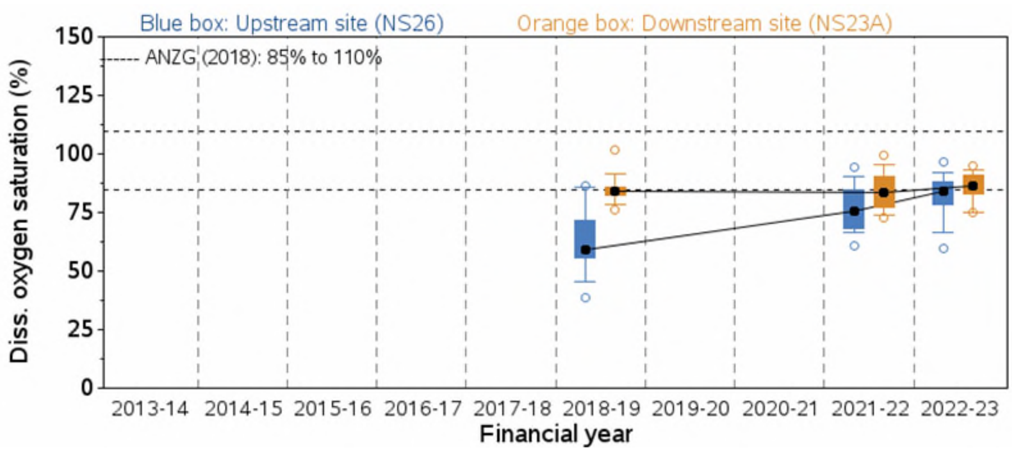
site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
NS26	1	0.29	0.5946	NS23A	1	0.06	0.8012



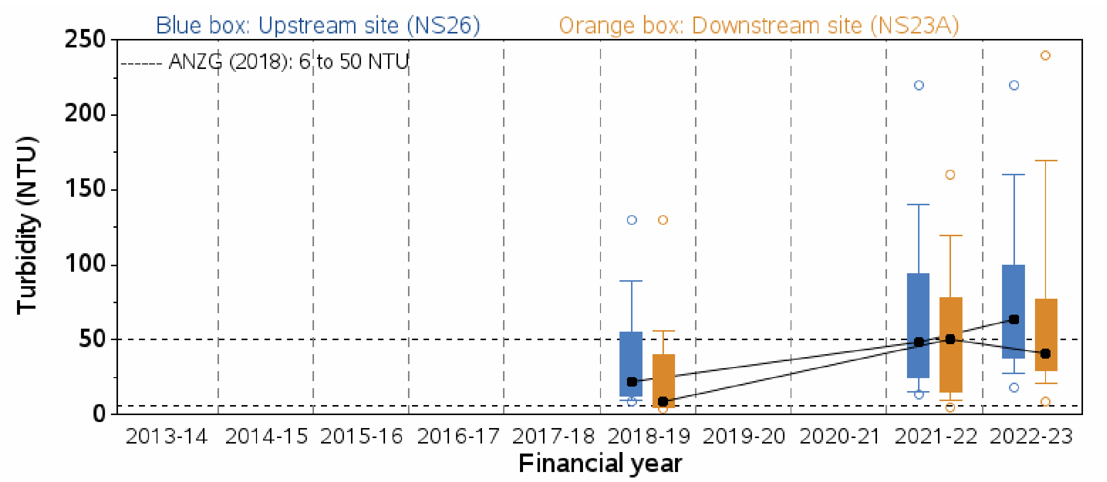
site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
NS26	1	0.23	0.6316	NS23A	1	0.45	0.5056



site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
NS26	1	0.61	0.439	NS23A	1	0.01	0.9247



site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
NS26	1	8.1	0.0066	NS23A	1	0.63	0.4314



site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
NS26	1	2.2	0.1448	NS23A	1	2.95	0.0924

Figure 4-35 Nutrients and physico-chemical water quality exception plots, upstream and downstream of St Marys WRRF

Ecosystem Receptor – Phytoplankton

Table 4-28 Gate 1 Analysis outcome summary – phytoplankton as chlorophyll-a, biovolume and species counts, upstream and downstream of St Marys WRRF discharge

Monitoring sites	Phytoplankton analytes			
	Chlorophyll-a	Total phytoplankton biovolume	Blue-green biovolume	Toxic blue-green count
Upstream tributary (NS26)	→	→	↗	→
Downstream tributary (NS23A)	→	→	→	→

↗	Upward trend	↘	Downward trend	→	no trend, p>0.05

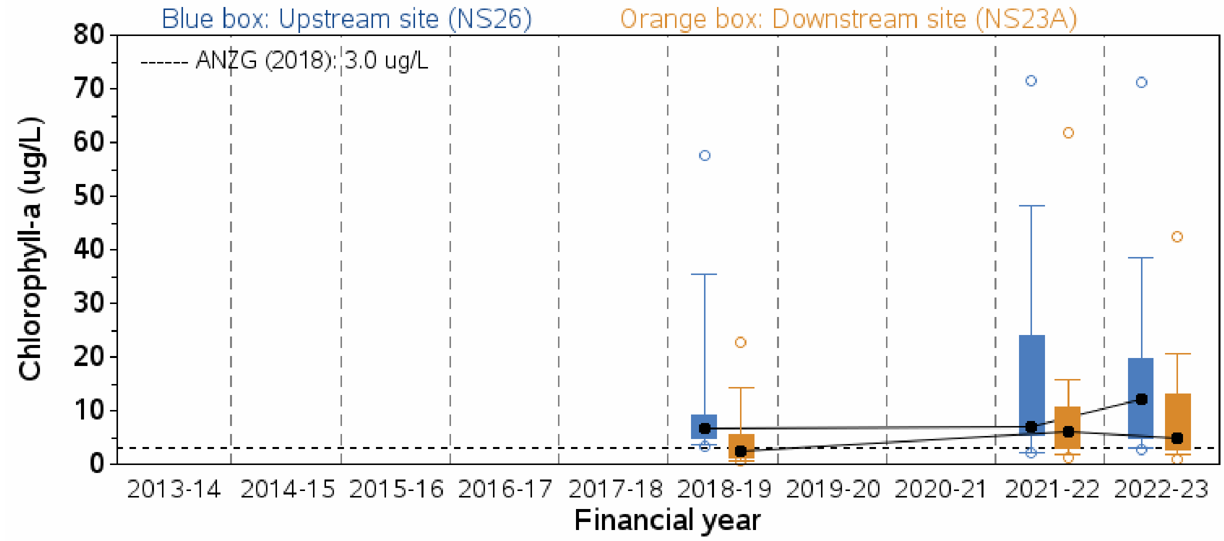
(green)	2022-23 Median value within the guideline limit	(white)	No guideline applicable
(yellow)	2022-23 Median value outside the guideline limit	(grey)	Insufficient data

Statistical analysis did not identify a trend in chlorophyll-a concentration at either the upstream or downstream sites in South Creek in 2022-23. However, the blue-green biovolume increased significantly at the upstream site (NS26) compared to earlier years.

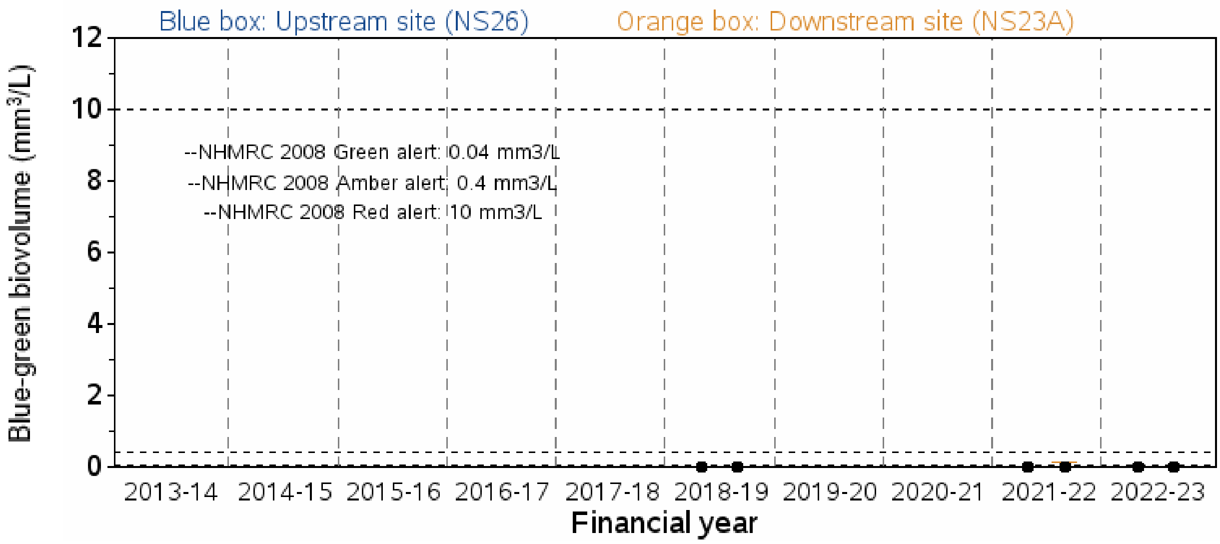
In the 2022-23 period, the median chlorophyll-a concentrations exceeded the ANZG (2018) guidelines at both upstream and downstream sites. Blue-green biovolume or toxic blue-green species counts were low and always within the NHMRC (2008) Amber Alert level at both sites.

Chlorophyll-a concentrations were generally elevated in 2022-23 and the majority of the phytoplankton samples qualified for species counts from both monitoring sites. Chlorophyll-a reached a peak of 71.2 µg/L at upstream site (NS26) on 2 September when no toxic blue-green species were detected. However on other dates, toxic species were detected in low numbers. *Phormidium* was found at this site in low numbers (553 cells/mL, on 10 August 20922).

At the downstream site (NS23A), chlorophyll-a peaked on 2 September 2023 (42.4 µg/L), when potentially toxic blue-green taxa *Microcystis* was found in low numbers (277 cells/mL).



site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
NS26	1	0.16	0.6951	NS23A	1	0.31	0.5795



site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
NS26	1	10.45	0.0038	NS23A	1	0.41	0.5347

Figure 4-36 Phytoplankton as chlorophyll-a, biovolume and species counts exception plots, upstream and downstream of St Marys WRRF

Ecosystem Receptor – Macroinvertebrates

No stream health impacts (as indicated by macroinvertebrates) were identified in South Creek downstream of where the St Marys WRRF discharges (Volume 2 Appendix A-8).

4.1.9 Quakers Hill WRRF

- The average concentration limit in the discharge from Quakers Hill WRRF was exceeded for aluminium during 2022-23. The South Creek bubble load limit for total phosphorus (combined St Marys, Quakers Hill and Riverstone WRRF discharge load) was also exceeded. All other parameters (concentrations and loads) were within EPL limits. There was an increasing trend in total phosphorus concentration in the discharge and decreasing trends in ammonia nitrogen and total nitrogen concentrations.
- Nutrient concentrations were steady at both the upstream and downstream site on Breakfast Creek during 2022-23.
- Chlorophyll-a concentrations were low at the downstream site with no sample analysed for phytoplankton biovolume. At upstream site toxic blue-green species was found in two of the three samples, but not reaching the NHMRC (2008) Amber Alert level.
- No stream health impacts (as indicated by macroinvertebrates) were identified for the waterways downstream of where Quakers Hill WRRF discharges

Pressure – Wastewater discharge

Table 4-29 Gate 1 Analysis outcome summary – Quakers Hill WRRF

Analytes / Quakers Hill WRRF	Nutrients			Conventional analytes					EC$_{50}$ Toxicity
	Ammonia Nitrogen	Total Nitrogen	Total Phosphorus	Biochemical Oxygen Demand	Chlorine (total residual)	Faecal Coliforms	Oil and Grease	Total Suspended Solids	
Concentration	↘	↘	↗	→	→	→		→	→
Load									

Analytes / Quakers Hill WRRF	Trace metals								Other chemicals / organics	
	Aluminium	Cadmium	Chromium	Copper	Lead	Mercury	Selenium	Zinc	Hydrogen sulfide (un-ionised)	Pesticides and PCBs
Concentration	→	→	→	→				→	→	
Load										

↗	Upward trend	↘	Downward trend	→	no trend, p>0.05

(green)	Within the Environment Protection Licence limit
(yellow)	Environment Protection Licence limit exceedance
(grey)	Analytes not required in the EPL or no concentration limit

The average concentration limit for aluminium in the Quakers Hill WRRF discharge was exceeded during the 2022-23 reporting period. All other concentrations were within the EPL limits. The South Creek bubble load limit (combined St Marys, Quakers Hill and Riverstone WRRF discharge load) for total phosphorus was exceeded during the 2022-23 period.

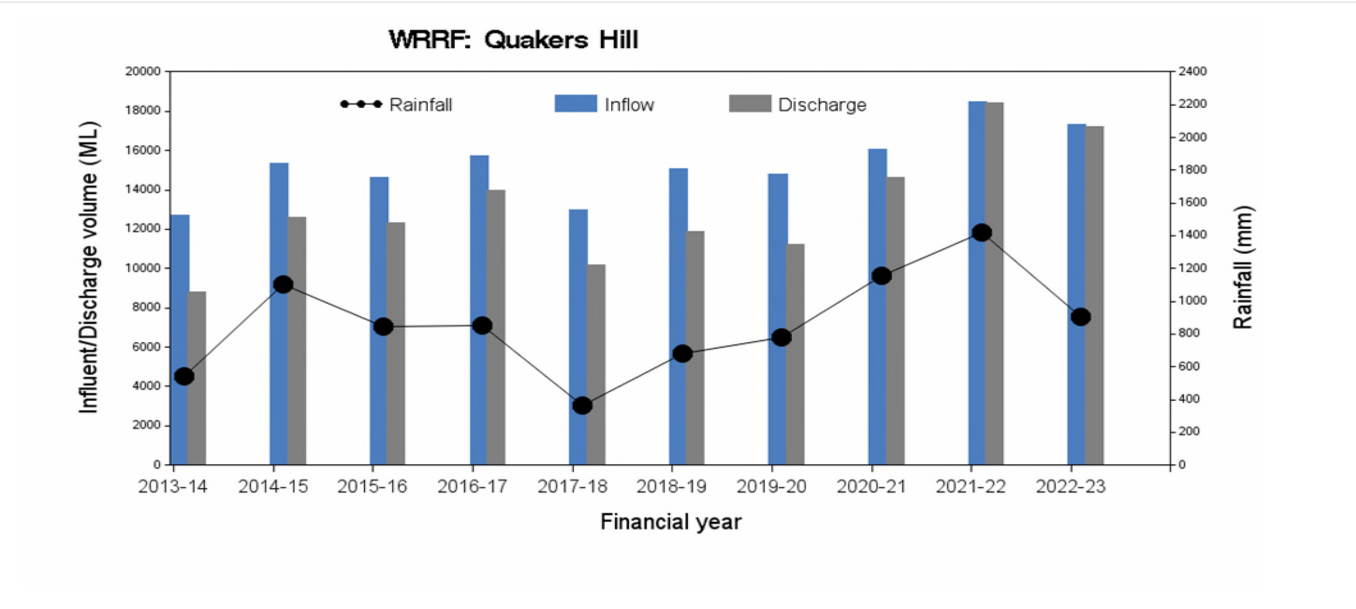
Statistical analysis identified a significantly increasing trend in total phosphorus and significantly decreasing trends in ammonia nitrogen and total nitrogen in the discharge from Quakers Hill WRRF in 2022-23 compared to the previous nine years.

One possible contributor to the average concentration limit exceedance for aluminium and the increasing total phosphorus concentration (and subsequent total phosphorus bubble load limit exceedance for the South Creek facilities) at Quakers Hill WRRF is that more than half the inflow was being diverted to activated granular sludge where treatment processes potentially led to a reduction in aluminium and phosphorus removal.

Sydney Water is continuing to optimise the operation of Quakers Hill WRRF whilst the Lower South Creek Treatment Upgrade Program (LSCTUP) upgrade is continuing. This includes increasing polymer and reducing alum dose rates. Once the LSCTUP is complete, polymer dosing optimisation is expected to lower final effluent aluminium and phosphorus concentrations.

The total phosphorus bubble load limit exceedance for the South Creek facilities was also influenced by the extreme wet weather events experienced within the catchment area between 2 – 11 July and 28 September – 10 October 2022. Quakers Hill WRRF contributed 63.9% of the total phosphorus load from 52.8% of the total flow from the three South Creek facilities.

Sydney Water is engaging with the EPA on wet weather load calculations under extreme weather events due to a skewing effect on calculated loads in extreme wet weather. Further collaboration between Sydney Water and EPA is required to progress.



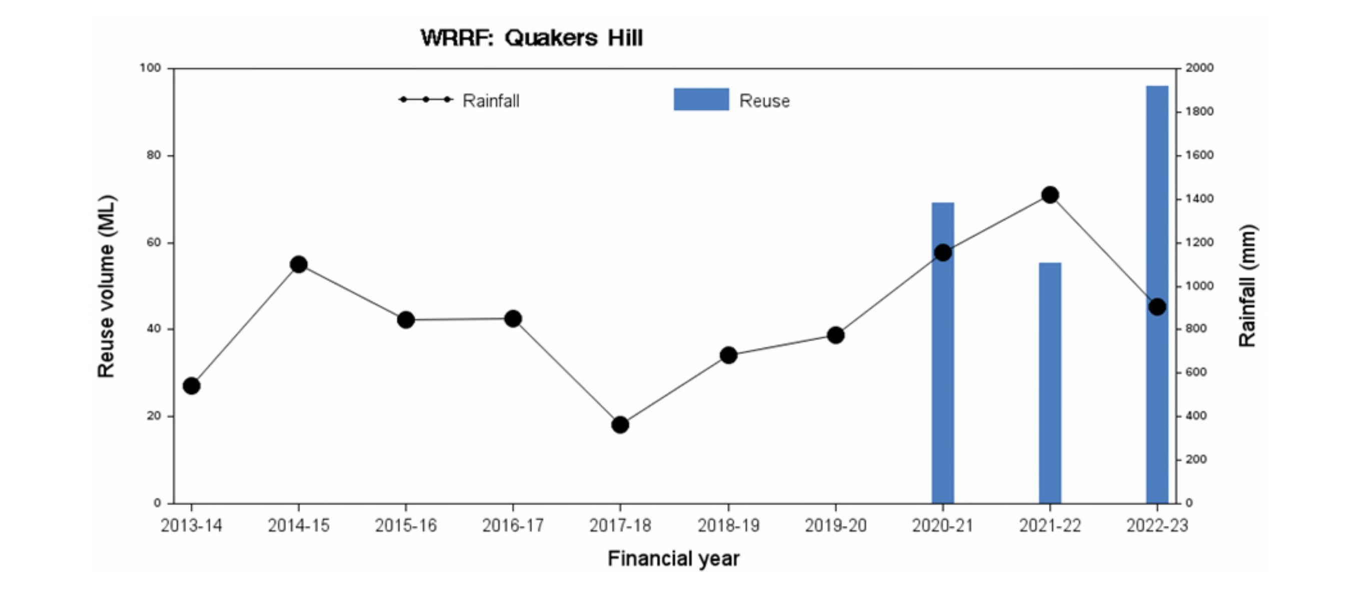
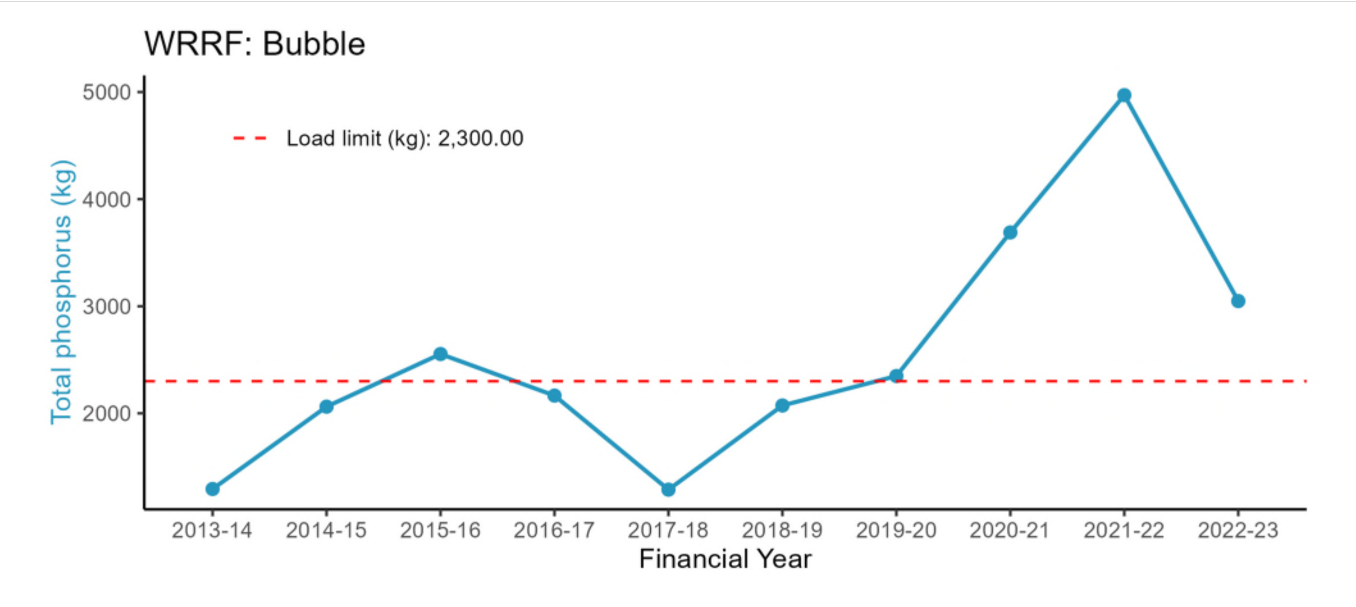
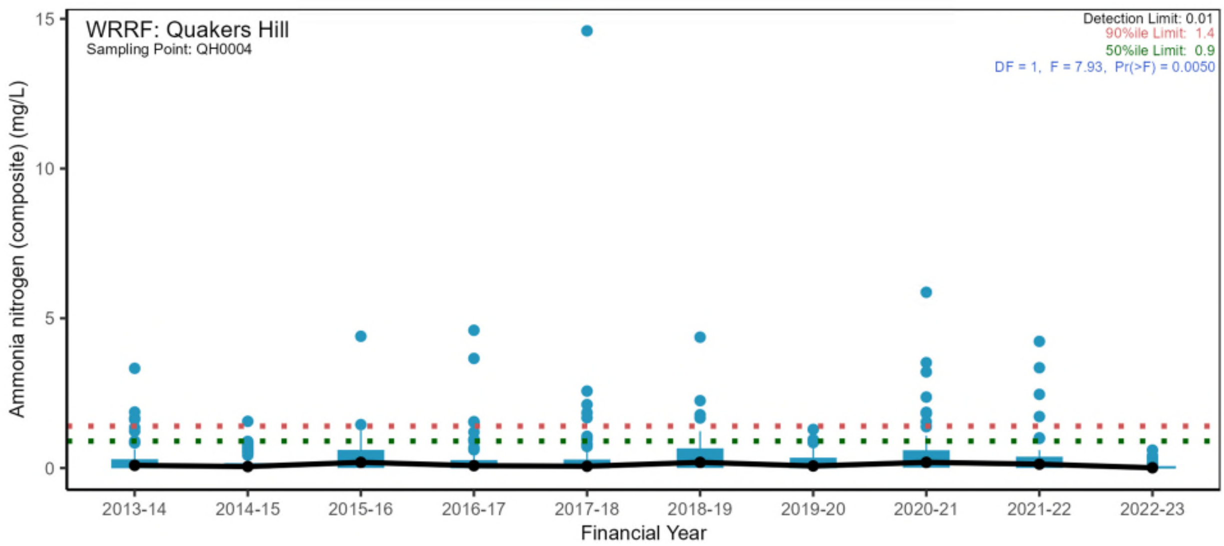
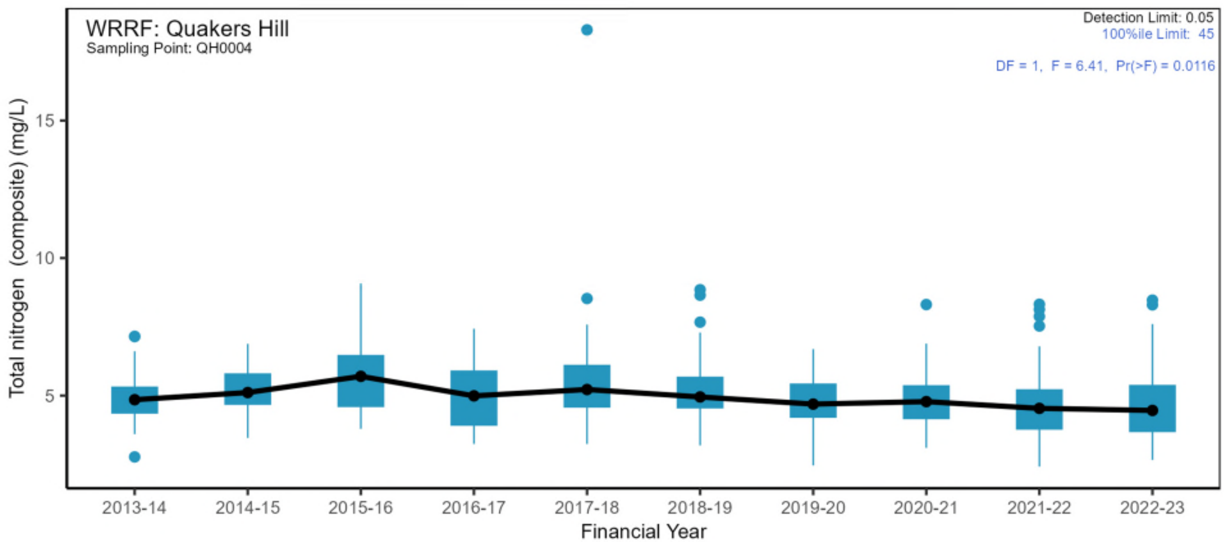


Figure 4-37 Quakers Hill WRRF inflow, discharge and reuse volume with catchment rainfall plots

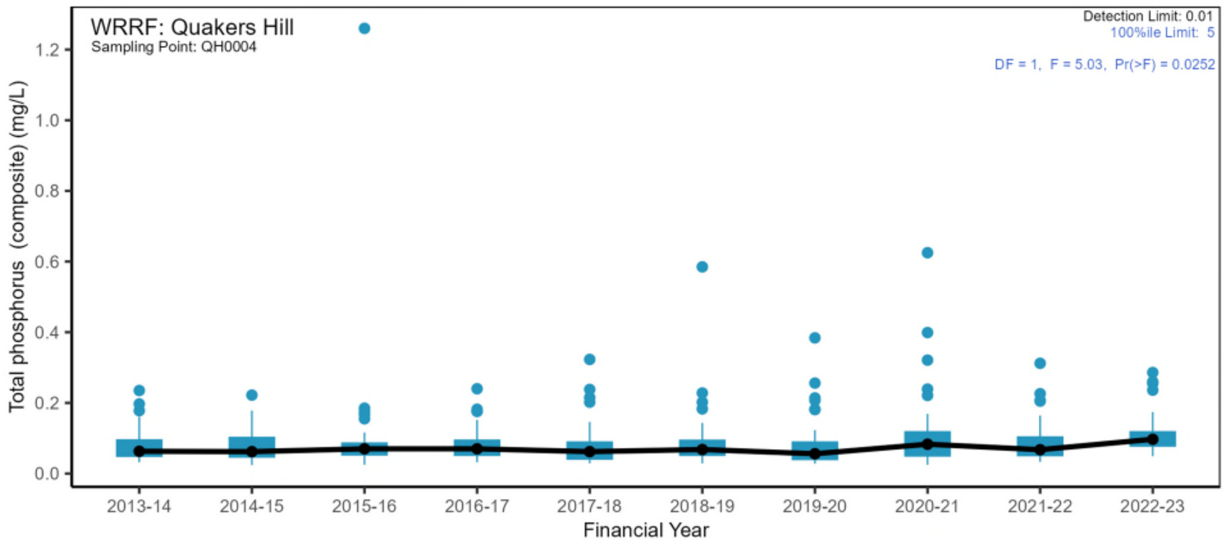




WRRF: Quakers Hill
Sampling Point: QH0004
Detection Limit: 0.01
90%ile Limit: 1.4
50%ile Limit: 0.9
DF = 1, F = 7.93, Pr(>F) = 0.0050
Ammonia nitrogen (composite) (mg/L)
Financial Year
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
2020-21
2021-22
2022-23



WRRF: Quakers Hill
Sampling Point: QH0004
Detection Limit: 0.05
100%ile Limit: 45
DF = 1, F = 6.41, Pr(>F) = 0.0116
Total nitrogen (composite) (mg/L)
Financial Year
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
2020-21
2021-22
2022-23



WRRF: Quakers Hill
Sampling Point: QH0004
Detection Limit: 0.01
100%ile Limit: 5
DF = 1, F = 5.03, Pr(>F) = 0.0252
Total phosphorus (composite) (mg/L)
Financial Year
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
2020-21
2021-22
2022-23

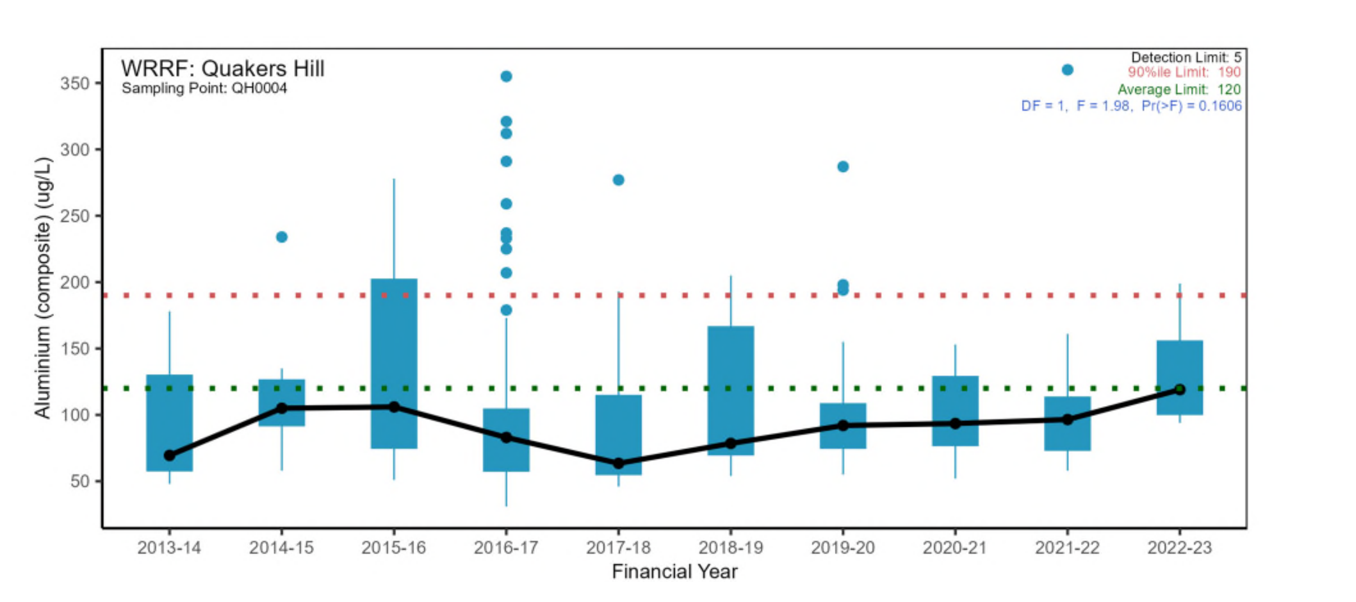


Figure 4-38 Quakers Hill WRRF discharge quality and toxicity exception plots

Stressor – Water quality

Table 4-30 Gate 1 Analysis outcome summary – water quality upstream and downstream of Quakers Hill WRRF discharge

Monitoring sites	Nutrient analytes					Physico-chemical analytes					
	Ammonia nitrogen	Oxidised nitrogen	Total nitrogen	Filterable total phosphorus	Total phosphorus	Conductivity	Dissolved oxygen	Dissolved oxygen saturation	pH	Temperature	Turbidity
Upstream tributary (NS090)	→	→	→	→	→	→	→	→	↗	→	→
Downstream tributary (NS087)	→	→	→	→	→	↗	→	↗	↗	→	→

↗	Upward trend	↘	Downward trend	→	no trend, p>0.05

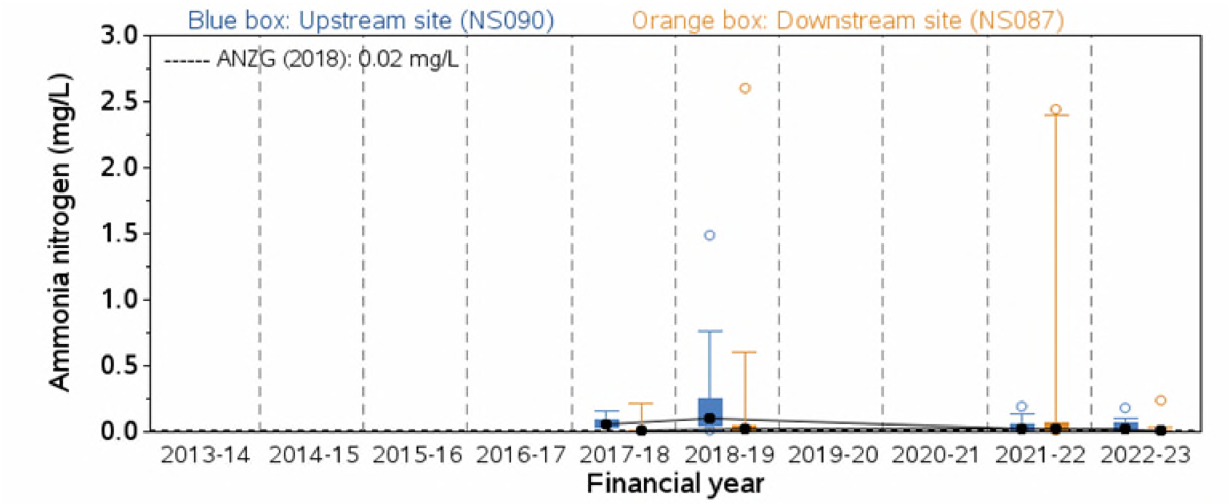
	2022-23 Median value within the guideline limit		No guideline applicable
	2022-23 Median value outside the guideline limit		Insufficient data

Quakers Hill WRRF discharges into Breakfast Creek that joins with Eastern Creek before joining South Creek. The upstream catchment includes a mix of land uses with semi-urban towns, reserves and residential houses.

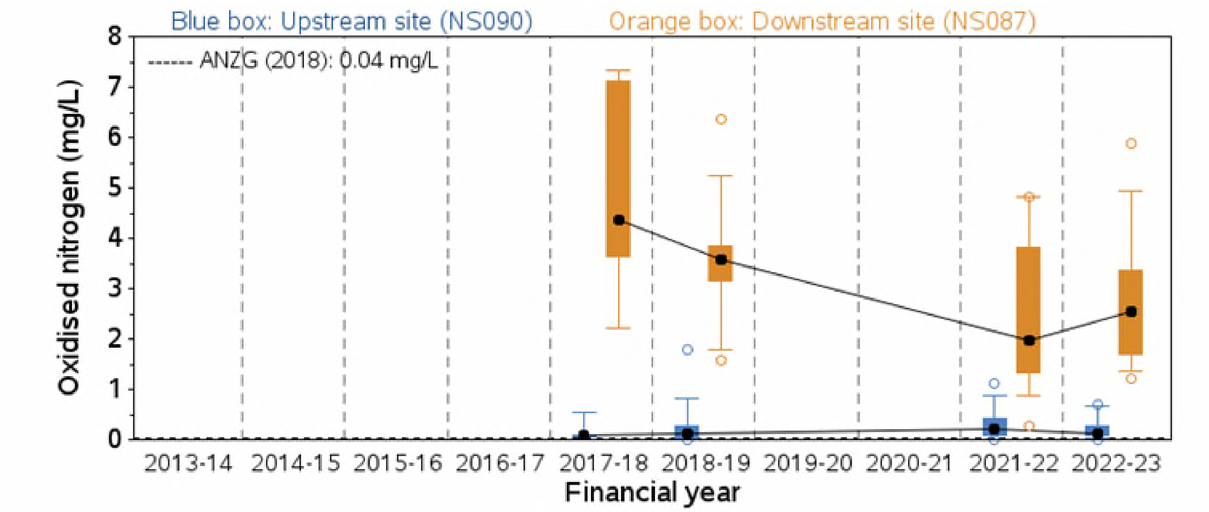
Nutrient concentrations were steady during 2022-23 at both the upstream and downstream Breakfast Creek sites. pH increased significantly at both upstream (NS090) and downstream (NS087) sites in 2022-23. Conductivity and dissolved oxygen saturation increased significantly at the downstream site (NS087).

Concentrations of key nitrogen analytes (oxidised nitrogen and total nitrogen) at the downstream Breakfast Creek site were notably higher in comparison to upstream concentrations indicating an impact from Quakers Hill WRRF. Statistical analysis will be included in SWAM reports from 2023-24 to further validate the trend.

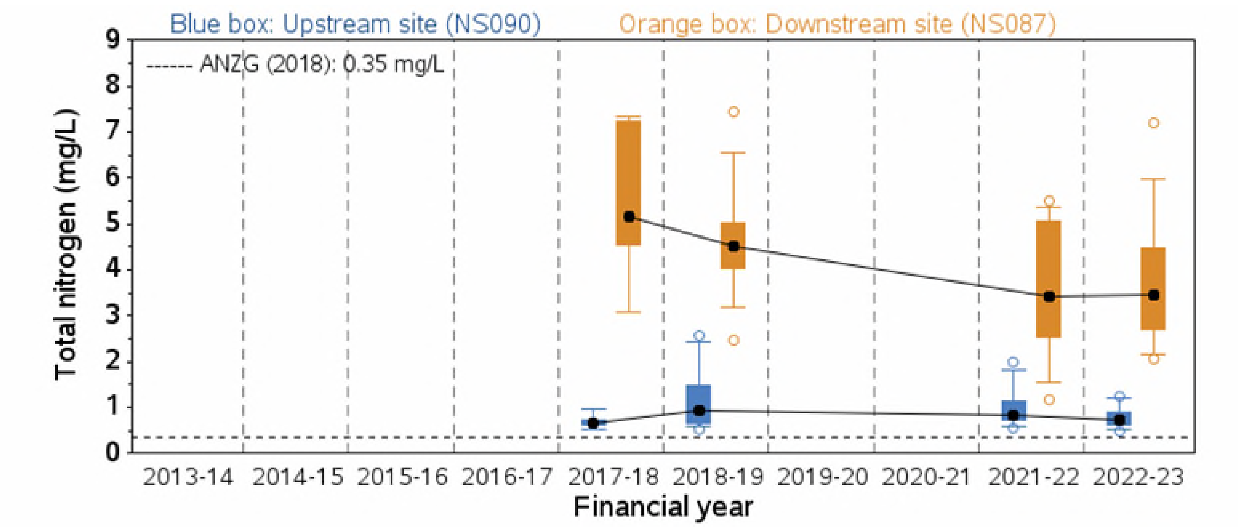
In the 2022-23 period, the median nutrient concentrations for all four analytes exceeded the respective ANZG (2018) for both upstream and downstream sites. The median dissolved oxygen saturation levels in the upstream site (NS090) and the median turbidity in the downstream site (NS087) were below ANZG (2018) lower limit guidelines.



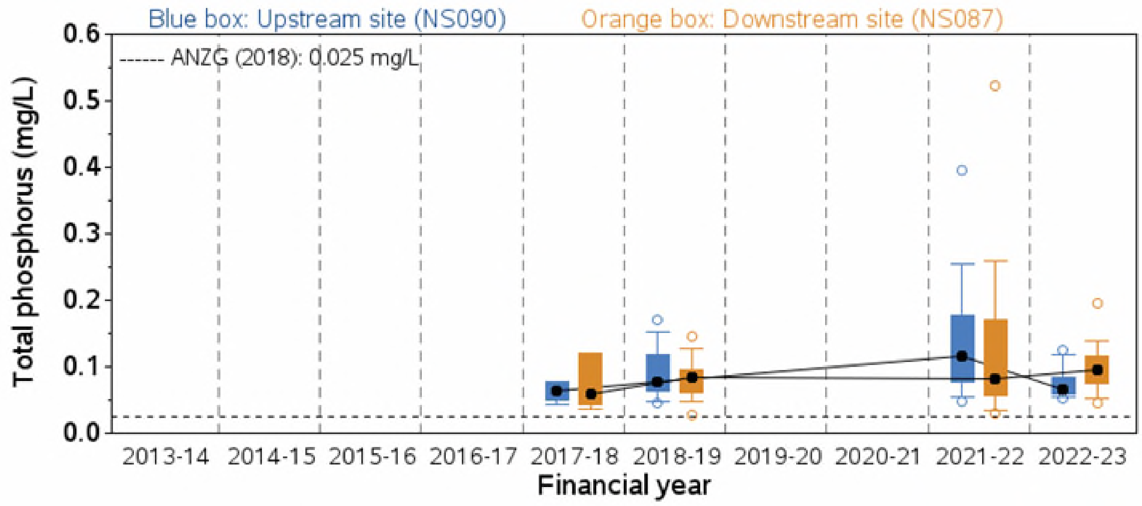
site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
NS090	1	2.01	0.1619	NS087	1	2.38	0.1289



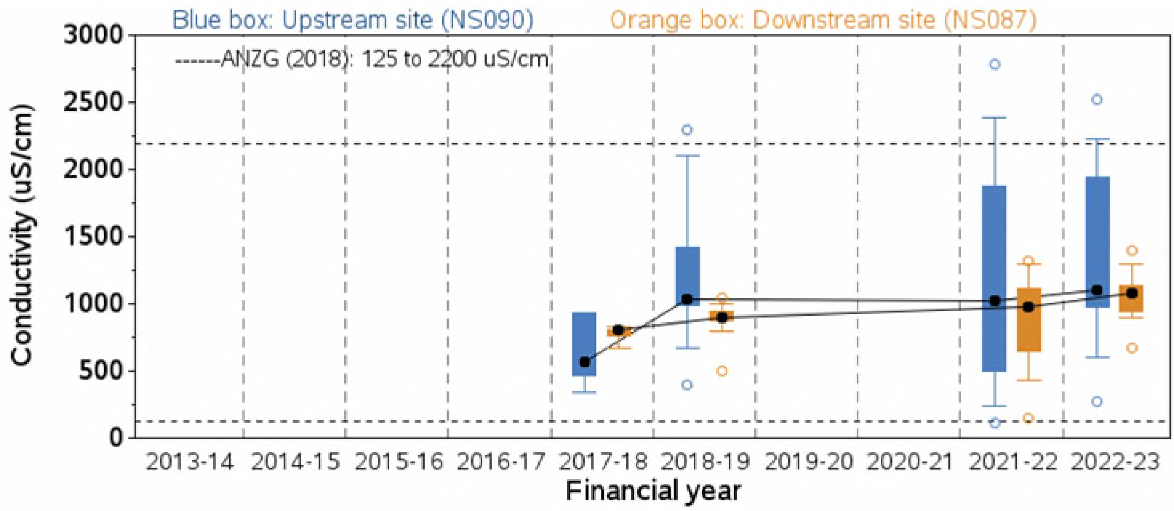
site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
NS090	1	0.65	0.4219	NS087	1	1.12	0.295



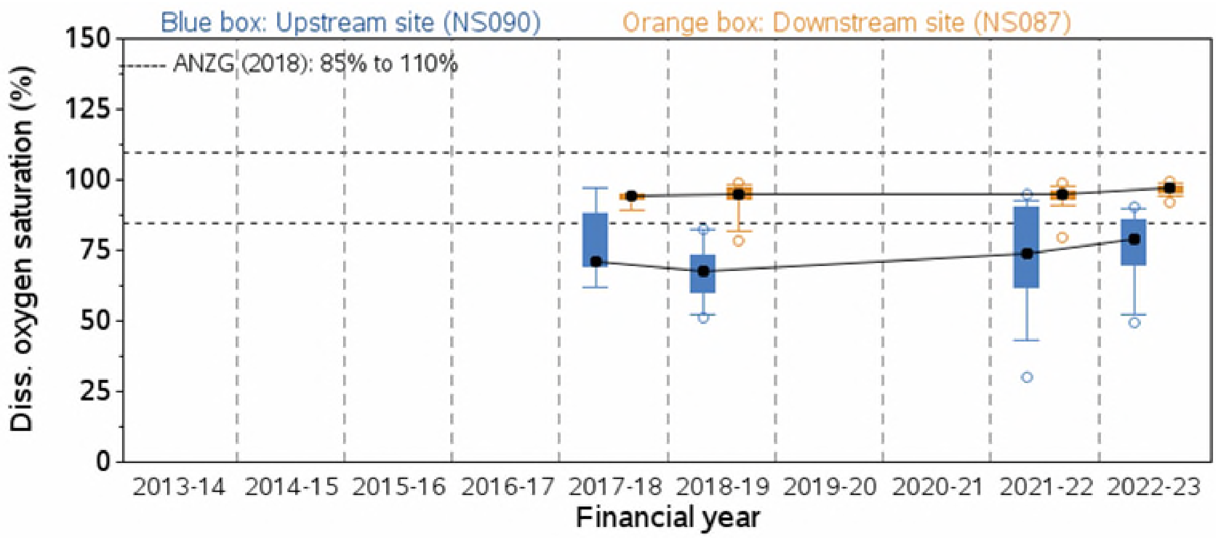
site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
NS090	1	3.57	0.0639	NS087	1	2.15	0.1479



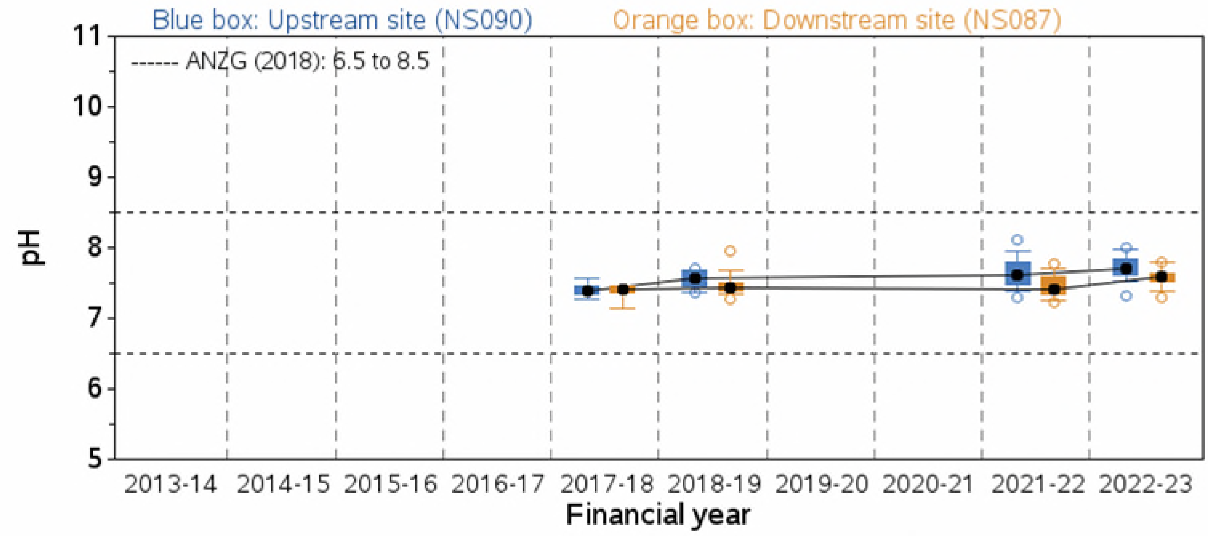
site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
NS090	1	3.66	0.0609	NS087	1	0.07	0.7953



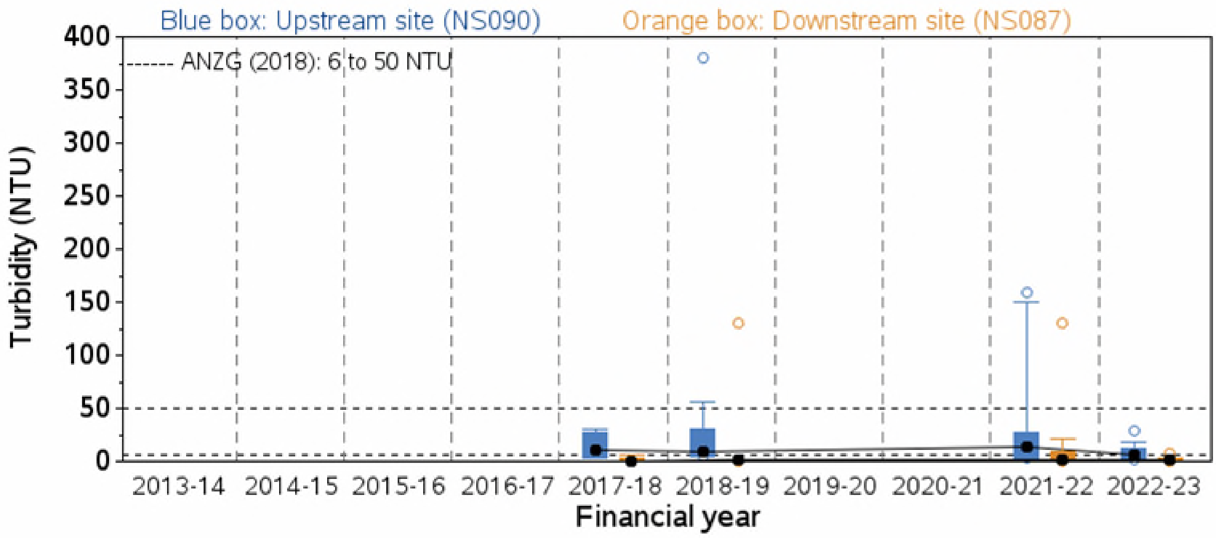
site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
NS090	1	1.6	0.2117	NS087	1	8.8	0.0044



site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
NS090	1	1.24	0.2695	NS087	1	5.95	0.0179



site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
NS090	1	7.09	0.0101	NS087	1	8.04	0.0064



site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
NS090	1	2.03	0.1597	NS087	1	1.16	0.2866

Figure 4-39 Nutrients and physico-chemical water quality exception plots, upstream and downstream of Quakers Hill WRRF

Ecosystem Receptor – Phytoplankton

Table 4-31 Gate 1 Analysis outcome summary – phytoplankton as chlorophyll-a, biovolume and species counts, upstream and downstream of Quakers Hill WRRF discharge

Monitoring sites	Phytoplankton analytes			
	Chlorophyll-a	Total phytoplankton biovolume	Blue-green biovolume	Toxic blue-green count
Upstream tributary (NS90)	→	→	→	→
Downstream tributary (NS87)	→			

↗	Upward trend	↘	Downward trend	→	no trend, p>0.05

(green)	2022-23 Median value within the guideline limit	(white)	No guideline applicable
(yellow)	2022-23 Median value outside the guideline limit	(grey)	Insufficient data

In 2022-23, there were no significantly increasing or decreasing trend identified in any of the phytoplankton analytes at the upstream or downstream Breakfast Creek sites.

In the 2022-23 period, the median chlorophyll-a concentration was lower than the ANZG (2018) guidelines at both upstream and downstream site.

Chlorophyll-a concentrations were generally low at the Breakfast Creek site with a low water retention time. Three of the 17 samples collected from the upstream site (NS090) exceeded the chlorophyll-a concentration of 7 µg/L in 2022-23, which triggered phytoplankton analysis. Chlorophyll-a concentrations reached 15.3 µg/L on 25 November 2022 when potentially toxic blue-green taxa *Microcystis* was found (622 cells/mL).

Chlorophyll-a concentrations were low for the downstream site (NS087) in 2022-23, where none of the samples qualified for biovolume measurements and species counts.

Ecosystem Receptor – Macroinvertebrates

No stream health impacts (as indicated by macroinvertebrates) were identified for the waterway downstream of where Quakers Hill WRRF discharges (Volume 2 Appendix A-9).

4.1.10 Riverstone WRRF

- The South Creek bubble load limit for total phosphorus (combined St Marys, Quakers Hill and Riverstone WRRF discharged load) was exceeded in 2022-23. All other parameters (concentrations and loads) monitored in the discharge from Riverstone WRRF were within EPL limits. There were decreasing trends in total nitrogen and total phosphorus concentrations in the discharge.
- Nutrient concentrations were steady at both the upstream and downstream site on Eastern Creek during 2022-23 in comparison to earlier years.
- Chlorophyll-a concentrations were very low at these sites with a low number of samples qualifying for phytoplankton biovolume and species counts. No potentially toxic blue-green species were found in any of these samples, and blue-green biovolume was always within the NHMRC (2008) Amber Alert level.
- No stream health impacts (as indicated by macroinvertebrates) were identified for the waterways downstream of where Riverstone WRRF discharges.

Pressure – Wastewater discharge

Table 4-32 Gate 1 Analysis outcome summary – Riverstone WRRF

Analytes / Riverstone WRRF	Nutrients			Conventional analytes						Trace Metals				Other
	Ammonia Nitrogen	Total Nitrogen	Total Phosphorus	Biochemical Oxygen Demand	Total Residual Chlorine	Faecal Coliforms	Oil and Grease	Total Suspended Solids	EC_{50} Toxicity	Aluminium	Copper	Iron	Zinc	Hydrogen sulfide (un-ionised)
Concentration	→	↘	↘	→	→	→		→	→	→	→	→	→	→
Load														

↗	Upward trend	↘	Downward trend	→	no trend, p>0.05

	Within the Environment Protection Licence limit
	Environment Protection Licence limit exceedance
	Analytes not required in the EPL or no concentration limit

All concentration and load limits in the discharge from Riverstone WRRF were within the EPL limits during the 2022-23 period. The South Creek bubble load limit (combined St Marys, Quakers Hill and Riverstone WRRF discharged load) for total phosphorus was exceeded during the 2022-23 reporting period.

Statistical analysis identified significantly decreasing trends in total nitrogen and total phosphorus during 2022-23 compared to the previous nine years.

The cause of the South Creek Bubble total phosphorus load limit exceedance was largely due to the extreme wet weather events experienced within the catchment area between 2 – 11 July and 28 September – 10 October 2022 with all three facilities operating under wet weather conditions.

Sydney Water is engaging with the EPA on wet weather load calculations under extreme weather events due to a skewing effect on calculated loads in extreme wet weather. Further collaboration between Sydney Water and EPA is required to progress.

Riverstone WRRF underwent a major upgrade in early 2019 that provided new and upgraded wastewater infrastructure, resulting in a significant reduction in nutrient concentrations and loads discharged. Since commissioning, whilst the overall trend in comparison to the previous nine years is significantly decreasing, total nitrogen concentrations have been slightly increasing alongside increasing inflows believed to be related to population growth within the catchment.

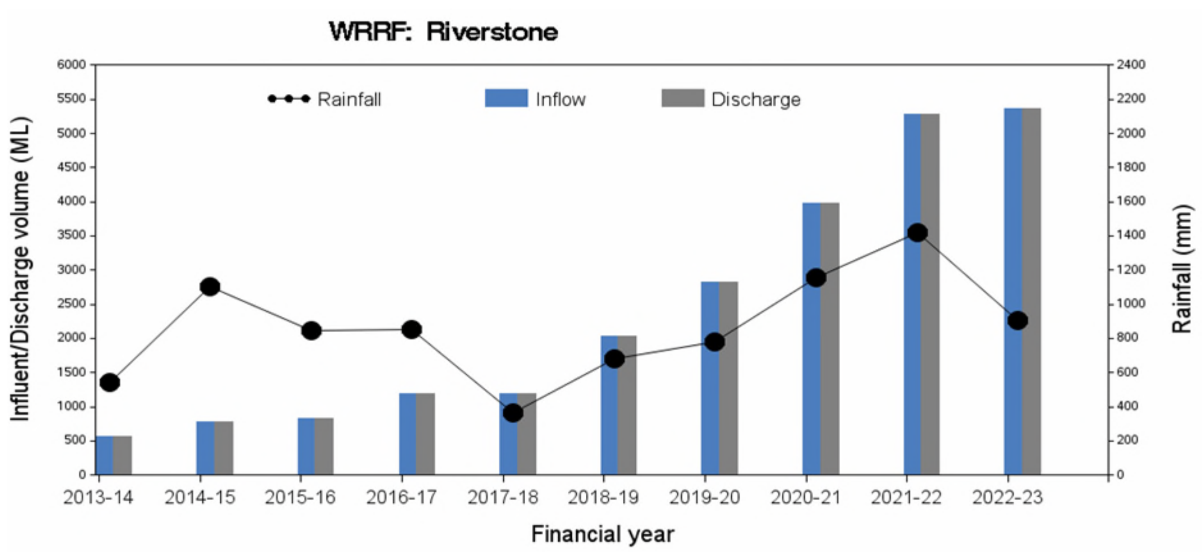
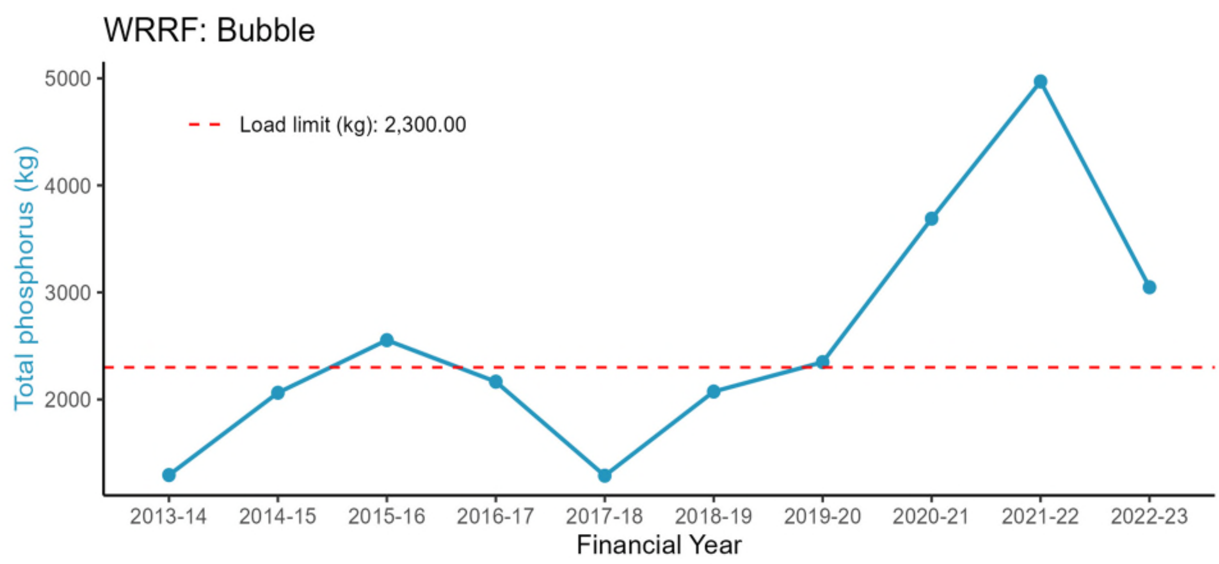


Figure 4-40 Riverstone WRRF inflow and discharge volume with catchment rainfall



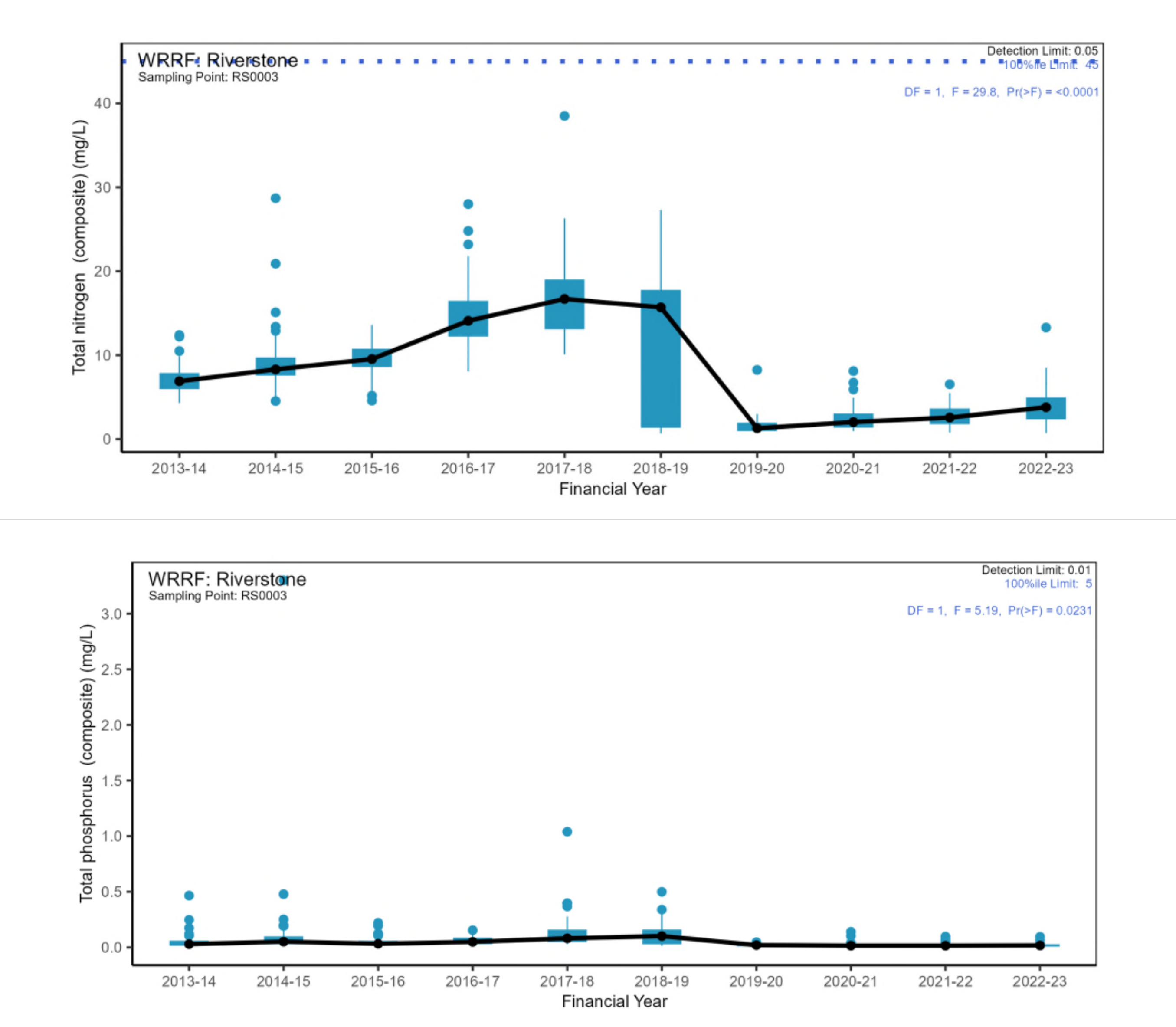


Figure 4-41 Riverstone WRRF discharge quality and toxicity exception plots

Stressor – Water quality

Table 4-33 Gate 1 Analysis outcome summary – water quality upstream and downstream of Riverstone WRRF discharge

Monitoring sites	Nutrient analytes					Physico-chemical analytes						
	Ammonia nitrogen	Oxidised nitrogen	Total nitrogen	Filterable total phosphorus	Total phosphorus	Conductivity	Dissolved oxygen	Dissolved oxygen saturation	pH	Temperature	Turbidity
Upstream tributary (NS082)	→	→	→	→	→	→	→	→	→	→	→
Downstream tributary (NS081)	→	→	→	→	→	→	→	↗	→	→	→

↗	Upward trend	↘	Downward trend	→	no trend, p>0.05

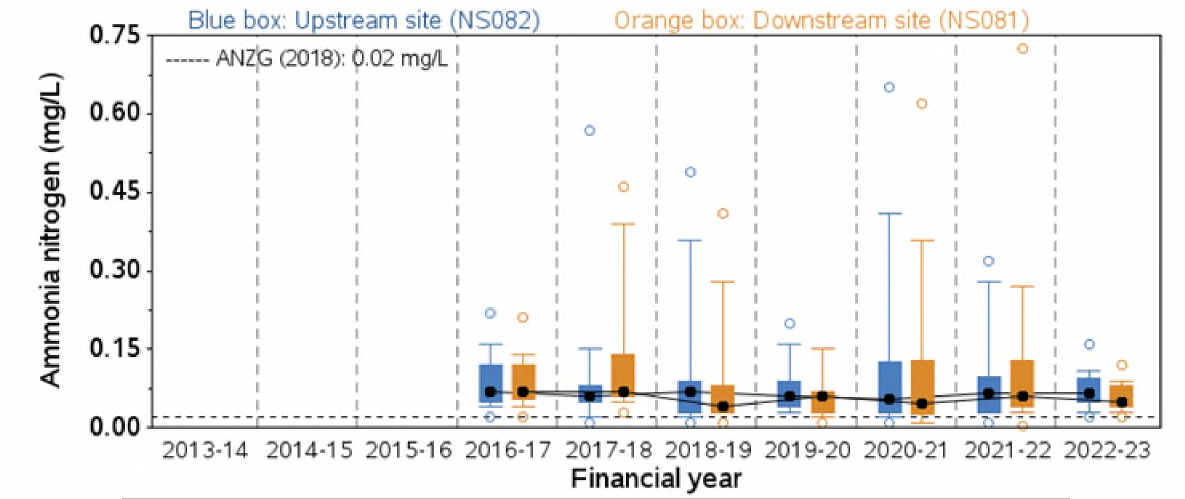
(green)	2022-23 Median value within the guideline limit	(white)	No guideline applicable
(yellow)	2022-23 Median value outside the guideline limit	(grey)	Insufficient data

Riverstone WRRF discharges into Eastern Creek that joins with South Creek before draining to Hawkesbury River at Windsor. The upstream catchment includes a mix of agricultural land uses, rural and residential areas that has grown in recent years.

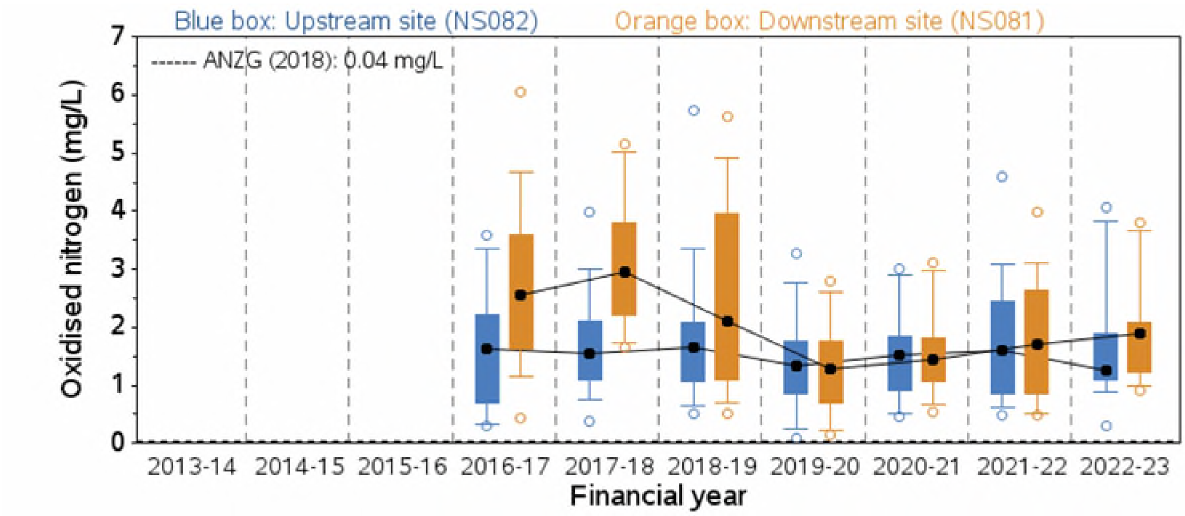
Statistical analysis confirmed that, nutrient concentrations were steady during 2022-23 at both upstream and downstream Eastern Creek sites. Dissolved oxygen saturations significantly increased at the downstream site (NS081) in 2022-23. No other significant trend was found in any of the nutrients or other water quality analytes at this site or the upstream site (NS082).

Concentrations of key nitrogen analytes (oxidised nitrogen and total nitrogen) at the downstream Eastern Creek site were notably higher in comparison to upstream concentrations indicating a possible impact from Riverstone WRRF. Statistical analysis will be included in SWAM reports from 2023-24 to further validate the trend.

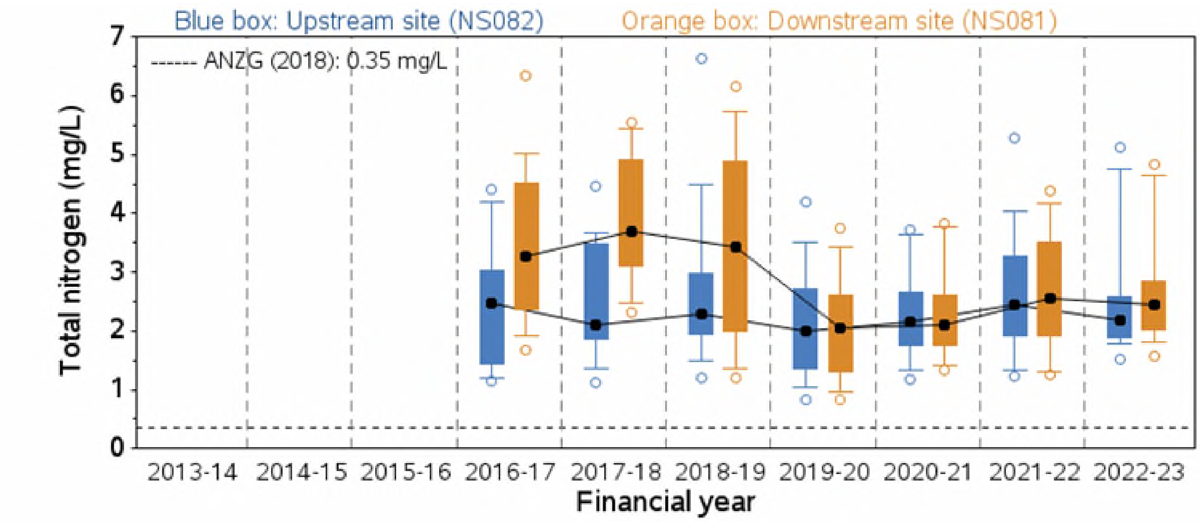
In the 2022-23 period, the median nutrient concentrations of all four analytes (ammonia nitrogen, oxidised nitrogen, total nitrogen and total phosphorus) exceeded the respective ANZG (2018) guidelines at both upstream and downstream sites.



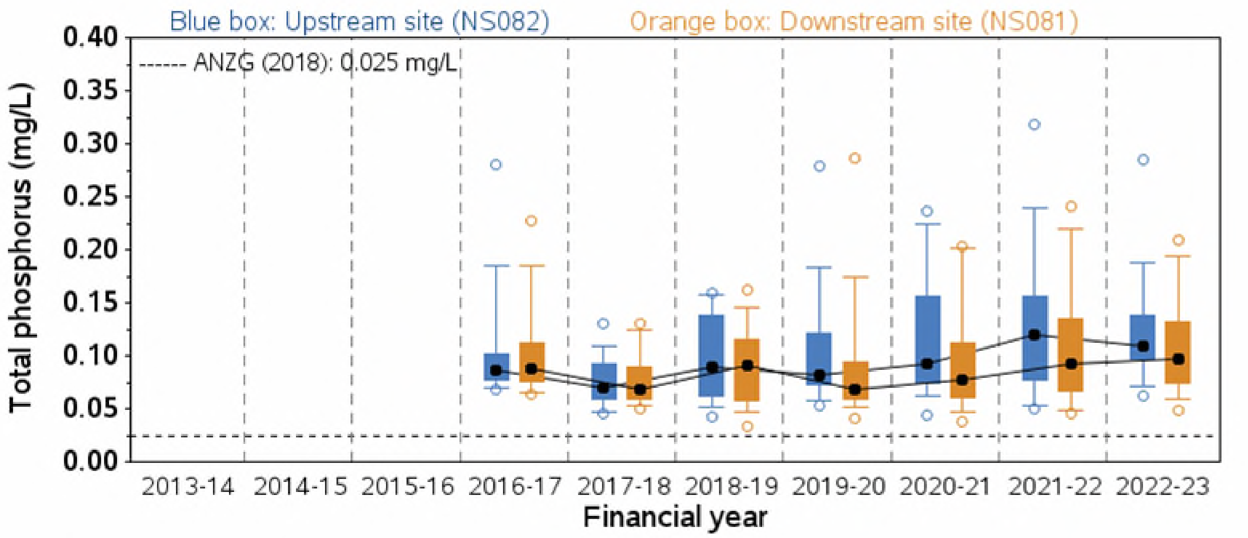
site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
NS082	1	0.63	0.4305	NS081	1	1.79	0.1831



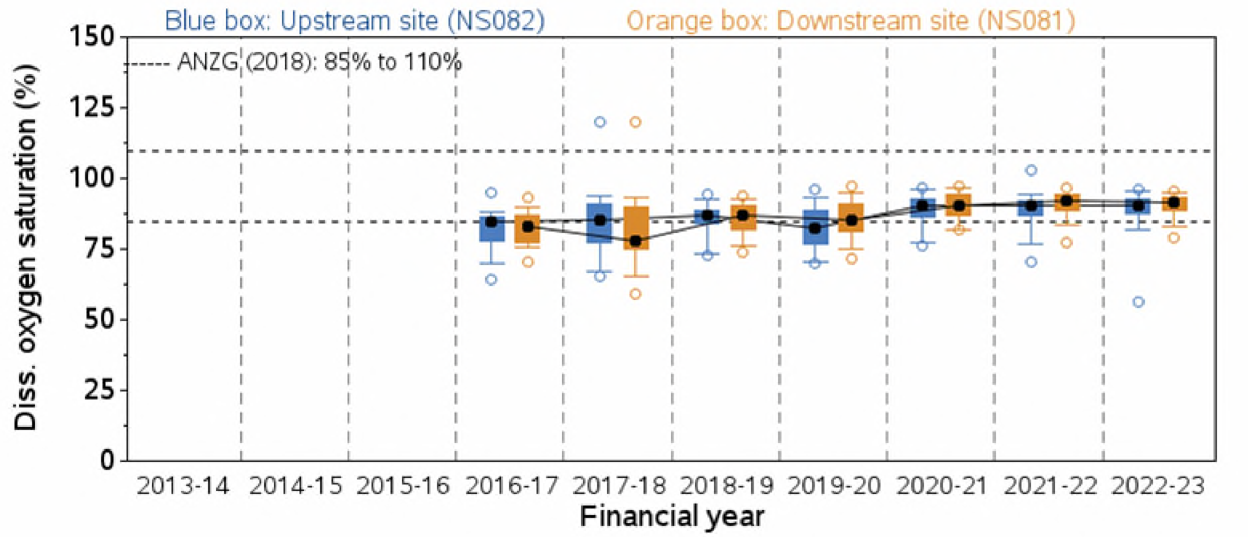
site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
NS082	1	0	0.9804	NS081	1	0.83	0.3637



site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
NS082	1	0.14	0.7061	NS081	1	0.74	0.3926



site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
NS082	1	1.6	0.2083	NS081	1	0.89	0.3465



site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
NS082	1	1.43	0.2349	NS081	1	4.15	0.0439

Figure 4-42 Nutrients and physico-chemical water quality exception plots, upstream and downstream of Riverstone WRRF

Ecosystem Receptor – Phytoplankton

Table 4-34 Gate 1 Analysis outcome summary – phytoplankton as chlorophyll-a, biovolume and species counts, upstream and downstream of Riverstone WRRF discharge

Monitoring sites	Phytoplankton analytes			
	Chlorophyll-a	Total phytoplankton biovolume	Blue-green biovolume	Toxic blue-green count
Upstream tributary (NS082)	→	→	→	→
Downstream tributary (NS081)	→			

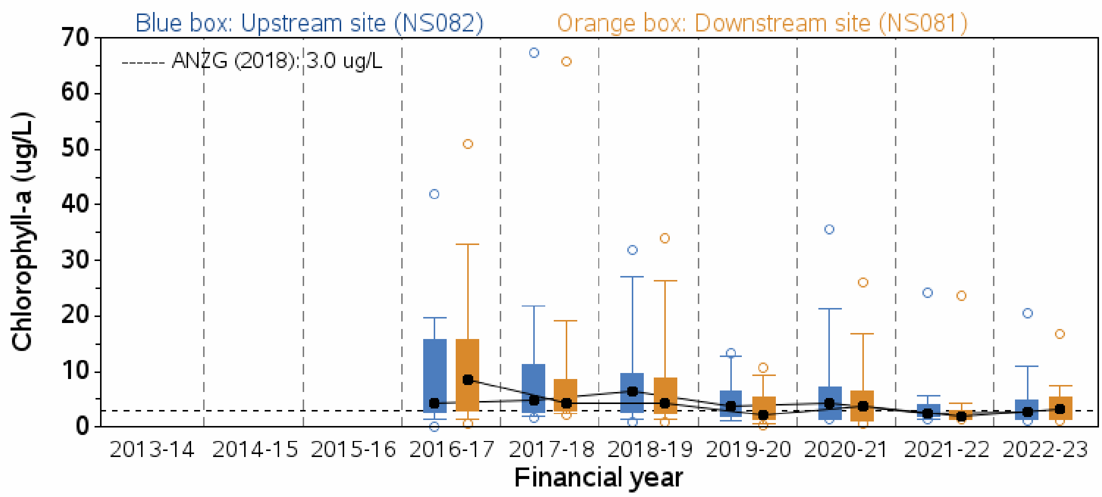
↗	Upward trend	↘	Downward trend	→	no trend, p>0.05

(green)	2022-23 Median value within the guideline limit	(white)	No guideline applicable
(yellow)	2022-23 Median value outside the guideline limit	(grey)	Insufficient data

In 2022-23, there were no significantly increasing or decreasing trends identified in any of the phytoplankton analytes at the upstream or downstream Eastern Creek sites.

In the 2022-23 period, the median chlorophyll-a concentration marginally exceeded the ANZG (2018) guideline at the downstream site (NS081).

Chlorophyll-a concentrations were generally low at these Eastern Creek sites with a low water retention time. Only three and two samples from the upstream and downstream site respectively qualified for species counts. No potentially toxic blue-green species were found in any of the samples and blue-green biovolume was always within the NHMRC (2008) Amber Alert level.



site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
NS082	1	1.18	0.2788	NS081	1	1.41	0.2383

Figure 4-43 Phytoplankton as chlorophyll-a, biovolume and species counts exception plots, upstream and downstream of Riverstone WRRF

Ecosystem Receptor – Macroinvertebrates

No stream health impacts (as indicated by macroinvertebrates) were identified for the waterway downstream of where the Riverstone WRRF discharges (Volume 2 Appendix A-10).

4.1.11 Rouse Hill WRRF

- All parameters (concentrations and loads) monitored in the discharge from Rouse Hill WRRF were within EPL limits. There were increasing trends in ammonia nitrogen and total nitrogen concentrations in the discharge.
- Nutrient concentrations were steady at both the upstream and downstream sites on Second Ponds Creek.
- Chlorophyll-a decreased significantly at the downstream Second Ponds Creek site in 2022-23. Chlorophyll-a concentrations were low at the upstream and downstream Second Pond Creek site. As such, only two samples were analysed for phytoplankton biovolume and species counts for the upstream site. No Blue-green species was found in these samples.
- No stream health impacts (as indicated by macroinvertebrates) were identified for the waterways downstream of where Rouse Hill WRRF discharges.

Pressure – Wastewater discharge

Table 4-35 Gate 1 Analysis outcome summary – Rouse Hill WRRF

Analytes / Rouse Hill WRRF	Nutrients			Conventional analytes						Trace Metals			
	Ammonia Nitrogen	Total Nitrogen	Total Phosphorus	Biochemical Oxygen Demand	Total Residual Chlorine	Faecal Coliforms	Oil and Grease	Total Suspended Solids	EC_{50} Toxicity	Aluminium	Copper	Iron	Zinc
Concentration	↗	↗	→	→	→	→		→	→	→	→	→	→
Load													

↗	Upward trend	↘	Downward trend	→	no trend, p>0.05

(green)	Within the Environment Protection Licence limit
(yellow)	Environment Protection Licence limit exceedance
(grey)	Analytes not required in the EPL or no concentration limit

All concentration and load limits in the discharge from Rouse Hill WRRF were within the EPL limits during the 2022-23 period.

Statistical analysis identified significantly increasing trends in ammonia nitrogen and total nitrogen during 2022-23 compared to the previous nine years.

The increasing trends in ammonia nitrogen and total nitrogen can be linked to population growth within the catchment and a reduction in biological processes due to an Intermittently Decanted Aerated Lagoon (IDAL) being offline for maintenance during the 2022-23 reporting period.

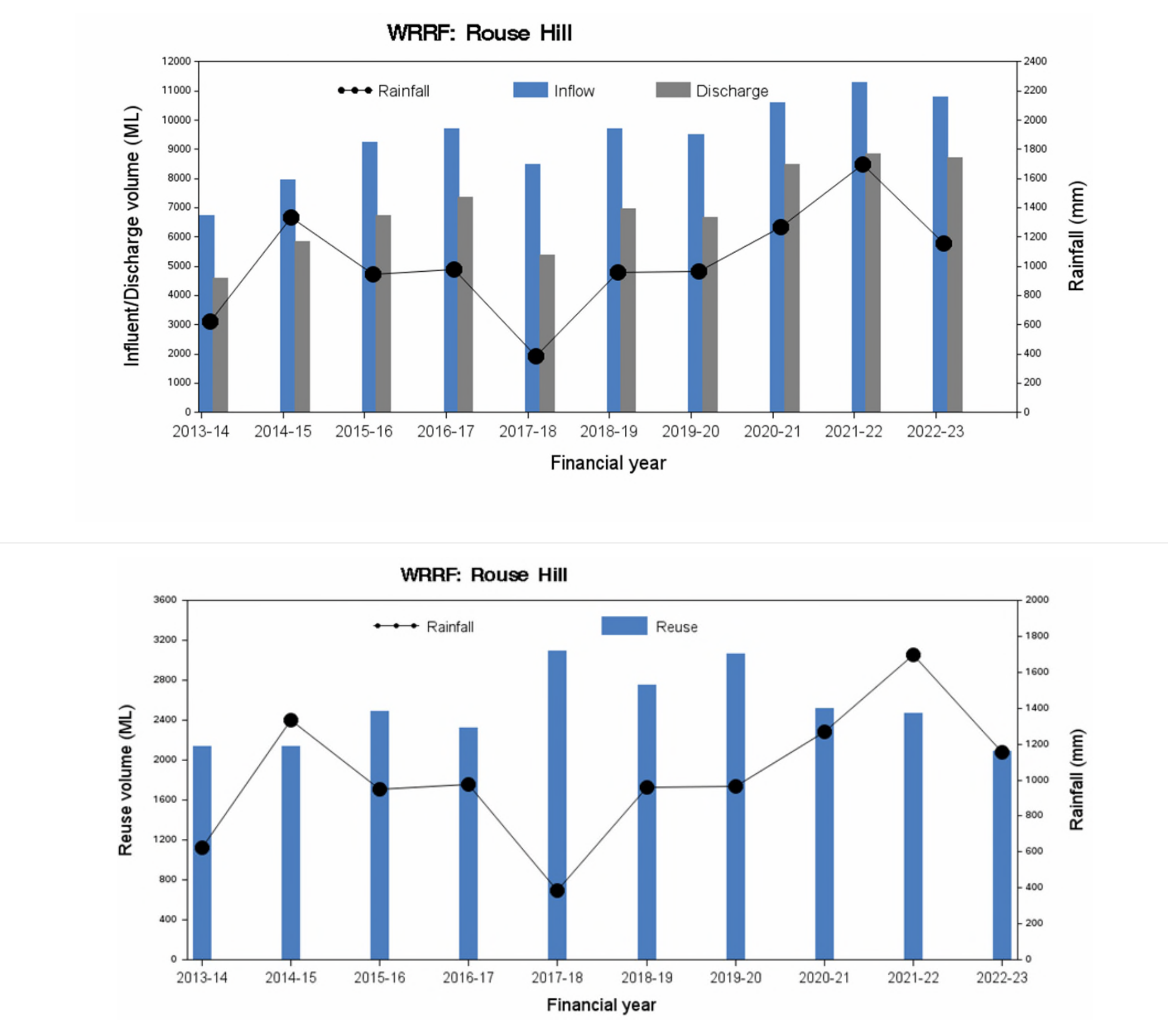
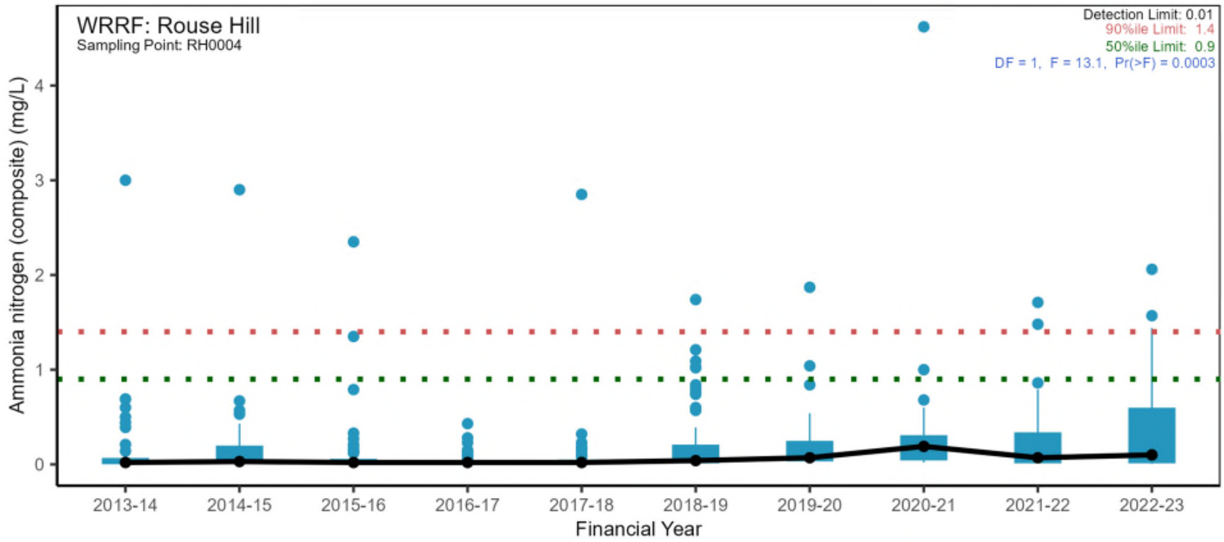


Figure 4-44 Rouse Hill WRRF inflow, discharge and reuse volume with catchment rainfall plots



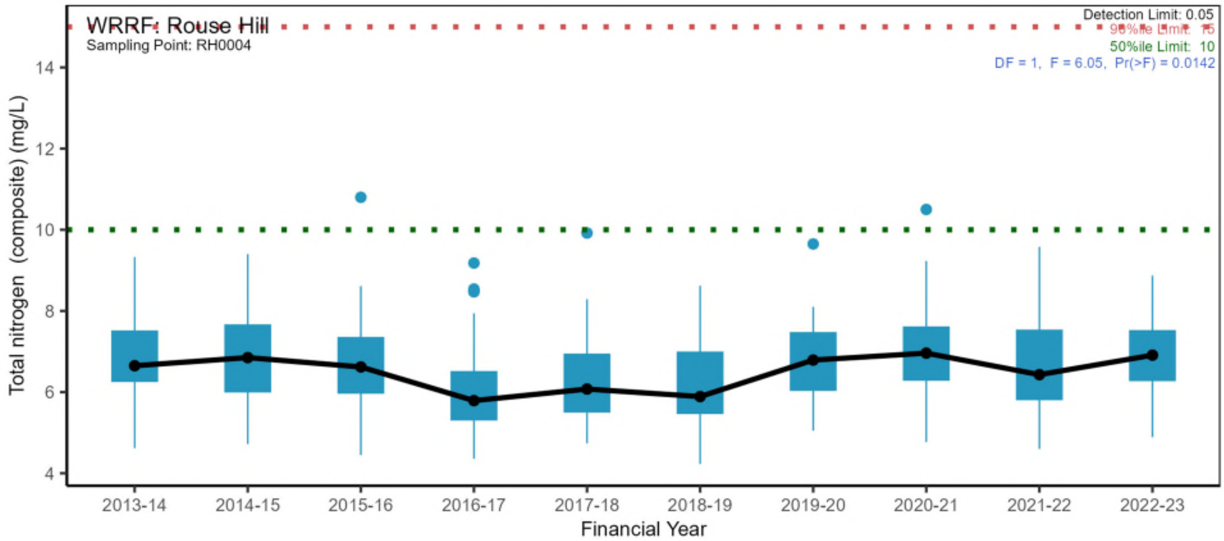


Figure 4-45 Rouse Hill WRRF discharge quality and toxicity exception plots

Stressor – Water quality

Table 4-36 Gate 1 Analysis outcome summary – water quality upstream and downstream of Rouse Hill WRRF discharges

Monitoring sites	Nutrient analytes					Physico-chemical analytes					
	Ammonia nitrogen	Oxidised nitrogen	Total nitrogen	Filterable total phosphorus	Total phosphorus	Conductivity	Dissolved oxygen	Dissolved oxygen saturation	pH	Temperature	Turbidity
Upstream tributary (NC53)	→	→	→	→	→	→	→	→	→	→	→
Downstream tributary (NC516)	→	→	→	→	→	→	↗	↗	→	→	→

↗	Upward trend	↘	Downward trend	→	no trend, p>0.05

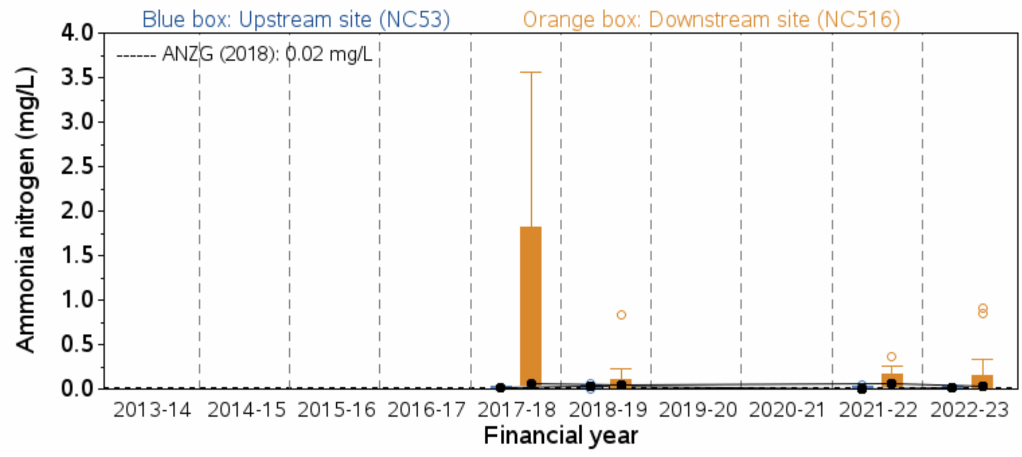
(green)	2022-23 Median value within the guideline limit	(white)	No guideline applicable
(yellow)	2022-23 Median value outside the guideline limit	(grey)	Insufficient data

Rouse Hill WRRF discharges into Second Ponds Creek which is an upstream tributary of Cattai Creek draining to the Hawkesbury River. The upstream catchment includes a mix of land uses including developed and fast growing housings areas.

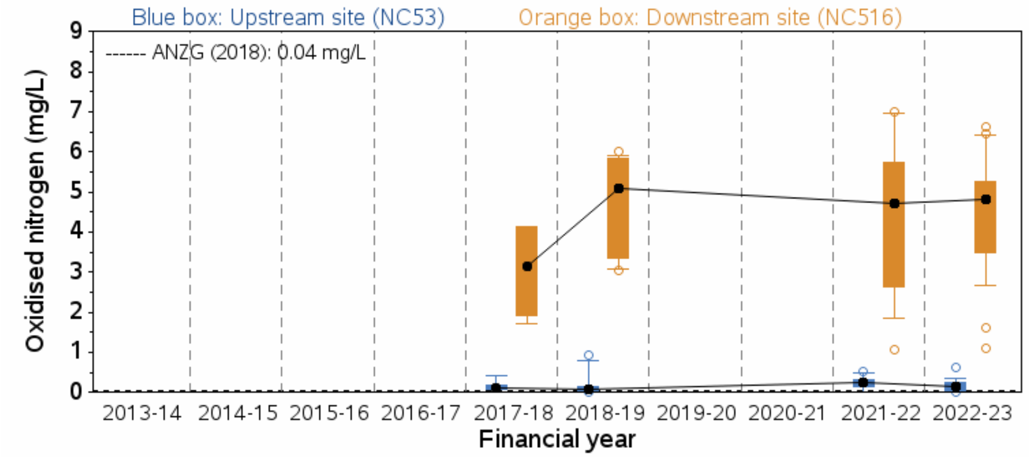
In 2022-23, none of the nutrients or water quality analytes exhibited a significant trend for the upstream site (NC53). Dissolved oxygen and dissolved oxygen saturation increased significantly at the downstream site (NC516).

Concentrations of ammonia nitrogen, oxidised nitrogen and total nitrogen at the downstream Second Ponds Creek site were notably higher in comparison to upstream concentrations indicating a localised impact from Rouse Hill WRRF. Statistical analysis will be included in SWAM reports from 2023-24 to further validate the trend.

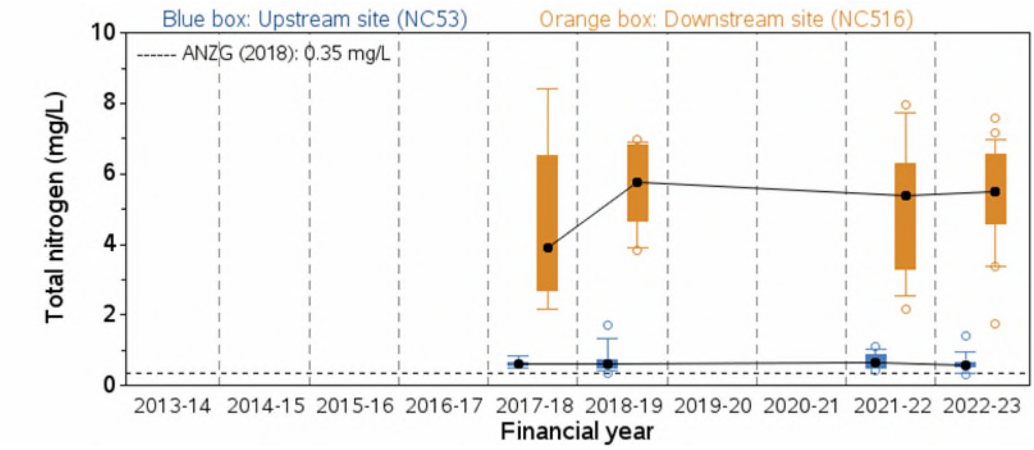
In the 2022-23 period, the median oxidised nitrogen, total nitrogen, total phosphorus, dissolved oxygen saturation and turbidity levels levels/ concentrations were exceeded/outside the respective ANZG (2018) guidelines at upstream site (NC53). At the downstream site (NC516), median nutrient concentrations for all four analytes exceeded the respective guidelines and median turbidity was below the ANZG (2018) lower limit guideline.



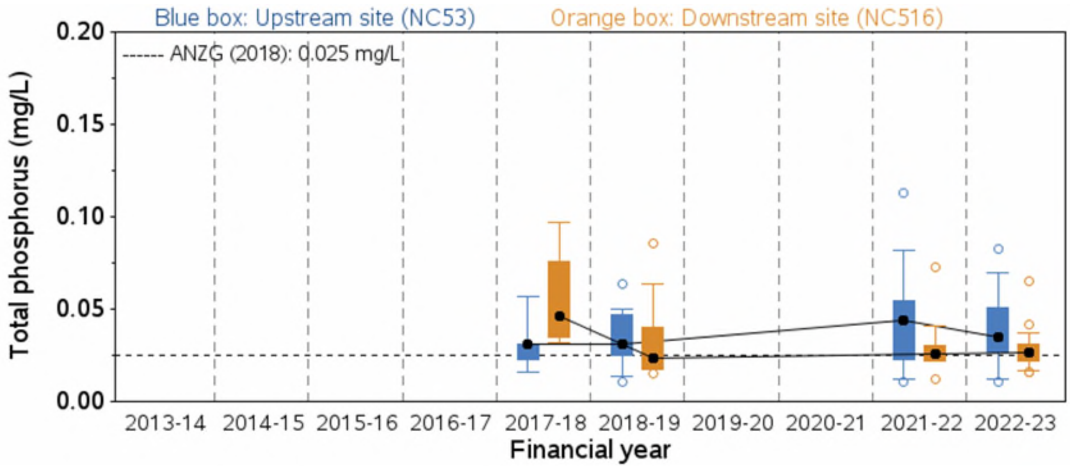
site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
NC53	1	2.21	0.1426	NC516	1	0.41	0.5259



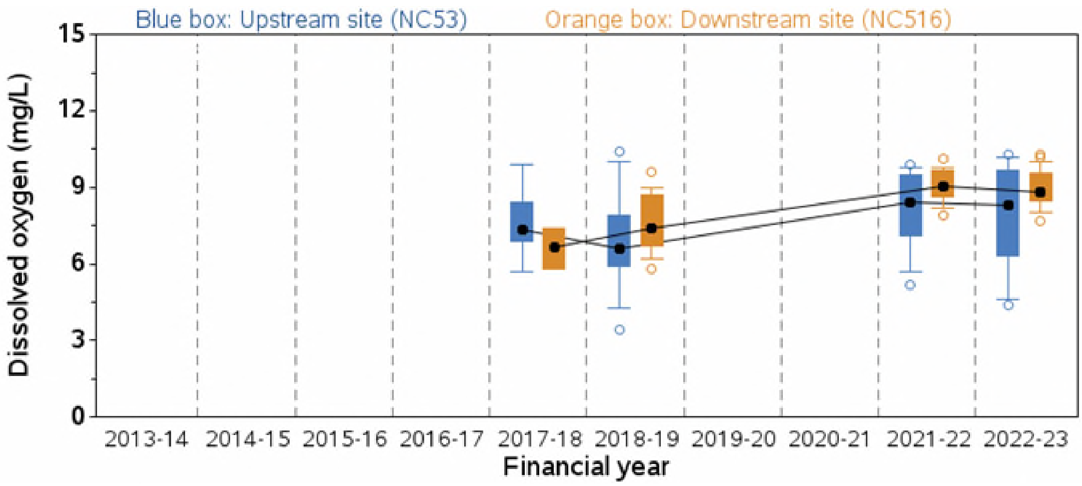
site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
NC53	1	0.27	0.6065	NC516	1	0.16	0.6918



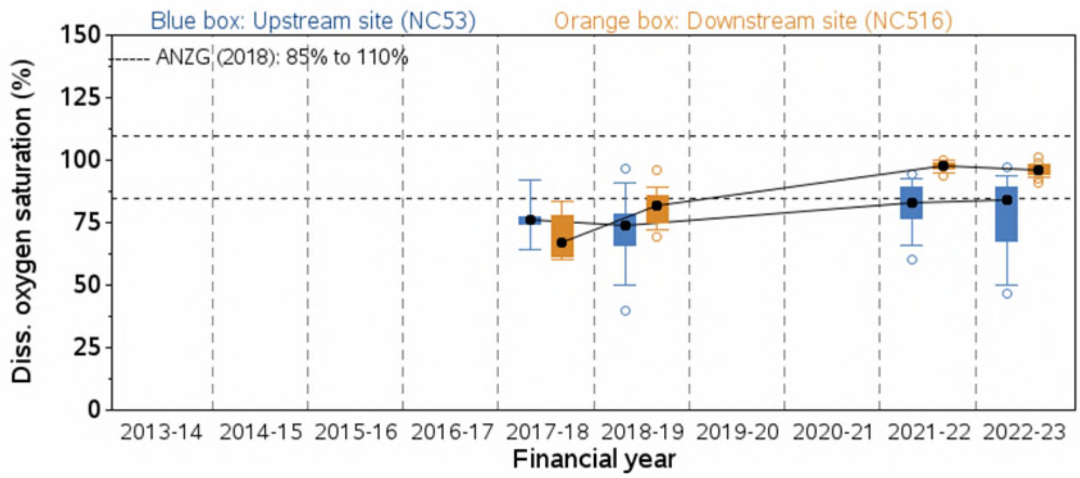
site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
NC53	1	1.06	0.3084	NC516	1	0.19	0.6615



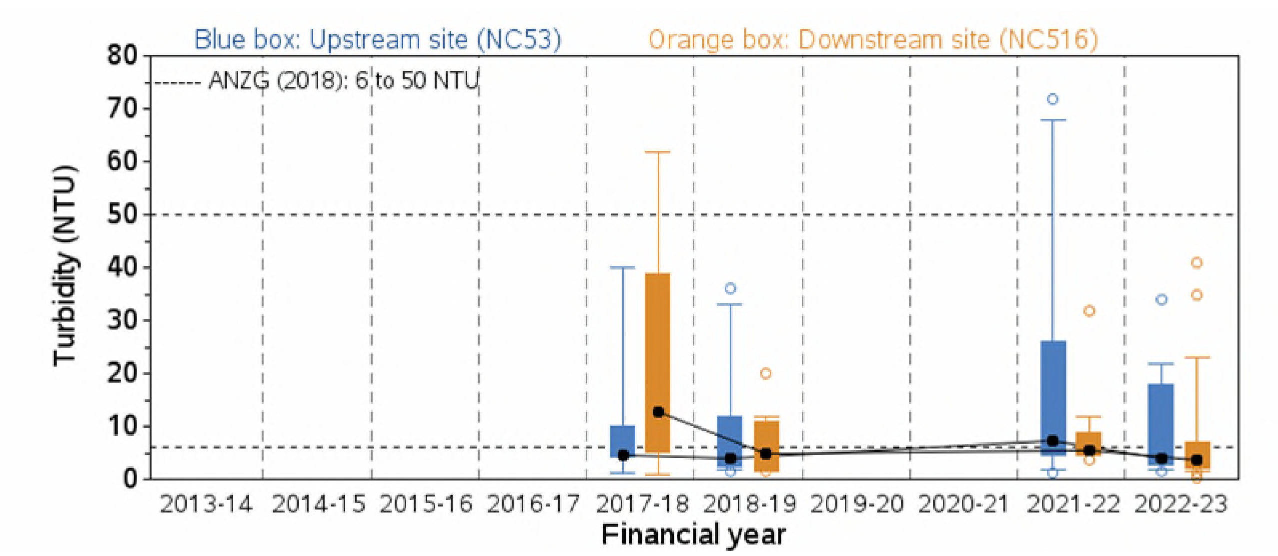
site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
NC53	1	0.07	0.7965	NC516	1	1.68	0.2012



site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
NC53	1	0.85	0.3595	NC516	1	6.68	0.0125



site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
NC53	1	0.4	0.5295	NC516	1	9.76	0.0029



site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
NC53	1	0.9	0.3468	NC516	1	0.19	0.6681

Figure 4-46 Nutrients and physico-chemical water quality exception plots, upstream and downstream of Rouse Hill WRRF

Ecosystem Receptor – Phytoplankton

Table 4-37 Gate 1 Analysis outcome summary – phytoplankton as chlorophyll-a, biovolume and species counts, upstream and downstream of Rouse Hill WRRF discharge

Monitoring sites	Phytoplankton analytes: Chlorophyll-a	Total phytoplankton biovolume	Blue-green biovolume	Toxic blue-green count
Upstream tributary (NC53)	→			
Downstream tributary (NC516)	↘			

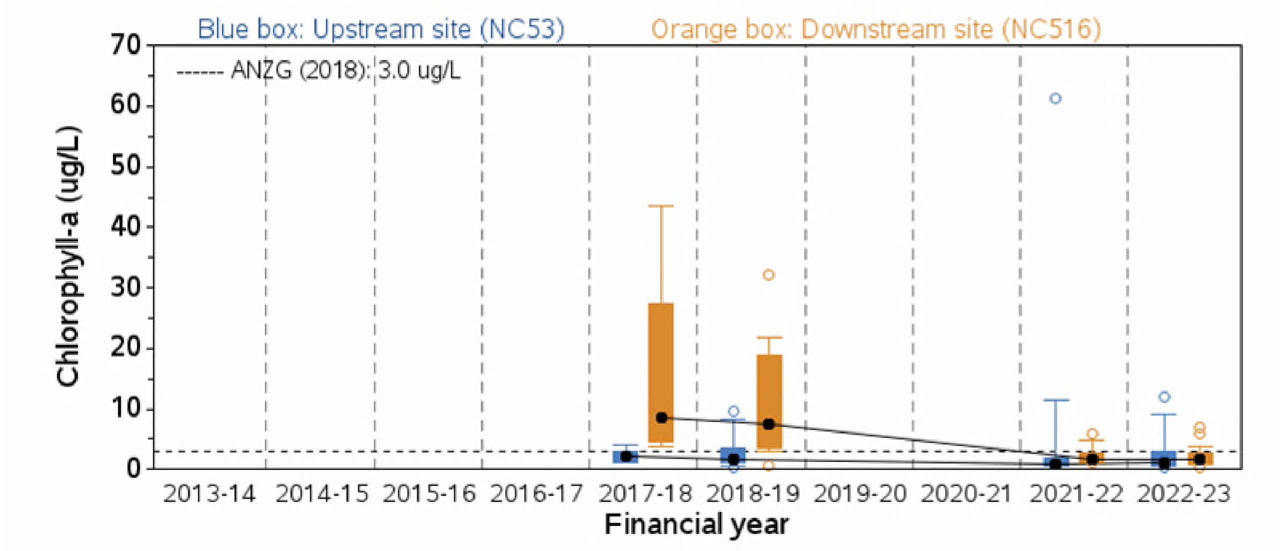
↗	Upward trend	↘	Downward trend	→	no trend, p>0.05

	2022-23 Median value within the guideline limit		No guideline applicable
	2022-23 Median value outside the guideline limit		Insufficient data

Chlorophyll-a decreased significantly at the downstream Second Ponds Creek site in 2022-23. There were no significantly increasing/decreasing trends identified in any of the phytoplankton analytes at upstream or downstream Second Pond Creek sites.

In the 2022-23 period, the median chlorophyll-*a* concentrations were within the ANZG (2018) guideline limit at both upstream and downstream site.

Two of the 17 samples collected from the upstream site (NC53) exceeded the chlorophyll-a concentration of 7 µg/L in 2022-23, which triggered phytoplankton analysis. None of the samples had any potentially toxic blue-green taxa. Chlorophyll-a concentrations were low for the downstream site (NC516) in 2022-23, where none of the samples were qualified for phytoplankton biovolume measurements and species counts.



site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
NC53	1	0.28	0.5999	NC516	1	6.27	0.0154

Figure 4-47 Phytoplankton as chlorophyll-a, biovolume and species counts exception plots, upstream and downstream of Rouse Hill WRRF

Ecosystem Receptor – Macroinvertebrates

No stream health impacts (as indicated by macroinvertebrates) were identified for the waterway downstream of where Rouse Hill WRRF discharges (Volume 2 Appendix A-11).

4.1.12 Castle Hill WRRF

- All parameters (concentrations and loads) monitored in the discharge from Castle Hill WRRF were within EPL limits. There were increasing trends in ammonia nitrogen, aluminium, and zinc concentrations, and decreasing trends in total nitrogen and total phosphorus concentrations in the discharge.
- Nutrient concentrations were steady at both the upstream and downstream sites on Cattai Creek during 2022-23.
- Chlorophyll-a concentrations were low at the upstream and downstream Cattai Creek site. Only one sample was analysed for phytoplankton biovolume and species counts. No toxic species were found.
- Stream health (as indicated by macroinvertebrates) suggest the downstream community structure in Cattai Creek was altered by wastewater discharge from Castle Hill WRRF in 2022-23.

Pressure – Wastewater discharge

Table 4-38 Gate 1 Analysis outcome summary – Castle Hill WRRF

Analytes / Castle Hill WRRF	Nutrients			Conventional analytes					Trace Metals					Other	
	Ammonia Nitrogen	Total Nitrogen	Total Phosphorus	Biochemical Oxygen Demand	Faecal Coliforms	Total Suspended Solids	Oil and Grease	EC_{50} Toxicity	Aluminium	Cadmium	Copper	Iron	Zinc	Diazinon	Hydrogen sulfide (un-ionised)
Concentration	↗	↘	↘	→	→	→		→	↗	→	→	→	↗	→	→
Load															

↗	Upward trend	↘	Downward trend	→	no trend, p>0.05

	Within the Environment Protection Licence limit
	Environment Protection Licence limit exceedance
	Analytes not required in the EPL or no concentration limit

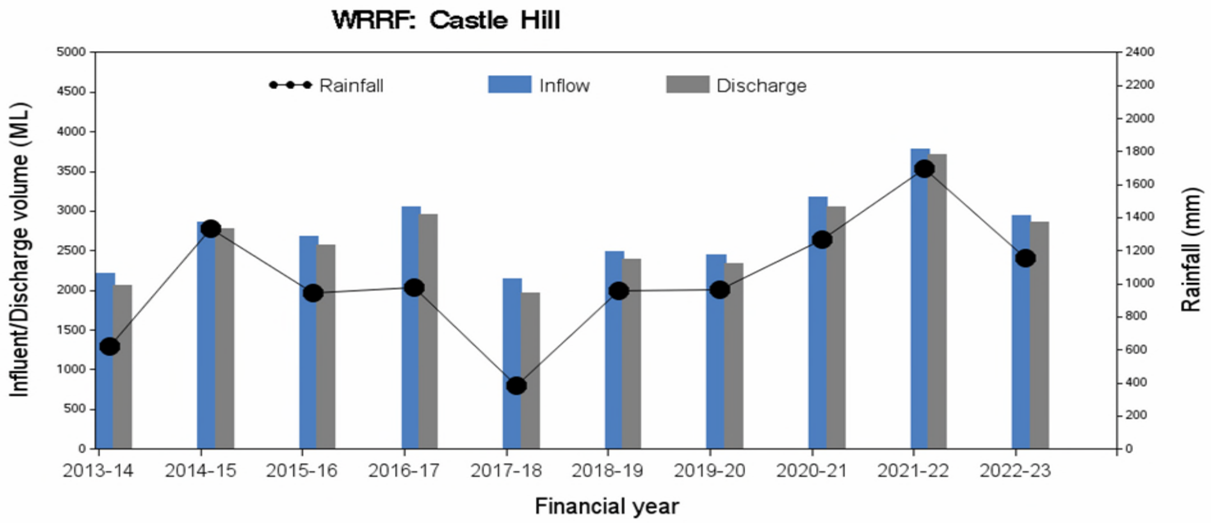
All concentration and load limits in the discharge from Castle Hill WRRF were within the EPL limits during the 2022-23 period.

Statistical analysis identified significantly increasing trends in ammonia nitrogen, aluminium, and zinc concentrations during 2022-23 compared to the previous nine years. Significantly decreasing trends were observed in total nitrogen and total phosphorus concentrations during the reporting period.

The ammonia nitrogen increasing trend can be linked to process issues at the facility during the 2022-23 reporting period.

The increasing trend in aluminium can be linked to the underperformance of tertiary filters requiring major periodic maintenance, leading to a reduced processing capability of aluminium. Two of the three filters were overhauled during the latter stages of the 2022-23 reporting period to improve filter performance. The increasing trend can also be linked to operational requirements for aluminium dosing, as the low phosphorus led to reduced aluminium precipitation, causing elevated concentration of aluminium in the liquid stream.

The cause of the increasing trend in zinc has yet to be identified. Castle Hill WRRF is operating as per design. Metal removal is incidental at the facility as processes are not designed to remove zinc.



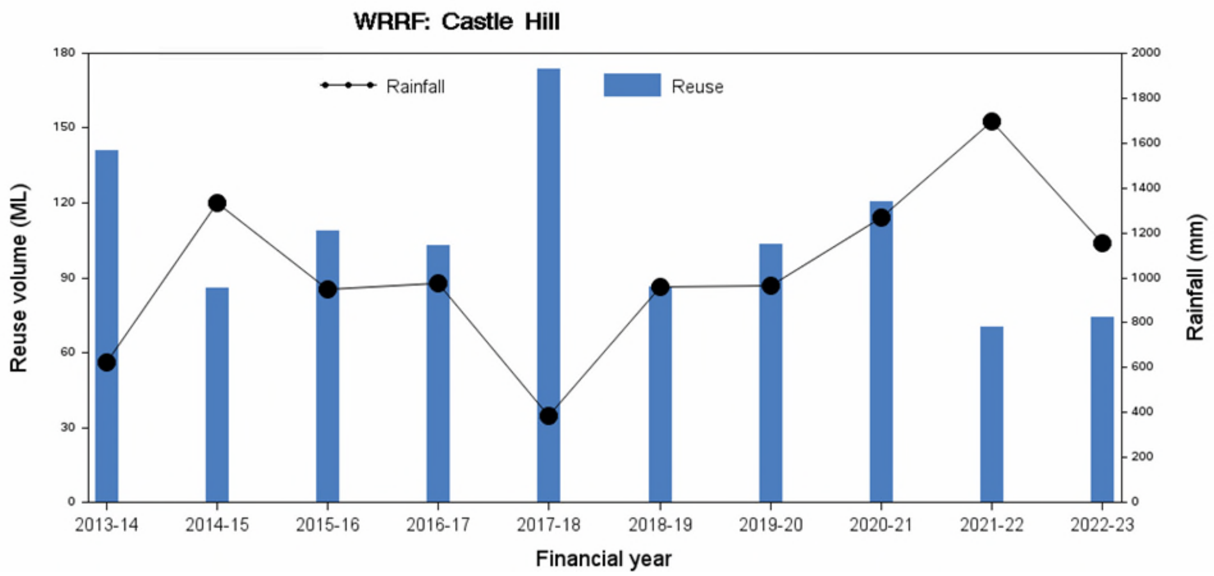
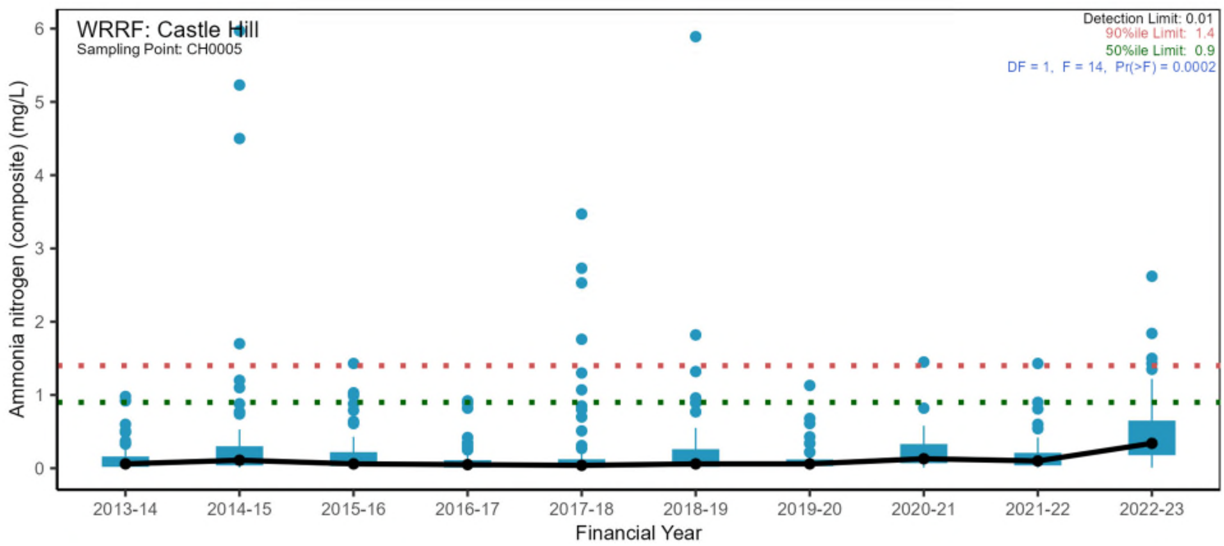
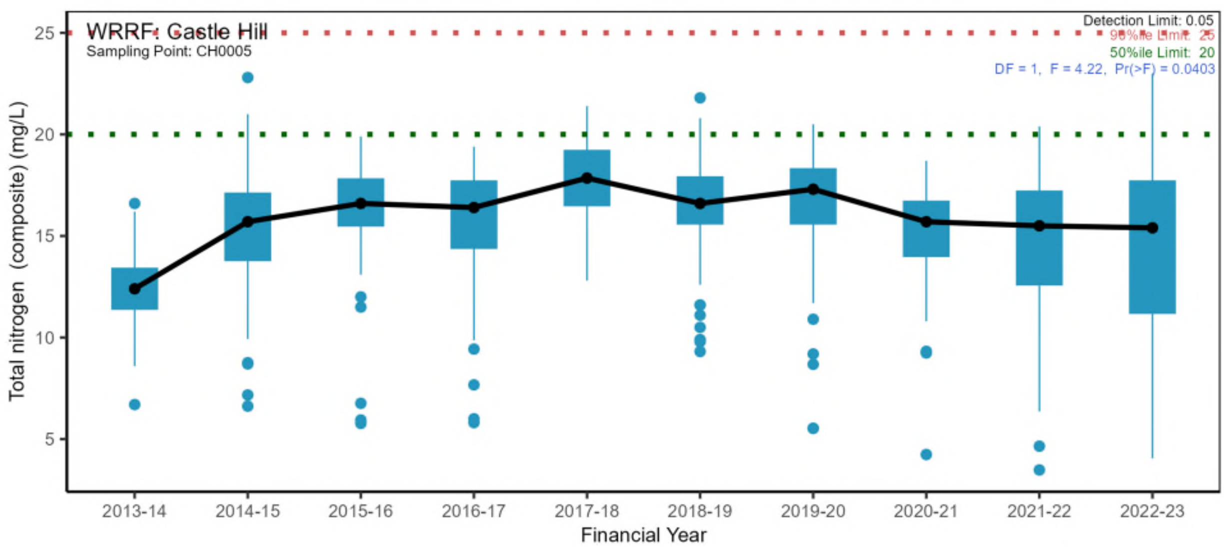
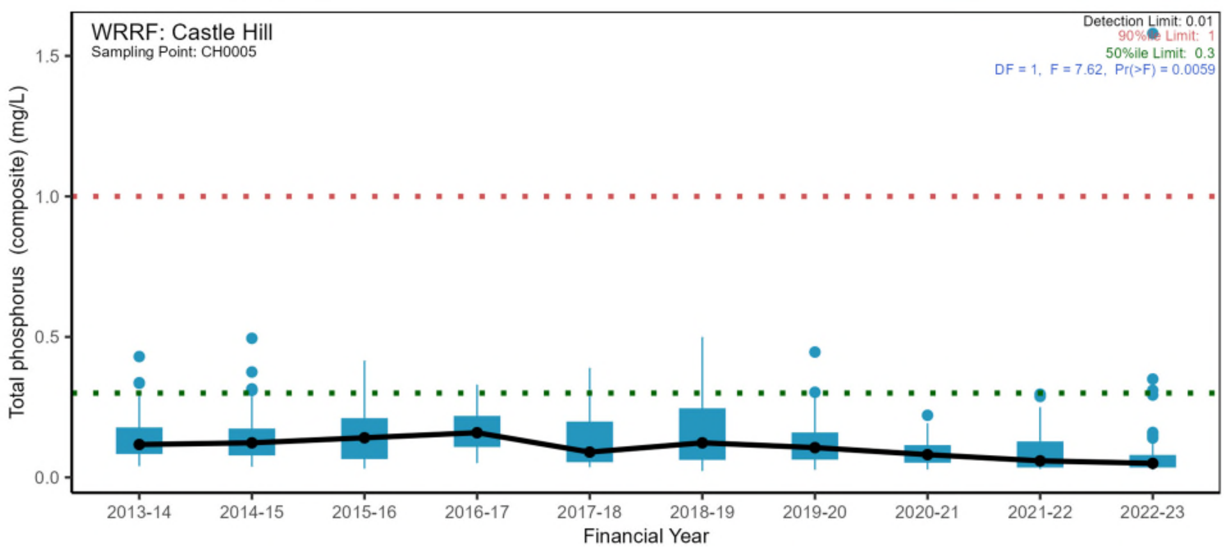


Figure 4-48 Castle Hill WRRF inflow, discharge and reuse volume with catchment rainfall plots


WRRF: Castle Hill
Sampling Point: CH0005
Detection Limit: 0.01
90%ile Limit: 1.4
50%ile Limit: 0.9
DF = 1, F = 14, Pr(>F) = 0.0002
Ammonia nitrogen (composite) (mg/L)
Financial Year


WRRF: Castle Hill
Sampling Point: CH0005
Detection Limit: 0.05
90%ile Limit: 25
50%ile Limit: 20
DF = 1, F = 4.22, Pr(>F) = 0.0403
Total nitrogen (composite) (mg/L)
Financial Year


WRRF: Castle Hill
Sampling Point: CH0005
Detection Limit: 0.01
90%ile Limit: 1
50%ile Limit: 0.3
DF = 1, F = 7.62, Pr(>F) = 0.0059
Total phosphorus (composite) (mg/L)
Financial Year

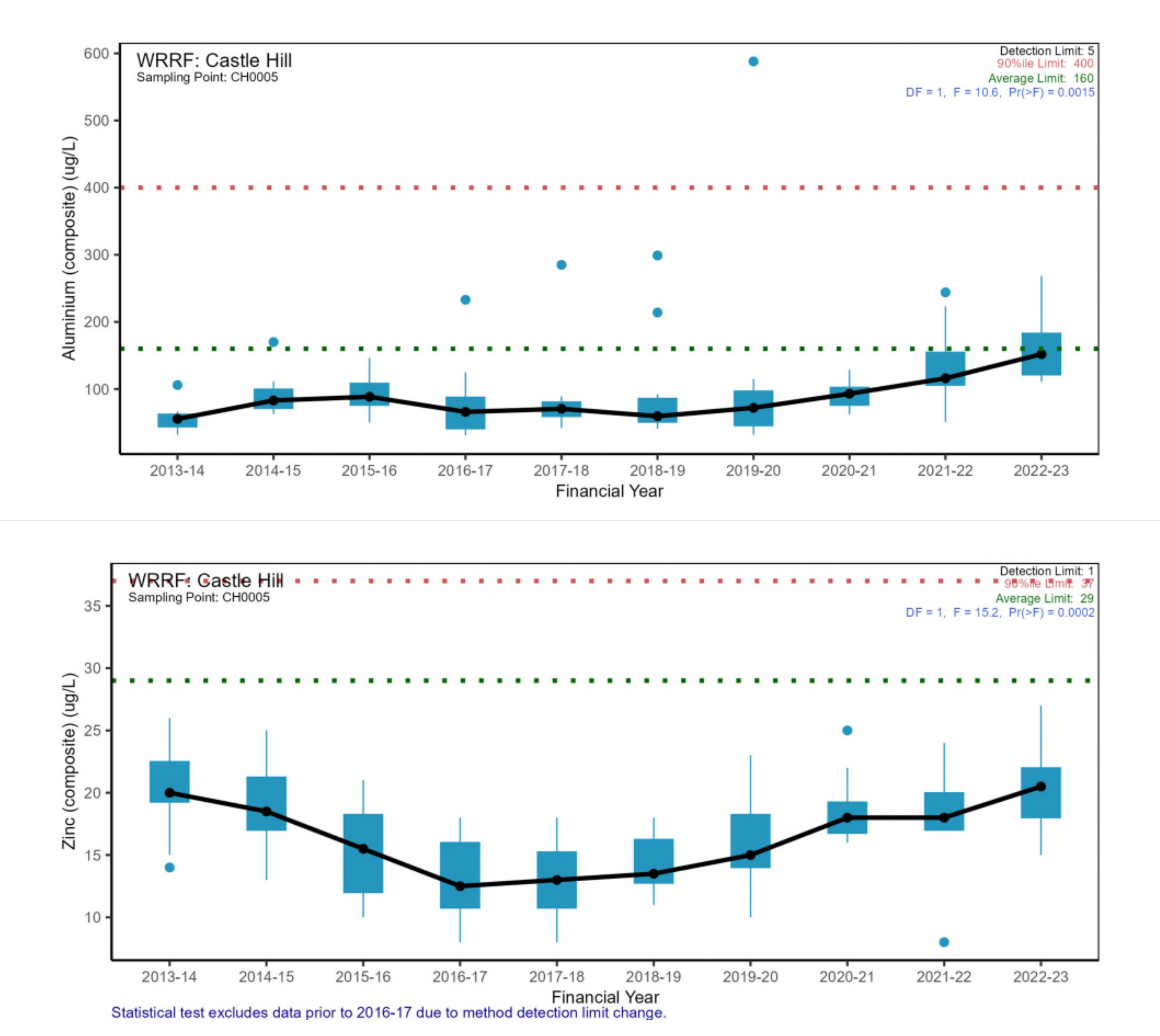


Figure 4-49 Castle Hill WRRF discharge quality and toxicity exception plots

Stressor – Water quality

Table 4-39 Gate 1 Analysis outcome summary – water quality upstream and downstream of Castle Hill WRRF discharge

Monitoring sites	Nutrient analytes					Physico-chemical analytes					
	Ammonia nitrogen	Oxidised nitrogen	Total nitrogen	Filterable total phosphorus	Total phosphorus	Conductivity	Dissolved oxygen	Dissolved oxygen saturation	pH	Temperature	Turbidity
Upstream tributary (NC8)	→	→	→	→	→	→	→	→	↘	→	→
Downstream tributary (NC75)	→	→	→	→	→	→	→	→	↘	→	→

↗	Upward trend	↘	Downward trend	→	no trend, p>0.05

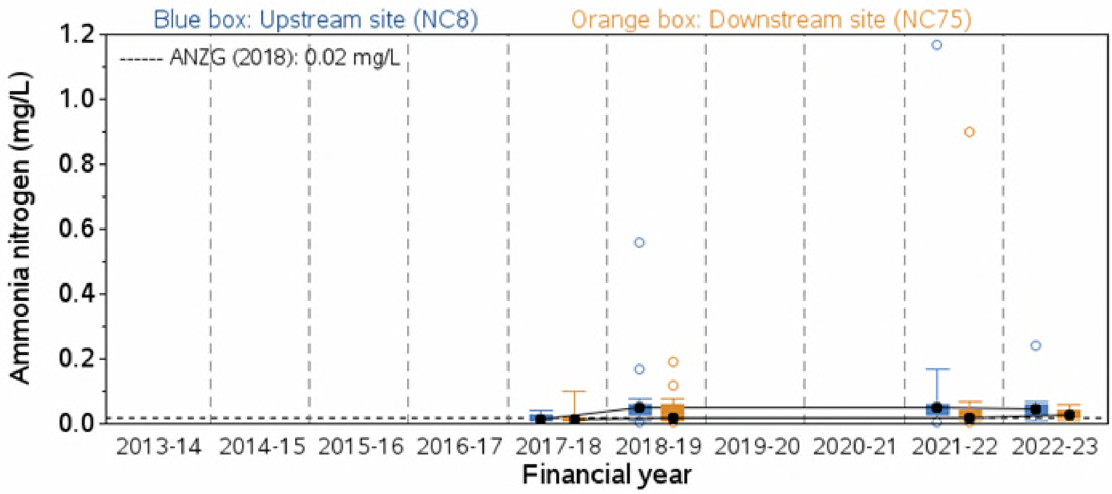
	2022-23 Median value within the guideline limit		No guideline applicable
	2022-23 Median value outside the guideline limit		Insufficient data

Castle Hill WRRF discharges into Castle Hill Creek that joins with the Cattai Creek about 500 m downstream. The upstream catchment control site on Cattai Creek (NC8) includes a mix of land uses with developed and rapidly growing housing areas.

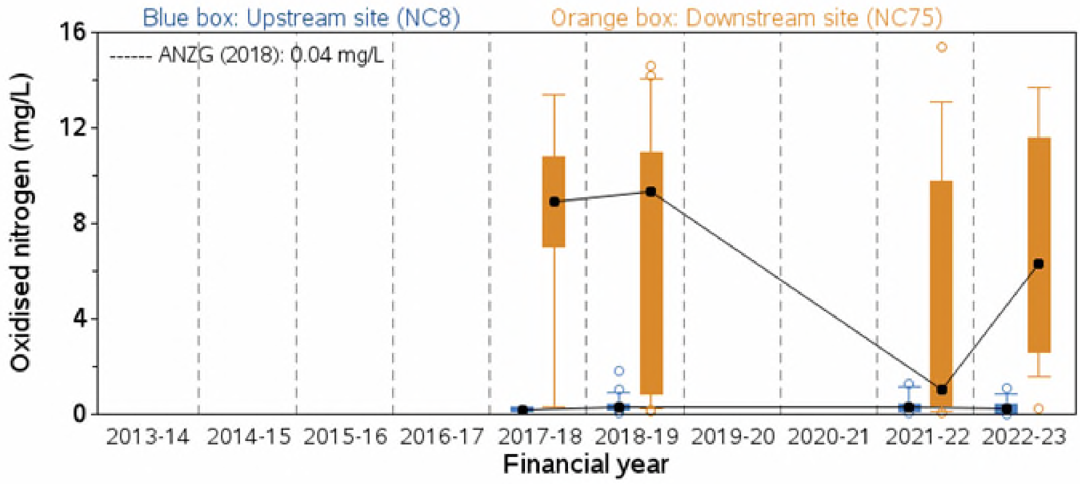
In 2022-23, pH showed a significantly decreasing trend at both upstream and downstream Cattai Creek sites. None of the other nutrients or water quality analytes showed a significant statistical trend.

Oxidised nitrogen and total nitrogen concentrations at the downstream Second Ponds Creek site were notably higher in comparison to upstream concentrations indicating an impact from Castle Hill WRRF. Statistical analysis will be included in SWAM reports from 2023-24 to further validate the trend.

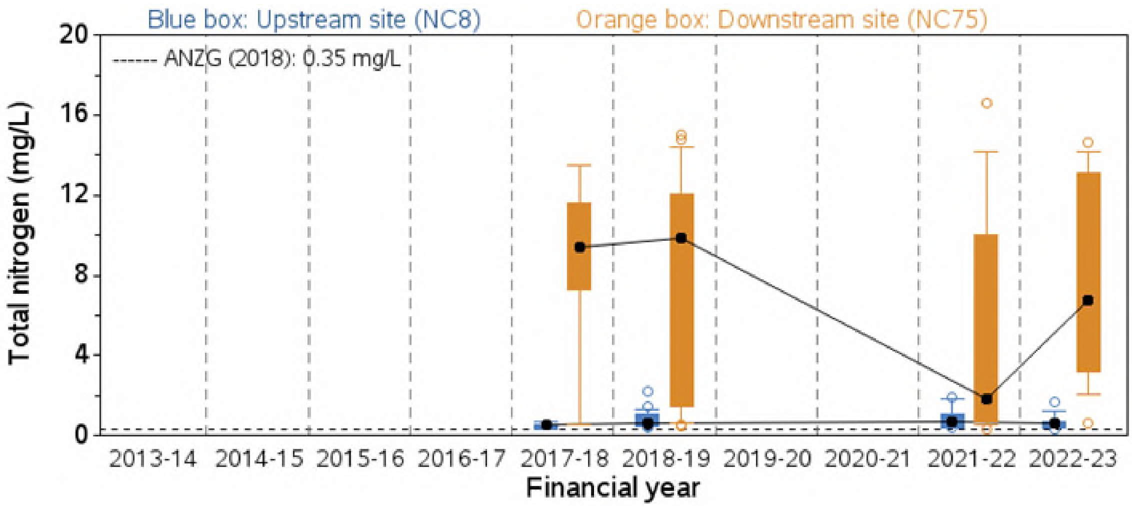
In the 2022-23 period, the median nutrient concentrations of all four analytes (ammonia nitrogen, oxidised nitrogen, total nitrogen and total phosphorus) exceeded the respective ANZG (2018) guidelines at both upstream and downstream site. Median turbidity was below the ANZG (2018) lower guideline limit at downstream site (NC75).



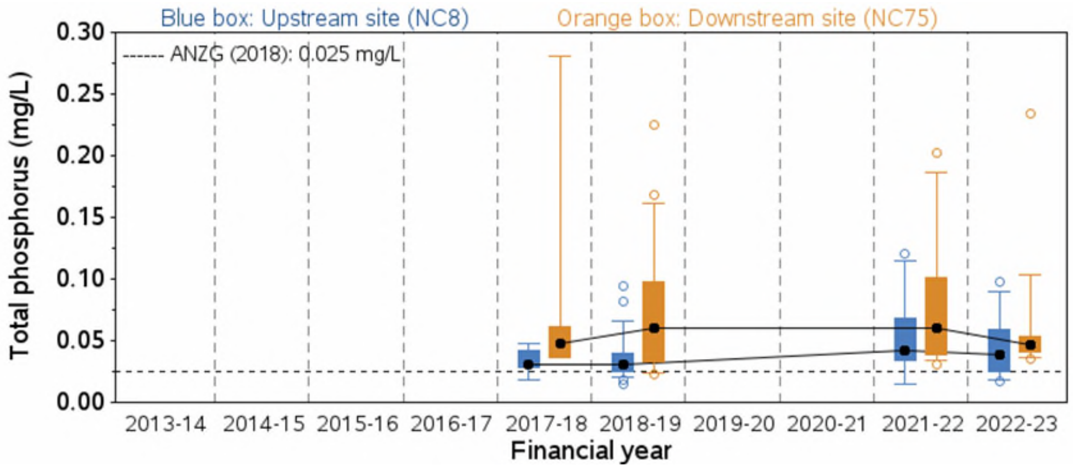
site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
NC8	1	0.43	0.5147	NC75	1	0.43	0.5137



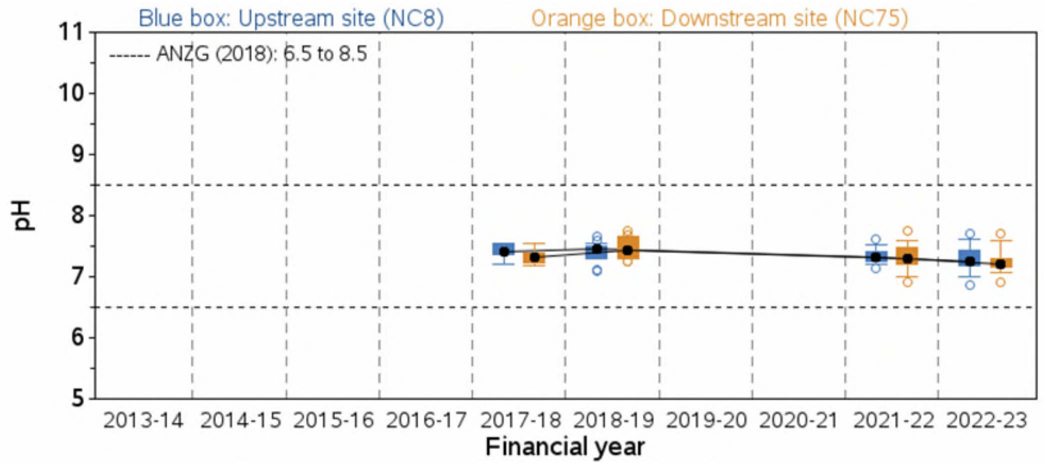
site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
NC8	1	0.59	0.4444	NC75	1	0.09	0.7616



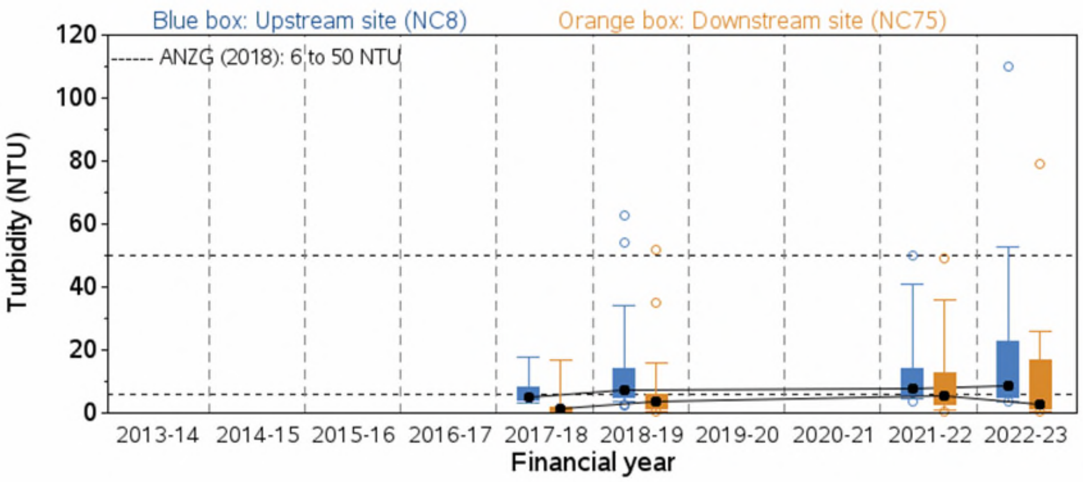
site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
NC8	1	0.78	0.3803	NC75	1	0.17	0.6783



site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
NC8	1	0.15	0.7038	NC75	1	1.09	0.2999



site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
NC8	1	5.3	0.0245	NC75	1	9.1	0.0037



site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
NC8	1	1.63	0.2062	NC75	1	0.47	0.4943

Figure 4-50 Nutrients and physico-chemical water quality exception plots, upstream and downstream of Castle Hill WRRF

Ecosystem Receptor – Phytoplankton

Table 4-40 Gate 1 Analysis outcome summary – phytoplankton as chlorophyll-a, biovolume and species counts, upstream and downstream of Castle Hill WRRF discharge

Monitoring sites	Phytoplankton analytes			
	Chlorophyll-a	Total phytoplankton biovolume	Blue-green biovolume	Toxic blue-green count
Upstream tributary (NC8)	→			
Downstream tributary (NC75)	→			

↗	Upward trend	↘	Downward trend	→	no trend, p>0.05

(green)	2022-23 Median value within the guideline limit		No guideline applicable
(yellow)	2022-23 Median value outside the guideline limit	(grey)	Insufficient data

In 2022-23, there was no significantly increasing/decreasing trends identified in any of the phytoplankton analytes at the upstream or downstream Cattai Creek sites.

The median chlorophyll-a concentrations were within the ANZG (2018) guideline limit at both the upstream and downstream sites.

Chlorophyll-a concentrations were low at both the upstream and downstream sites, with only one sample at the downstream site qualifying for analysis. No toxic species were found.

Ecosystem Receptor – Macroinvertebrates

The 2022-23 macroinvertebrate results suggested localised ecosystem impacts in Cattai Creek, downstream of Castle Hill WRRF. Multivariate testing outcomes suggest downstream community structure in Cattai Creek was altered by wastewater discharge from Castle Hill WRRF in 2022-23 (Volume 2 Appendix A-12).

Table 4-41 t-test of upstream-downstream SIGNAL-SG scores of 2022-23 samples from Cattai Creek near Castle Hill WRRF

Waterway	Method	Statistic	DF	P value
Cattai Creek	Welch Two Sample t-test	2.96	9.4	0.015

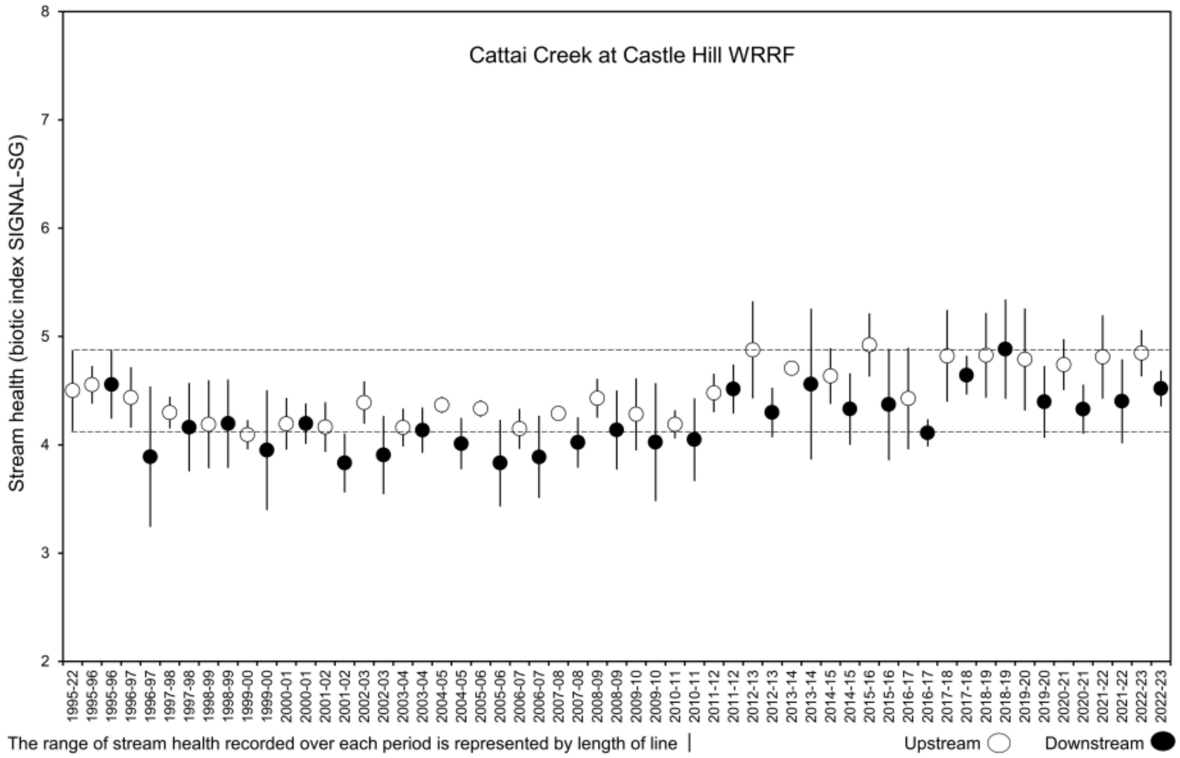


Figure 4-51 Stream health of Cattai Creek near Castle Hill WRRF

4.1.13 West Hornsby WRRF

- All parameters (concentrations and loads) monitored in the discharge from West Hornsby WRRF were within EPL limits. There were decreasing trends in total nitrogen and zinc concentrations in the discharge.
- Oxidised nitrogen, total nitrogen and total phosphorus concentrations increased significantly at the upstream control site on Waitara Creek. At the downstream site, concentrations of key nitrogen analytes (oxidised nitrogen and total nitrogen) and conductivity improved/decreased significantly.
- Chlorophyll-a concentrations were low at the upstream and downstream Waitara Creek sites. Only one sample from each site was analysed for phytoplankton biovolume and species counts. No toxic species were found.
- Stream health outcomes (as indicated by macroinvertebrates) suggest the downstream community structure in Waitara Creek was altered by wastewater discharge from West Hornsby WRRF in 2022-23

Pressure – Wastewater discharge

Table 4-42 Gate 1 Analysis outcome summary – West Hornsby WRRF

Analytes / West Hornsby WRRF	Nutrients			Conventional analytes				EC_{50}	Trace Metals				Other
	Ammonia Nitrogen	Total Nitrogen	Total Phosphorus	Biochemical Oxygen Demand	Faecal Coliforms	Oil and Grease	Total Suspended Solids		Aluminium	Copper	Iron	Zinc	Hydrogen sulfide (un-ionised)
Concentration	→	↘	→	→	→		→	→	→	→	→	↘	→
Load													

↗	Upward trend	↘	Downward trend	→	no trend, p>0.05

	Within the Environment Protection Licence limit
	Environment Protection Licence limit exceedance
	Analytes not required in the EPL or no concentration limit

All concentration and load limits in the discharge from West Hornsby WRRF were within the EPL limits during the 2022-23 period.

Statistical analysis identified significantly decreasing trends in total nitrogen and zinc concentrations during 2022-23 compared to the previous nine years.

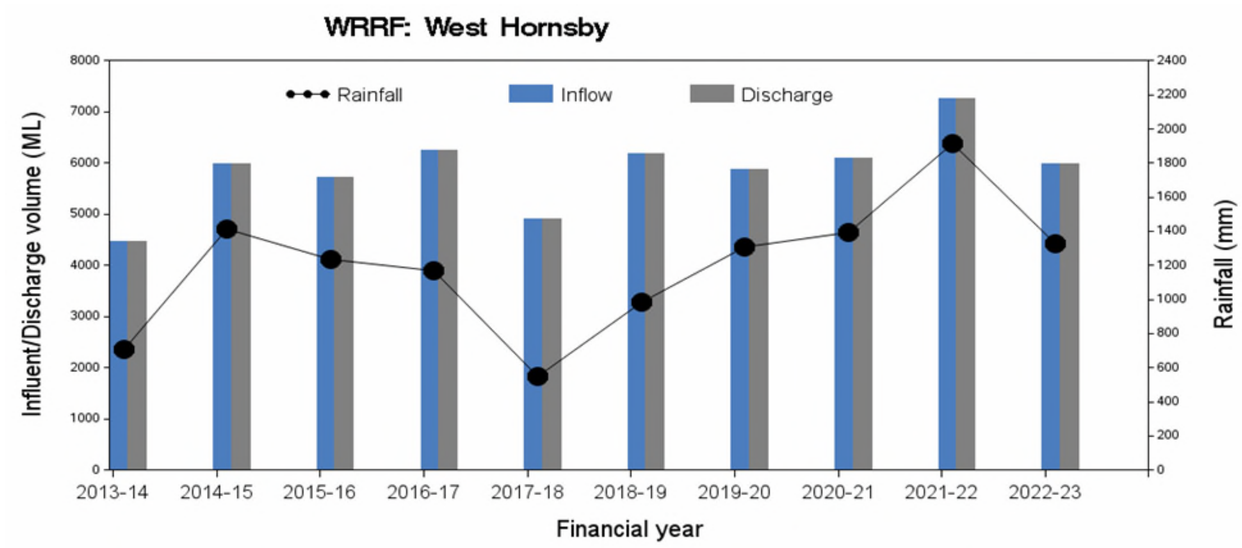
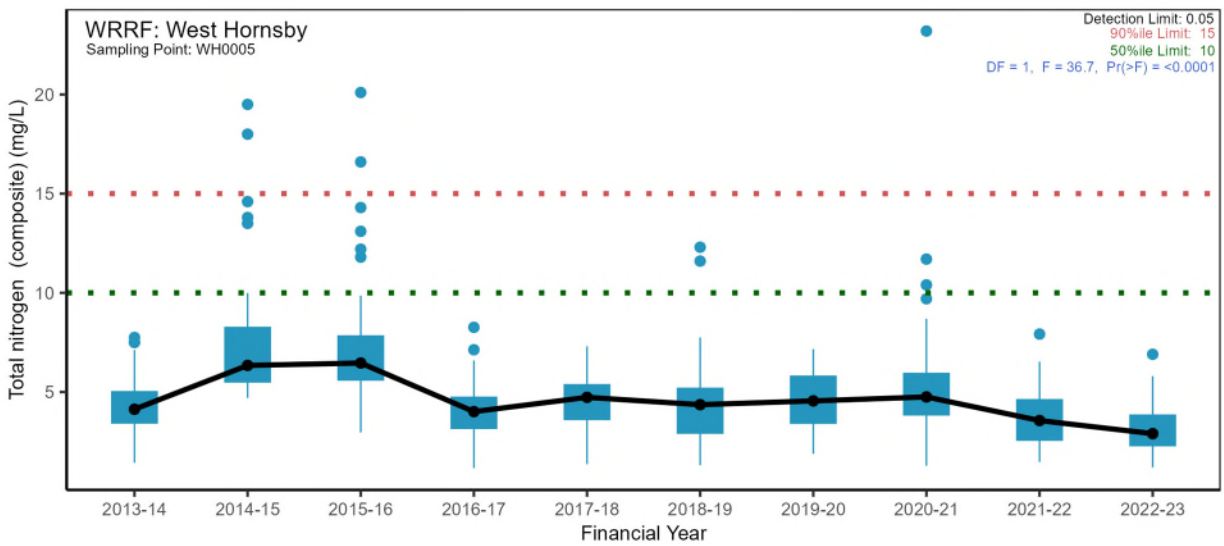


Figure 4-52 West Hornsby WRRF inflow and discharge volume with catchment rainfall



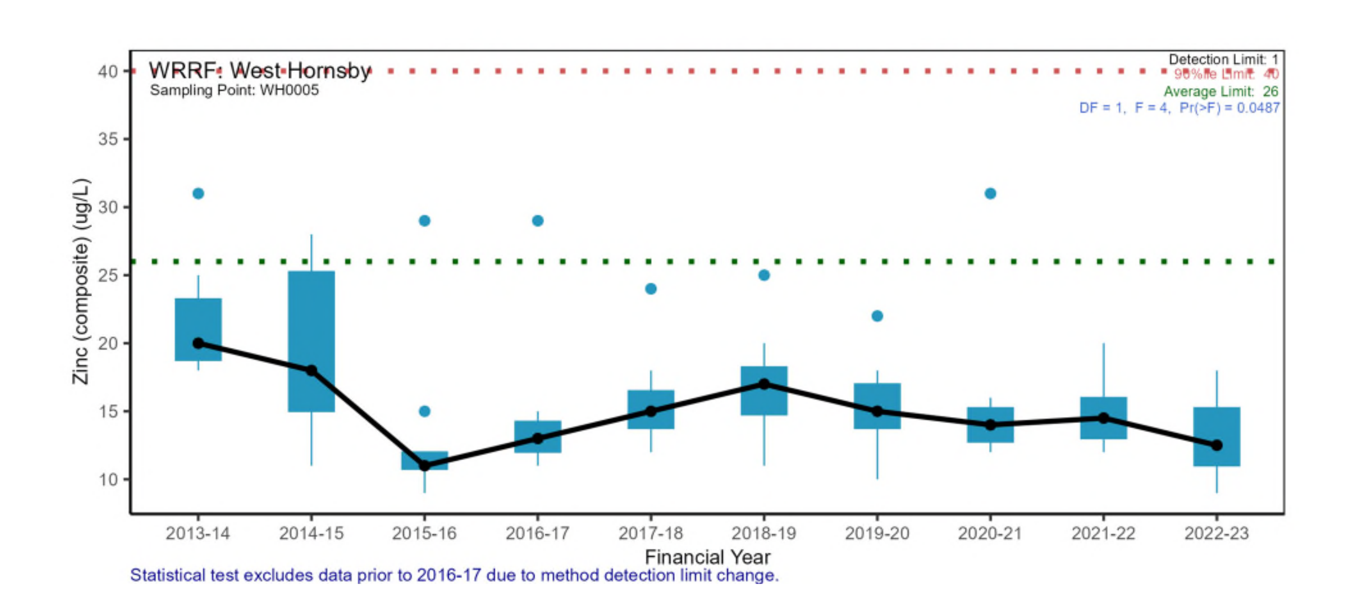


Figure 4-53 West Hornsby WRRF discharge quality and toxicity exception plots

Stressor – Water quality

Table 4-43 Gate 1 Analysis outcome summary – water quality upstream and downstream of West Hornsby WRRF discharge

Monitoring sites	Nutrient analytes					Physico-chemical analytes					
	Ammonia nitrogen	Oxidised nitrogen	Total nitrogen	Filterable total phosphorus	Total phosphorus	Conductivity	Dissolved oxygen	Dissolved oxygen saturation	pH	Temperature	Turbidity
Upstream tributary (NB83)	→	↗	↗	→	↗	→	→	→	→	→	→
Downstream tributary (NB825)	→	↘	↘	→	→	↘	→	→	→	→	→

↗	Upward trend	↘	Downward trend	→	no trend, p>0.05

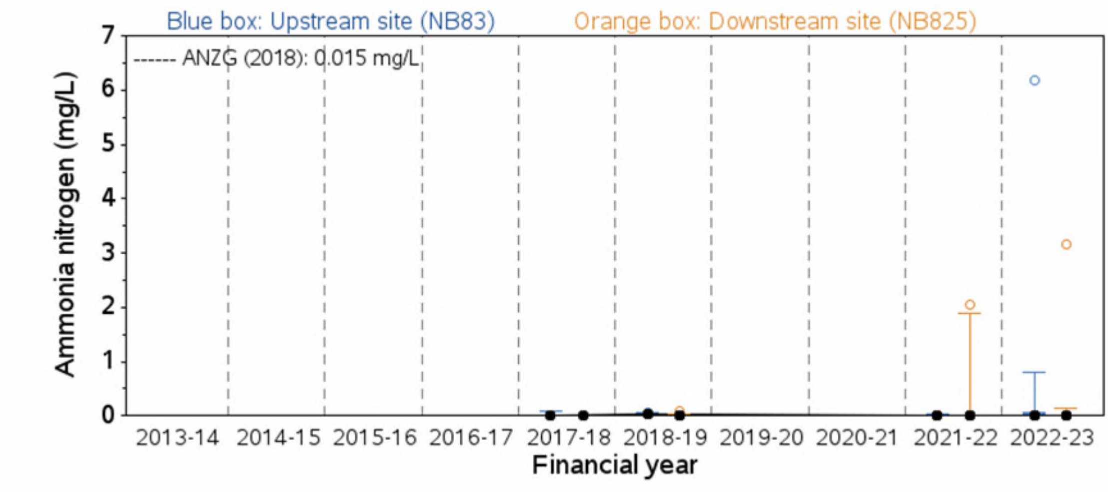
	2022-23 Median value within the guideline limit		No guideline applicable
	2022-23 Median value outside the guideline limit		Insufficient data

West Hornsby WRRF discharges into Waitara Creek which is a tributary to Berowra Creek draining to the Berowra estuary of the greater Hawkesbury-Nepean River. The upstream Waitara Creek catchment includes a mix of land uses including bushland, rural and housing both developing and developed.

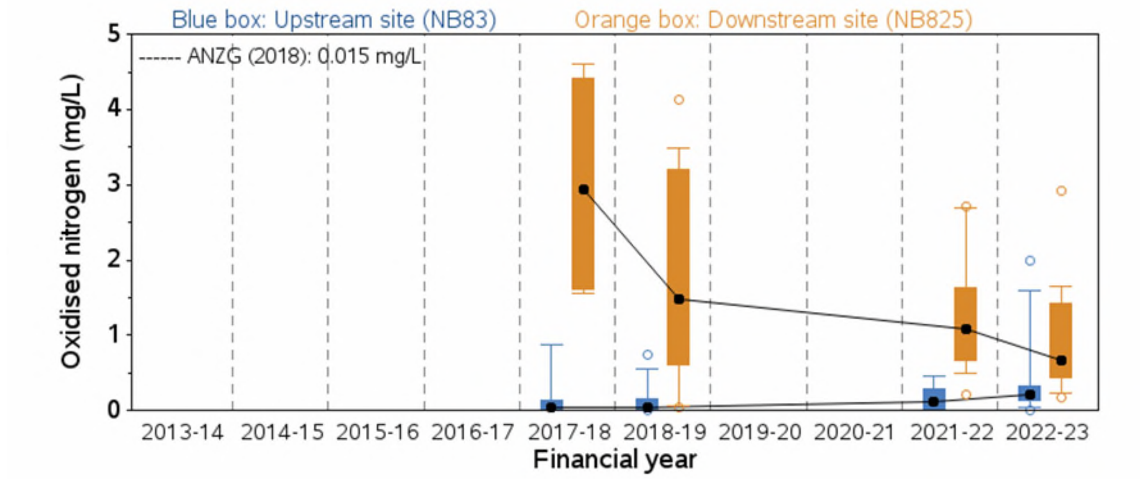
Oxidised nitrogen, total nitrogen and total phosphorus concentrations increased significantly in 2022-23 at the upstream control site of Waitara Creek (NB83). At the downstream site, oxidised nitrogen, total nitrogen and conductivity significantly decreased in 2022-23. This may be linked with the decreasing concentration of total nitrogen in West Hornsby WRRF discharges.

Concentrations of key nitrogen analytes (oxidised nitrogen and total nitrogen) and the conductivity level at the downstream Waitara Creek site were notably higher in comparison to upstream concentration/level indicating an impact from West Hornsby WRRF. Statistical analysis will be included in SWAM reports from 2023-24 to further validate the trend.

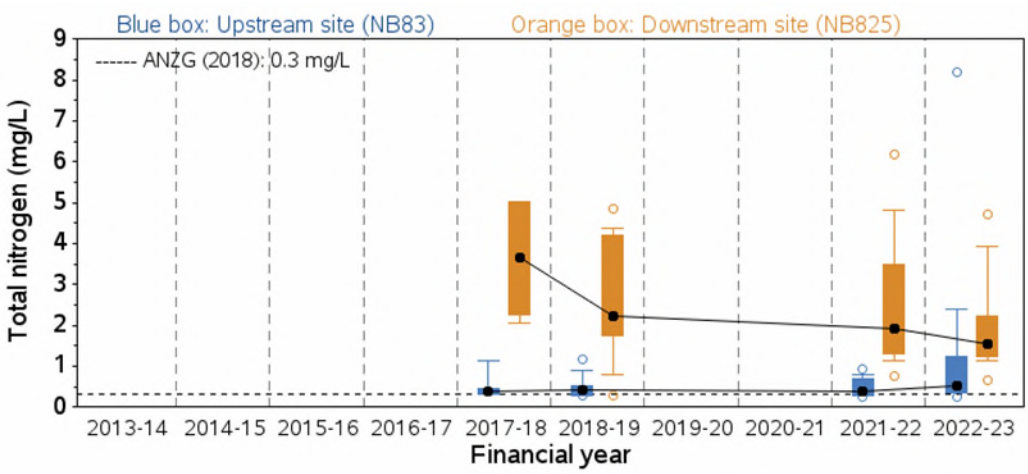
In the 2022-23 period, the median ammonia nitrogen, oxidised nitrogen, total nitrogen and total phosphorus concentrations at the upstream site (NB83) exceeded the respective ANZG (2018) guidelines. At the downstream site (NB825), the median oxidised nitrogen, total nitrogen and total phosphorus concentrations exceeded the respective guidelines and median turbidity was below the ANZG (2018) lower guideline limit.



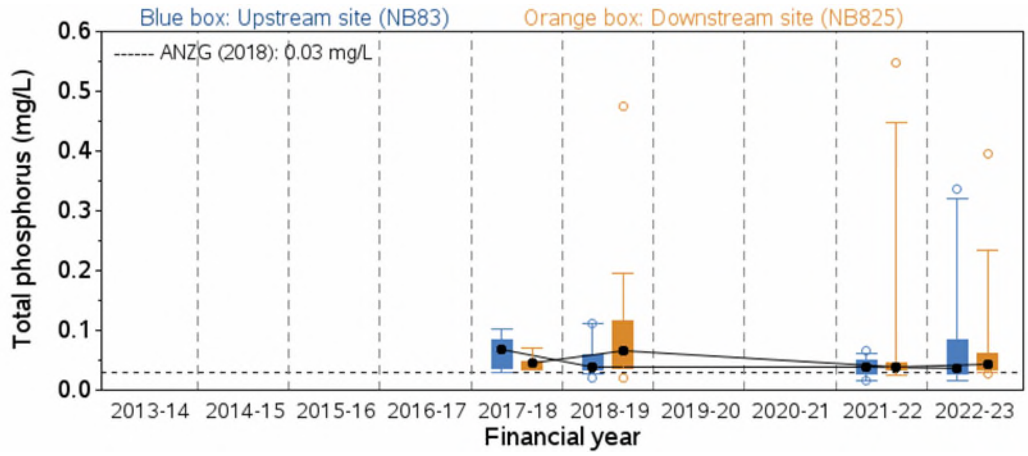
site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
NB83	1	3.28	0.0753	NB825	1	0.29	0.5927



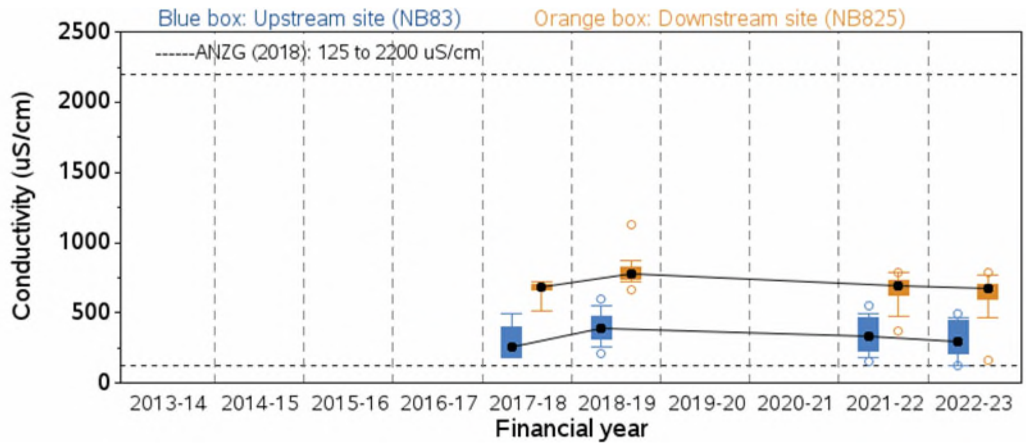
site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
NB83	1	6.09	0.0167	NB825	1	6.44	0.014



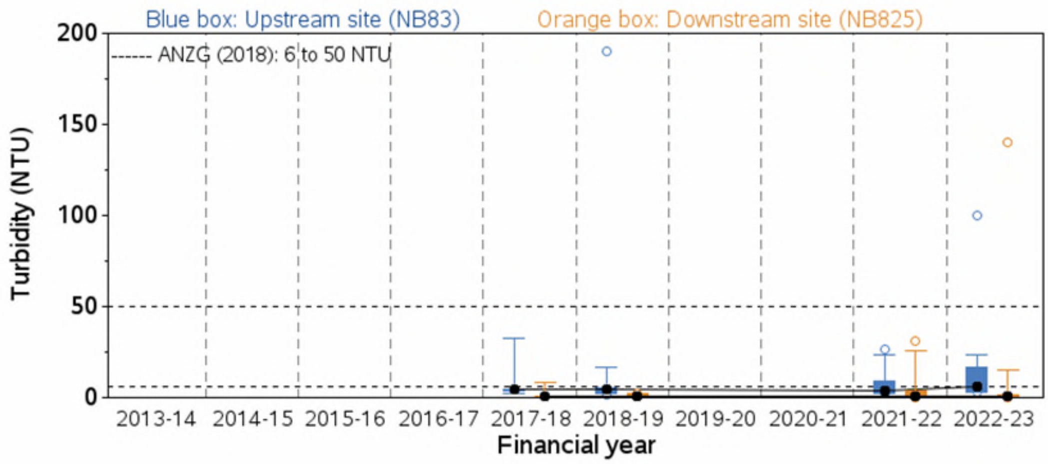
site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
NB83	1	5.32	0.0248	NB825	1	4.64	0.0355



site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
NB83	1	4.56	0.0371	NB825	1	0.18	0.6694



site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
NB83	1	1.28	0.2626	NB825	1	5.38	0.024



site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
NB83	1	0.12	0.7331	NB825	1	1.66	0.2023

Figure 4-54 Nutrients and physico-chemical water quality exception plots, upstream and downstream of West Hornsby WRRF

Ecosystem Receptor – Phytoplankton

Table 4-44 Gate 1 Analysis outcome summary – phytoplankton as chlorophyll-a, biovolume and species counts, upstream and downstream of West Hornsby WRRF discharge

Monitoring sites	Phytoplankton analytes			
	Chlorophyll-a	Total phytoplankton biovolume	Blue-green biovolume	Toxic blue-green count
Upstream tributary (NB83)	→			
Downstream tributary (NB825)	→			

↗	Upward trend	↘	Downward trend	→	no trend, p>0.05

	2022-23 Median value within the guideline limit		No guideline applicable
	2022-23 Median value outside the guideline limit		Insufficient data

In 2022-23, there was no significantly increasing/decreasing trend identified in any of the phytoplankton analytes at the upstream or downstream Waitara Creek sites.

The median chlorophyll-a concentration was lower than the ANZG (2018) guidelines at both upstream and downstream sites.

Only one sample from each of the upstream and downstream site exceeded the chlorophyll-a concentration of 7 µg/L in 2022-23, which triggered phytoplankton analysis. None of these samples had any potentially toxic blue-green taxa.

Ecosystem Receptor – Macroinvertebrates

The 2022-23 macroinvertebrate results suggested localised ecosystem impacts in Waitara Creek, downstream of West Hornsby WRRF. Multivariate testing outcomes suggest downstream community structure in Waitara Creek was altered by wastewater discharge from West Hornsby WRRF in the most recent period (Volume 2 Appendix A-13).

Table 4-45 t-test of upstream-downstream SIGNAL-SG scores of 2022-23 samples from Waitara Creek near West Hornsby WRRF

Waterway	Method	Statistic	DF	P value
Waitara Creek	Welch Two Sample t-test	4.56	10.0	0.001

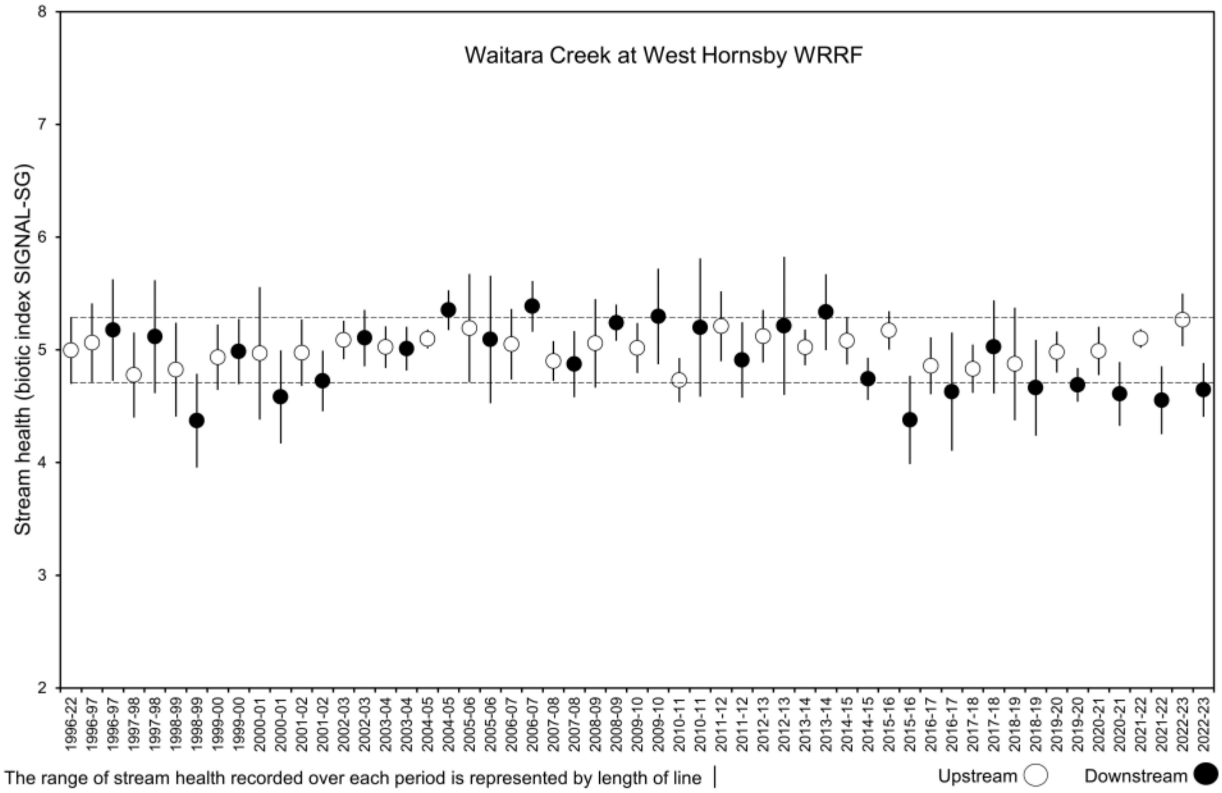


Figure 0-55 Stream health of Waitara Creek near West Hornsby WRRF

4.1.14 Hornsby Heights WRRF

- All parameters (concentrations and loads) monitored in the discharge from Hornsby Heights WRRF were within EPL limits. There was a decreasing trend in zinc concentration in the discharge.
- Nutrient concentrations were steady at both the upstream and downstream sites on Calna Creek during 2022-23.
- Chlorophyll-a concentrations were low at both the upstream and downstream Calna Creek sites. Two samples were analysed for phytoplankton biovolume and species counts for the upstream site. No toxic species were found.
- Stream health results (as indicated by macroinvertebrates) suggest the downstream community structure in Calna Creek has been consistently altered by wastewater discharge from the Hornsby Heights WRRF through the 2011 to 2023 monitoring period.

Pressure – Wastewater discharge

Table 4-46 Gate 1 Analysis outcome summary – Hornsby Heights WRRF

Analytes / Hornsby Heights WRRF	Nutrients			Conventional analytes					Trace Metals				Other	
	Ammonia Nitrogen	Total Nitrogen	Total Phosphorus	Biochemical Oxygen Demand	Faecal Coliforms	Oil and Grease	Total Suspended Solids	EC_{50} Toxicity	Aluminium	Copper	Iron	Zinc	Diazinon	Hydrogen sulfide (un-ionised)
Concentration	→	→	→	→	→		→	→	→	→	→	↘	→	→
Load														

↗	Upward trend	↘	Downward trend	→	no trend, p>0.05

(green)	Within the Environment Protection Licence limit
(yellow)	Environment Protection Licence limit exceedance
(grey)	Analytes not required in the EPL or no concentration limit

All concentration and load limits in the discharge from Hornsby Heights WRRF were within the EPL limits during the 2022-23 period.

Statistical analysis identified a significantly decreasing trend in zinc concentrations during 2022-23 compared to the previous nine years.

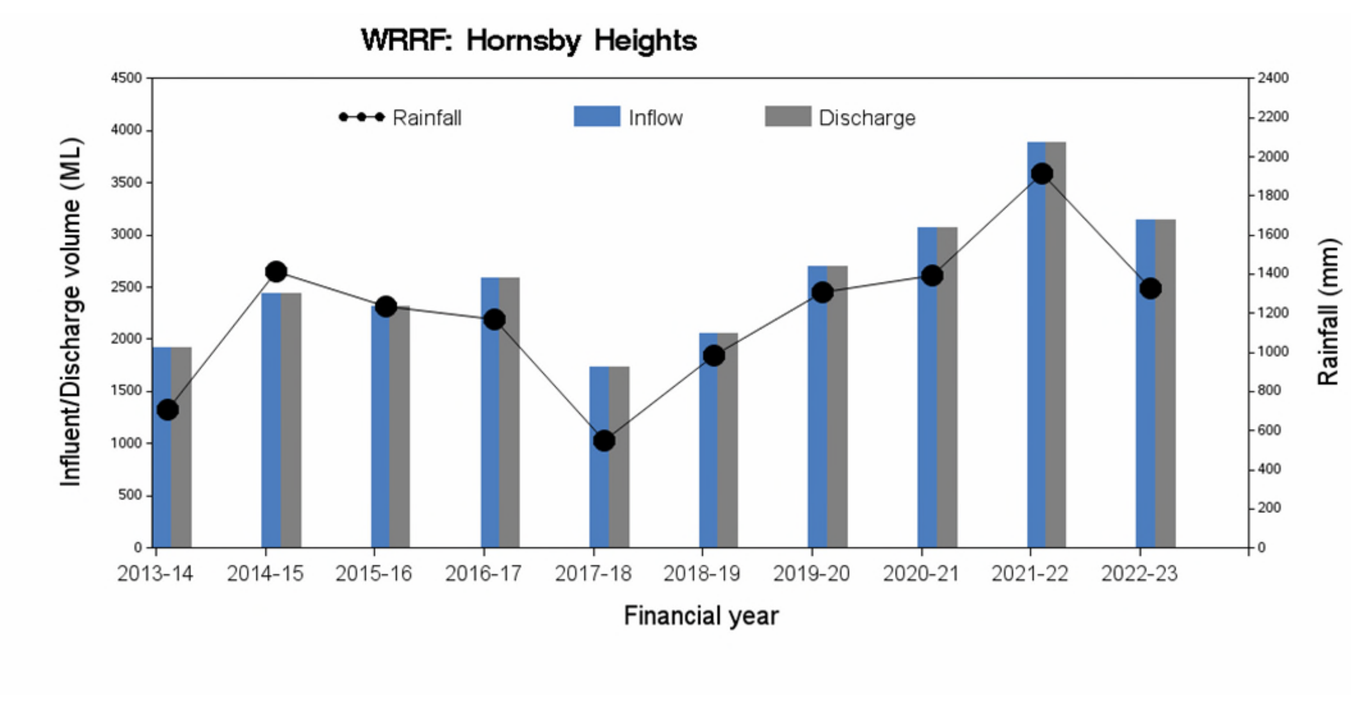


Figure 4-56 Hornsby Heights WRRF inflow and discharge volume with catchment rainfall

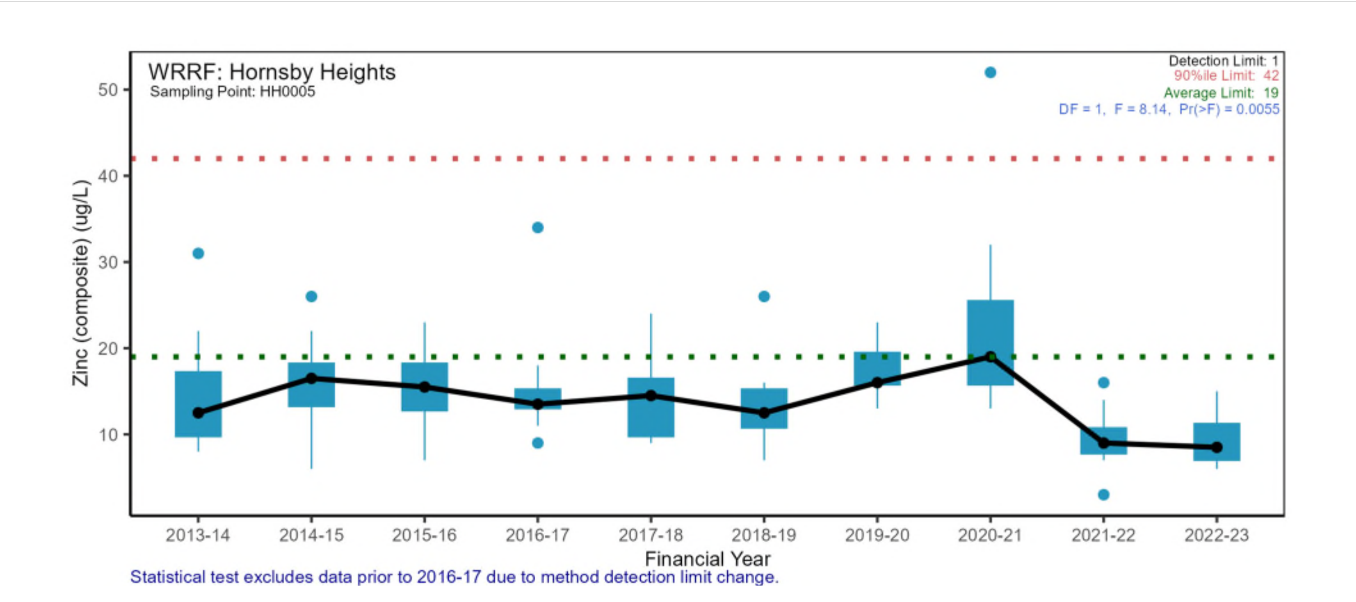


Figure 4-57 Hornsby Heights WRRF discharge quality and toxicity exception plots

Stressor – Water quality

Table 4-47 Gate 1 Analysis outcome summary – water quality upstream and downstream of Hornsby Heights WRRF discharge

Monitoring sites	Nutrient analytes					Physico-chemical analytes					
	Ammonia nitrogen	Oxidised nitrogen	Total nitrogen	Filterable total phosphorus	Total phosphorus	Conductivity	Dissolved oxygen	Dissolved oxygen saturation	pH	Temperature	Turbidity
Upstream tributary (NB43)	→	→	→	→	→	↘	→	↗	→	→	→
Downstream tributary (NB42)	→	→	→	→	→	→	→	↗	→	→	→

↗	Upward trend	↘	Downward trend	→	no trend, p>0.05

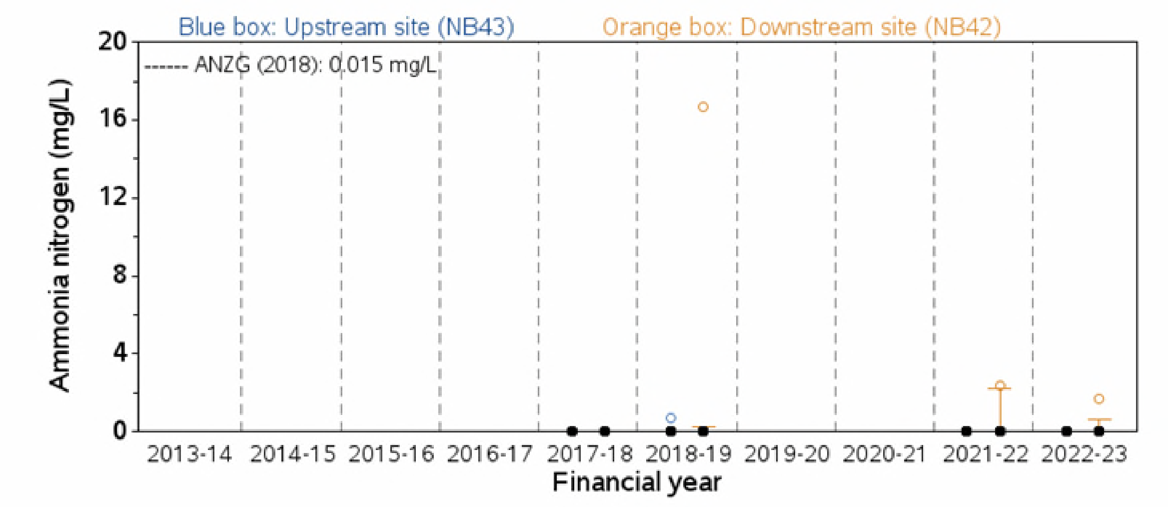
	2022-23 Median value within the guideline limit		No guideline applicable
	2022-23 Median value outside the guideline limit		Insufficient data

Hornsby Heights WRRF discharges into Calna Creek which is a tributary of Berowra Creek draining to Berowra estuary of the greater Hawkesbury-Nepean River. The upstream Calna Creek catchment contains a mix of land uses including rural, residential and bushland.

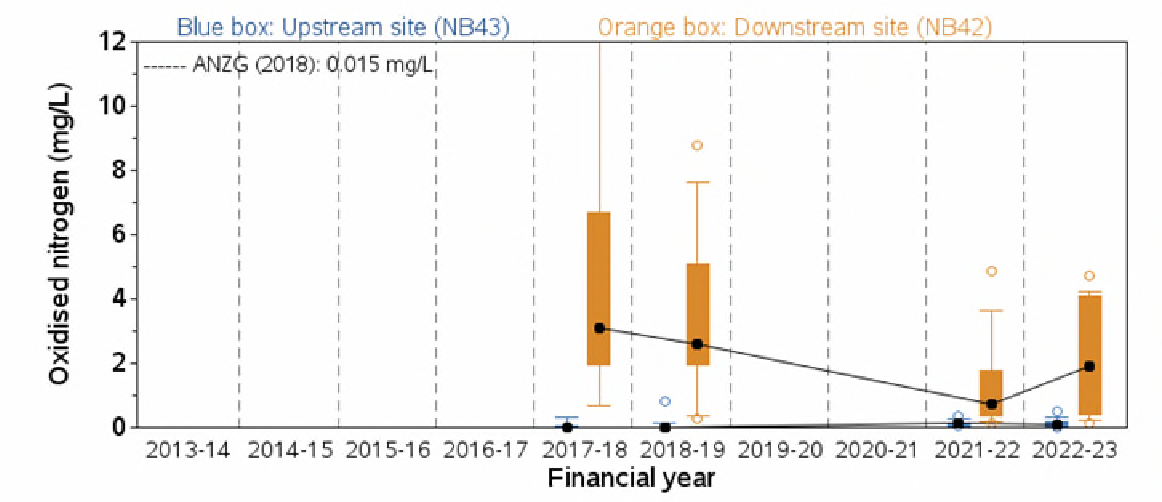
In 2022-23, none of the nutrients exhibited a significant trend for the upstream site on Calna Creek (NB43) compared to earlier years. Conductivity decreased at the upstream site. Dissolved oxygen saturation improved/increased at both upstream and downstream site in 2022-23.

Concentrations of key nitrogen analytes (oxidised nitrogen and total nitrogen) and conductivity at the downstream Calna Creek site were notably higher in comparison to the upstream concentration/level indicating an impact from Hornsby Heights WRRF. Statistical analysis will be included in SWAM reports from 2023-24 to further validate the trend.

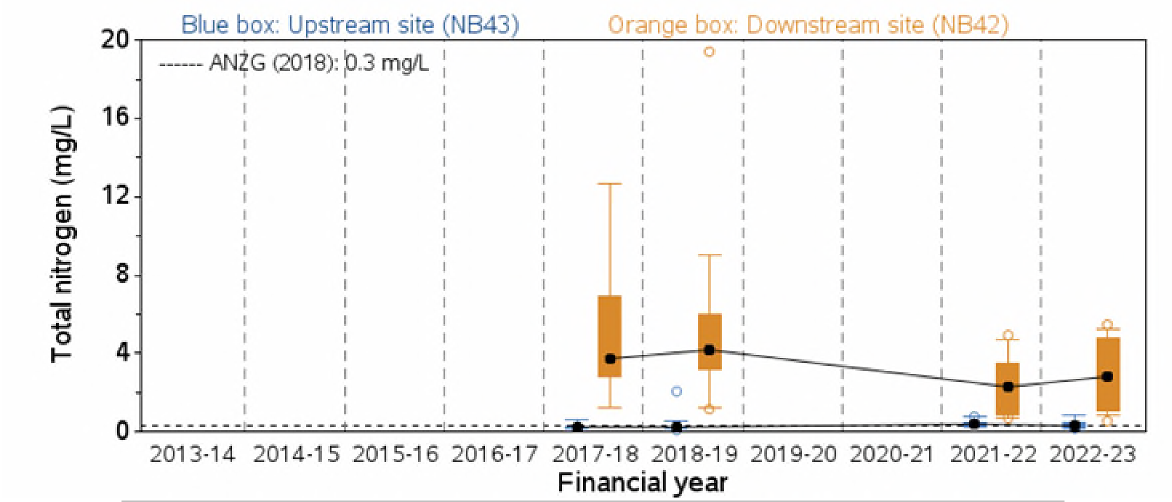
In the 2022-23 period, the median oxidised nitrogen, total nitrogen and total phosphorus concentrations at the upstream site (NB43) exceeded the respective ANZG (2018) guidelines. At the downstream site (NB42) the median concentrations of all four nutrient analytes exceeded the respective guidelines. Median turbidity for this site was below the lower guideline limit.



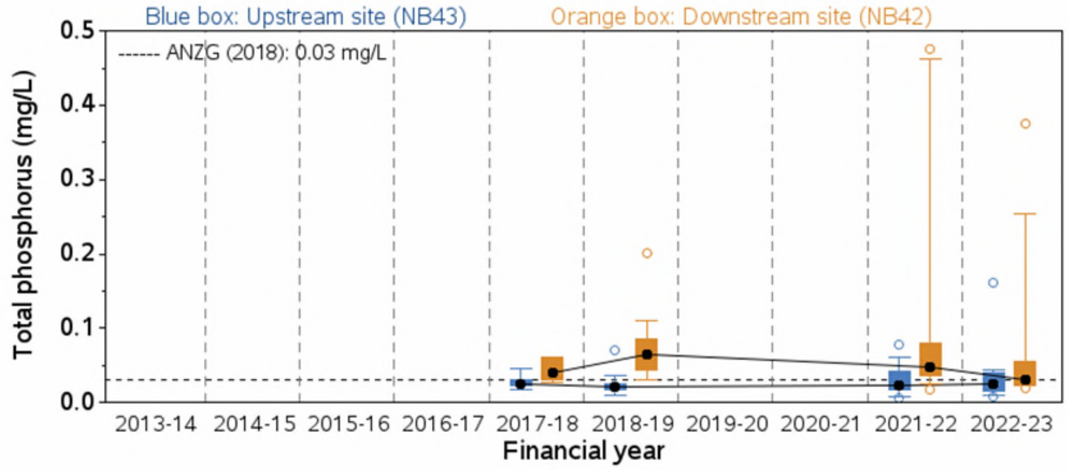
site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
NB43	1	0.35	0.5574	NB42	1	0.36	0.5527



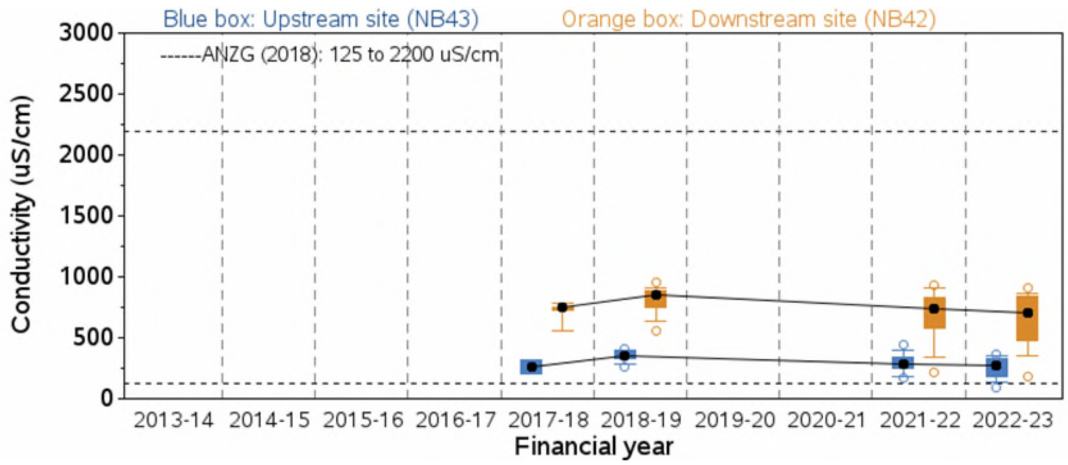
site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
NB43	1	0.66	0.4205	NB42	1	0.94	0.3375



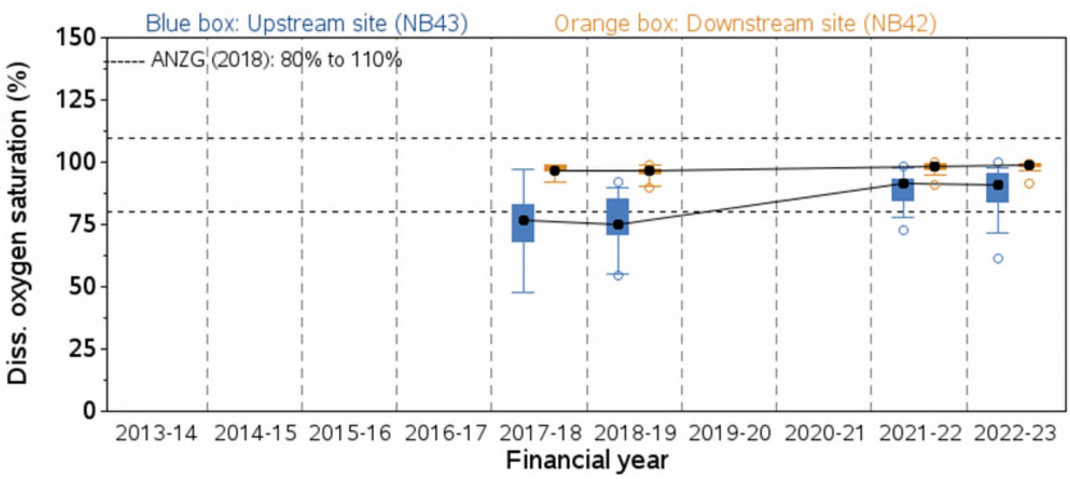
site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
NB43	1	0.08	0.7751	NB42	1	1.49	0.227



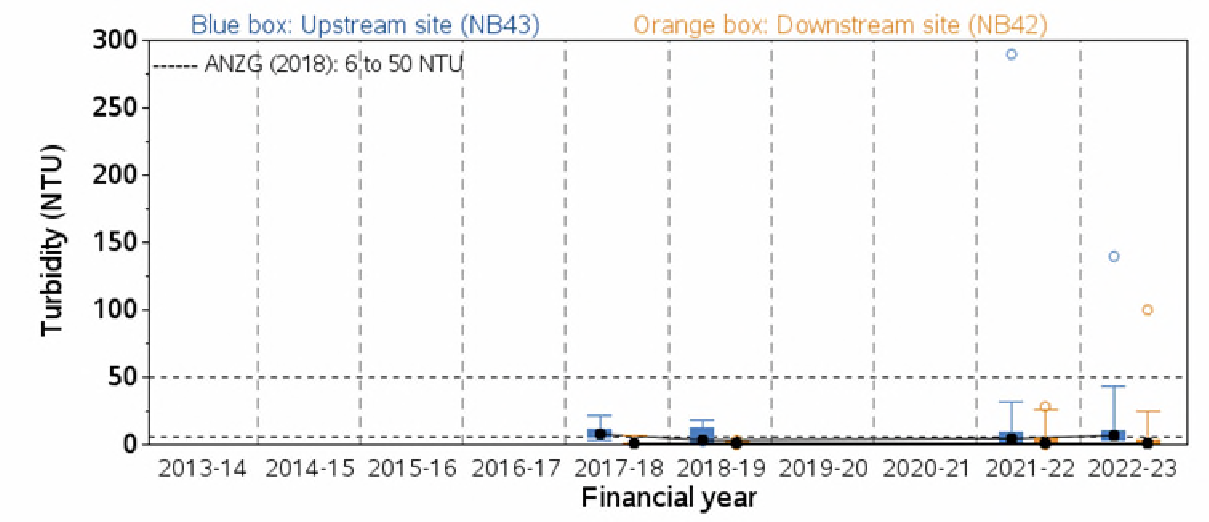
site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
NB43	1	0.44	0.5083	NB42	1	0.21	0.6506



site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
NB43	1	5.66	0.0208	NB42	1	1.43	0.2374



site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
NB43	1	5.53	0.0223	NB42	1	4.47	0.0391



site	DF	F Value	Pr>F	site	DF	F Value	Pr>F
NB43	1	0.02	0.9019	NB42	1	2.3	0.1353

Figure 4-58 Nutrients and physico-chemical water quality exception plots, upstream and downstream of Hornsby Heights WRRF

Ecosystem Receptor – Phytoplankton

Table 4-48 Gate 1 Analysis outcome summary – phytoplankton as chlorophyll-a, biovolume and species counts, upstream and downstream of Hornsby Heights WRRF discharge

	Phytoplankton analytes			
Monitoring sites	Chlorophyll-a	Total phytoplankton biovolume	Blue-green biovolume	Toxic blue-green count
Upstream tributary (NB43)	→			
Downstream tributary (NB42)	→			

↗	Upward trend	↘	Downward trend	→	no trend, p>0.05

	2022-23 Median value within the guideline limit		No guideline applicable
	2022-23 Median value outside the guideline limit		Insufficient data

In 2022-23, there was no significantly increasing/decreasing trends identified in any of the phytoplankton analytes at the upstream or downstream Calna Creek sites.

In the 2022-23 period, the median chlorophyll-a concentration was lower than the ANZG (2018) guideline at both the upstream and downstream site.

Two of the 18 samples collected from the upstream site (NB43) exceeded the chlorophyll-a concentration of 7 µg/L in 2022-23, which triggered phytoplankton analysis. None of the samples had any potentially toxic blue-green taxa. Chlorophyll-a concentrations were low for the downstream site (NB42) in 2022-23, where none of the samples were qualified for phytoplankton biovolume measurements and species counts.

Ecosystem Receptor – Macroinvertebrates

No measurable negative impact on downstream stream health (based on macroinvertebrate indicators) was detected in the t-test for Calna Creek for 2022-2023. However, the SIGNAL-SG control chart from the Calna Creek sites upstream and downstream of Hornsby Heights WRRF suggests a persistent impact over the last ten financial years. Multivariate results suggest downstream community structure in Calna Creek has been consistently altered by wastewater discharge from the Hornsby Heights WRRF through the 2011 to 2023 monitoring period.

Table 4-49 t-test of upstream-downstream SIGNAL-SG scores of 2022-23 samples from Calna Creek near Hornsby Heights WRRF

Waterway	Method	Statistic	DF	P value
Calna Creek	Welch Two Sample t-test	1.84	3.1	0.160

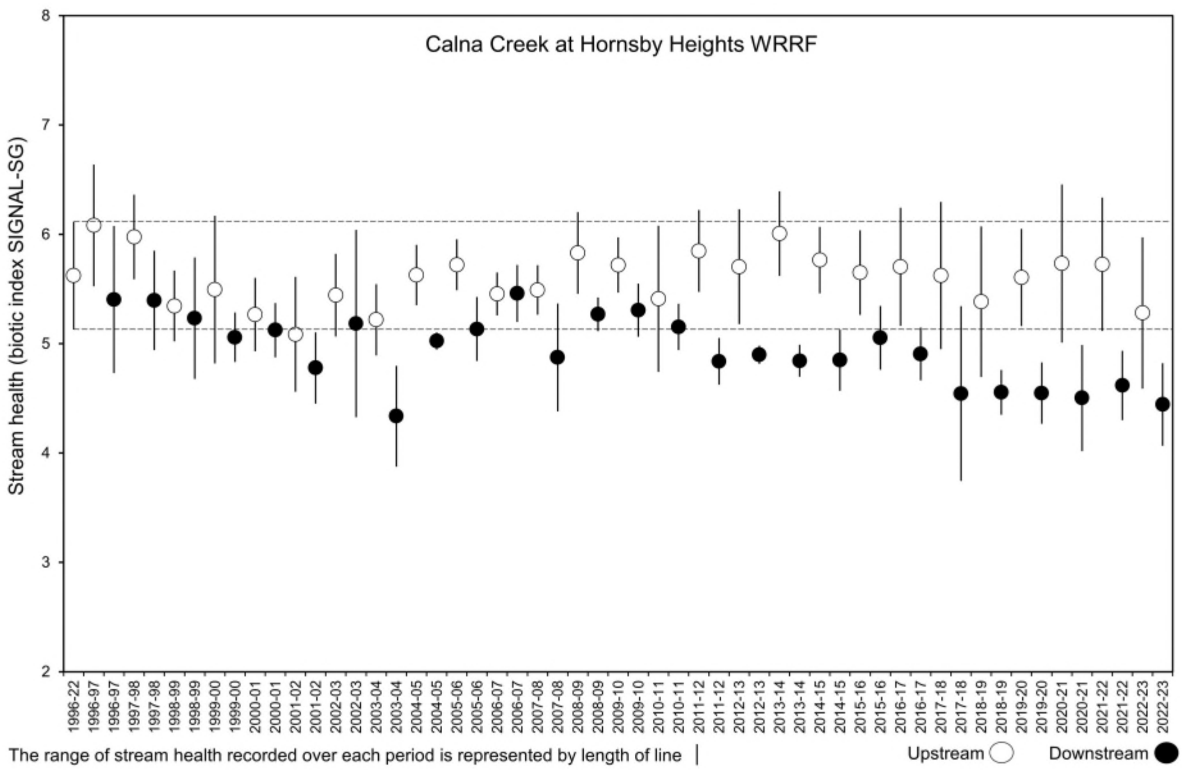


Figure 4-59 Stream health of Calna Creek near Hornsby Heights WRRF

4.1.15 Brooklyn WRRF

- All parameters (concentrations and loads) monitored in the discharge from Brooklyn WRRF were within EPL limits. No significant trends were identified in the discharge.

Pressure – Wastewater discharge

Table 4-50 Gate 1 Analysis outcome summary – Brooklyn WRRF

Analytes / Brooklyn WRRF	Nutrients			Conventional analytes			
	Ammonia Nitrogen	Total Nitrogen	Total Phosphorus	Biochemical Oxygen Demand	Faecal Coliforms	Total Suspended Solids	EC_{50} Toxicity
Concentration	→	→	→	→	→	→	→

↗	Upward trend	↘	Downward trend	→	no trend, p>0.05

(green)	Within the Environment Protection Licence limit
(yellow)	Environment Protection Licence limit exceedance
(grey)	Analytes not required in the EPL or no concentration limit

All concentration limits in the discharge from Brooklyn WRRF were within the EPL limits during the 2022-23 reporting period. There are no load limits applicable to Brooklyn WRRF. Statistical analysis did not identify any significant trends in the discharge from Brooklyn WRRF during the 2022-23 reporting period.

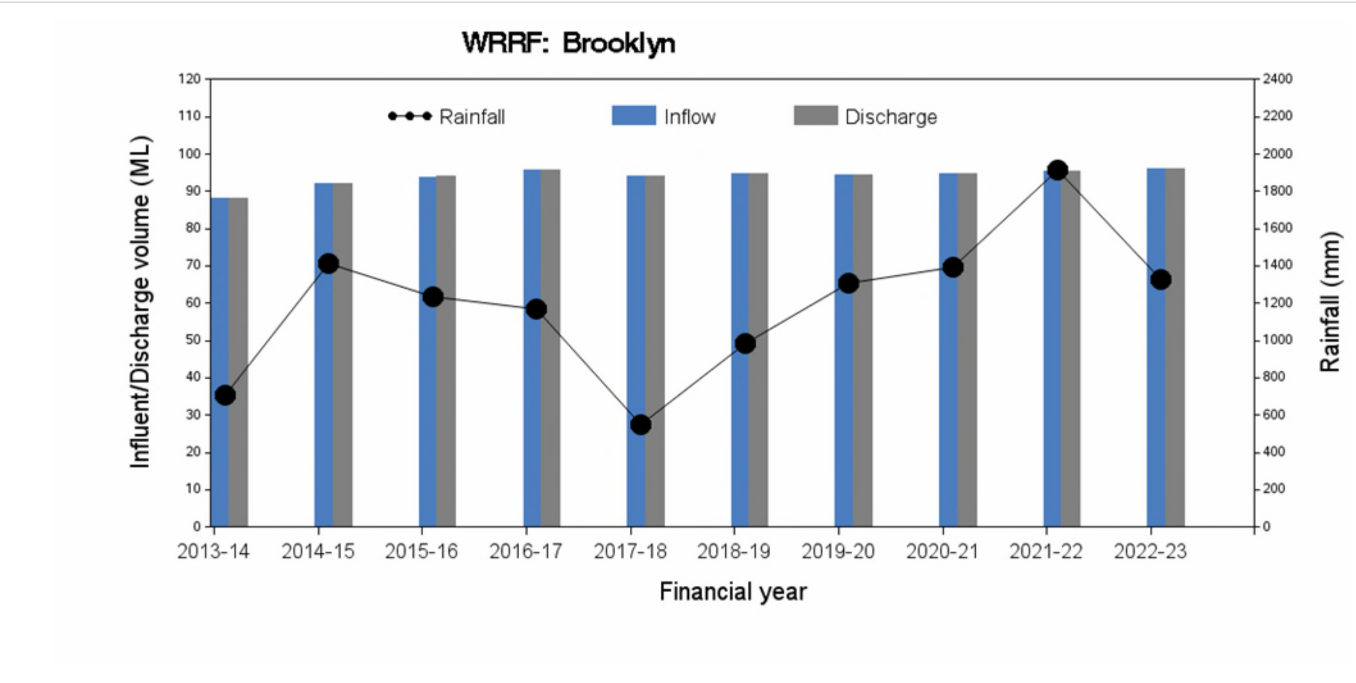


Figure 4-60 Brooklyn WRRF inflow and discharge volume with catchment rainfall

Stressor – Water quality

Water quality monitoring near the Brooklyn outfall is not recommended for regular monitoring in the new SWAM program given treatment level, receiving environment, mixing and dilution.

Ecosystem Receptor – Phytoplankton

Water quality monitoring near the Brooklyn outfall is not recommended for regular monitoring in the new SWAM program given treatment level, receiving environment, mixing and dilution.

Ecosystem Receptor – Macroinvertebrates

Brooklyn WRRF lies in the Hawkesbury estuary, where freshwater macroinvertebrate monitoring is not suitable due to tidal conditions, depth and fast flows (see STSIMP Recommendations Report for further information).

4.2 Georges River

The treated wastewater discharged from the Georges River discharging WRRFs in 2022-23 and the population serviced by these WRRFs are shown in Table 4-51.

This section contains a summary of exceptions for the Georges River discharging WRRFs.

Trend plots of discharge volume and catchment specific rainfall are presented first, and then reuse volume where applicable.

Trend plots showing the concentration of analytes in the discharge were only presented where they exceeded the respective EPL limit for a WRRF during the 2022-23 monitoring period, or there was a significant increase/decrease in concentrations in 2022-23 in comparison to earlier years.

All trend plots showing the analyte concentration data for Georges River WRRFs, including applicable concentration limits, can be found in Volume 2 Appendix B.

An electronic appendix file on summary of results for all WRRFs by year has been provided to the EPA.

Table 4-51 Georges River WRRFs operated by Sydney Water

WRRFs	Treatment level	Discharge 2022-23 (ML/year)[a]	Projected population 2022-23[b]	Discharge location
Fairfield*	Primary	2,380	0*	Treated wastewater occasionally discharged to Orphan School Creek (to Georges River) during wet weather. Remainder transferred to Malabar WRRF.
Glenfield**	Secondary with disinfection	1,036	169,990	Treated wastewater occasionally discharged to Georges River in wet weather. Remainder transferred to Liverpool WRRF.
Liverpool**	Secondary with disinfection	8,510	89,900	Treated wastewater occasionally discharged to Georges River in wet weather. Remainder transferred to Malabar WRRF.

[a] Discharge volume excludes onsite and offsite reuse.

[b] Projected populations (at 30 June 2023) are based on forecasts by the Australian Bureau of Statistics and the DPE.

*Fairfield WRRF not directly servicing any households.

**Part of Malabar system. Wastewater is discharged during wet weather only.

4.2.1 Glenfield WRRF

Pressure – Wastewater discharge

Table 4-52 Gate 1 Analysis outcome summary – Glenfield WRRF

Analytes / Glenfield WRRF	Conventional analytes	
	Biochemical Oxygen Demand	Total Suspended Solids
Concentration	→	↗

↗	Upward trend	↘	Downward trend	→	no trend, p>0.05

(green)	Within the Environment Protection Licence limit
(yellow)	Environment Protection Licence limit exceedance

All concentration limits in the discharge from Glenfield WRRF were within the Malabar EPL 372 limits during the 2022-23 reporting period. Under EPL 372 condition L3.5, as set by the EPA, the 100th percentile limits can be exceeded during wet weather where it was the sole cause of the exceedance. This condition was met at Glenfield WRRF for total suspended solids on 2 July 2022.

Statistical analysis identified a significantly increasing trend in total suspended solids concentration in the wet weather discharge from Glenfield WRRF compared to the past nine years. This can be associated with extreme wet weather events since February 2020, with prior drought conditions magnifying the effect of recent wetter years.

Under dry weather conditions, flows received at Glenfield WRRF are transferred to Liverpool WRRF for recycled water treatment or sent to Malabar WRRF.

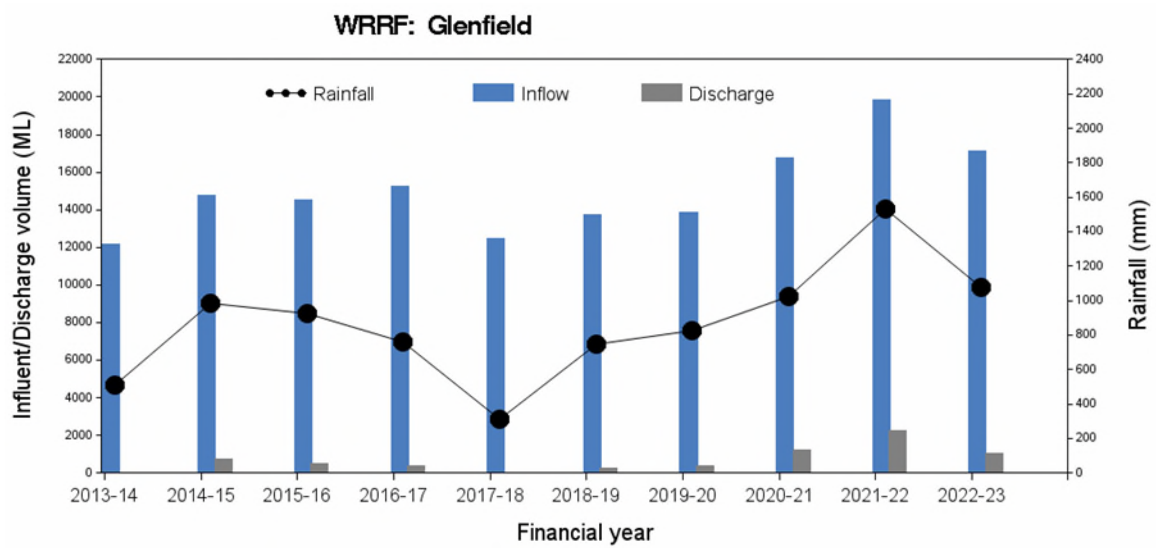


Figure 4-61 Glenfield WRRF inflow and discharge volume with catchment rainfall

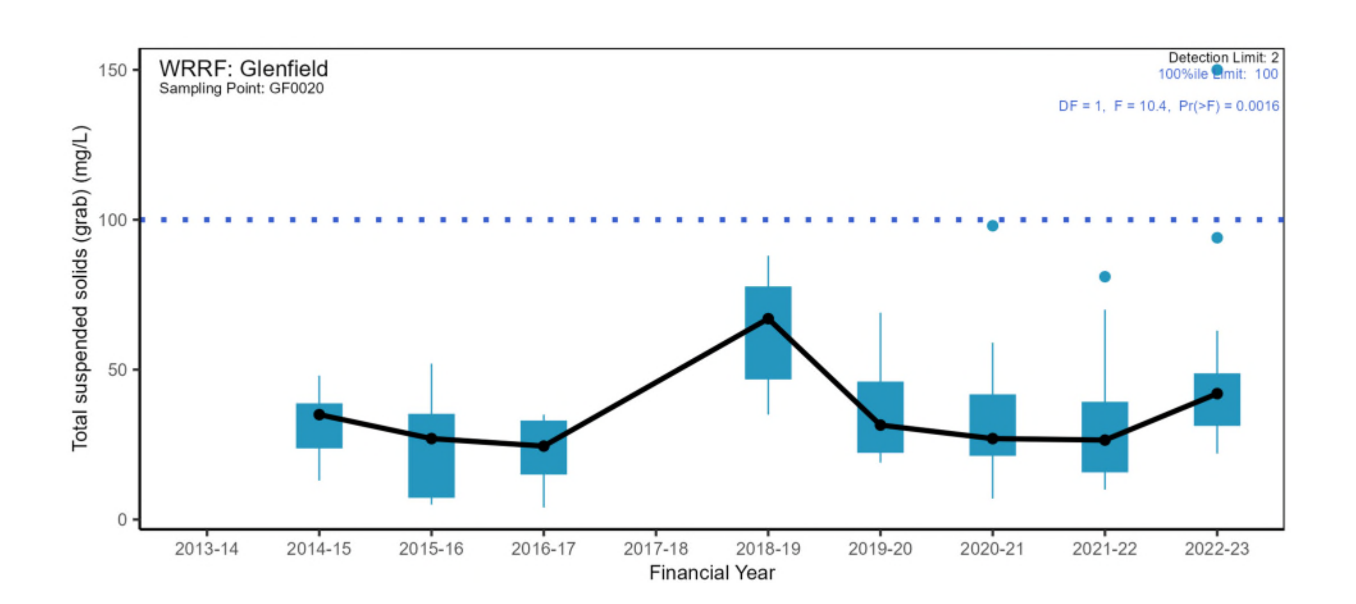


Figure 4-62 Glenfield WRRF discharge quality and toxicity exception plots

Stressor – Water quality

The water quality monitoring program for the Glenfield WRRF commenced from July 2023 as part of the new SWAM program. The outcome of these monitoring results will be included in SWAM report from 2023-24.

Ecosystem Receptor – Phytoplankton

The ecosystem receptor monitoring program for the Glenfield WRRF commenced from July 2023 as part of the new SWAM program. The outcome of these monitoring results will be included in SWAM report from 2023-24.

Ecosystem Receptor – Macroinvertebrates

The macroinvertebrate monitoring program for the Glenfield WRRF commenced from July 2023 as part of the new SWAM program. The outcome of these monitoring results will be included in SWAM report from 2023-24.

4.2.2 Fairfield WRRF

Pressure – Wastewater discharge

Table 4-53 Gate 1 Analysis outcome summary – Fairfield WRRF

Analytes / Fairfield WRRF	Conventional analytes	
	Biochemical Oxygen Demand	Total Suspended Solids
Concentration	→	→

↗	Upward trend	↘	Downward trend	→	no trend, p>0.05

(green)	Within the Environment Protection Licence limit
(yellow)	Environment Protection Licence limit exceedance

All concentration limits in the discharge from the Fairfield storm plant were within the Malabar EPL 372 limits during the 2022-23 reporting period. Under EPL 372 condition L3.5, as set by the EPA, the 100th percentile limits can be exceeded during wet weather where it was the sole cause of the exceedance. This condition was met at Fairfield storm plant for biochemical oxygen demand on 6 July and 6 October 2022.

Statistical analysis did not identify any significant trends in the discharge from the Fairfield storm plant during the 2022-23 reporting period.

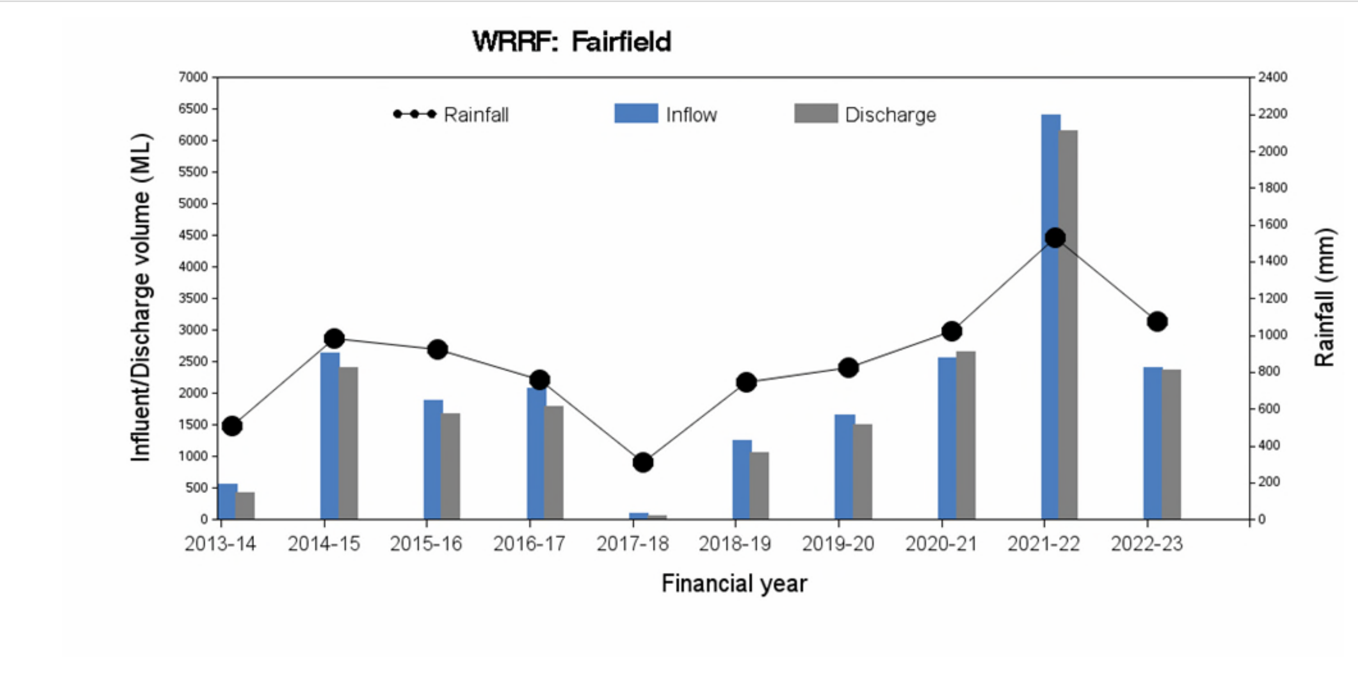


Figure 4-63 Fairfield WRRF inflow and discharge volume with catchment rainfall

Stressor – Water quality

Feasibility study required to inform an appropriate monitoring design and indicators (van Dam et al. 2023)

Ecosystem Receptor – Phytoplankton

Feasibility study required to inform an appropriate monitoring design and indicators (van Dam et al. 2023)

Ecosystem Receptor – Macroinvertebrates

Feasibility study required to inform an appropriate monitoring design and indicators (van Dam et al. 2023)

4.2.3 Liverpool WRRF

Pressure – Wastewater discharge

Table 4-54 Gate 1 Analysis outcome summary – Liverpool WRRF

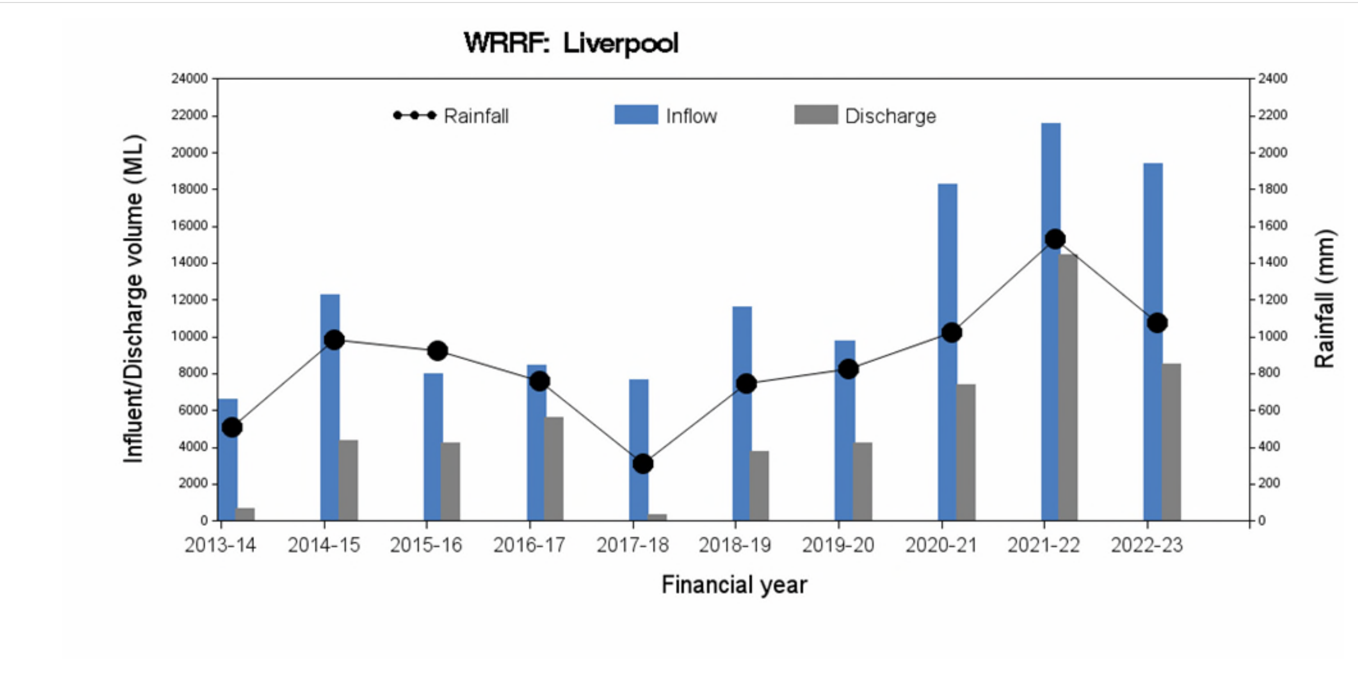
Analytes / Liverpool WRRF	Conventional analytes	
	Biochemical Oxygen Demand	Total Suspended Solids
Concentration EPA ID 15 (Chipping Norton Discharge)	↗	↗
Concentration EPA ID 76 (Recycled Water Reuse)	→	→
Concentration EPA ID 81 (Liverpool Discharge)	→	→

↗	Upward trend	↘	Downward trend	→	no trend, p>0.05

(green)	Within the Environment Protection Licence limit
(yellow)	Environment Protection Licence limit exceedance

All concentration limits in the discharge from Liverpool WRRF were within the Malabar EPL 372 limits during the 2022-23 reporting period. Under EPL 372 condition L3.5, as set by the EPA, the 100th percentile limits can be exceeded during wet weather where it was the sole cause of the exceedance. This condition was met at Liverpool WRRF for biochemical oxygen demand on 21, 24, 26 July, 24 August, 5, 24 September 2022, 14 March 2023 and total suspended solids on 24 July 2022 and 14 March 20023.

Statistical analysis identified a significantly increasing trend in biochemical oxygen demand and total suspended solids concentrations in the wet weather discharge from Liverpool WRRF EPA ID 15 (effluent diversion structure at Chipping Norton) compared to the past nine years. Like Glenfield WRRF, these trends can be associated with extreme wet weather events since February 2020, with prior drought conditions magnifying the effect of recent wetter years.



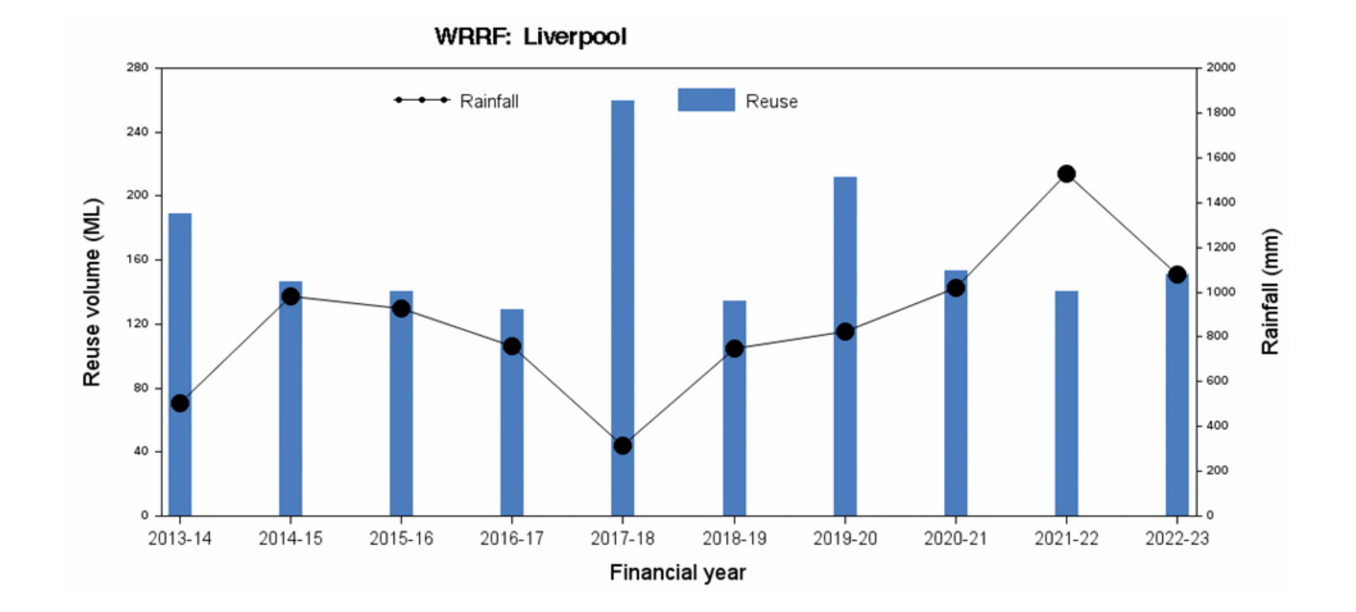
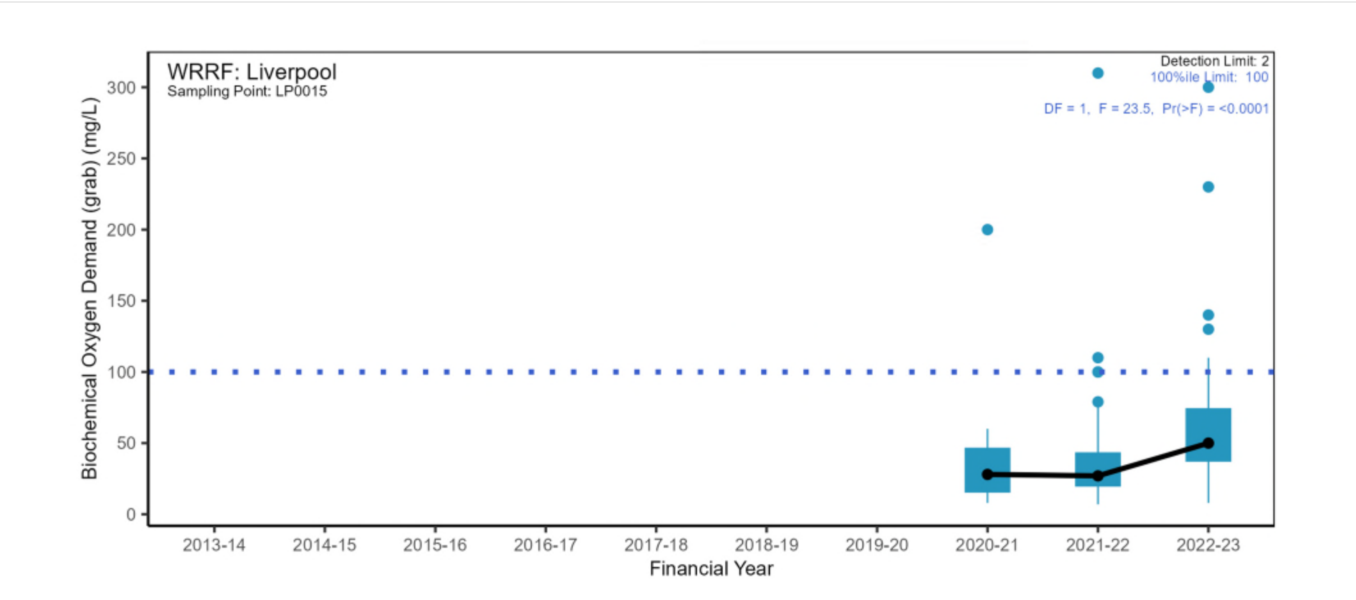


Figure 4-64 Liverpool WRRF inflow, discharge and reuse volume with catchment rainfall plots



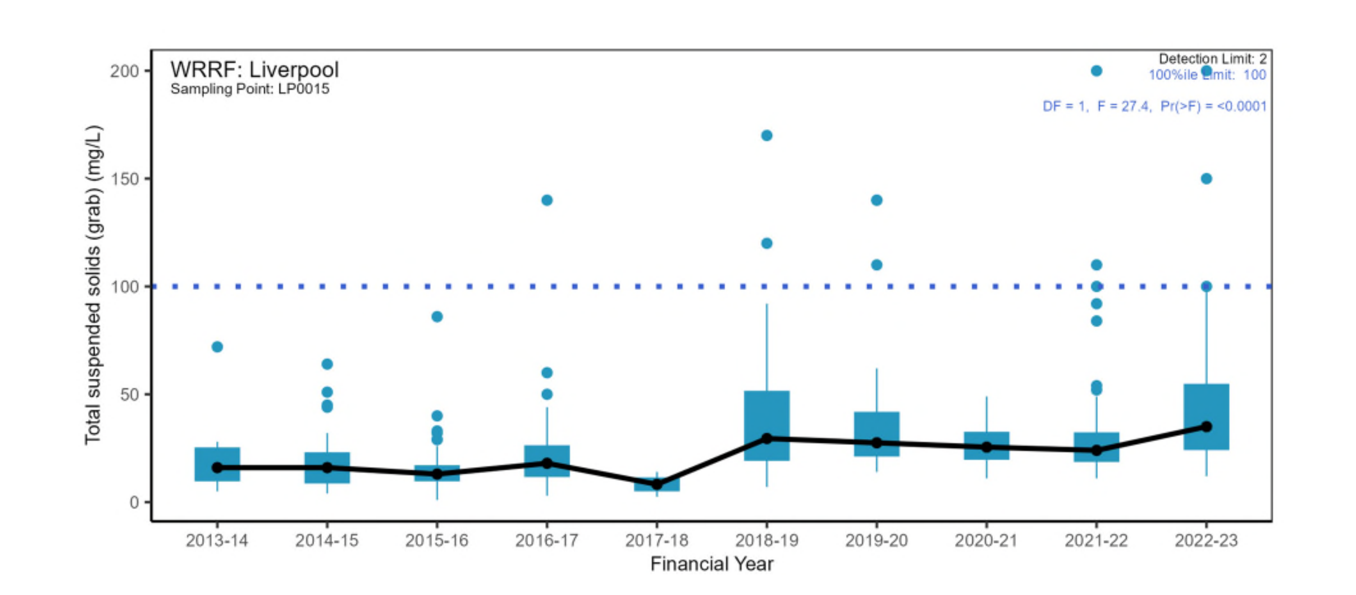


Figure 4-65 Liverpool WRRF discharge quality and toxicity exception plots

Stressor – Water quality

Feasibility study required to inform an appropriate monitoring design and indicators (van Dam et al. 2023).

Ecosystem Receptor – Phytoplankton

Feasibility study required to inform an appropriate monitoring design and indicators (van Dam et al. 2023).

Ecosystem Receptor – Macroinvertebrates

Feasibility study required to inform an appropriate monitoring design and indicators (van Dam et al. 2023).

4.3 Other monitoring – freshwater

4.3.1 Other long-term Hawkesbury-Nepean River sites (SoE)

Receiving water quality was monitored at 12 long-term monitoring sites that can't be directly linked with the WRRF impact assessment. Seven of these sites are along the mainstream river from the upstream Nepean River at Wallacia Bridge to the downstream Hawkesbury River at Leets Vale. Five other sites were monitored at four major tributaries, South Creek, Cattai Creek, Colo River and Berowra Creek. The analytes included key nutrients, physico-chemical analytes chlorophyll-a, phytoplankton volume and species counts.

Monitoring data for these sites are presented for assessing the SoE at each site individually for temporal trends or comparison against national guidelines and water quality objectives.

Temporal trend plots for all these sites by each analyte are included in Volume 2 (Appendix C-1). The exception trend plots on water quality analytes for each of these sites are presented in this section when:

- there was either an increasing or decreasing trend in 2022-23 year or
- the yearly (2022-23) median results exceeded the relevant guideline limit.

A summary of Gate-1 Analysis outcomes are presented in Table 4-55 and Table 4-56. The 2022-23 year was dominated by wet weather throughout the Hawkesbury-Nepean River catchment but eased from a peak in 2021-22. Trends in nutrients, physico-chemical water quality, chlorophyll-a and phytoplankton biovolume or counts were mixed and varied by site in 2022-23. Notably, nutrient concentrations (nitrogen and/or phosphorus) increased at the Nepean River sites. Most importantly, chlorophyll-a improved/ decreased at two main Hawkesbury River sites that are historically prone to phytoplankton blooms.

- Statistical analysis confirmed that oxidised nitrogen and total nitrogen concentrations increased in 2022-23 at three Nepean River sites (Wallacia, Opposite Fitzgeralds Creek and Yarramundi) and the Hawkesbury River site at Sackville Ferry.
- In 2022-23, filterable total phosphorus concentrations increased at two Nepean River sites (Opposite Fitzgeralds Creek and Yarramundi) and decreased in Berowra Creek at Calabash Bay. Total phosphorus concentrations increased in the Nepean River opposite Fitzgeralds Creek and decreased at Wilberforce and Off Cattai SRA in the Hawkesbury River.
- The 2022-23 median oxidised nitrogen and total nitrogen concentrations exceeded the ANZG guideline at all 12 monitoring sites, the only exception being total nitrogen in the Colo River. The median ammonia nitrogen concentration exceeded the guideline at four sites, namely the Nepean River at Wallacia, South Creek, Cattai Creek and Berowra Creek at Calabash Bay.
- Conductivity increased at the Nepean River at Wallacia, and decreased at Cattai Creek, Hawkesbury River at Leets Vale and the two Berowra Creek sites. Conductivity was above the freshwater guideline at the two estuarine sites in Berowra Creek.
- The dissolved oxygen concentration and/or dissolved oxygen saturation level improved/increased at five of the 12 sites in 2022-23 but deteriorated/decreased in Berowra Creek at Calabash Bay. pH increased in the Colo River in 2022-23 but decreased in Berowra

Creek at Calabash Bay. Turbidity increased significantly at three sites (Nepean River Opposite Fitzgeralds Creek and Yarramundi and Berowra Creek Off Square Bay

- The 2022-23 median dissolved oxygen saturation remained below ANZG (2018) lower guideline limit at Cattai Creek. The water clarity was good at most monitoring sites as indicated by low median turbidity. The only exception was lower South Creek where turbidity was significantly higher than the upper guideline limit. At three other sites turbidity was below the lower guideline limit (Colo River and two Berowra Creek sites).
- In 2022-23, chlorophyll-a concentrations decreased at two Hawkesbury River sites (Off Cattai SRA and Sackville Ferry) that are historically prone to phytoplankton blooms. The 2022-23 median chlorophyll-a concentrations exceeded the ANZG (2018) guideline at 11 of 12 SoE monitoring sites. The only exception was the reference site on the Colo River (N2202).
- Total phytoplankton biovolume increased in the Hawkesbury River at Wilberforce. There was no significant temporal trend in phytoplankton biovolume or species count at any other site in 2022-23.
- The median blue-green biovolume or toxic blue-green counts were within the NHMRC (2008) Amber guideline in 2022-23 at all 12 sites. However, toxic blue-green count Amber Alert was observed in the Hawkesbury River at Leets Vale on four times during 2022-23. No other sites had Amber Alerts or Red Alerts in 2022-23.

Table 4-55 Gate 1 Analysis outcome summary – water quality of long-term SoE sites, Hawkesbury-Nepean River catchment

Monitoring sites	Nutrient analytes					Physico-chemical analytes					
	Ammonia nitrogen	Oxidised nitrogen	Total nitrogen	Filterable total phosphorus	Total phosphorus	Conductivity	Dissolved oxygen	Dissolved oxygen saturation	pH	Temperature	Turbidity
Nepean River at Wallacia Bridge (N67)	→	↗	↗	→	→	↗	→	→	→	→	→
Nepean River opposite Fitzgeralds Creek (N51)	→	↗	↗	↗	↗	→	↗	↗	→	→	↗
Nepean River at Yarramundi Bridge (N44)	→	↗	↗	↗	→	→	↗	↗	→	→	↗
Lower South Creek at Fitzroy pedestrian bridge (NS04A)	→	→	→	→	→	→	↗	↗	→	→	→
Hawkesbury River at Wilberforce (N35)	↘	→	→	→	↘	→	↗	↗	→	→	→
Lower Cattai Creek at Cattai Road Bridge (NC11A)	→	→	→	→	→	↘	→	↗	→	→	→
Hawkesbury River Off Cattai SRA (N3001)	→	→	→	→	↘	→	→	→	→	→	→
Hawkesbury River at Sackville Ferry (N26)	→	↗	→	→	→	→	→	→	→	→	→
Lower Colo River at Putty Road Bridge (N2202)	→	→	→	→	→	→	→	→	↗	→	→
Hawkesbury River at Leets Vale (N18)	→	→	→	→	→	↘	↗	↗	→	→	→
Berowra Creek at Calabash Bay (NB13)	→	→	→	↘	→	↘	→	↘	↘	→	→
Berowra Creek, Off Square Bay (NB11)	→	→	→	→	→	↘	→	→	→	→	↗

↗	Upward trend	↘	Downward trend	→	no trend, p>0.05

(green)	2022-23 Median value within the guideline limit	(white)	No guideline applicable
(yellow)	2022-23 Median value outside the guideline limit	(grey)	Insufficient data

Table 4-56 Gate 1 Analysis outcome summary – phytoplankton as chlorophyll-a, biovolume and species counts, long-term SoE sites, Hawkesbury-Nepean River catchment

Monitoring sites	Phytoplankton analytes			
	Chlorophyll-a	Total phytoplankton biovolume	Blue-green biovolume	Toxic blue-green count
Nepean River at Wallacia Bridge (N67)	→	→	→	→
Nepean River opposite Fitzgeralds Creek (N51)	→	→	→	→
Nepean River at Yarramundi Bridge (N44)	→	→	→	→
Lower South Creek at Fitzroy pedestrian bridge (NS04A)	→	→	→	→
Hawkesbury River at Wilberforce (N35)	→	↗	→	→
Lower Cattai Creek at Cattai Road Bridge (NC11A)	→	→	→	→
Hawkesbury River Off Cattai SRA (N3001)	↘	→	→	→
Hawkesbury River at Sackville Ferry (N26)	↘	→	→	→
Lower Colo River at Putty Road Bridge (N2202)	→			
Hawkesbury River at Leets Vale (N18)	→	→	→	→
Berowra Creek at Calabash Bay (NB13)	→	→	→	
Berowra Creek, Off Square Bay (NB11)	→	→		

↗	Upward trend	↘	Downward trend	→	no trend, p>0.05

	2022-23 Median value within the guideline limit		No guideline applicable
	2022-23 Median value outside the guideline limit		Insufficient data

N67: Nepean River at Wallacia Bridge

The Nepean River at Wallacia Bridge (N67) is about 4 km upstream of the Warragamba River confluence. The immediate upstream area is less developed with a mix of natural and agricultural catchments. The water quality at this site may be also influenced by other upstream catchment factors including West Camden WWRF discharges (about 30 km upstream), Picton WRRF discharges and environmental water releases from Warragamba Dam.

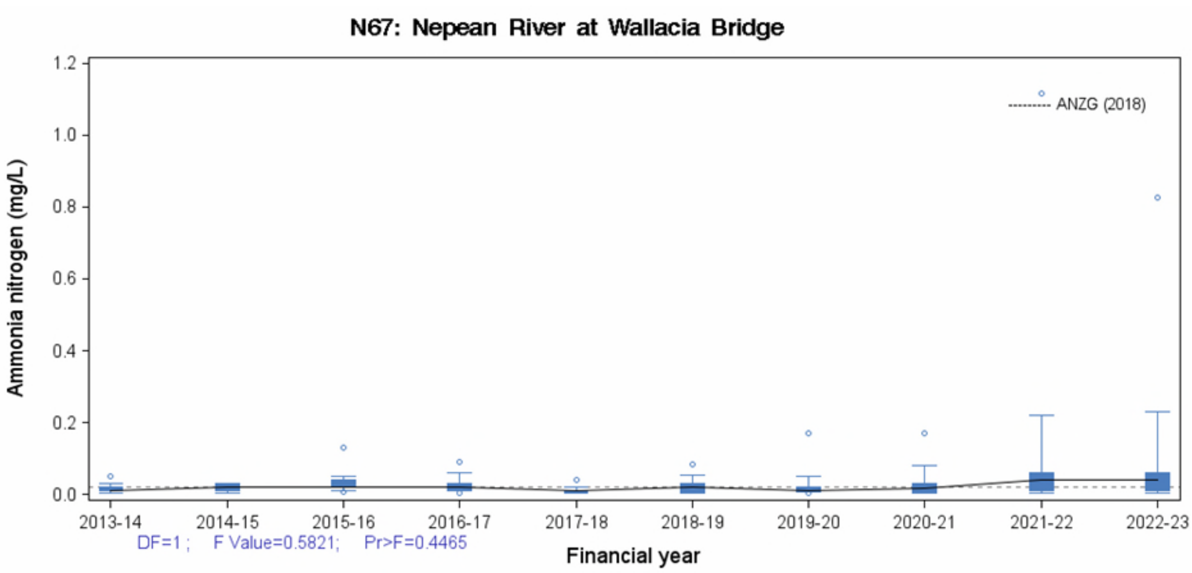
Statistical analysis confirmed that, oxidised nitrogen and total nitrogen concentrations were significantly higher in the Nepean River at Wallacia Bridge (N67) in 2022-23 compared to earlier nine years. Conductivity also increased significantly in 2022-23.

In the 2022-23 period, the median ammonia nitrogen, oxidised nitrogen, total nitrogen and chlorophyll-a concentrations exceeded the respective ANZG (2018) guidelines.

The chlorophyll-a and phytoplankton biovolume or blue-green biovolume, toxic blue-green species counts were steady at this site in 2022-23.

Five of the 17 samples collected from N67 qualified for a phytoplankton biovolume and species count when chlorophyll-a was higher than 7.0 µg/L. Chlorophyll-a concentrations reached 44.2 µg/L on 16 December 2022, however the presence of blue-greens was minimal and no potentially toxic species were present. On 17 February 2023, the potentially toxic blue-green taxa *Microcystis* was found in another sample (498 cells/mL).

There were no other significant statistical trends and/or exceptions (median values higher than the guideline limits) for any other water quality or phytoplankton analyte at N67 in 2022-23.



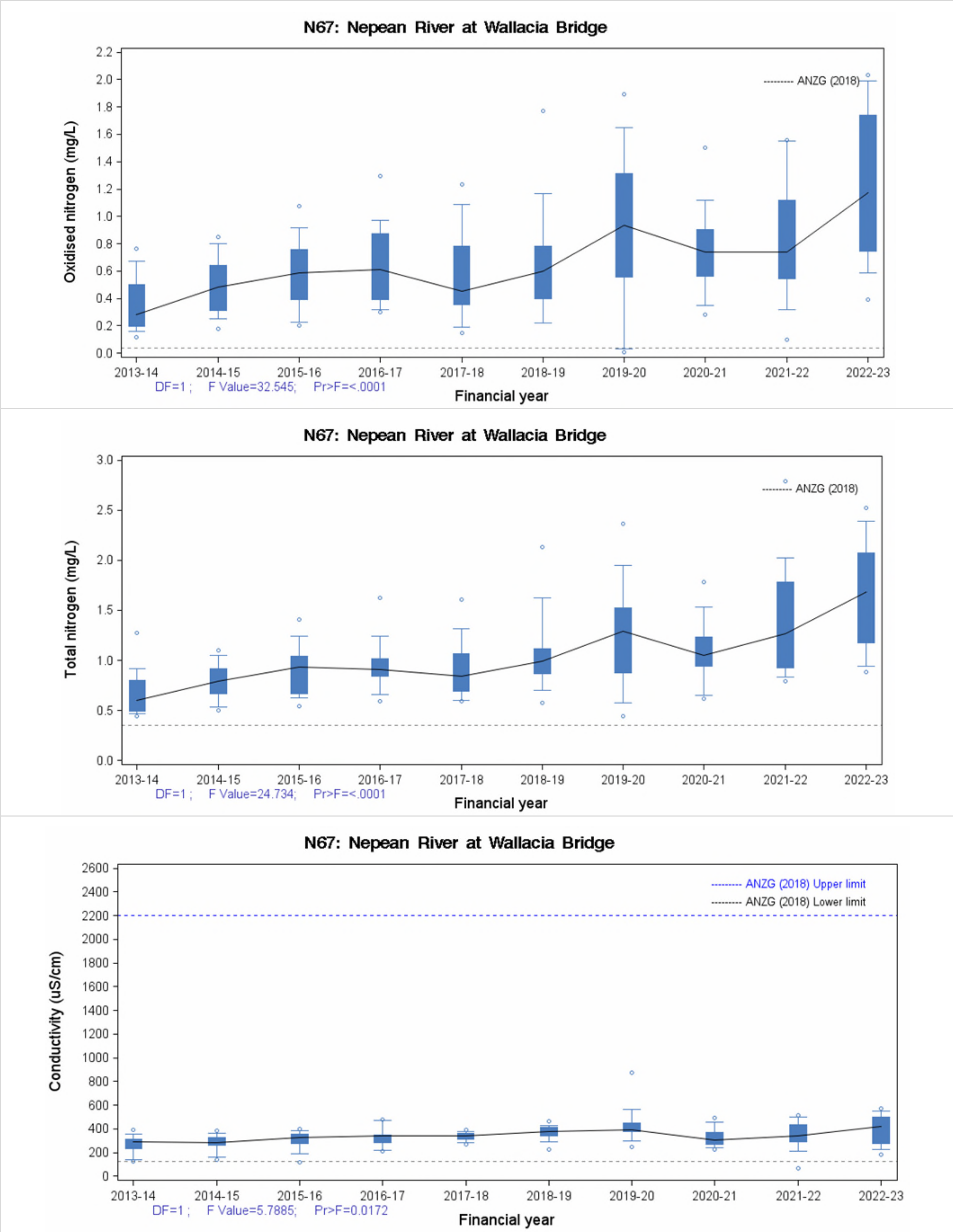


Figure 4-66 Nutrients and physico-chemical water quality exception plots, Nepean River at Wallacia Bridge (N67)

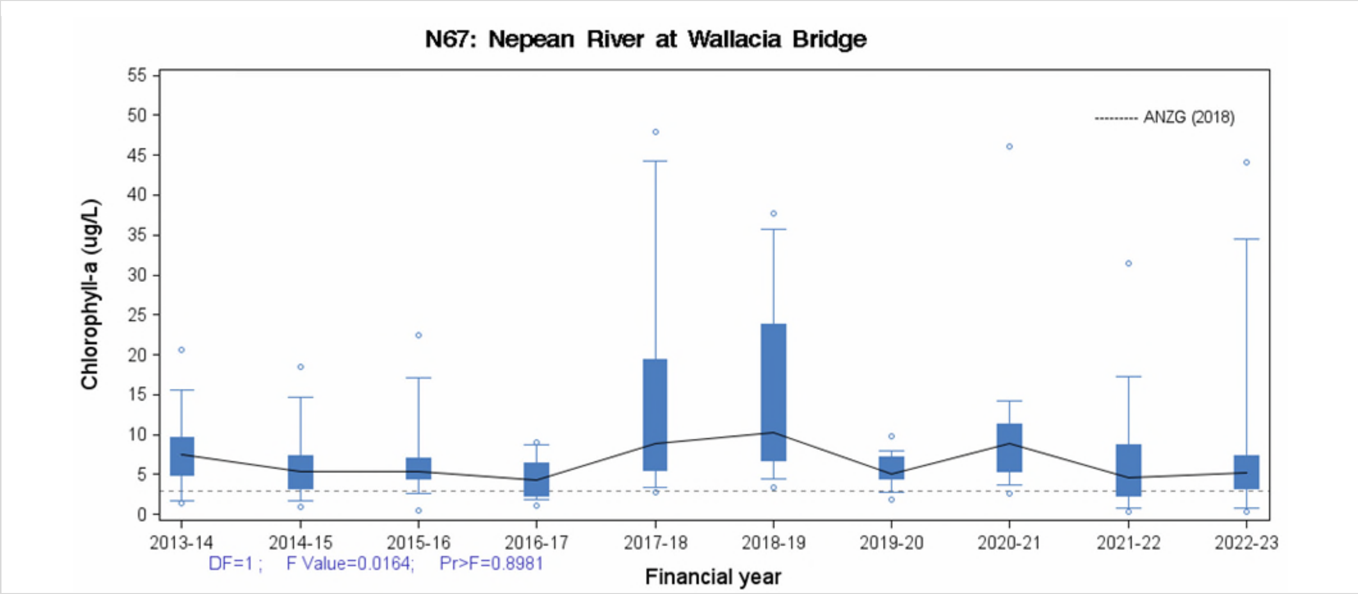


Figure 4-67 Phytoplankton as chlorophyll-a exception plot, Nepean River at Wallacia Bridge (N67)

N51: Nepean River opposite Fitzgerald Creek

The Nepean River site opposite Fitzgeralds Creek (N51) is about 5 km downstream of Penrith Weir. Penrith WRRF discharges treated wastewater effluent to Boundary Creek, a small tributary entering the Nepean River below Penrith Weir. Boundary Creek also receives highly treated recycled water from the St Marys Advanced Water Treatment Plant (AWTP) that may help to improve the water quality at this site. Sand mining and agricultural activities may also impact the water quality at this site, although the sand mining ceased in September 2019 with the Penrith Lakes area now under rehabilitation and redevelopment (Quarry 2020). The site often contains submerged macrophyte beds and the occasional floating macrophyte species.

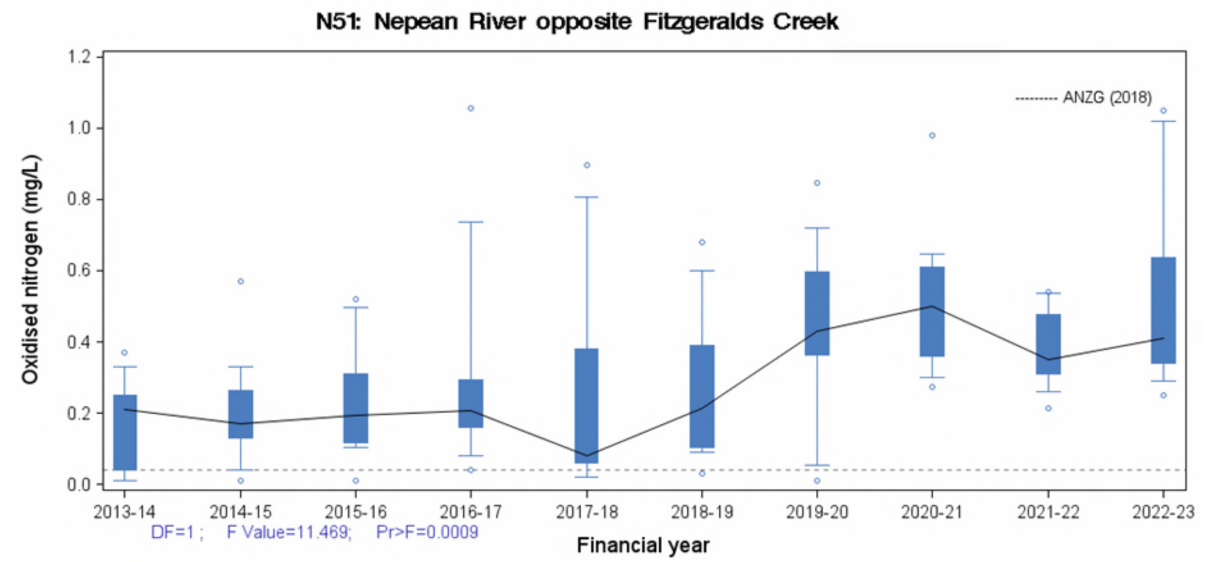
Statistical analysis confirmed a significantly increasing trend in oxidised nitrogen, total nitrogen, filterable total phosphorus and total phosphorus at N51 in 2022-23 compared to the previous nine years' results. Among physico-chemical analytes, dissolved oxygen, dissolved oxygen saturation and turbidity were also significantly higher in 2022-23.

In the 2022-23 period, the median oxidised nitrogen, total nitrogen, total phosphorus and chlorophyll-a concentrations exceeded the respective ANZG (2018) guidelines.

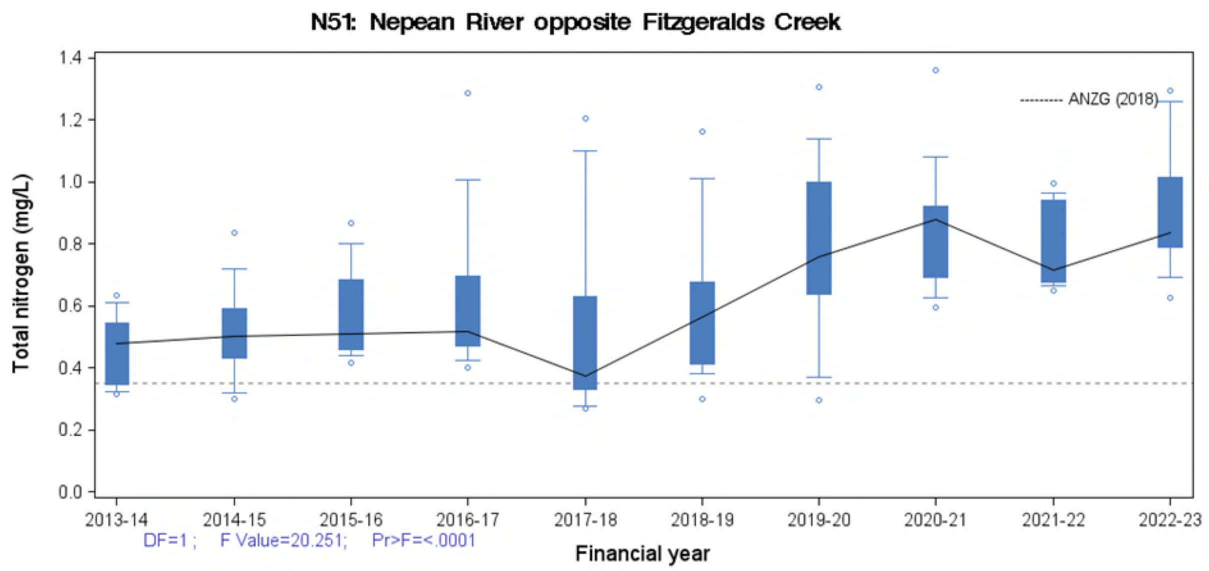
The chlorophyll-a and phytoplankton biovolume or blue-green biovolume, toxic blue-green species counts were steady at this site in 2022-23.

Five of the 17 samples collected from N51 were qualified for a phytoplankton biovolume and species count when chlorophyll-a were higher than 7.0 µg/L. Miscellaneous blue-green taxa were present in these samples but no toxic blue-green species was found in any sample.

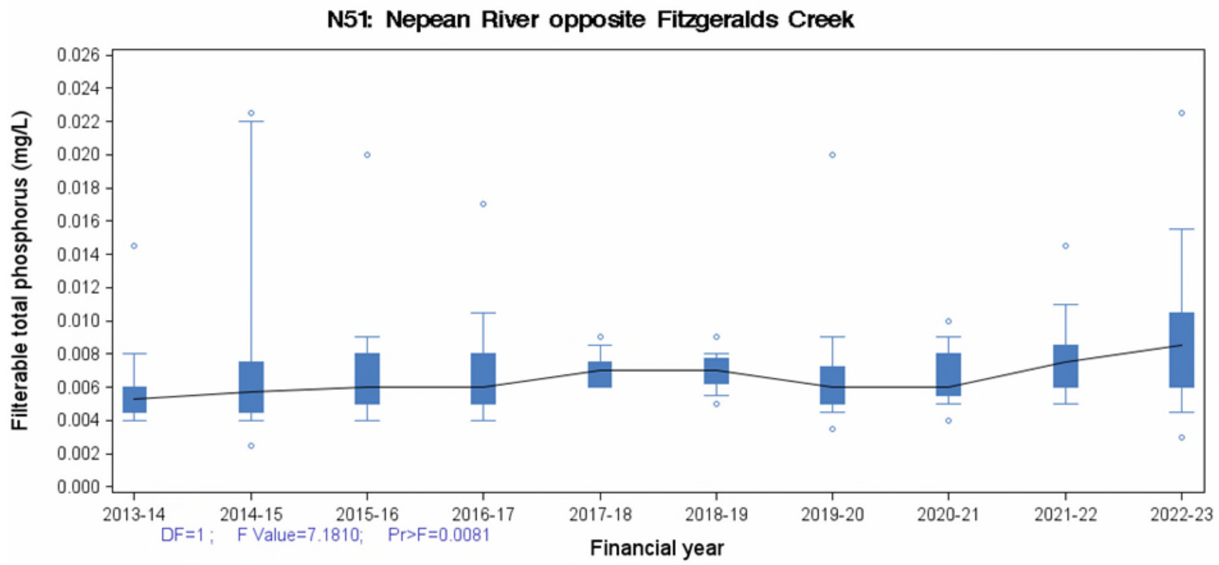
There were no other significant statistical trends and/or exceptions (median values higher than the guideline limits) for any other water quality or phytoplankton analyte at N51 in 2022-23.



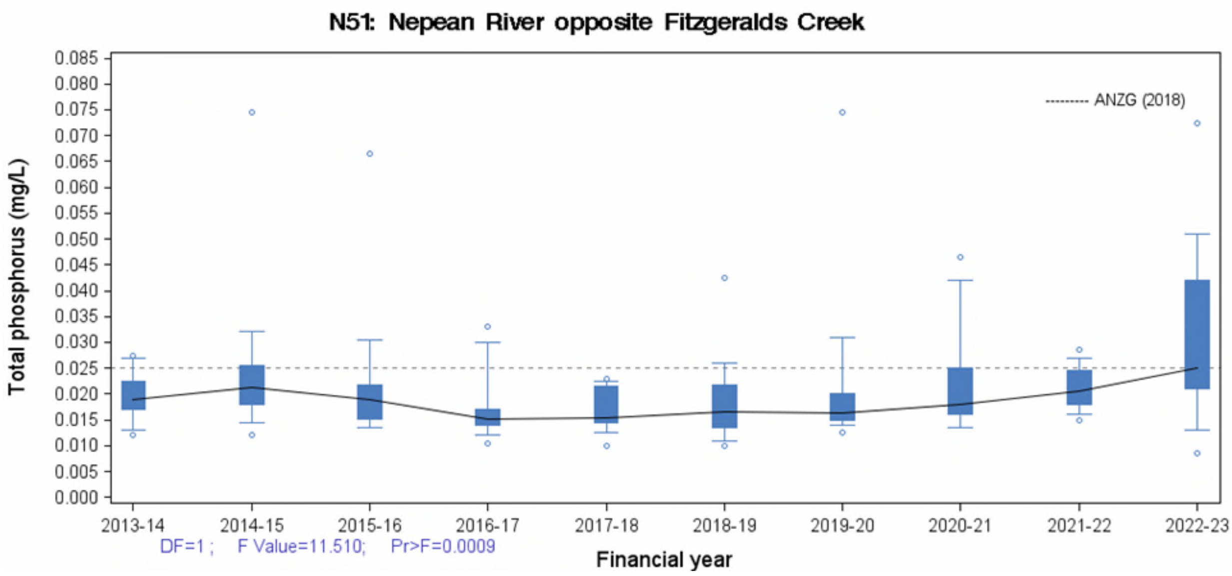
N51: Nepean River opposite Fitzgeralds Creek
ANZG (2018)
Oxidised nitrogen (mg/L)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
2020-21
2021-22
2022-23
DF=1 ; F Value=11.469; Pr>F=0.0009
Financial year

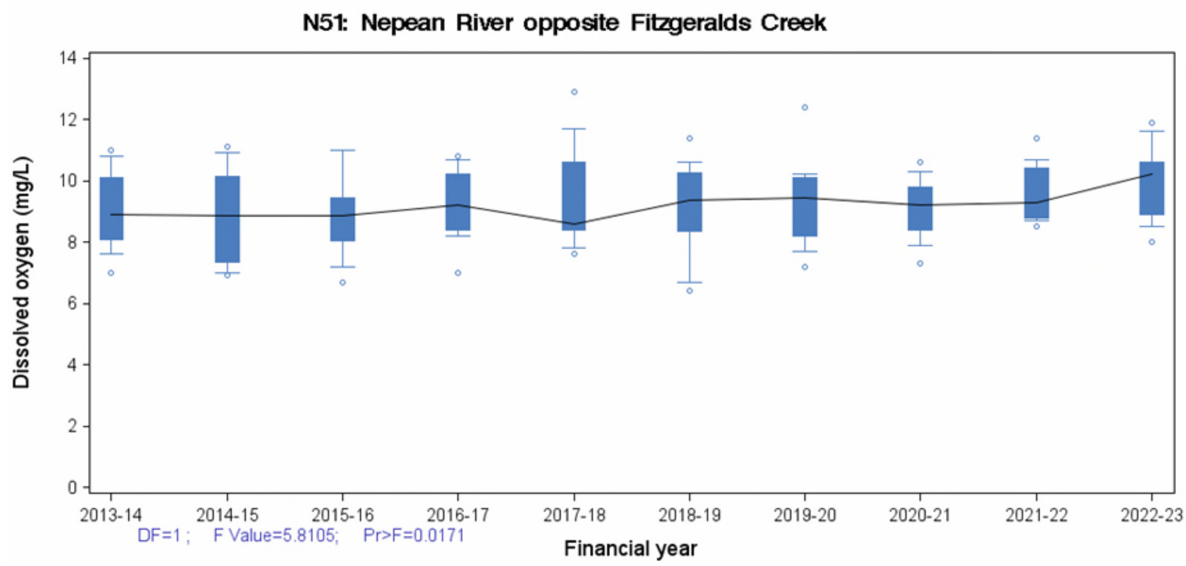


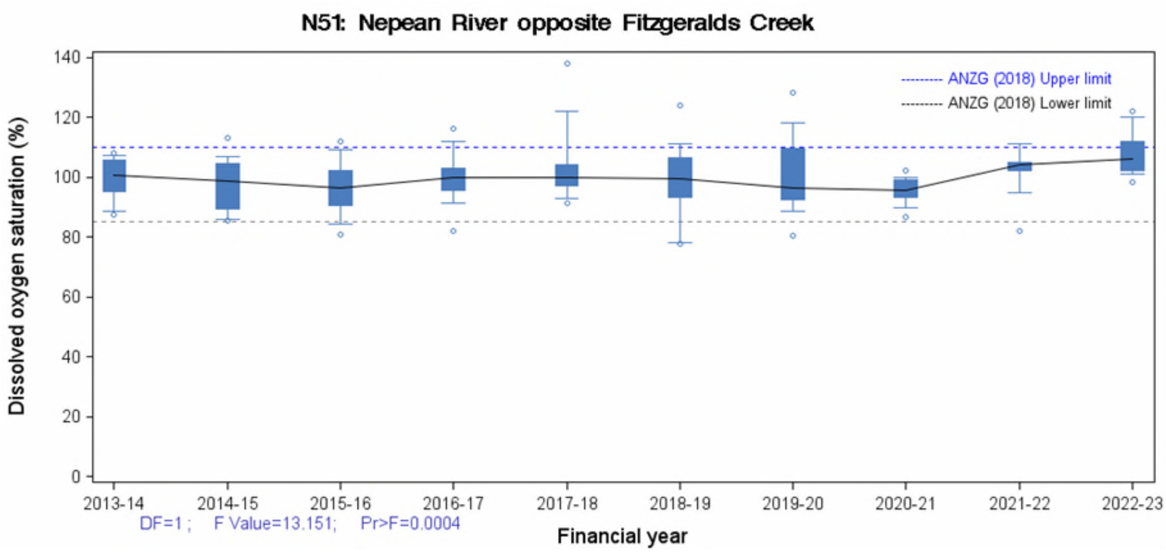
N51: Nepean River opposite Fitzgeralds Creek
ANZG (2018)
Total nitrogen (mg/L)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
2020-21
2021-22
2022-23
DF=1 ; F Value=20.251; Pr>F=<.0001
Financial year



N51: Nepean River opposite Fitzgeralds Creek
Filterable total phosphorus (mg/L)
0.026
0.024
0.022
0.020
0.018
0.016
0.014
0.012
0.010
0.008
0.006
0.004
0.002
0.000
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
2020-21
2021-22
2022-23
DF=1 ; F Value=7.1810; Pr>F=0.0081
Financial year


N51: Nepean River opposite Fitzgeralds Creek
Total phosphorus (mg/L)
0.085
0.080
0.075
0.070
0.065
0.060
0.055
0.050
0.045
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
ANZG (2018)
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
2020-21
2021-22
2022-23
DF=1 ; F Value=11.510; Pr>F=0.0009
Financial year


N51: Nepean River opposite Fitzgeralds Creek
Dissolved oxygen (mg/L)
14
12
10
8
6
4
2
0
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
2020-21
2021-22
2022-23
DF=1 ; F Value=5.8105; Pr>F=0.0171
Financial year


N51: Nepean River opposite Fitzgeralds Creek
Dissolved oxygen saturation (%)
140
120
100
80
60
40
20
0
ANZG (2018) Upper limit
ANZG (2018) Lower limit
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
2020-21
2021-22
2022-23
DF=1 ; F Value=13.151; Pr>F=0.0004
Financial year

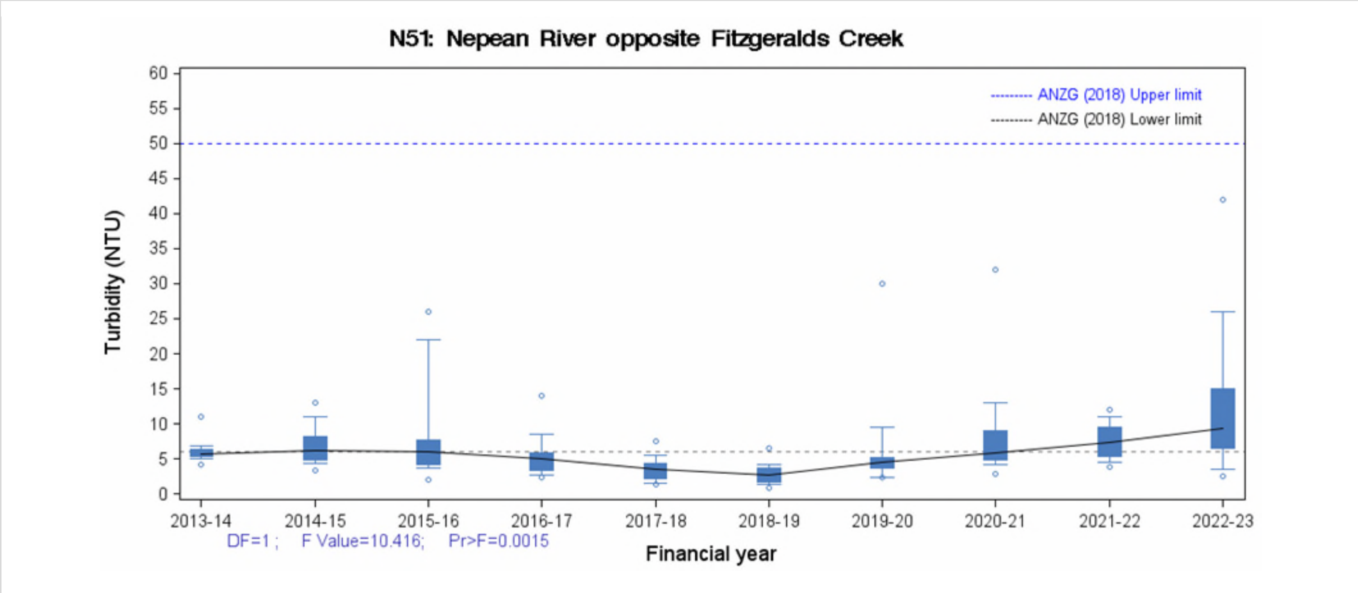


Figure 4-68 Nutrients and physico-chemical water quality exception plots, Nepean River opposite Fitzgerald Creek (N51)

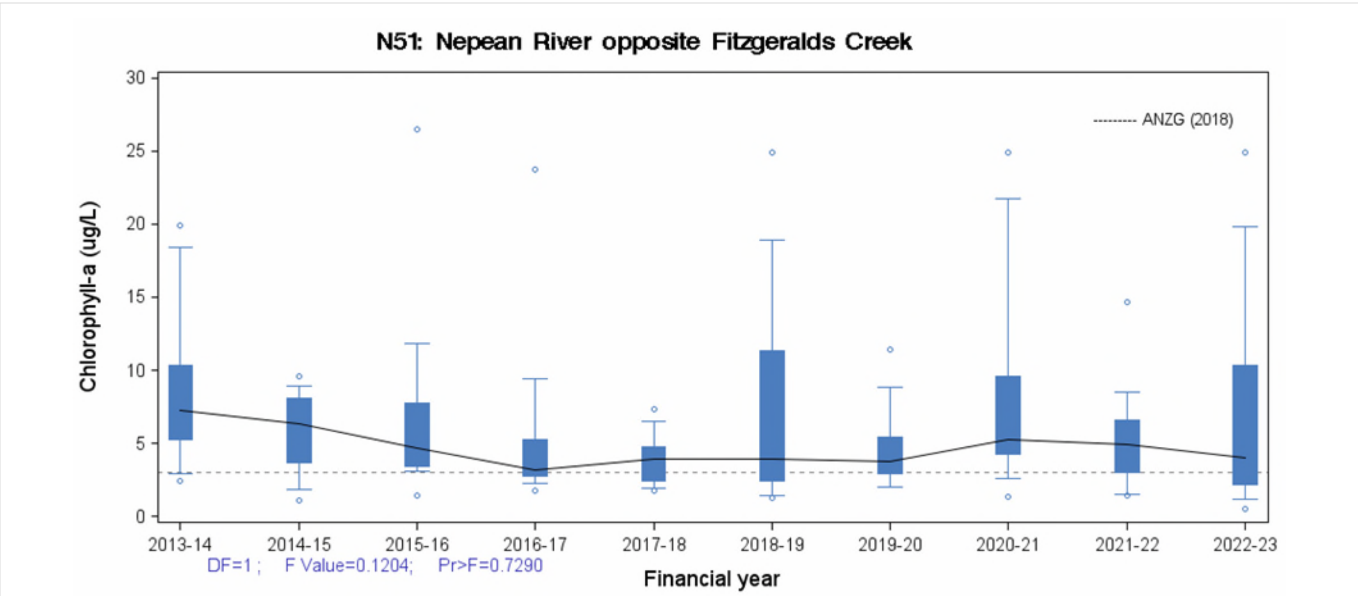


Figure 4-69 Phytoplankton as chlorophyll-a exception plot, Nepean River Nepean River opposite Fitzgerald Creek (N51)

N44: Nepean River at Yarramundi Bridge

The Nepean River at Yarramundi Bridge (N44) is located just before the confluence with the Grose River. The site is situated downstream of Winmalee lagoon where Winmalee WRRF discharges treated wastewater. Yarramundi is the freshwater upper tidal limit for the Hawkesbury-Nepean River.

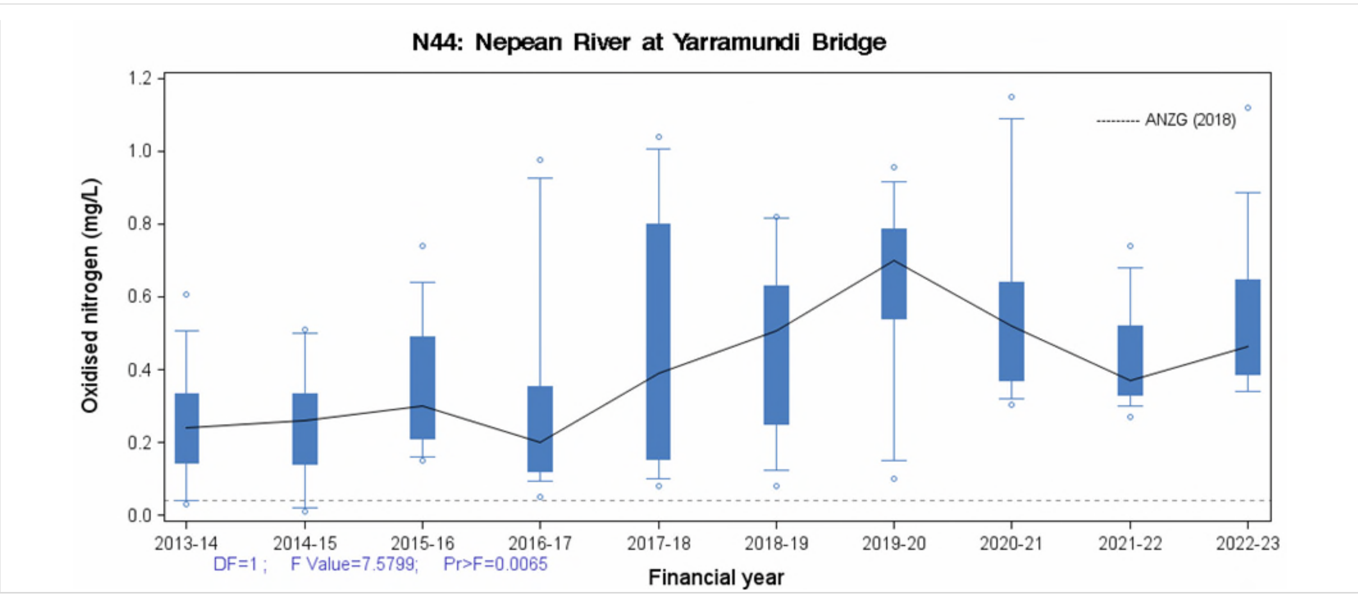
The water quality of the Nepean River at Yarramundi Bridge showed significantly increased concentrations of oxidised nitrogen, total nitrogen and filterable total phosphorus in 2022-23. Among physico-chemical analytes, dissolved oxygen, dissolved oxygen saturation and turbidity were also significantly higher in 2022-23.

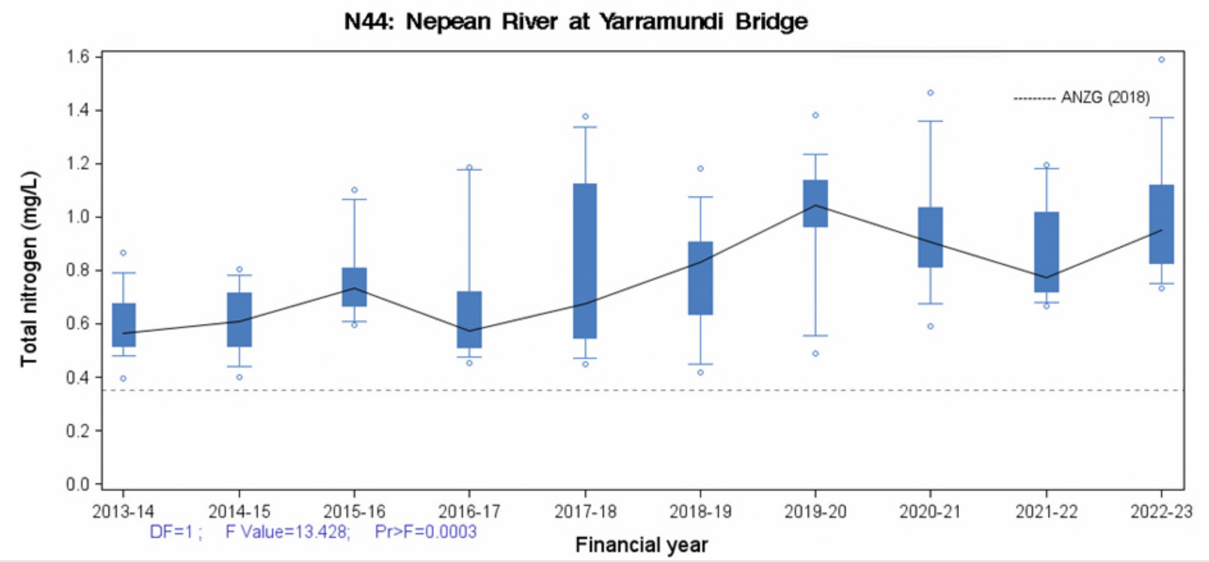
In the 2021-22 period, the median oxidised nitrogen, total nitrogen, total phosphorus and chlorophyll-a concentrations exceeded the respective ANZG (2018) guidelines.

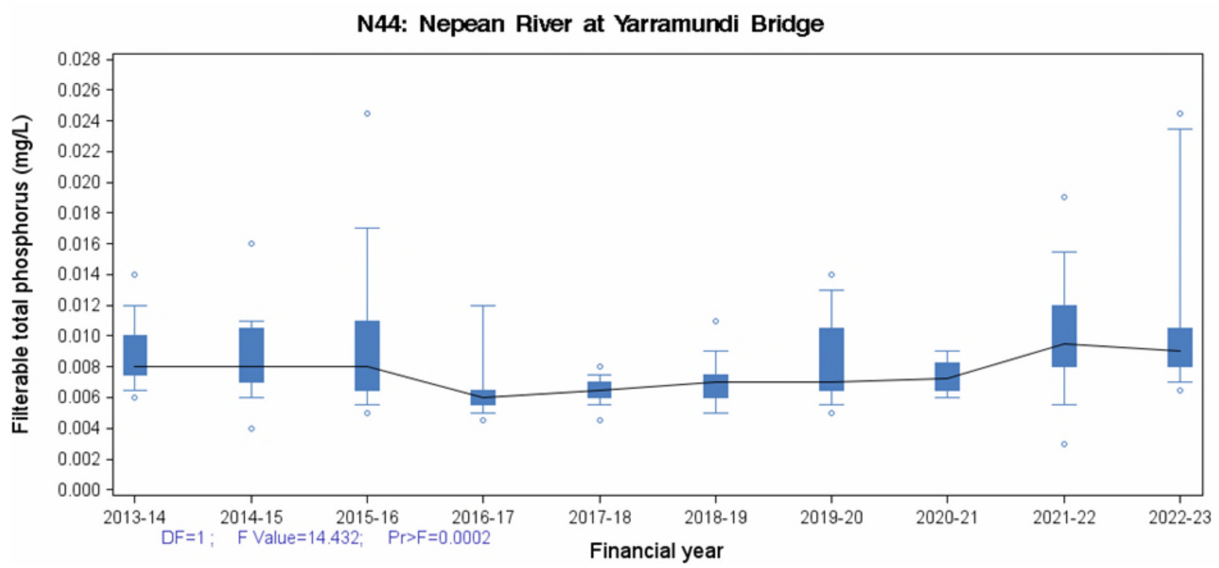
The chlorophyll-a and phytoplankton biovolume or blue-green biovolume, toxic blue-green species counts were steady at this site in 2022-23.

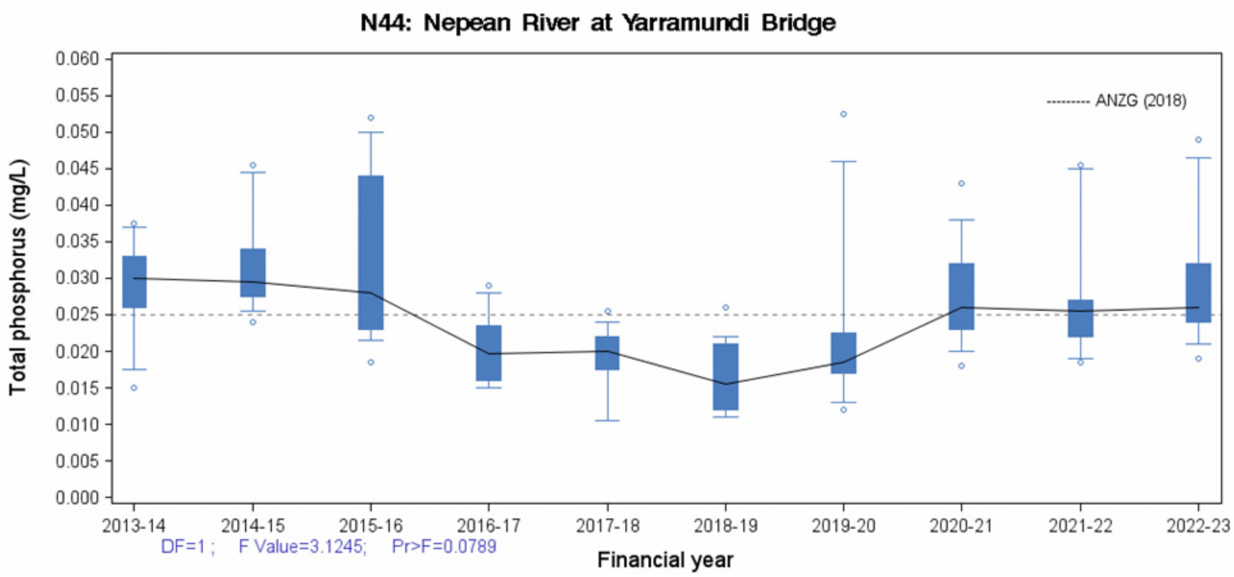
Nine of the 17 samples collected from N44 were qualified for a phytoplankton biovolume and species count when chlorophyll-a were higher than 7.0 μg/L. Chlorophyll-a in these samples ranged between 7.8 and 14.6 μg/L. Potentially toxic blue-green species were present in two of these samples, maximum of 659 cell/mL on 10 March 2023 (*Aphanizomenonaceae*).

There were no other significant statistical trends and/or exceptions (median values higher than the guideline limits) for any other water quality or phytoplankton analyte at N44 in 2022-23.




N44: Nepean River at Yarramundi Bridge
Total nitrogen (mg/L)
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
ANZG (2018)
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
2020-21
2021-22
2022-23
DF=1 ; F Value=13.428; Pr>F=0.0003
Financial year


N44: Nepean River at Yarramundi Bridge
Filterable total phosphorus (mg/L)
0.028
0.026
0.024
0.022
0.020
0.018
0.016
0.014
0.012
0.010
0.008
0.006
0.004
0.002
0.000
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
2020-21
2021-22
2022-23
DF=1 ; F Value=14.432; Pr>F=0.0002
Financial year


N44: Nepean River at Yarramundi Bridge
Total phosphorus (mg/L)
0.060
0.055
0.050
0.045
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
ANZG (2018)
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
2020-21
2021-22
2022-23
DF=1 ; F Value=3.1245; Pr>F=0.0789
Financial year

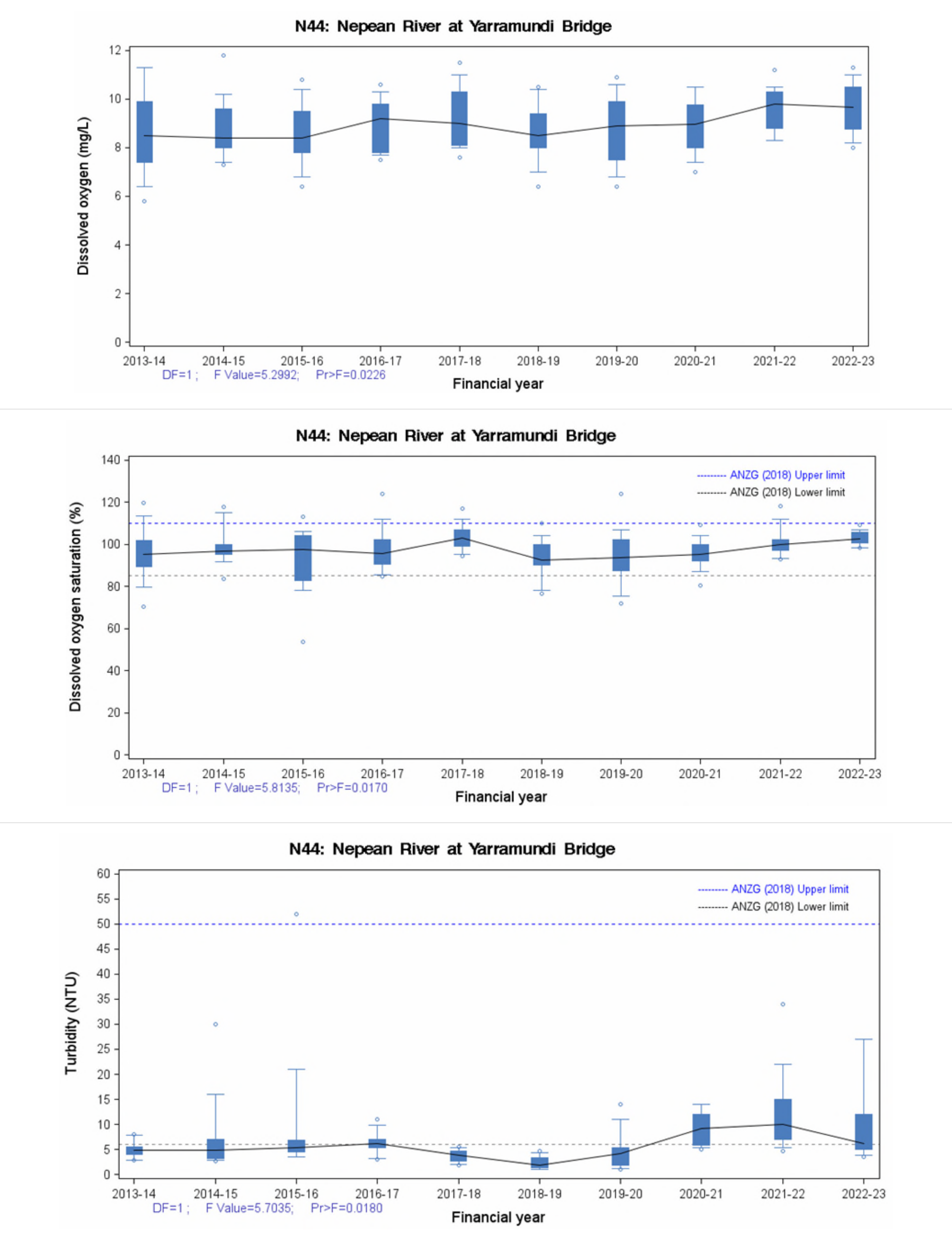


Figure 4-70 Nutrients and physico-chemical water quality exception plots, Nepean River at Yarramundi Bridge (N44)

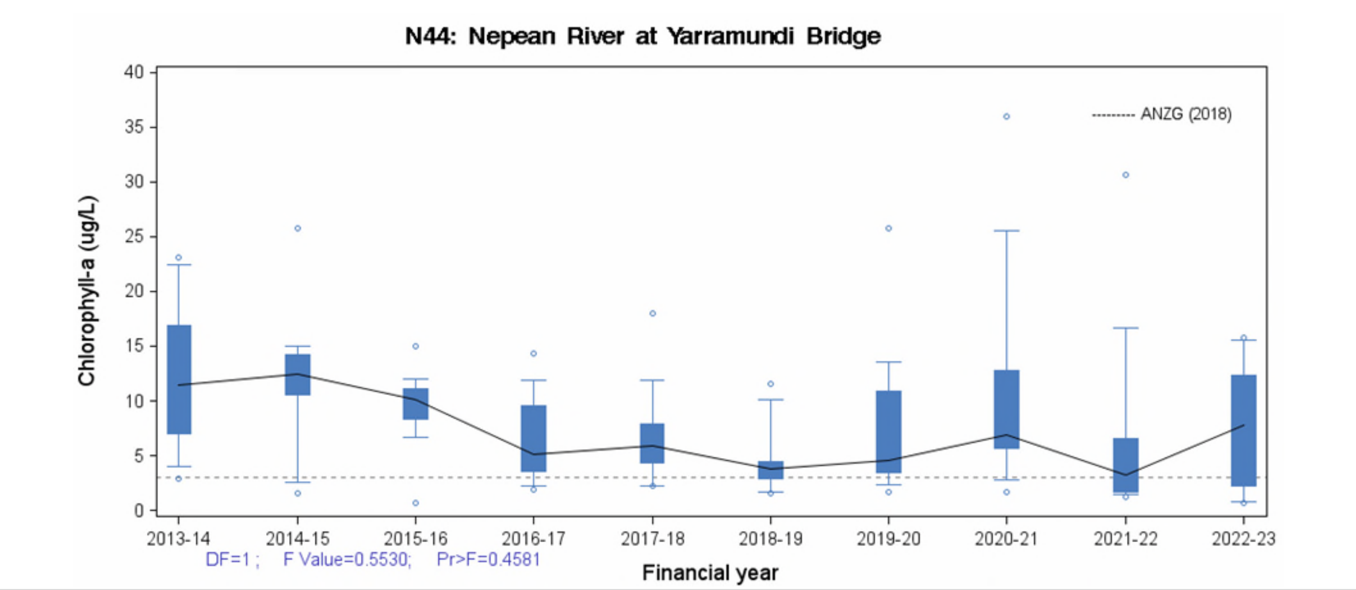


Figure 4-71 Phytoplankton as chlorophyll-a exception plot, Nepean River at Yarramundi Bridge (N44)

NS04A: Lower South Creek at Fitzroy Bridge

South Creek is one of the major tributaries to the Hawkesbury River. It originates at Narellan and travels 64 km before entering the Hawkesbury River at Windsor. The land along South Creek is used for rural applications including grazing and market gardening, and intensive agriculture such as poultry farming. It also has both residential and industrial land uses that have increased in recent years. South Creek and its tributaries receive tertiary treated wastewater discharges from three Sydney Water WRRFs (St Marys, Riverstone and Quakers Hill) and two council WRRFs (McGraths Hill and South Windsor). The lower South Creek water quality monitoring site (NS04A) is located at Fitzroy Bridge, about 2 km upstream of the confluence with the Hawkesbury River. Although the lower part of the creek is tidal, the water quality at this site is expected to represent overall quality of South Creek before joining the river.

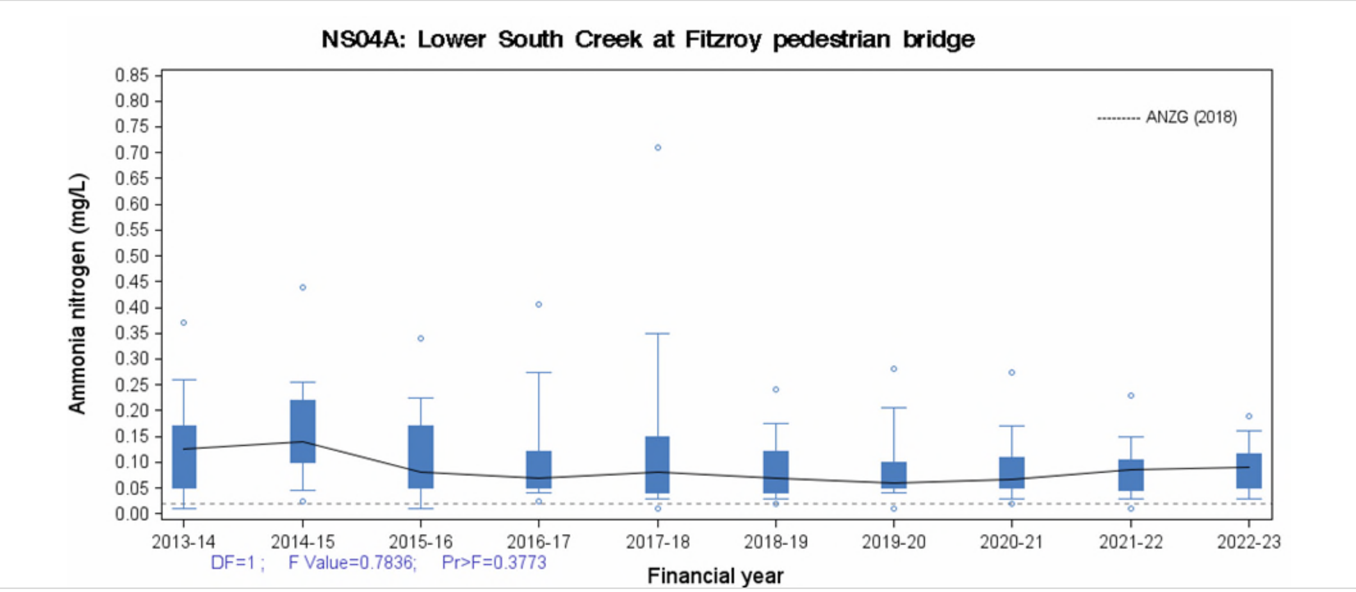
In 2022-23, concentrations of nutrient analytes were steady at NS04A. Among physico-chemical water quality analytes, dissolved oxygen concentration and saturation were higher/ improved in the 2022-23 year.

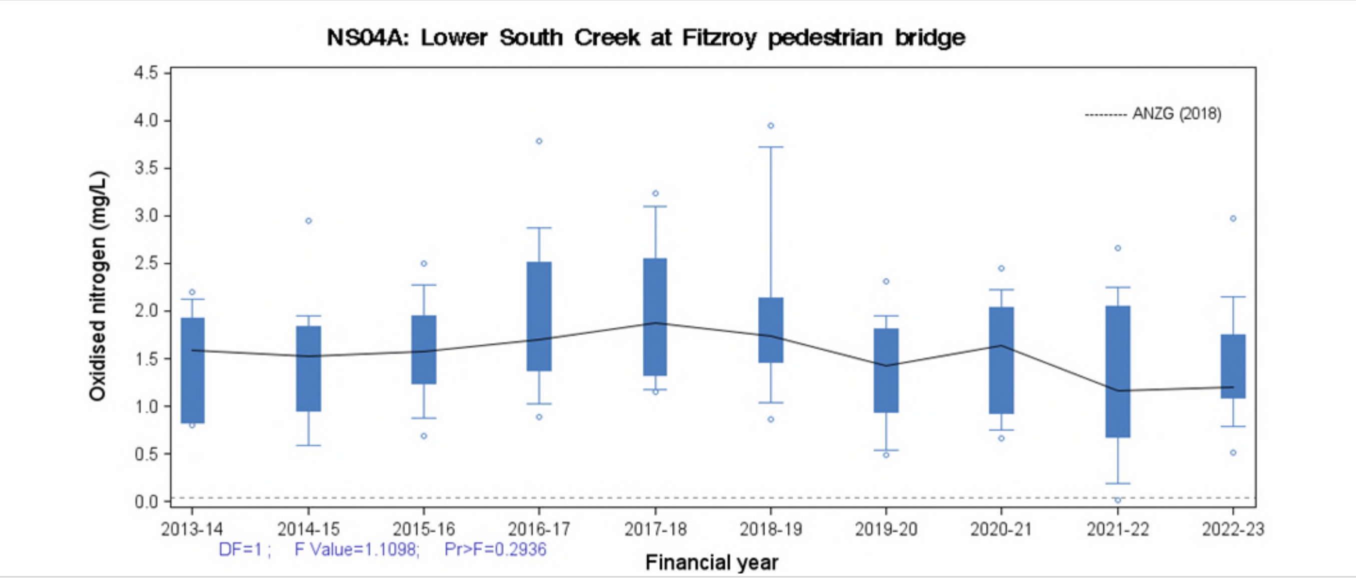
The median ammonia nitrogen, oxidised nitrogen, total nitrogen, total phosphorus and chlorophyll-a concentrations in South Creek exceeded the respective ANZG (2018) guidelines in 2022-23. The creek was turbid with the median level exceeding the higher guideline limit in 2022-23 (median = 71 NTU).

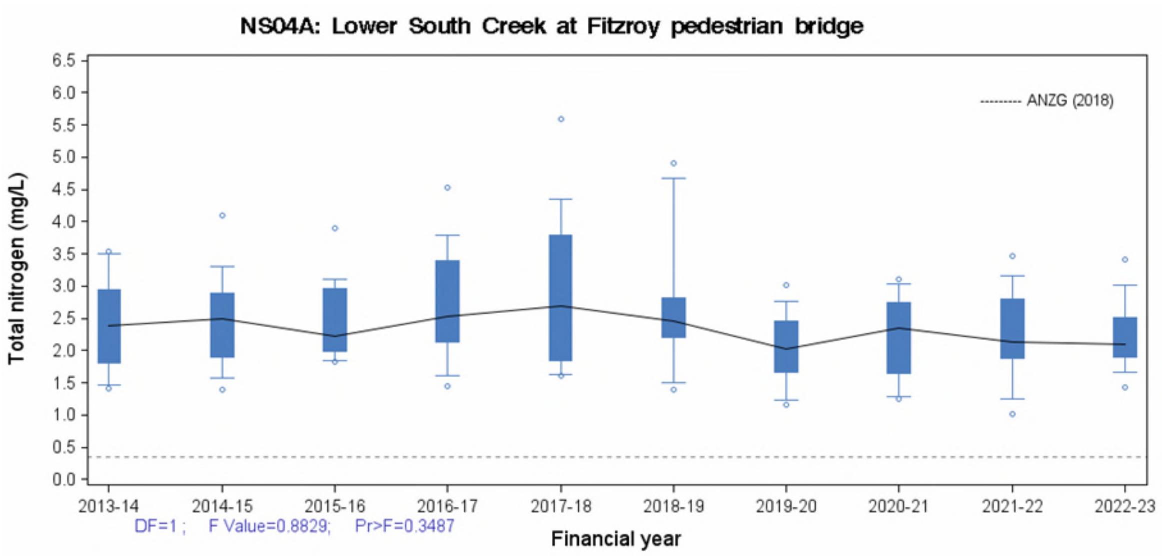
The chlorophyll-a and phytoplankton biovolume or blue-green biovolume, toxic blue-green species counts were steady at this site in 2022-23.

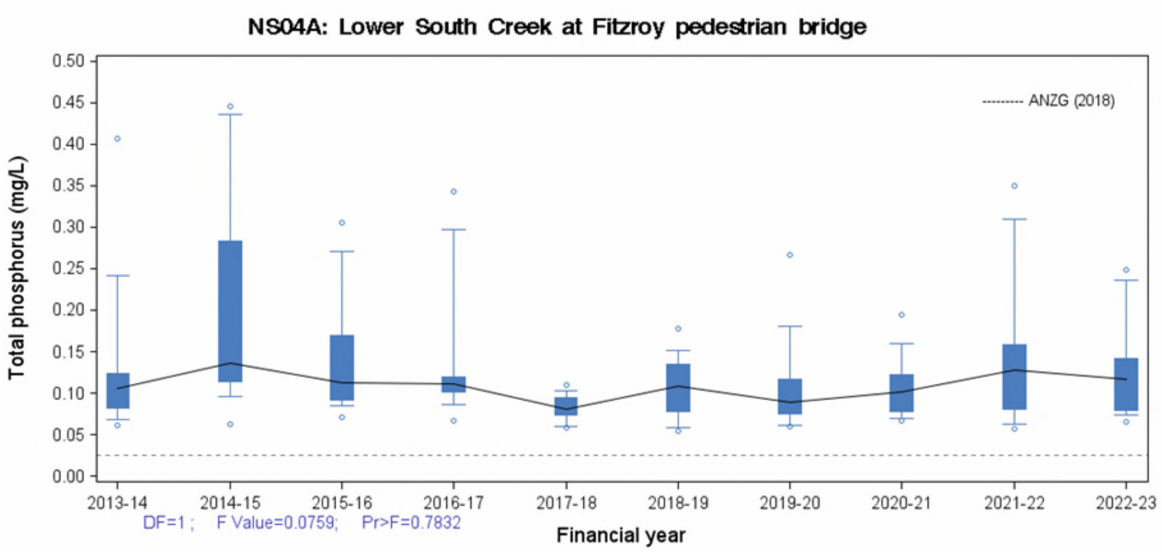
Eight of the 17 samples collected from NS04A qualified for a phytoplankton biovolume and species count when chlorophyll-a was higher than 7.0 µg/L. Potentially toxic blue-green species were present in two of these samples. The maximum chlorophyll-a concentration of 34.3 µg/L was recorded 6 January 2023, when toxic blue-green taxa *Aphanizomenonaceae* reached 3,460 cells/mL.

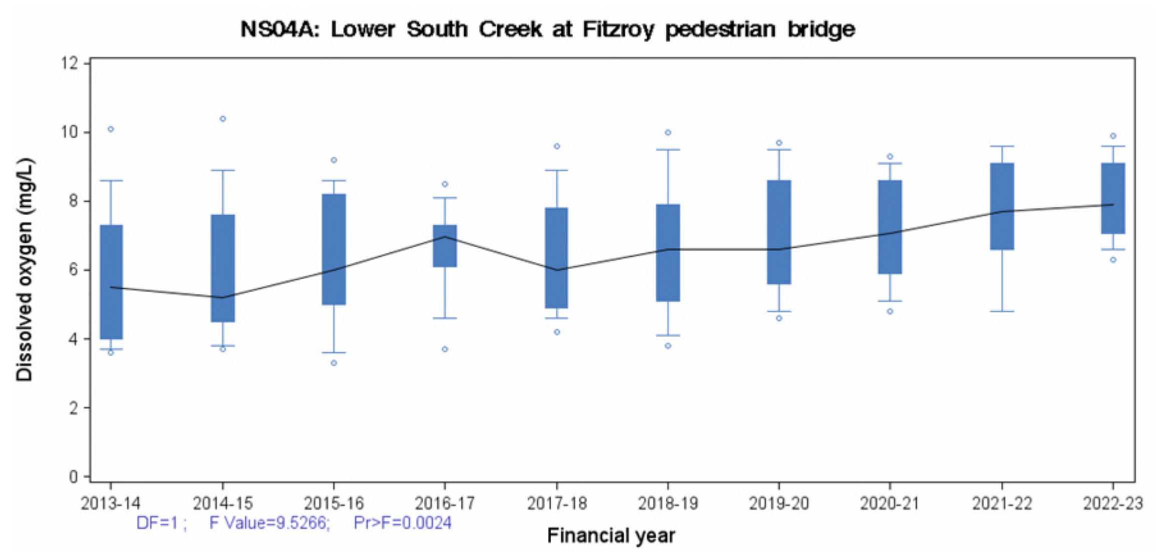
There were no other significant statistical trends and/or exceptions (median values higher than the guideline limits) for any other water quality or phytoplankton analytes at NS04A in 2022-23.

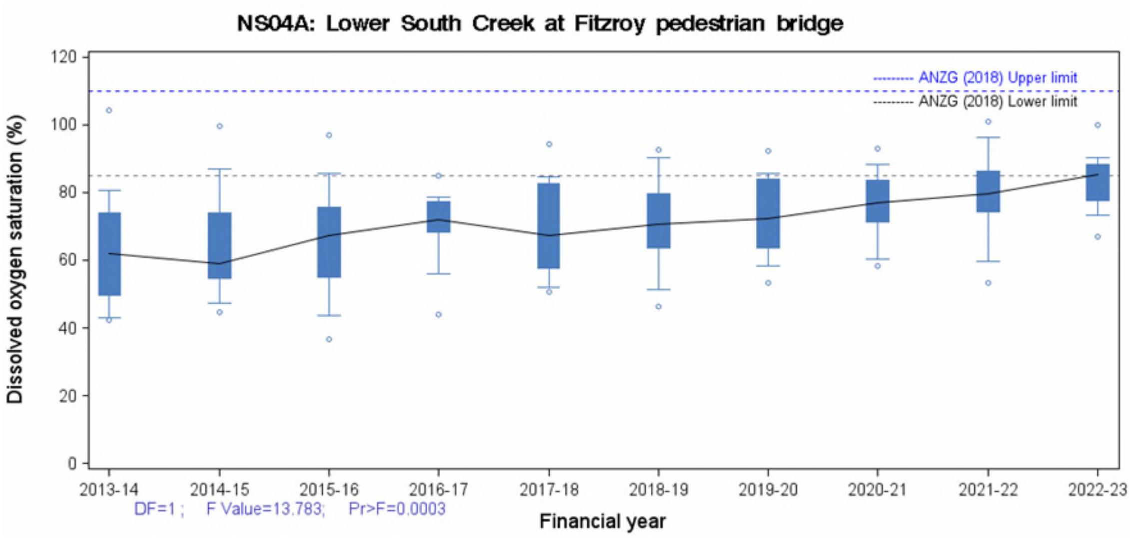





NS04A: Lower South Creek at Fitzroy pedestrian bridge
Total nitrogen (mg/L)
ANZG (2018)
Financial year
DF=1 ; F Value=0.8829; Pr>F=0.3487


NS04A: Lower South Creek at Fitzroy pedestrian bridge
Total phosphorus (mg/L)
ANZG (2018)
Financial year
DF=1 ; F Value=0.0759; Pr>F=0.7832


NS04A: Lower South Creek at Fitzroy pedestrian bridge
Dissolved oxygen (mg/L)
Financial year
DF=1 ; F Value=9.5266; Pr>F=0.0024



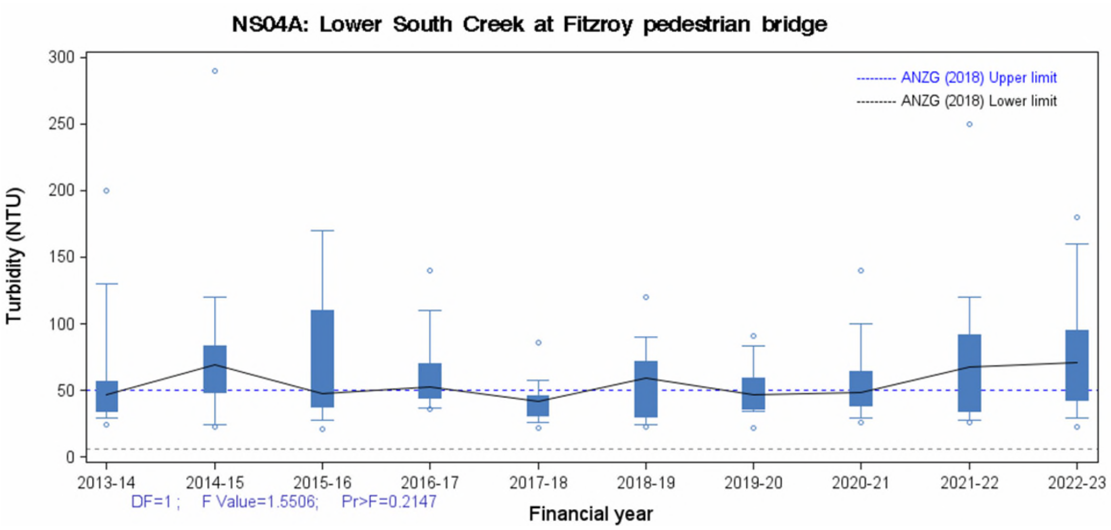


Figure 4-72 Nutrients and physico-chemical water quality exception plots, Lower South Creek at Fitzroy Bridge (NS04A)

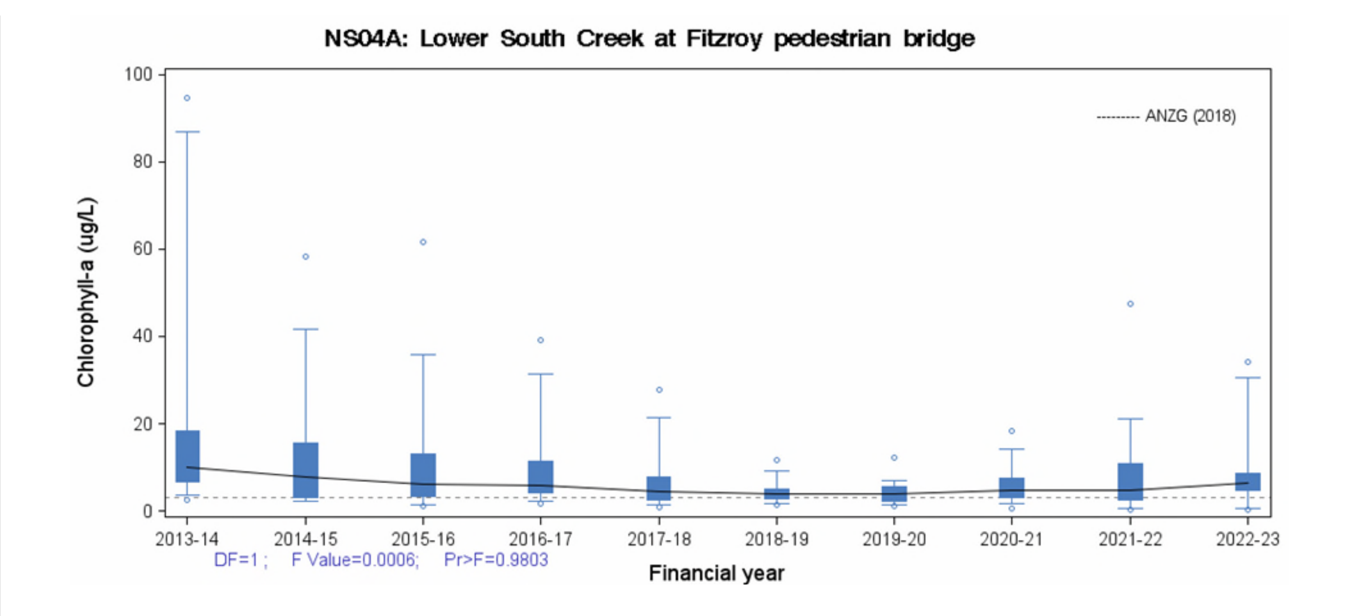


Figure 4-73 Phytoplankton as chlorophyll-a exception plot, Lower South Creek at Fitzroy Bridge (NS04A)

N35: Hawkesbury River at Wilberforce

The Hawkesbury River site at Wilberforce (N35) is located about 5 km downstream of the confluence with South Creek. Water quality at this site is affected by the quality and magnitude of flows coming from South Creek. Historically, there have been water quality concerns at this site due to elevated nutrient concentrations, chlorophyll-a and phytoplankton blooms, especially potentially toxic blue-green blooms. The width and depth of the river, combined with the high nutrients, tidal influence and long residence time has made it prone to phytoplankton blooms in the past.

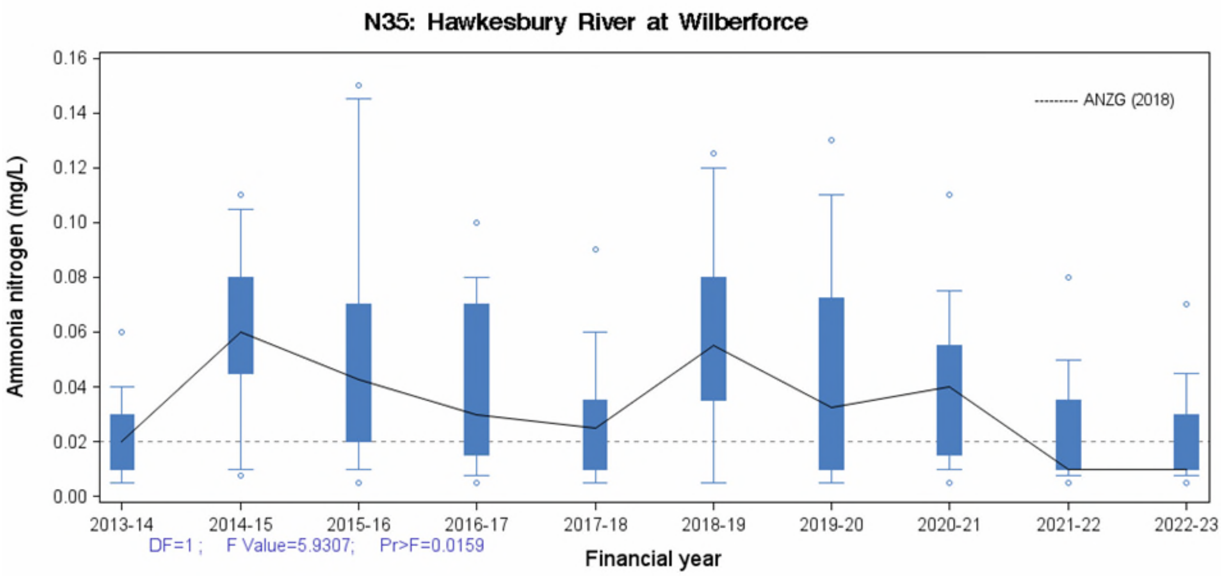
In 2022-23, ammonia nitrogen and total phosphorus significantly decreased at Wilberforce, indicating a potential improvement in nutrient conditions than earlier years. Among physico-chemical water quality analytes, dissolved oxygen concentration and saturation were also improved or higher in the 2022-23 year.

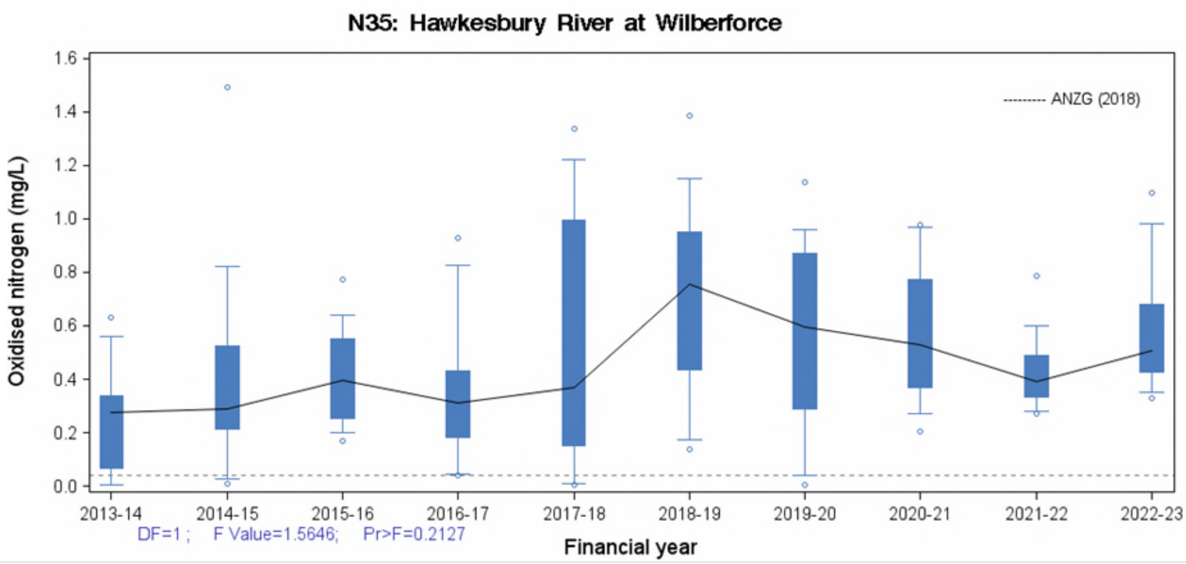
The median ammonia nitrogen, oxidised nitrogen, total nitrogen, total phosphorus and chlorophyll-a concentrations at N35 exceeded the respective ANZG (2018) guidelines in 2022-23.

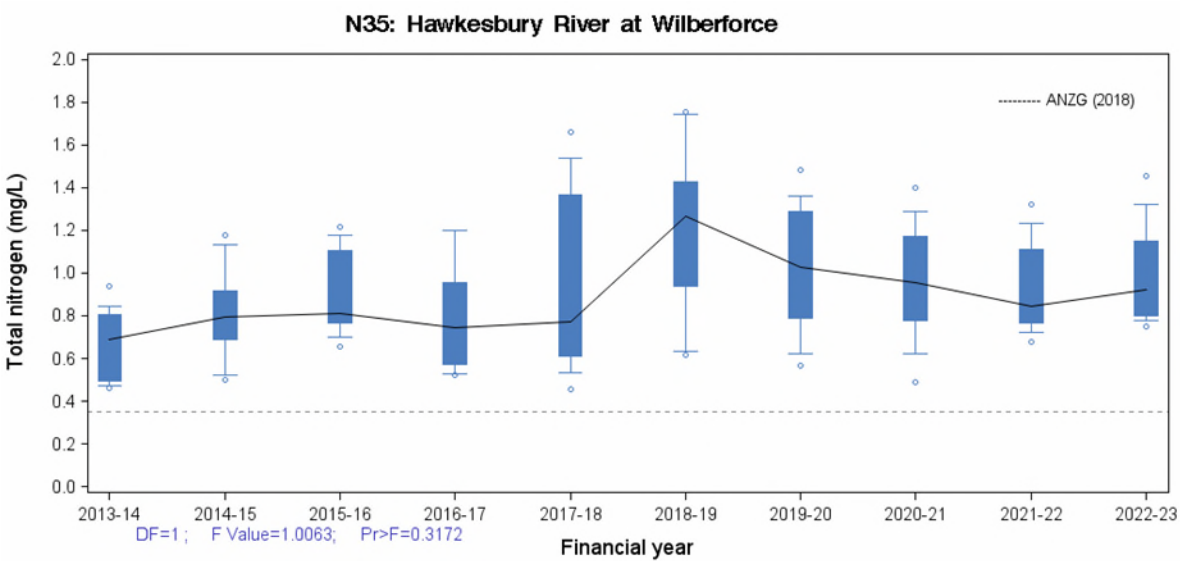
Chlorophyll-a concentration was steady at N35, however, the total phytoplankton biovolume increased significantly in 2022-23.

Ten of the 17 samples collected from N35 qualified for a phytoplankton biovolume and species count when chlorophyll-a was higher than 7.0 µg/L. Chlorophyll-a in these samples ranged between 7.0 and 41.2 µg/L. Potentially toxic blue-green species were present in five of these samples, maximum of 830 cells/mL (*Phormidium*) on 26 June 2023.

There were no other significant statistical trends and/or exceptions (median values higher than the guideline limits) for any other water quality or phytoplankton analyte at N35 in 2022-23.


N35: Hawkesbury River at Wilberforce
Ammonia nitrogen (mg/L)
ANZG (2018)
Financial year
DF=1 ; F Value=5.9307; Pr>F=0.0159


N35: Hawkesbury River at Wilberforce
Oxidised nitrogen (mg/L)
ANZG (2018)
Financial year
DF=1 ; F Value=1.5646; Pr>F=0.2127


N35: Hawkesbury River at Wilberforce
Total nitrogen (mg/L)
ANZG (2018)
Financial year
DF=1 ; F Value=1.0063; Pr>F=0.3172

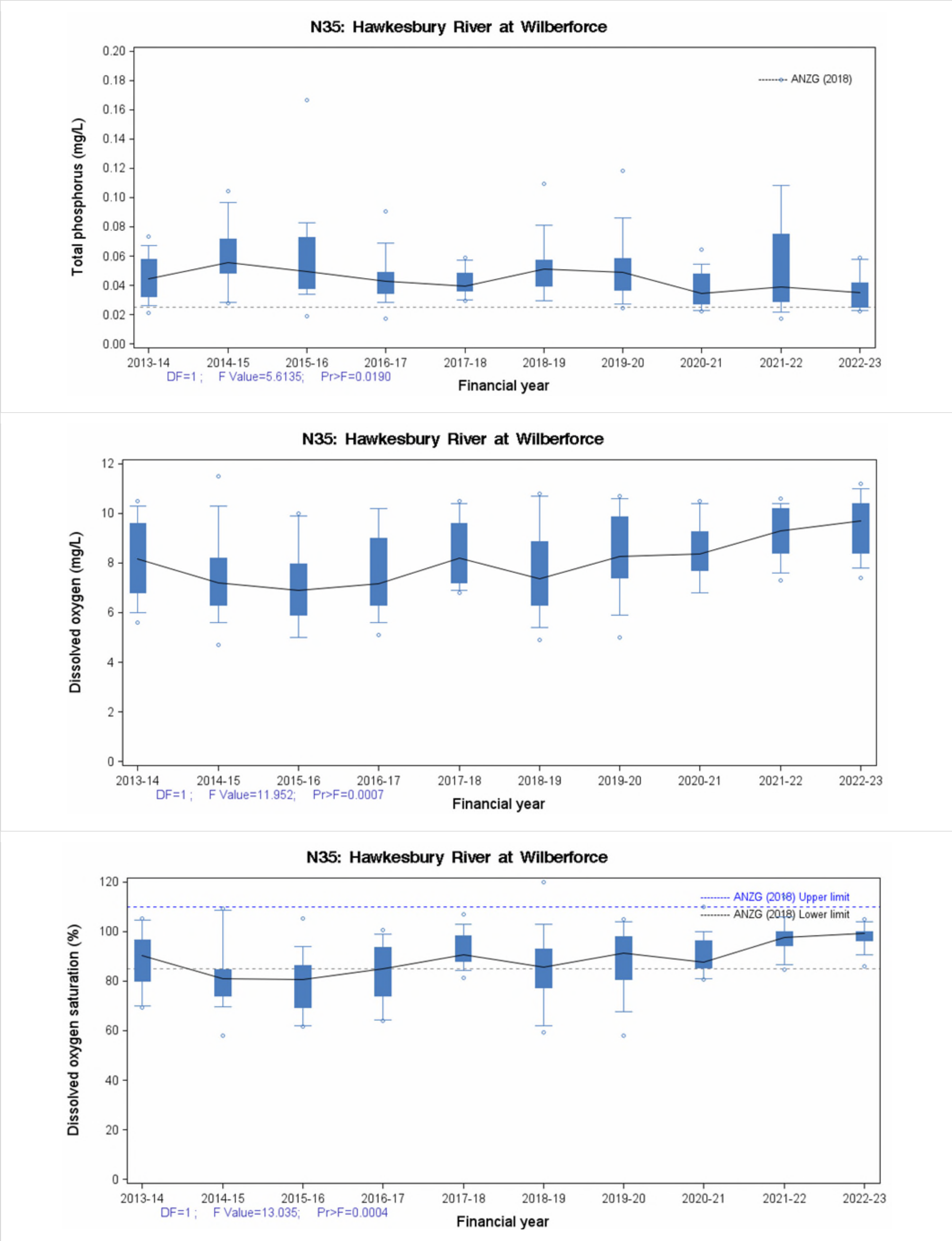
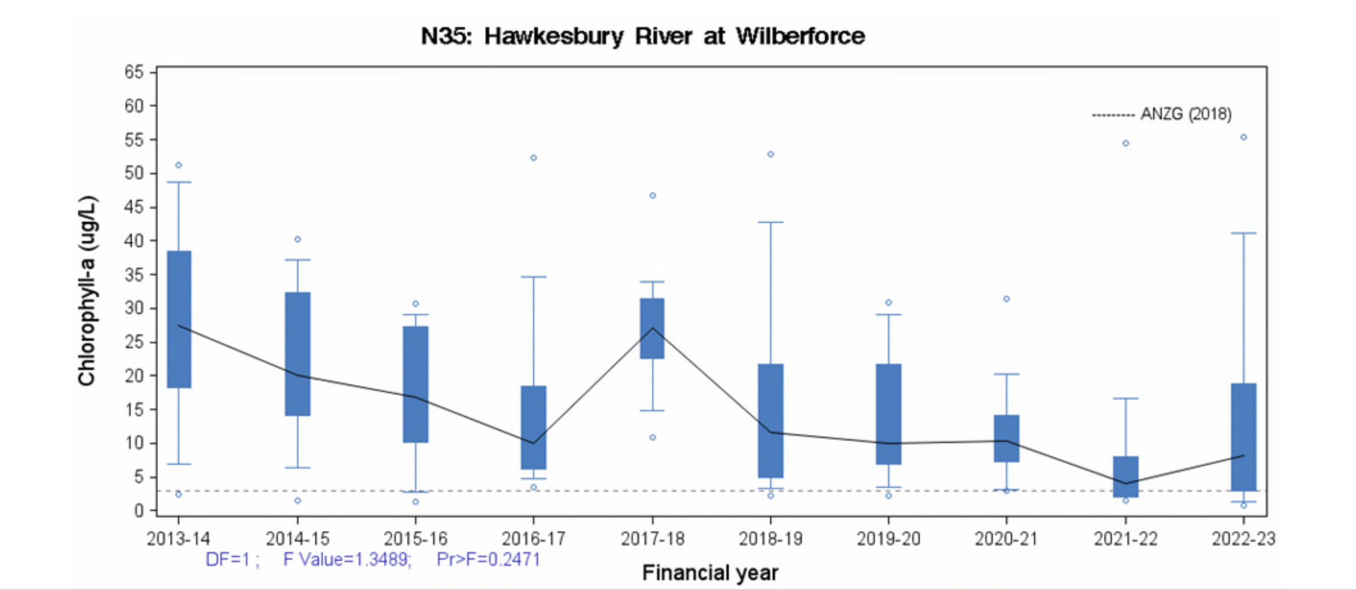


Figure 4-74 Nutrients and physico-chemical water quality exception plots, Hawkesbury River at Wilberforce (N35)



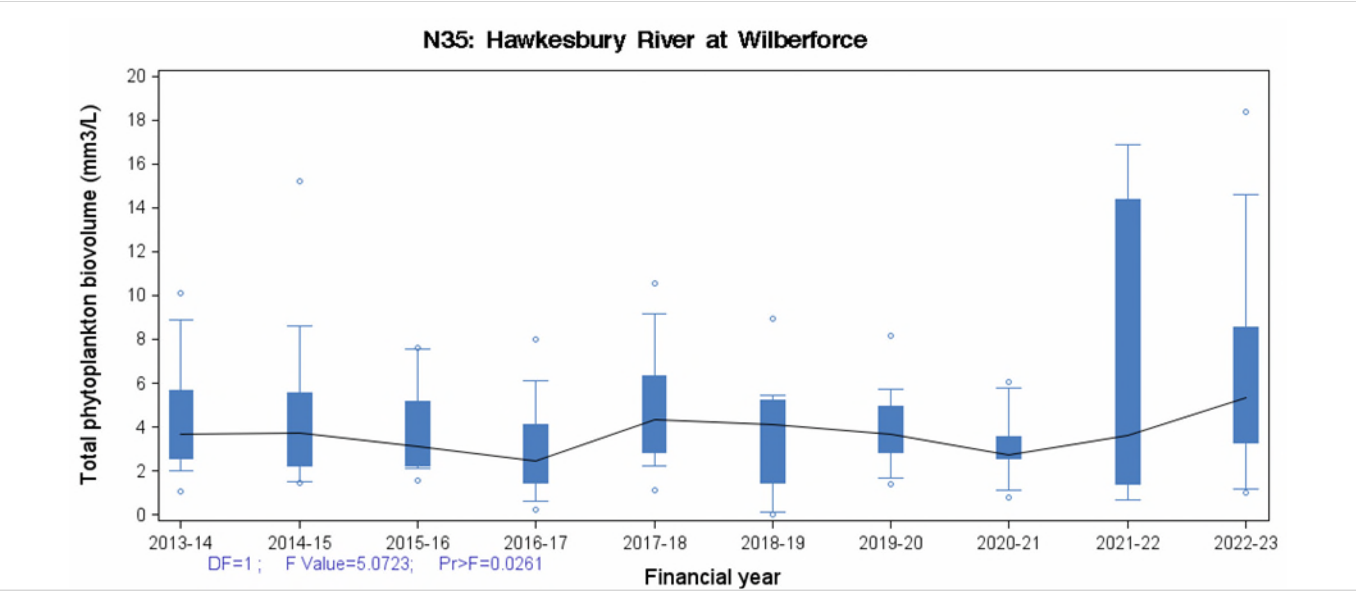


Figure 4-75 Phytoplankton as chlorophyll-a and total phytoplankton biovolumes exception plots, Hawkesbury River at Wilberforce (N35)

NC11A: Lower South Creek at Cattai Ridge Road

Lower Cattai Creek at Cattai Ridge Road (NC11A) is a major tributary of the Hawkesbury River draining one of the fastest growing urban catchments of Sydney. The upper Cattai Creek catchment land use influences are new urban development and light industrial activities. Further down the catchment, land uses are for rural and agricultural purposes. Two Sydney Water WRRFs (Castle Hill and Rouse Hill) operate in the Cattai Creek catchment. The Rouse Hill WRRF discharges via a constructed wetland or bypassing directly to Seconds Ponds Creek, a tributary of Cattai Creek. Castle Hill WRRF discharges directly to the upper Cattai Creek. This water quality monitoring site is located at Cattai Ridge Road, about 7 km upstream of the confluence with the Hawkesbury River.

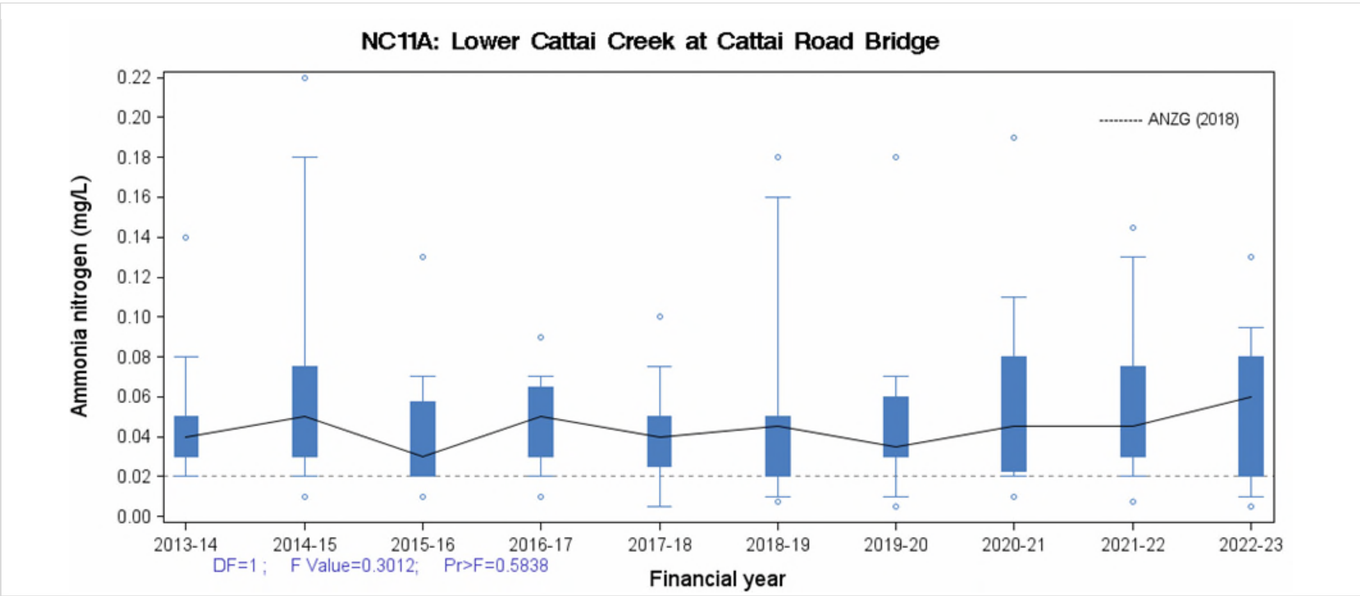
In 2022-23, there were no significantly increasing trends identified in any of the nutrients, chlorophyll-a or phytoplankton analytes at Cattai Creek (NC11A) compared to the previous nine years.

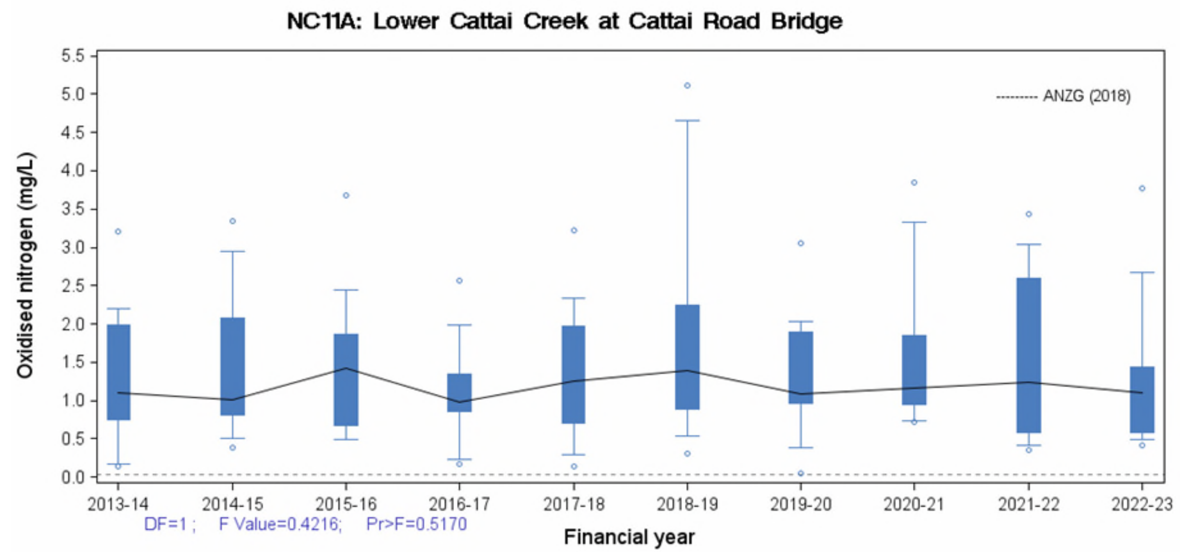
The median ammonia nitrogen, oxidised nitrogen, total nitrogen, total phosphorus and chlorophyll-a concentrations in Cattai Creek exceeded the respective ANZG (2018) guidelines in 2022-23.

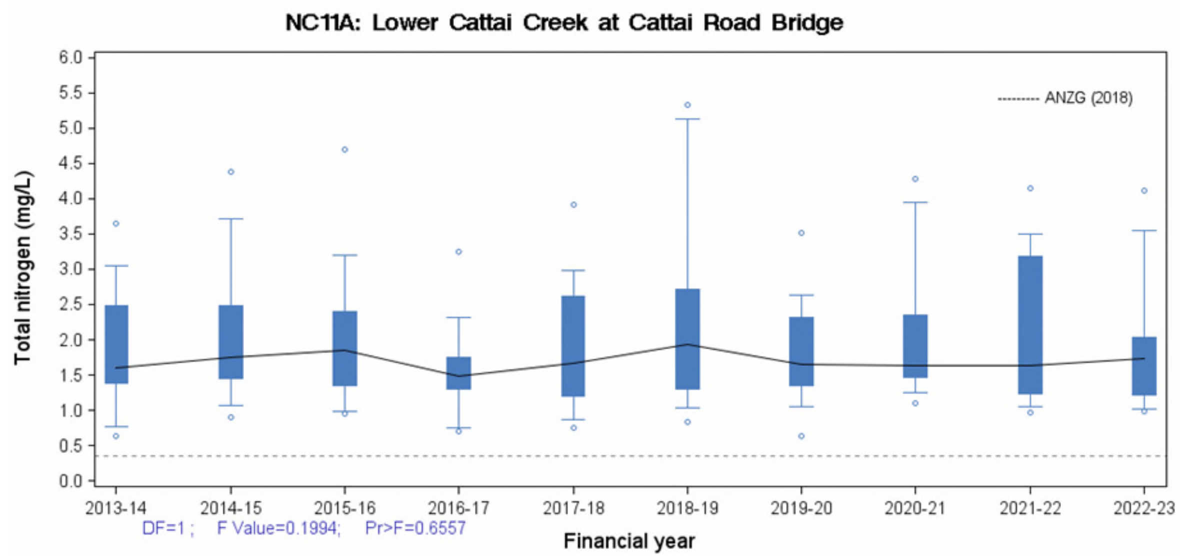
Among physico-chemical water quality analytes, conductivity was significantly lower and dissolved oxygen saturation were higher/improved in the 2022-23 year. However, the median dissolved oxygen saturation remained below ANZG (2018) lower guideline limit.

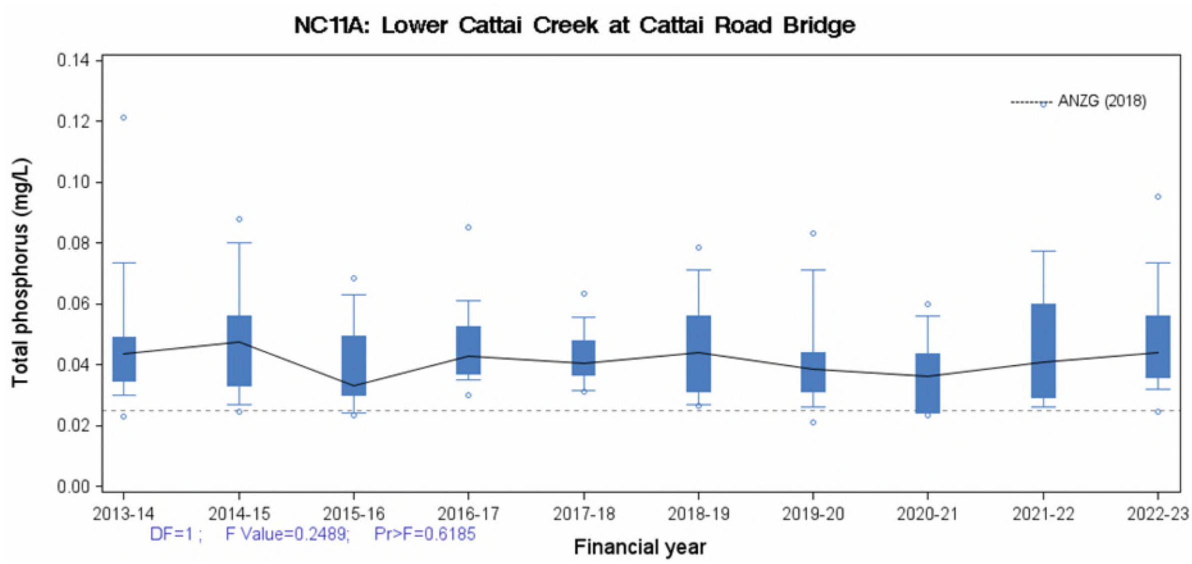
Six of the 17 samples collected from NC11A were qualified for a phytoplankton biovolume and species count when chlorophyll-a was higher than 7.0 µg/L. Chlorophyll-a in these samples ranged between 7.6 and 68.1 µg/L. No potentially toxic blue-green species were found in any of these samples.

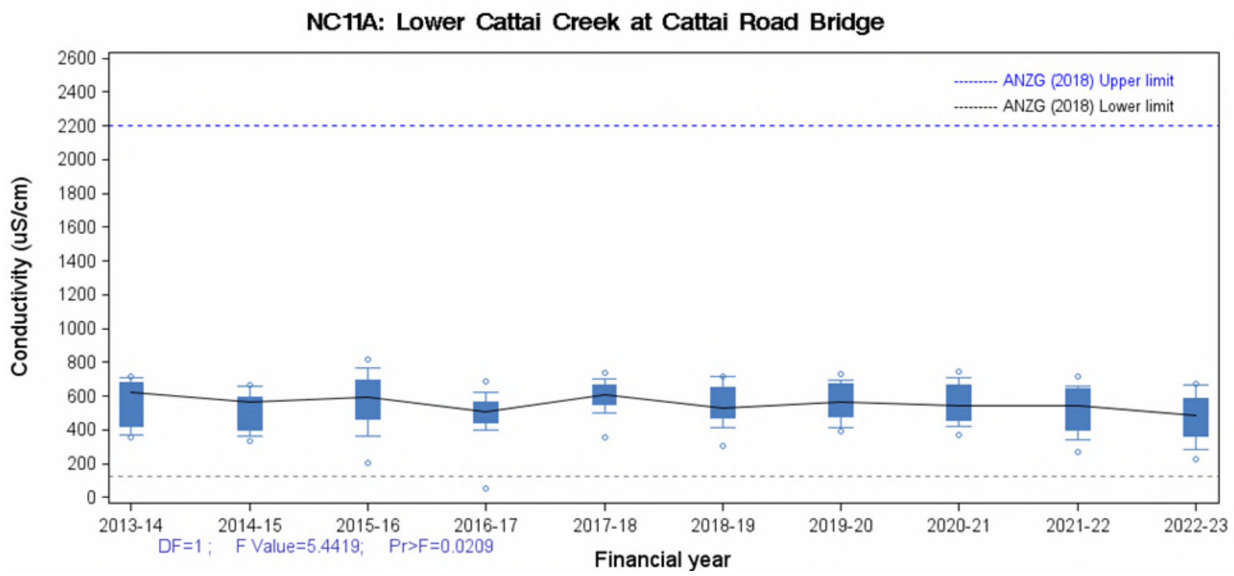
There were no other significant statistical trends and/or exceptions (median values higher than the guideline limits) for any other water quality or phytoplankton analyte at NC11A in 2022-23.




NC11A: Lower Cattai Creek at Cattai Road Bridge
Oxidised nitrogen (mg/L)
ANZG (2018)
2013-14 2014-15 2015-16 2016-17 2017-18 2018-19 2019-20 2020-21 2021-22 2022-23
DF=1 ; F Value=0.4216; Pr>F=0.5170
Financial year


NC11A: Lower Cattai Creek at Cattai Road Bridge
Total nitrogen (mg/L)
ANZG (2018)
2013-14 2014-15 2015-16 2016-17 2017-18 2018-19 2019-20 2020-21 2021-22 2022-23
DF=1 ; F Value=0.1994; Pr>F=0.6557
Financial year


NC11A: Lower Cattai Creek at Cattai Road Bridge
Total phosphorus (mg/L)
ANZG (2018)
2013-14 2014-15 2015-16 2016-17 2017-18 2018-19 2019-20 2020-21 2021-22 2022-23
DF=1 ; F Value=0.2489; Pr>F=0.6185
Financial year



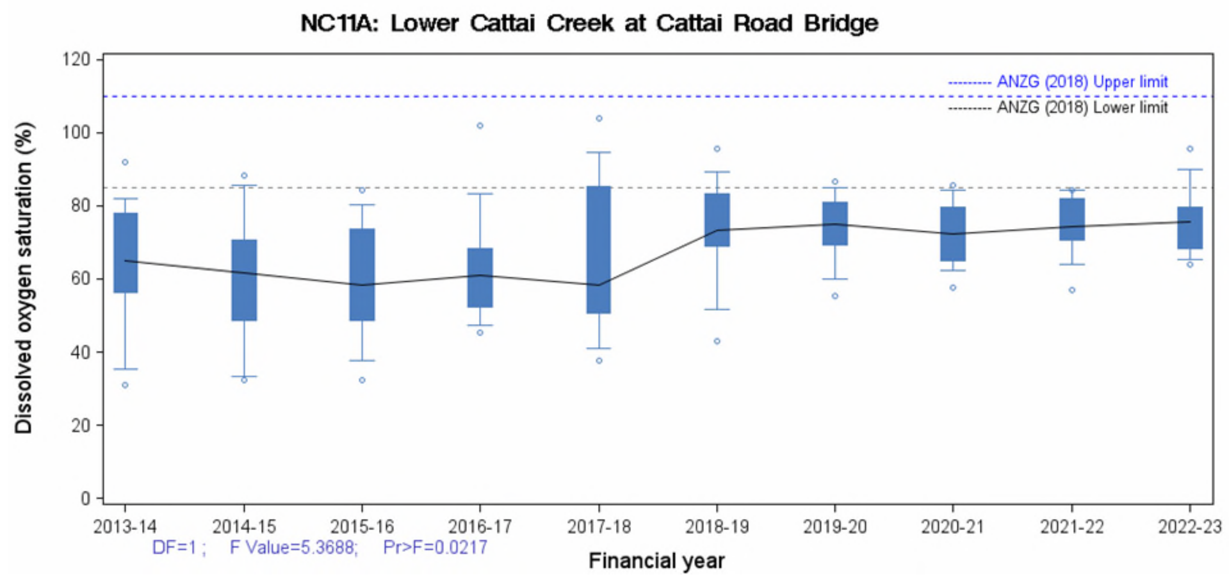


Figure 4-76 Nutrients and physico-chemical water quality exception plots, Lower Cattai Creek at Cattai Ridge Road (NC11A)

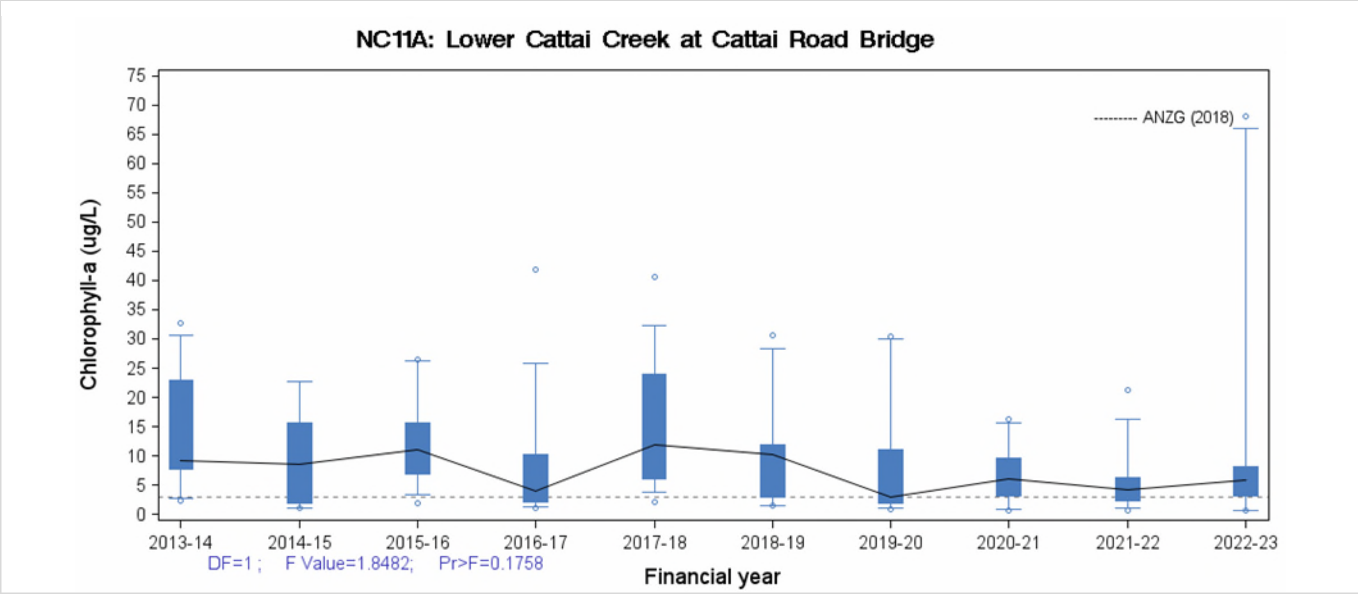


Figure 4-77 Phytoplankton as chlorophyll-a exception plot, Lower Cattai Creek at Cattai Ridge Road (NC11A)

N3001: Hawkesbury River off Cattai SRA

The Hawkesbury River off Cattai SRA (N3001) is located about 2 km downstream of the confluence with Cattai Creek. The water quality at this site is influenced by flows from both South Creek and Cattai Creek. Historically, this site has exhibited high nutrients, high chlorophyll-a concentrations and phytoplankton blooms.

In 2022-23, there were no significantly increasing trends identified in any of the nutrients and phytoplankton analytes at Cattai SRA (N3001) compared to the previous nine years. Chlorophyll-a concentrations significantly decreased at this site in 2022-23.

The median oxidised nitrogen, total nitrogen, total phosphorus and chlorophyll-a concentrations at N3001 exceeded the respective ANZG (2018) guidelines in 2022-23.

Ten of the 18 samples collected from N3001 qualified for a phytoplankton biovolume and species count when chlorophyll-a was higher than 7.0 μg/L. Chlorophyll-a in these samples ranged between 7.4 and 38.6 μg/L. Potentially toxic blue-green species were present in three of these samples, with a maximum of 539 cells/mL (*Microcystis)* on 9 May 2023.

There were no other significant statistical trends and/or exceptions (median values higher than the guideline limits) for any other water quality or phytoplankton analyte at N3001 in 2022-23.

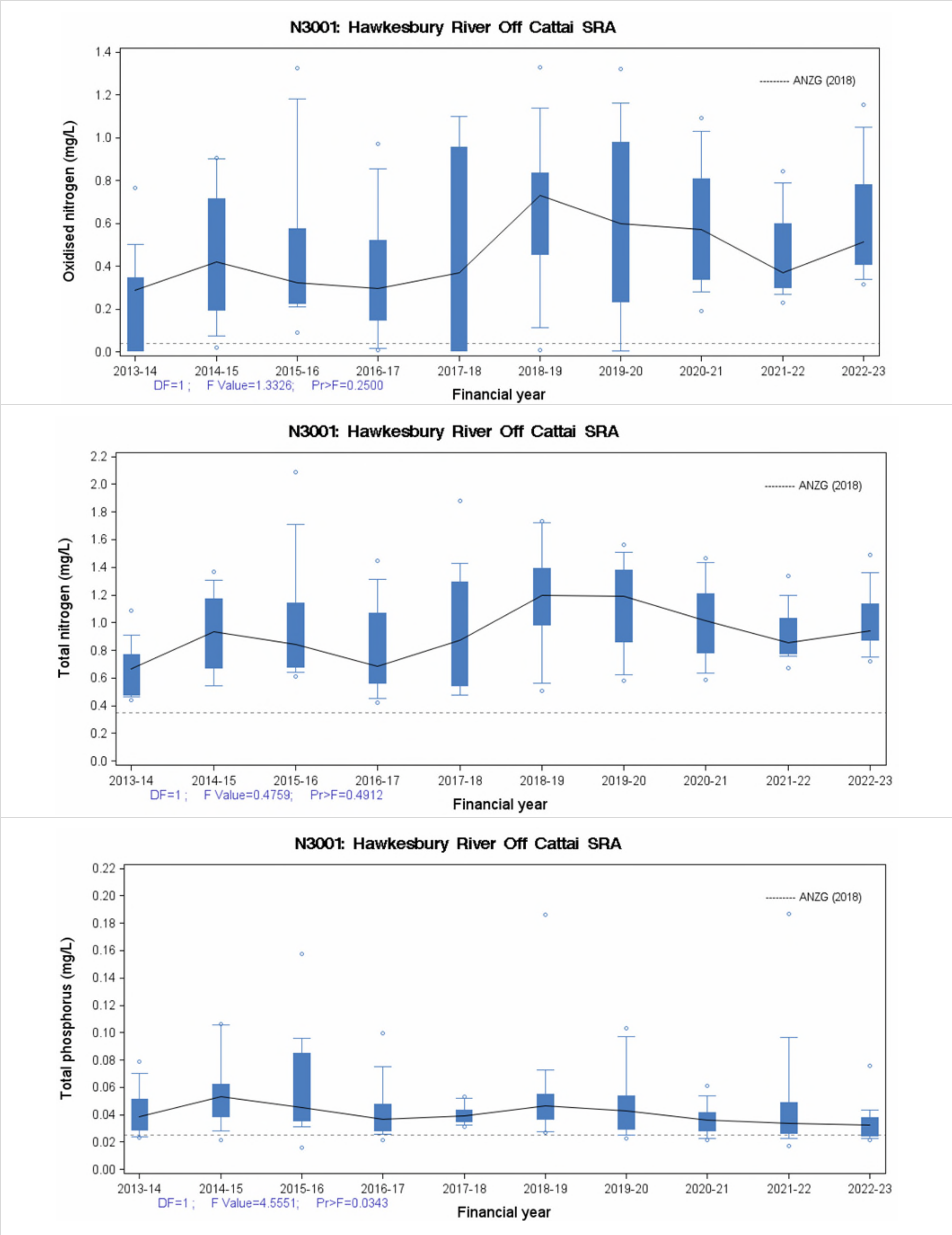


Figure 4-78 Nutrients and physico-chemical water quality exception plots, Hawkesbury River off Cattai SRA (N3001)

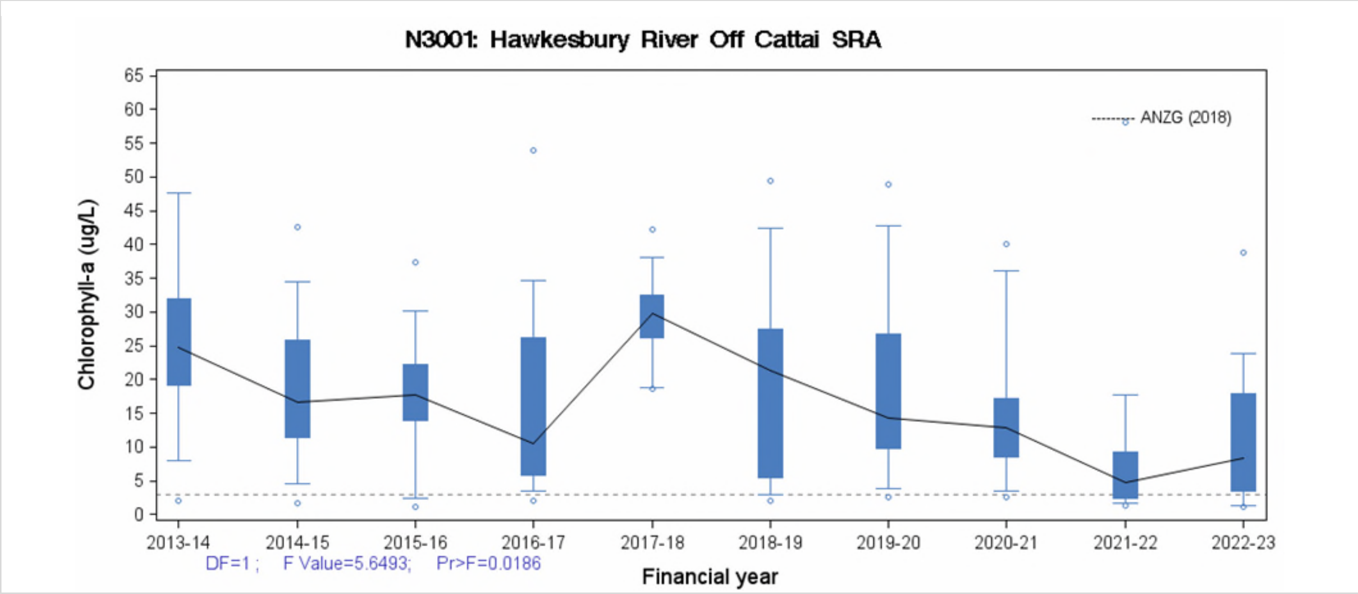


Figure 4-79 Phytoplankton as chlorophyll-a exception plot, Hawkesbury River off Cattai SRA (N3001)

N26: Hawkesbury River at Sackville Ferry

The Hawkesbury River at the Sackville Ferry (N26) site is located about 18 km downstream of the Cattai Creek confluence with the Hawkesbury River. Historically, this site has had the highest incidences of phytoplankton blooms, especially toxic blue-greens species.

In 2022-23, oxidised nitrogen concentrations increased significantly compared to the previous nine years. Chlorophyll-a concentrations significantly decreased at this site in 2022-23.

The median oxidised nitrogen, total nitrogen, total phosphorus and chlorophyll-a concentrations at N26 exceeded the respective ANZG (2018) guidelines in 2022-23.

Ten of the 18 samples collected from this site were counted for phytoplankton as the chlorophyll-a concentrations exceeded the phytoplankton counting threshold of 7.0 μg/L. Chlorophyll-a in these samples ranged between 8.3 and 24.6 μg/L. Potentially toxic blue-green species were present in majority of these samples (seven out of 10) in low number. The maximum number of toxic species was found on 9 March 2023, *Dolichospermum circinale* 1,490 cells/mL.

There were no other significant statistical trends and/or exceptions (median values higher than the guideline limits) for any other water quality or phytoplankton analyte at N26 in 2022-23.

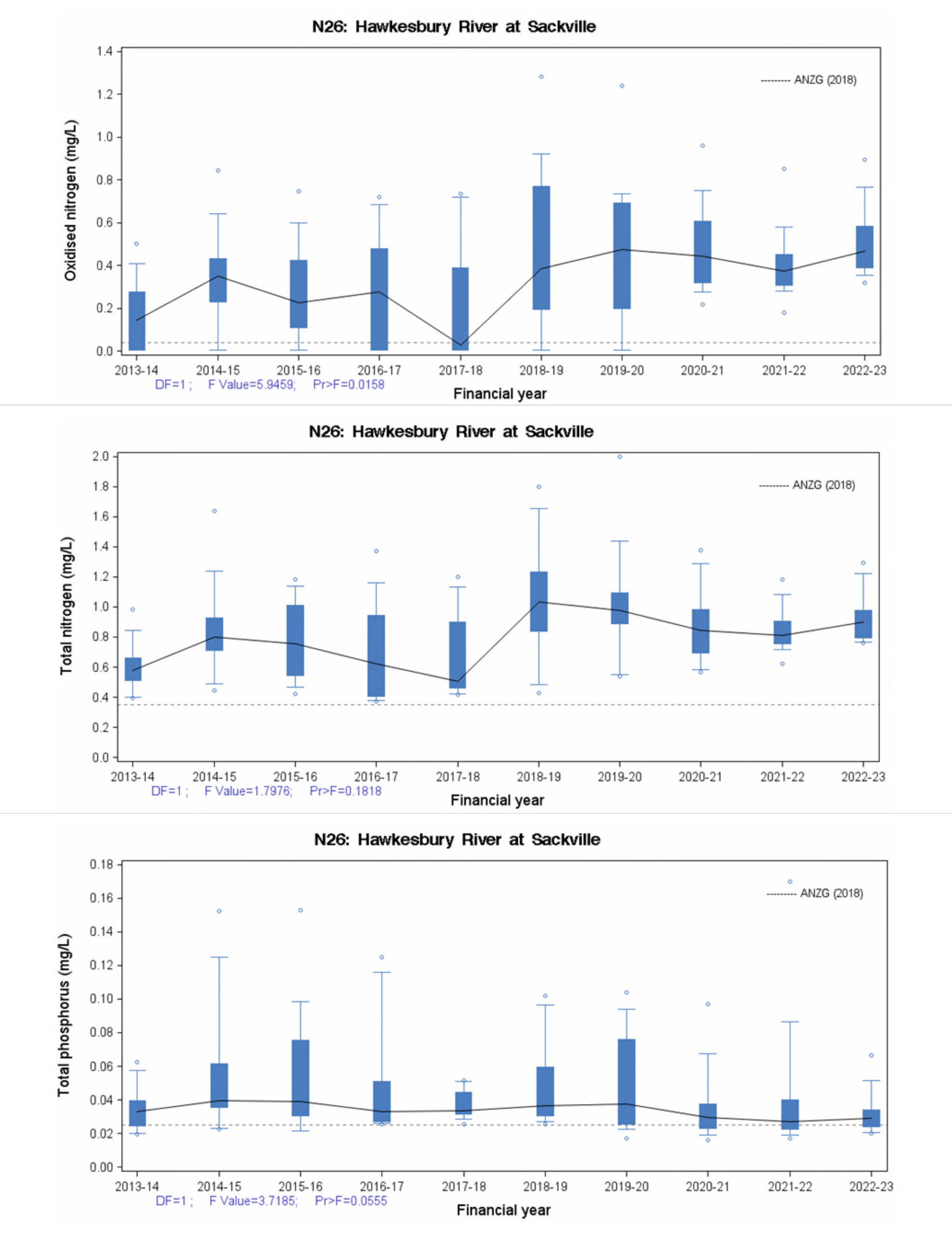


Figure 4-80 Nutrients and physico-chemical water quality exception plots, Hawkesbury River at Sackville Ferry (N26)

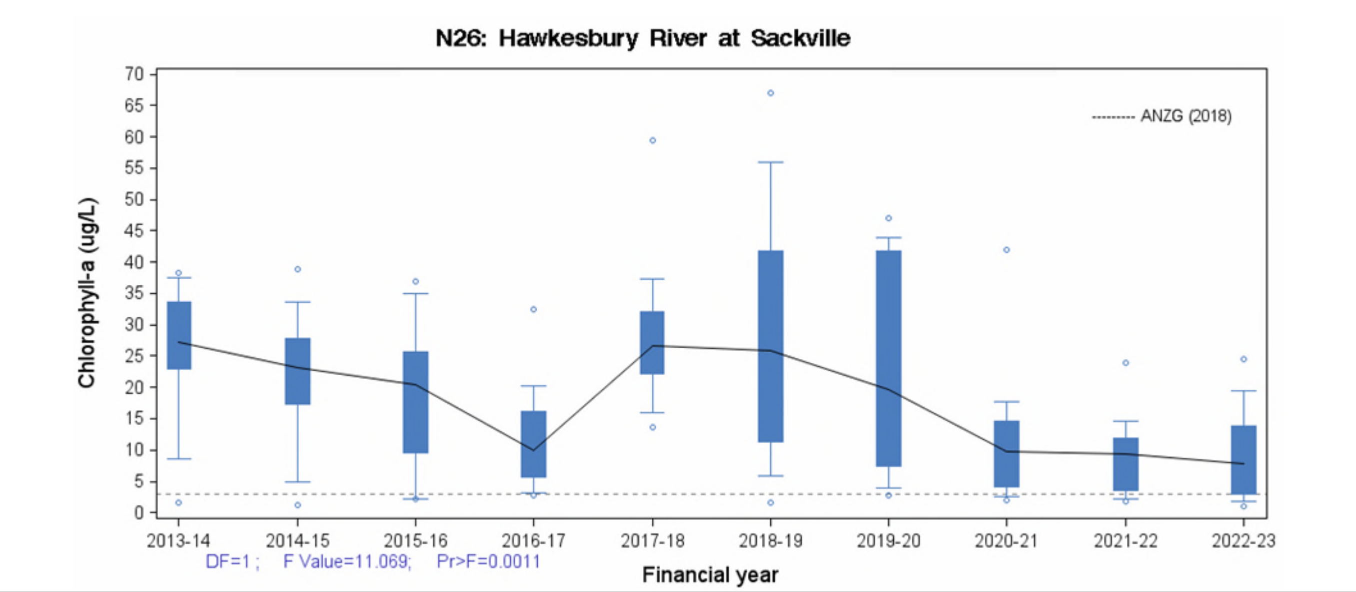


Figure 4-81 Phytoplankton as chlorophyll-a exception plot, Hawkesbury River at Sackville Ferry (N26)

N2202: Lower Colo River at Putty Road

The Colo River is one of the major tributaries of the Hawkesbury River, joining at Lower Portland. The Colo River catchment consists of mostly pristine and undisturbed areas. About 80% of the catchment is comprised of the Greater Blue Mountain's World Heritage Area. The monitoring site is located at Putty Road, about 12 km upstream of the confluence with the Hawkesbury River, and is considered a control site.

The 2022-23 water quality at the reference site of Colo River (N2202) was mostly steady. The only exception was pH, that increased in comparison to earlier years.

In the 2022-23 period, the median oxidised nitrogen concentration exceeded the ANZG (2018) guideline limit. Median turbidity for this site was below the lower limit guideline.

Chlorophyll-a concentrations were relatively low at this site and lowest median concentration (<1 µg/L) recorded among all monitoring sites in the Hawkesbury-Nepean River. None of the 17 samples qualified for phytoplankton counting.

There were no other significant statistical trends and/or exceptions (median values higher than the guideline limits) for any other water quality or phytoplankton analyte at N2202 in 2022-23.

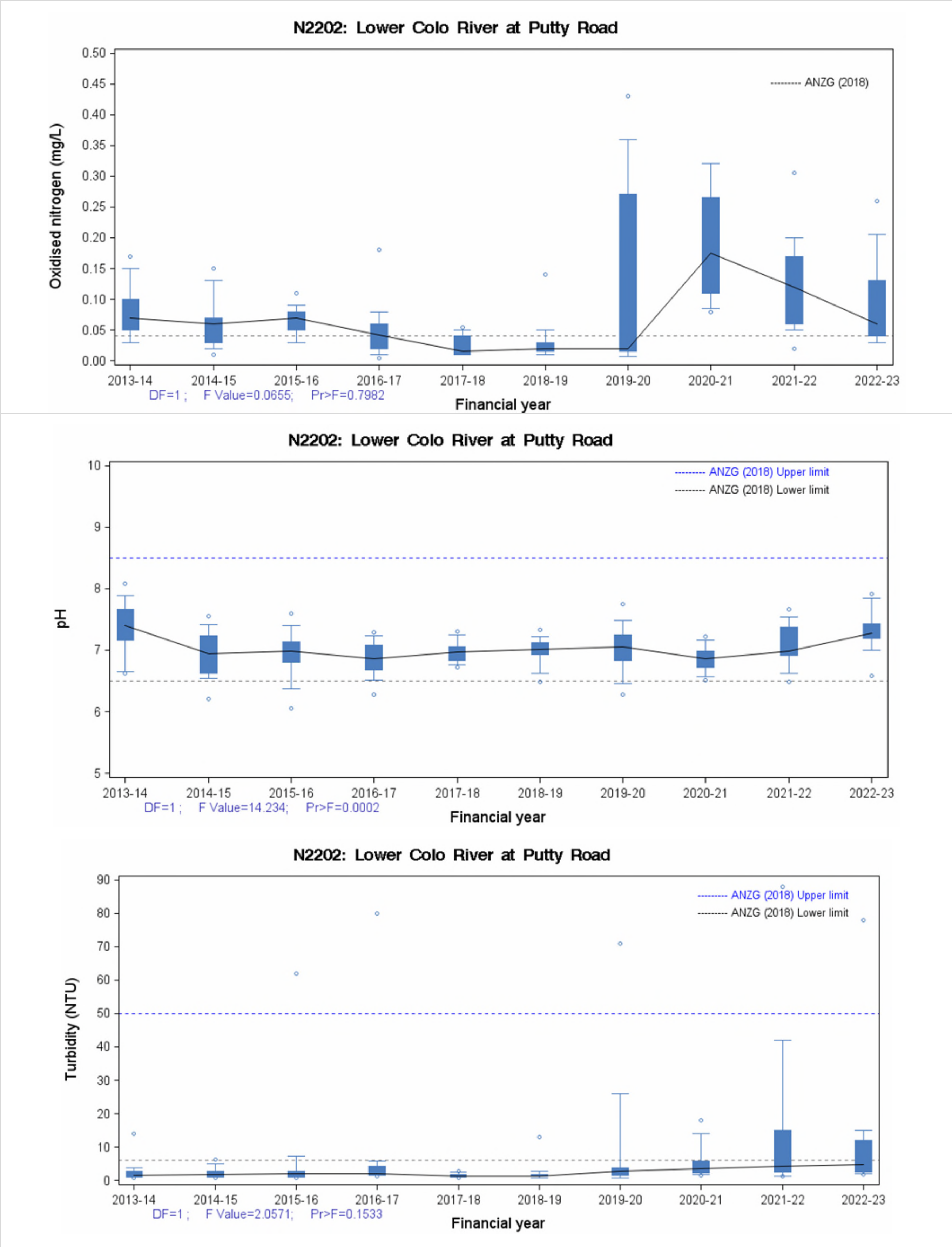


Figure 4-82 Nutrients and physico-chemical water quality exception plots, Lower Colo River at Putty Road (N2202)

N18: Hawkesbury River at Leets Vale

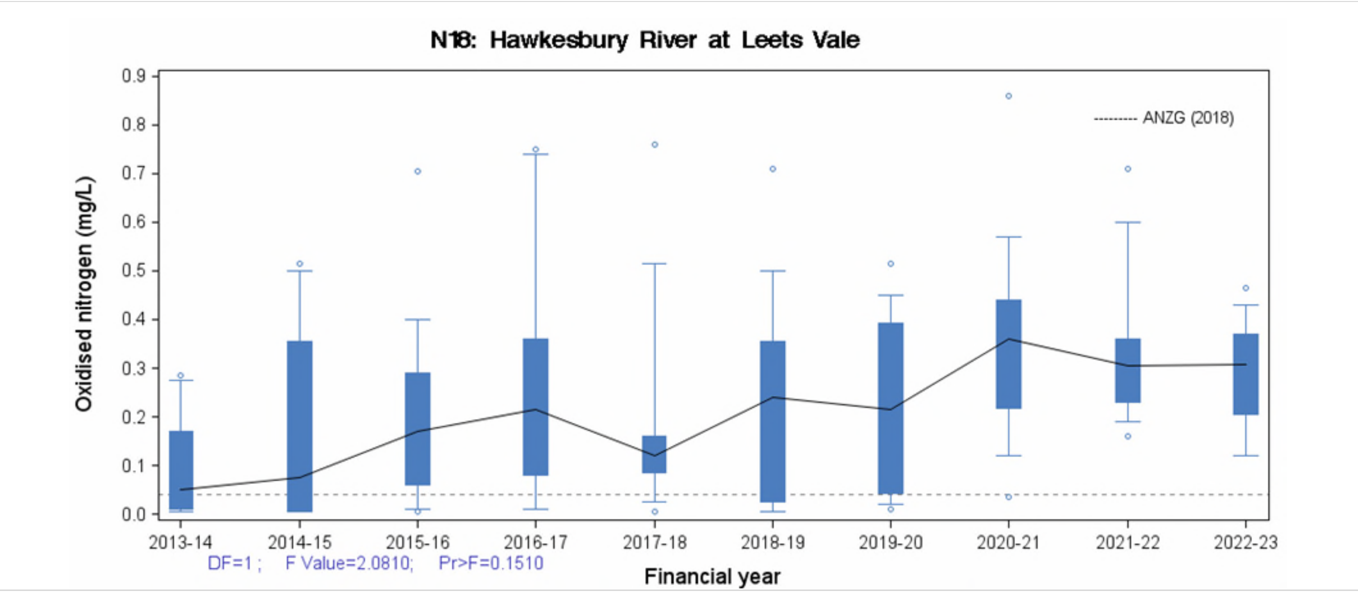
The Hawkesbury River at Leets Vale (N18) is located about 12 km downstream of the Colo River confluence, receives relatively high-quality inflows from the Colo River as well as occasional strong tidal influences causing periodic high salinity levels.

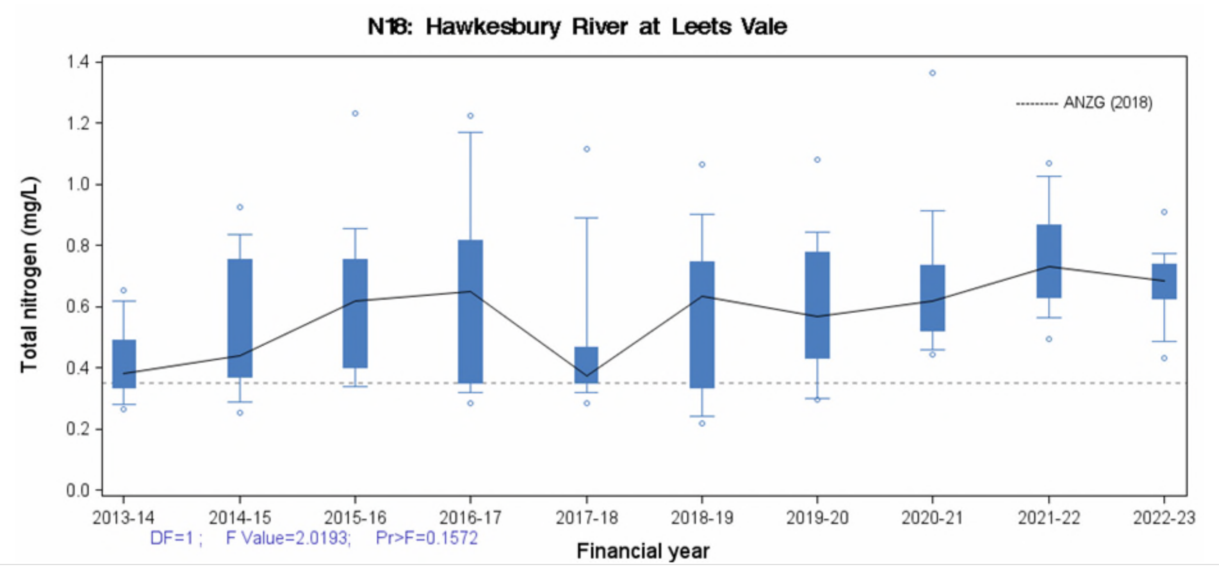
In 2022-23, nutrient concentrations remained steady at Leets Vale. Among physico-chemical water quality analytes, conductivity decreased and dissolved oxygen (concentration and saturation) increased (improved) in the 2022-23 year.

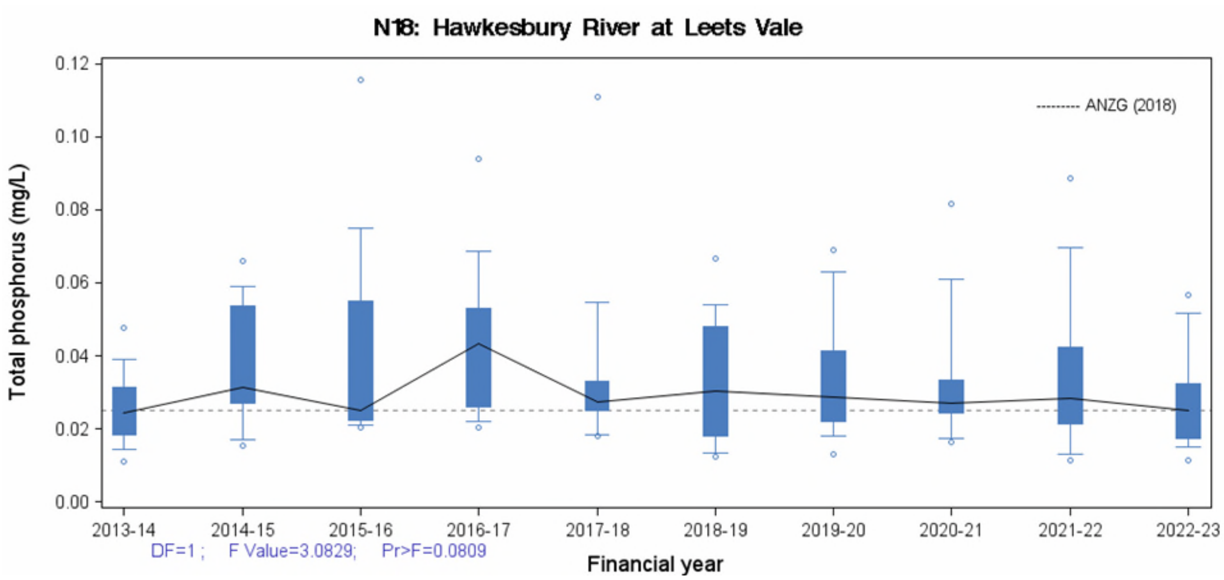
The median oxidised nitrogen, total nitrogen, total phosphorus and chlorophyll-a concentrations at N18 exceeded the respective ANZG (2018) guidelines in 2022-23.

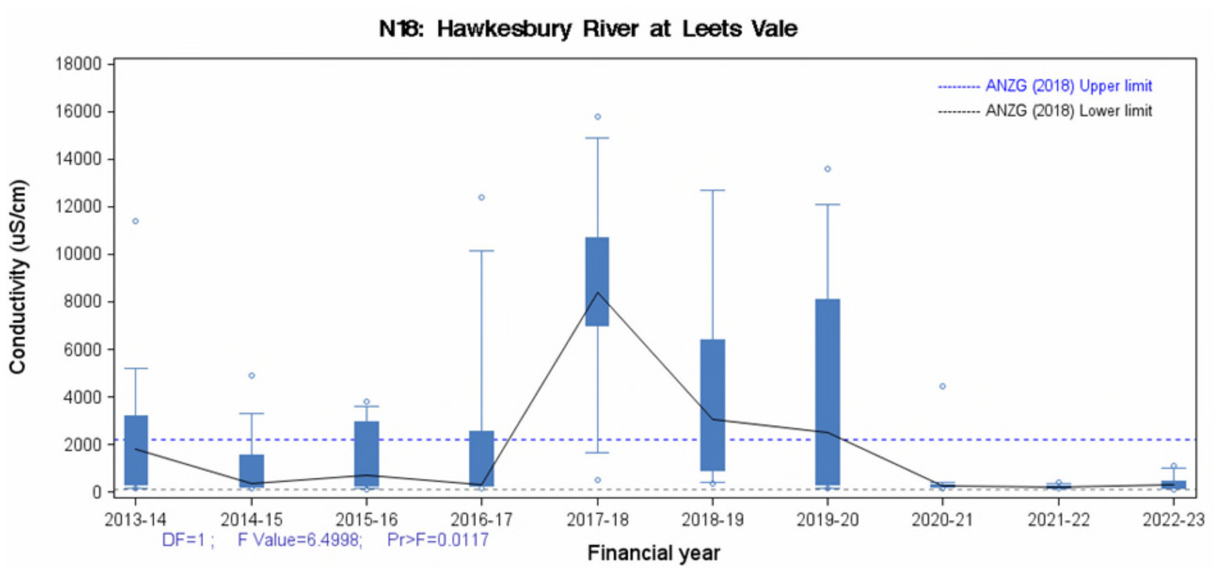
Ten of the 18 samples collected from N18 qualified for a phytoplankton biovolume and species count when chlorophyll-a was higher than 7.0 µg/L. Chlorophyll-a in these samples ranged between 7.1 and 30.6 µg/L. Potentially toxic blue-green counts reached NHMRC (2008) Amber Alert in four of these samples, with a maximum count on 20 April 2023 (13,800 cell/mL) when *Aphanizomenonaceae*, *Microcystis* and *Radiocystis,* were present.

There were no other significant statistical trends and/or exceptions (median values higher than the guideline limits) for any other water quality or phytoplankton analyte at N18 in 2022-23.




N18: Hawkesbury River at Leets Vale
Total nitrogen (mg/L)
ANZG (2018)
Financial year
DF=1 ; F Value=2.0193; Pr>F=0.1572


N18: Hawkesbury River at Leets Vale
Total phosphorus (mg/L)
ANZG (2018)
Financial year
DF=1 ; F Value=3.0829; Pr>F=0.0809


N18: Hawkesbury River at Leets Vale
Conductivity (uS/cm)
ANZG (2018) Upper limit
ANZG (2018) Lower limit
Financial year
DF=1 ; F Value=6.4998; Pr>F=0.0117

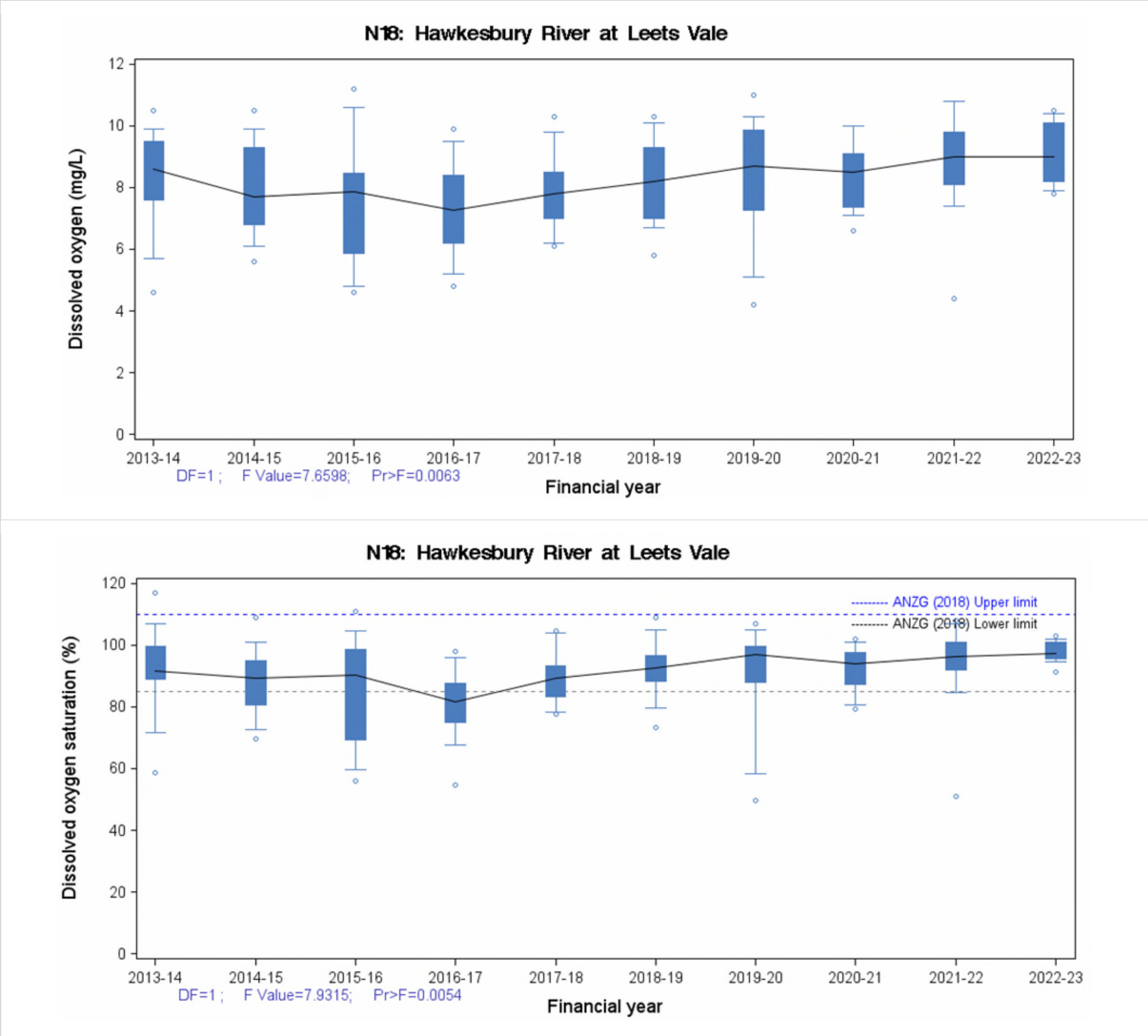


Figure 4-83 Nutrients and physico-chemical water quality exception plots, Hawkesbury River at Leets Vale (N18)

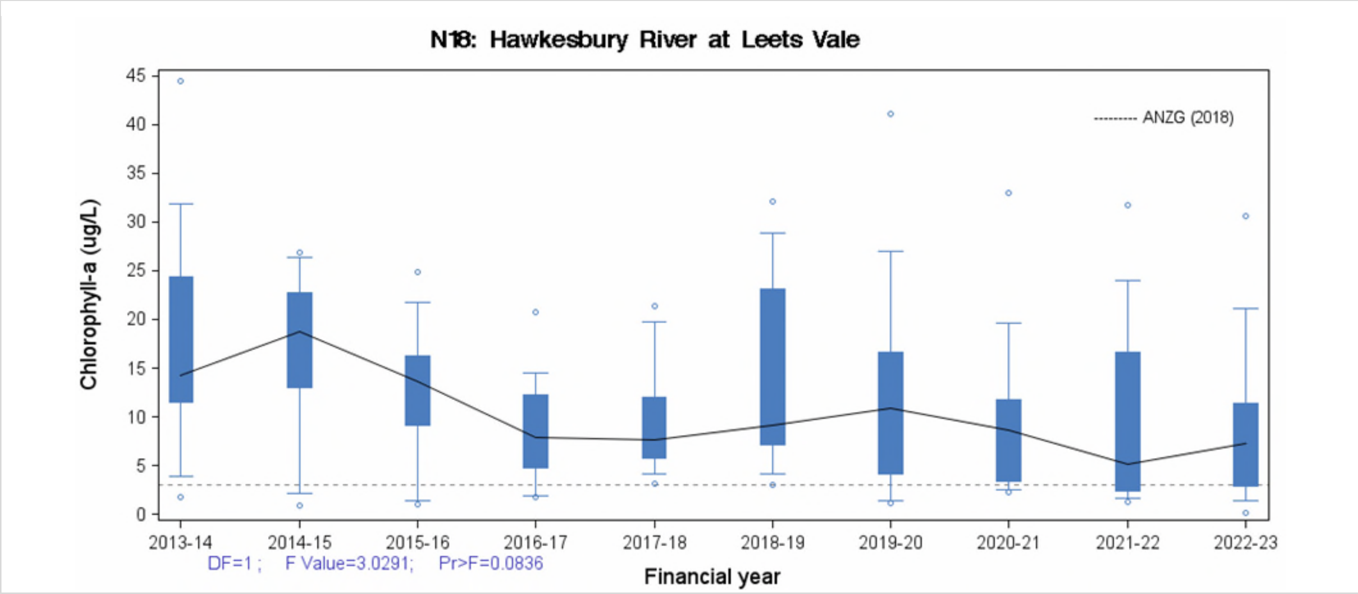


Figure 4-84 Phytoplankton as chlorophyll-a exception plot, Hawkesbury River at Leets Vale (N18)

NB13: Berowra Creek at Calabash Bay

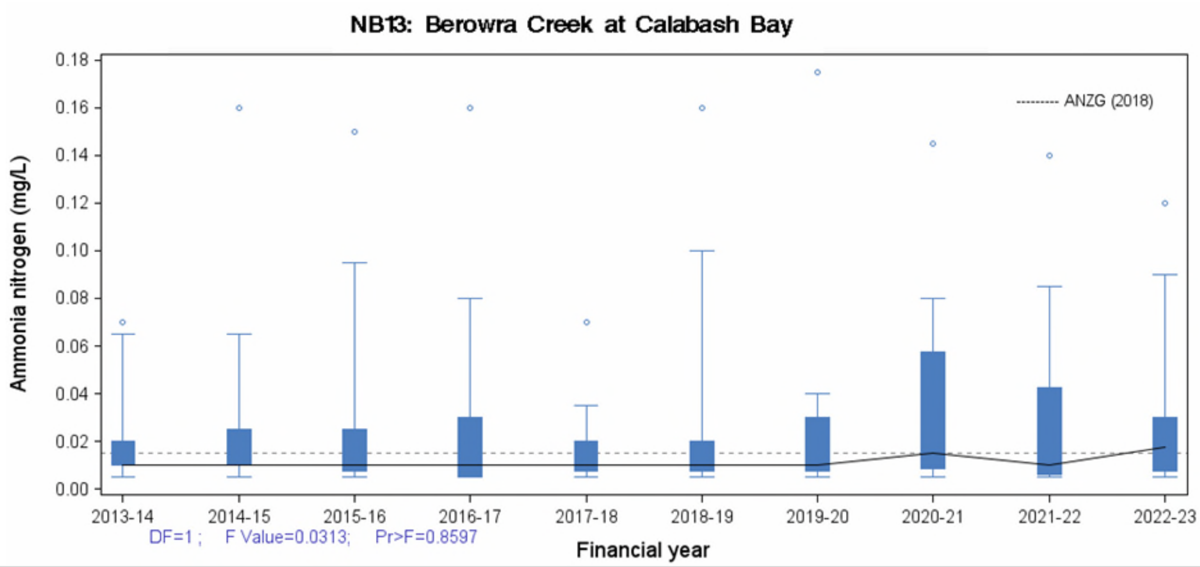
The Berowra Creek site at Calabash Bay (NB13) is located at Cunio Point in the Berowra estuary of the Hawkesbury River. There is strong tidal influence at this site and the water quality is affected by various sources of pollution from the upstream Berowra Creek catchment such as urban run-off, run-off from unsewered areas, agricultural cultivation involving fertiliser use, bushland and two licensed Sydney Water WRRF discharge points. Hornsby Heights WRRF discharges to Calna Creek, a tributary of Berowra Creek, while West Hornsby WRRF discharges to Waitara Creek, also a tributary of Berowra Creek.

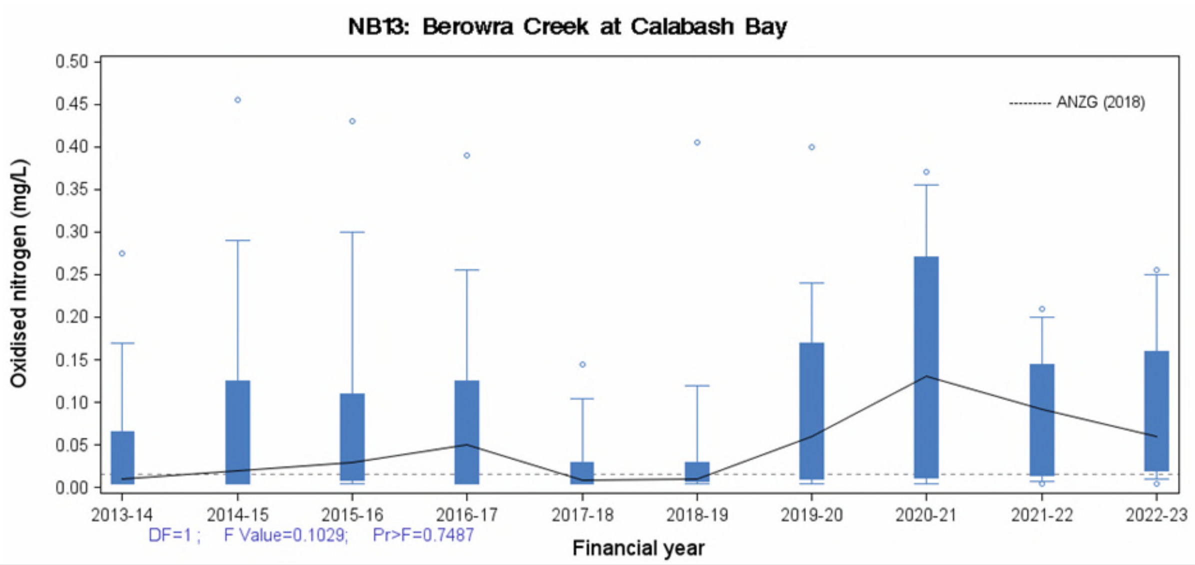
In 2022-23, filterable total phosphorus significantly decreased/improved at Calabash Bay (NB13). Among physico-chemical water quality analytes, conductivity, dissolved oxygen concentration and saturation decreased in the 2022-23 year.

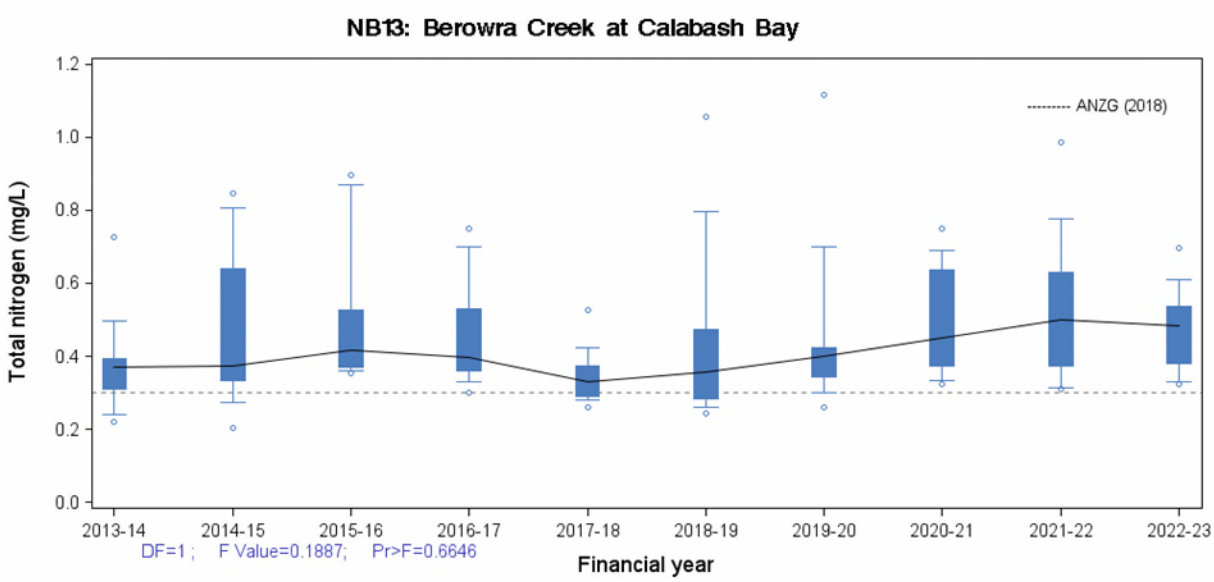
The median ammonia nitrogen, oxidised nitrogen, total nitrogen, conductivity and chlorophyll-a concentrations at NB13 exceeded the respective ANZG (2018) guidelines in 2022-23. Median turbidity was below the lower guideline limit.

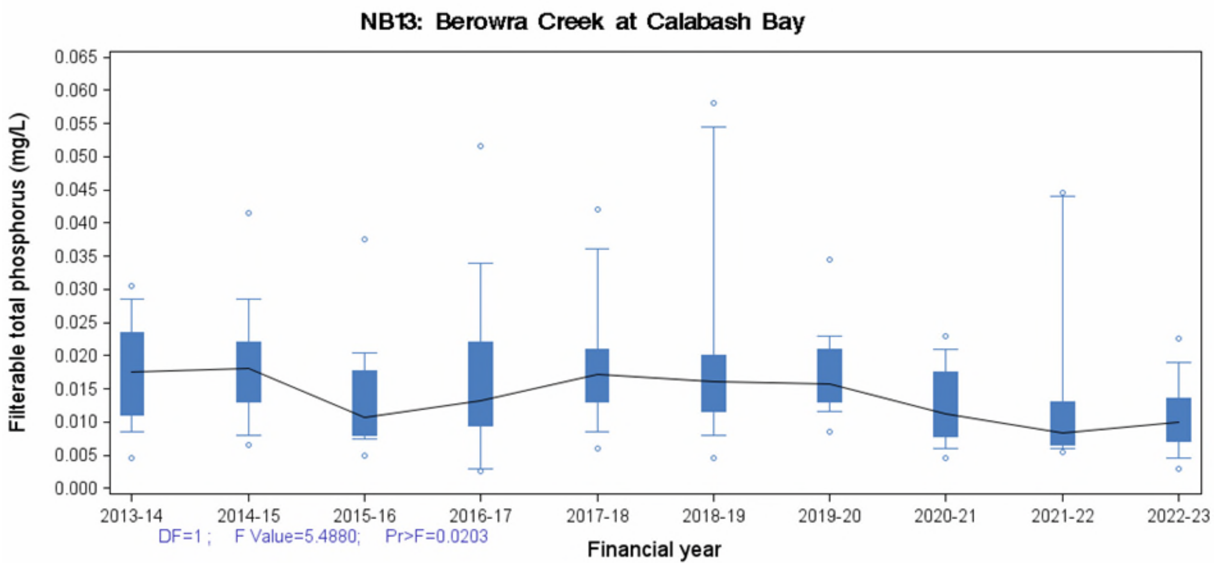
Ten of the 18 samples exceeded a chlorophyll-a concentration of 7 μg/L which triggered phytoplankton analysis in 2022-23. As usual, blue-green biovolume or toxic blue-green species counts were not a problem for this estuarine site. Potentially toxic dinoflagellates or golden brown (Chrysophyta) taxa were found in moderate numbers in five of these samples. The highest number of toxic species was found on 20 Apr 2023: *Heterocapsa* 346 cells/mL and *Prorocentrum minimum* 346 cells/mL.

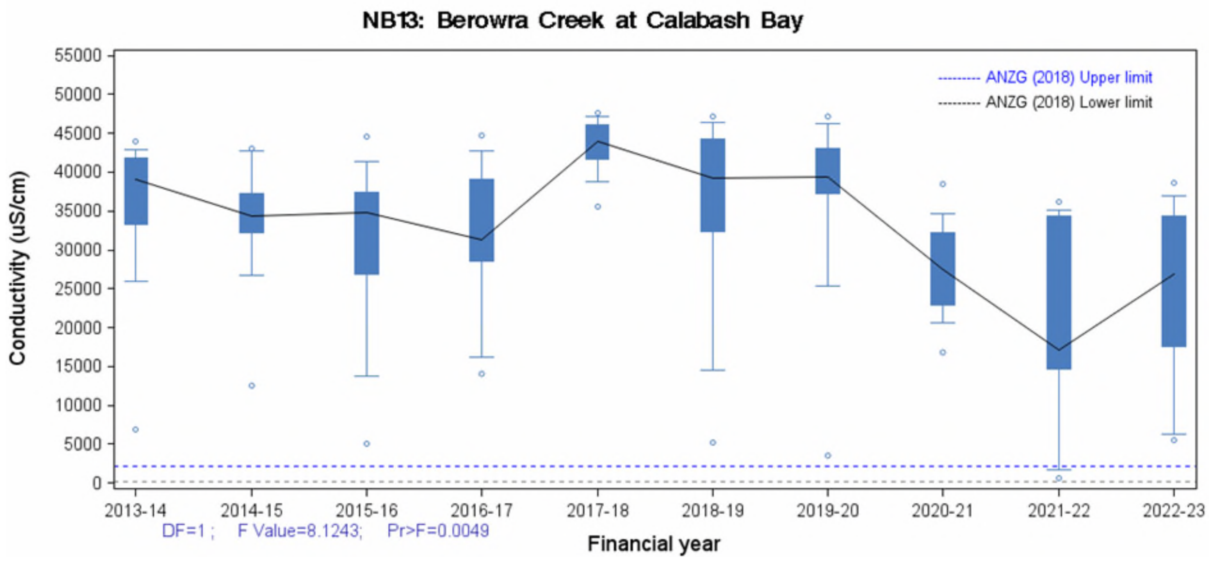
There were no other significant statistical trends and/or exceptions (median values higher than the guideline limits) for any other water quality or phytoplankton analyte at NB13 in 2022-23.

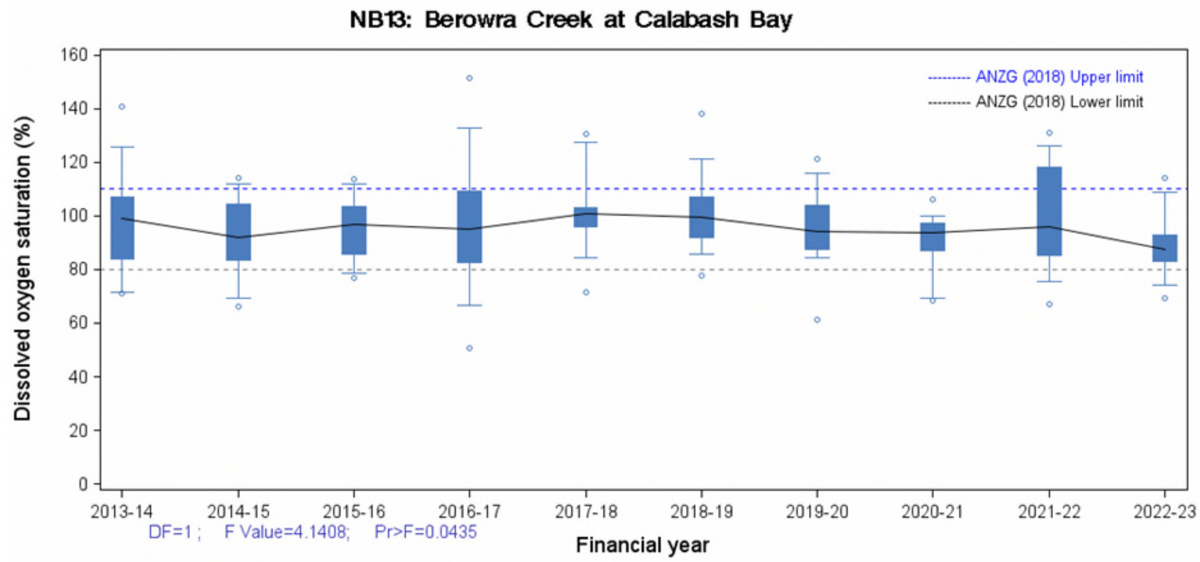

NB13: Berowra Creek at Calabash Bay
Ammonia nitrogen (mg/L)
ANZG (2018)
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
2020-21
2021-22
2022-23
DF=1 ; F Value=0.0313; Pr>F=0.8597
Financial year


NB13: Berowra Creek at Calabash Bay
Oxidised nitrogen (mg/L)
ANZG (2018)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
2020-21
2021-22
2022-23
DF=1 ; F Value=0.1029; Pr>F=0.7487
Financial year


NB13: Berowra Creek at Calabash Bay
Total nitrogen (mg/L)
ANZG (2018)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
2020-21
2021-22
2022-23
DF=1 ; F Value=0.1887; Pr>F=0.6646
Financial year


NB13: Berowra Creek at Calabash Bay
Filterable total phosphorus (mg/L)
0.065
0.060
0.055
0.050
0.045
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
2020-21
2021-22
2022-23
DF=1 ; F Value=5.4880; Pr>F=0.0203
Financial year


NB13: Berowra Creek at Calabash Bay
ANZG (2018) Upper limit
ANZG (2018) Lower limit
Conductivity (uS/cm)
55000
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
2020-21
2021-22
2022-23
DF=1 ; F Value=8.1243; Pr>F=0.0049
Financial year


NB13: Berowra Creek at Calabash Bay
ANZG (2018) Upper limit
ANZG (2018) Lower limit
Dissolved oxygen saturation (%)
160
140
120
100
80
60
40
20
0
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
2020-21
2021-22
2022-23
DF=1 ; F Value=4.1408; Pr>F=0.0435
Financial year

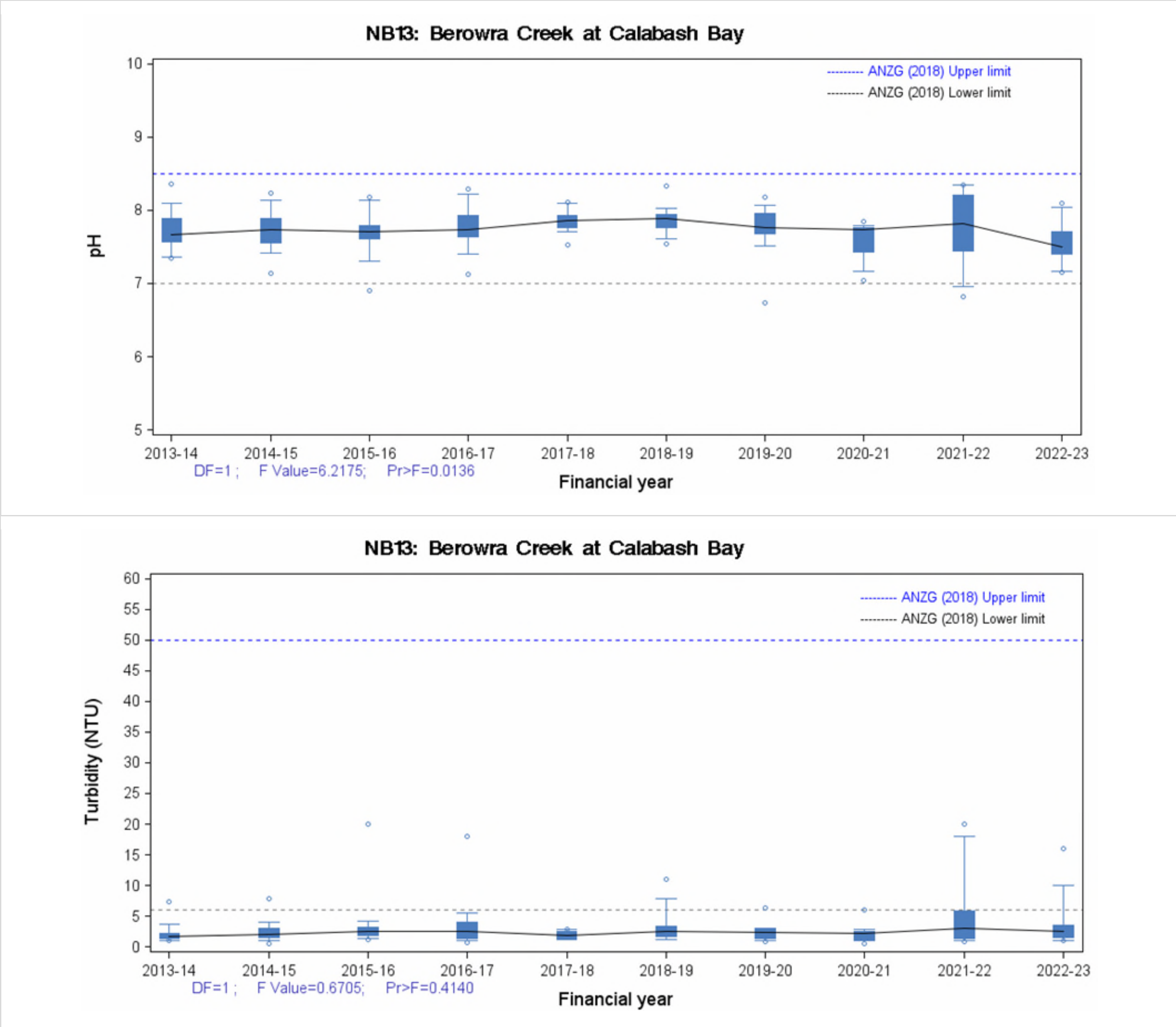


Figure 4-85 Nutrients and physico-chemical water quality exception plots, Berowra Creek at Calabash Bay (NB13)

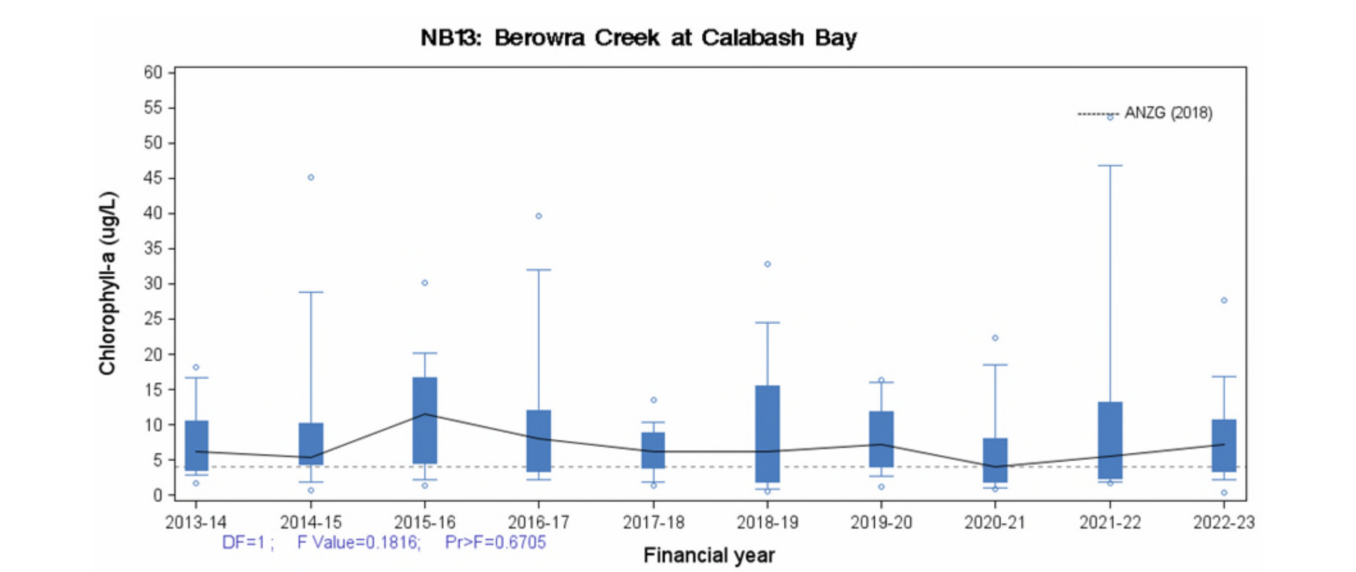


Figure 4-86 Phytoplankton as chlorophyll-a exception plot, Berowra Creek at Calabash Bay (NB13)

NB11: Berowra Creek off Square Bay

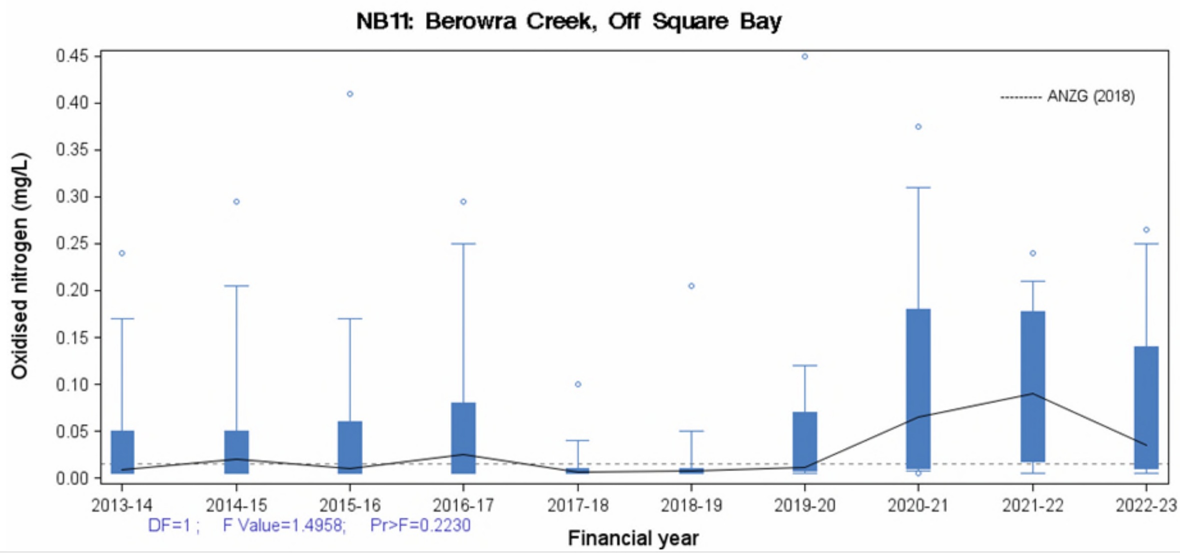
The Berowra Creek site at Calabash Bay (NB13) is located at Cunio Point in the Berowra estuary of the Hawkesbury River. There is strong tidal influence at this site and the water quality is affected by various sources of pollution from the upstream Berowra Creek catchment such as urban run-off, run-off from unsewered areas, agricultural cultivation involving fertiliser use, bushland and two licensed Sydney Water WRRF discharge points. Hornsby Heights WRRF discharges to Calna Creek, a tributary of Berowra Creek, while West Hornsby WRRF discharges to Waitara Creek, also a tributary of Berowra Creek.

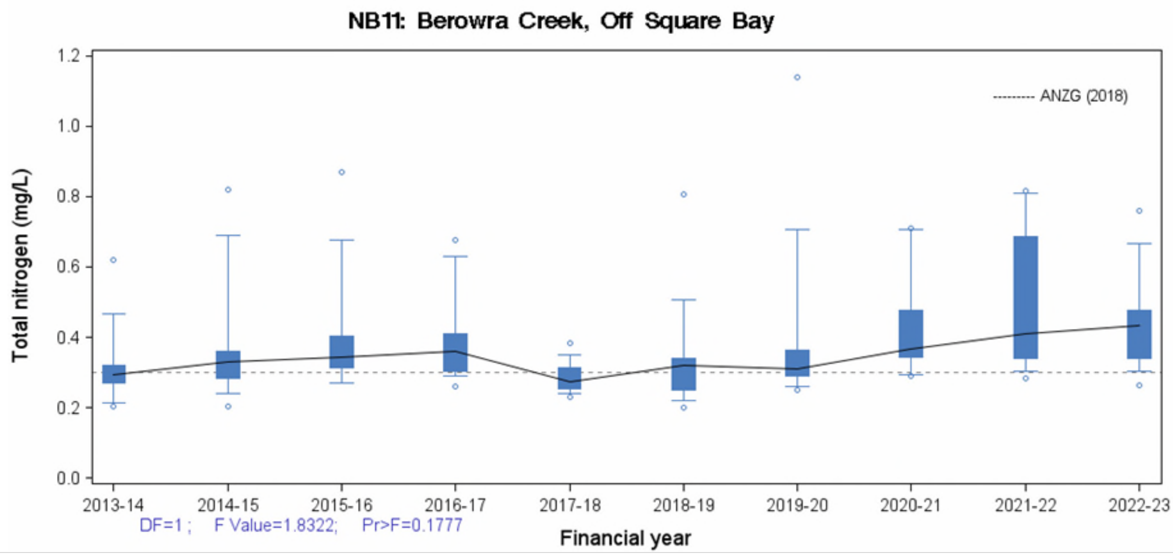
In 2022-23, there were no significantly increasing/decreasing trends identified in any of the nutrients, chlorophyll-a and phytoplankton analytes at Cattai SRA (N3001) compared to the previous nine years. Among the physico-chemical analytes, conductivity was significantly lower and turbidity significantly higher in 2022-23.

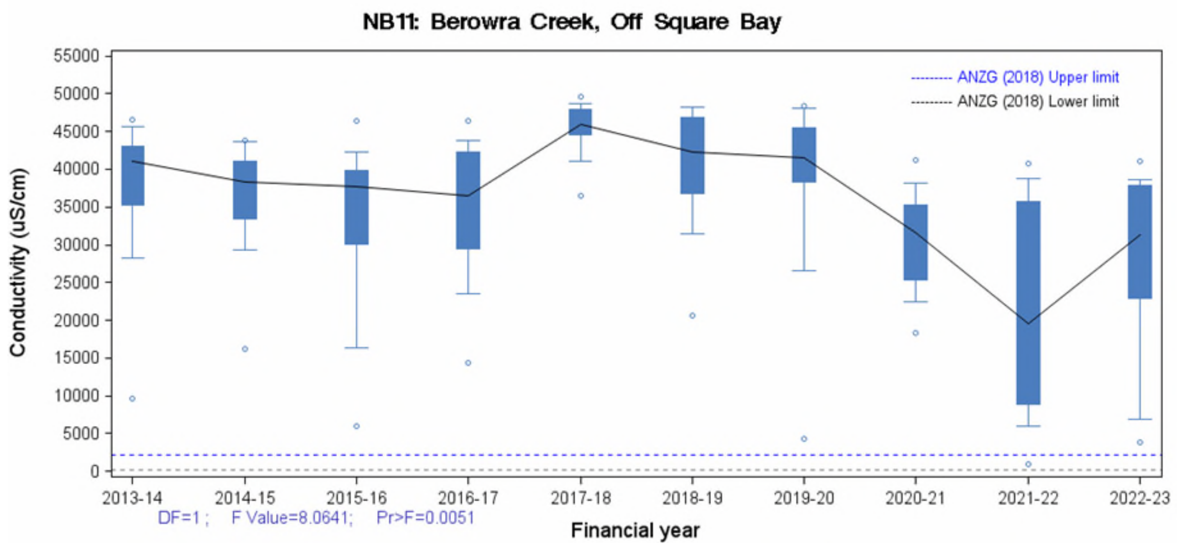
The median oxidised nitrogen, total nitrogen, conductivity and chlorophyll-a concentrations at NB11 exceeded the respective ANZG (2018) guidelines in 2022-23. Median turbidity was below the lower guideline limit.

Twelve of the 18 samples exceeded a chlorophyll-a concentration of 7 μg/L which triggered phytoplankton analysis in 2022-23. As usual, blue-green biovolume or toxic blue-green species counts were not a problem for this estuarine site. Potentially toxic dinoflagellates or golden brown (Chrysophyta) taxa were found in moderate numbers in seven of these samples. Highest number of toxic species was found on 9 March 2023: *Heterocapsa* 87 cells/mL and *Prorocentrum minimum* 139 cells/mL.

There were no other significant statistical trends and/or exceptions (median values higher than the guideline limits) for any other water quality or phytoplankton analyte at NB11 in 2022-23.


NB11: Berowra Creek, Off Square Bay
Oxidised nitrogen (mg/L)
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
ANZG (2018)
2013-14 2014-15 2015-16 2016-17 2017-18 2018-19 2019-20 2020-21 2021-22 2022-23
DF=1 ; F Value=1.4958; Pr>F=0.2230
Financial year


NB11: Berowra Creek, Off Square Bay
Total nitrogen (mg/L)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
ANZG (2018)
2013-14 2014-15 2015-16 2016-17 2017-18 2018-19 2019-20 2020-21 2021-22 2022-23
DF=1 ; F Value=1.8322; Pr>F=0.1777
Financial year


NB11: Berowra Creek, Off Square Bay
Conductivity (uS/cm)
55000
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
ANZG (2018) Upper limit
ANZG (2018) Lower limit
2013-14 2014-15 2015-16 2016-17 2017-18 2018-19 2019-20 2020-21 2021-22 2022-23
DF=1 ; F Value=8.0641; Pr>F=0.0051
Financial year

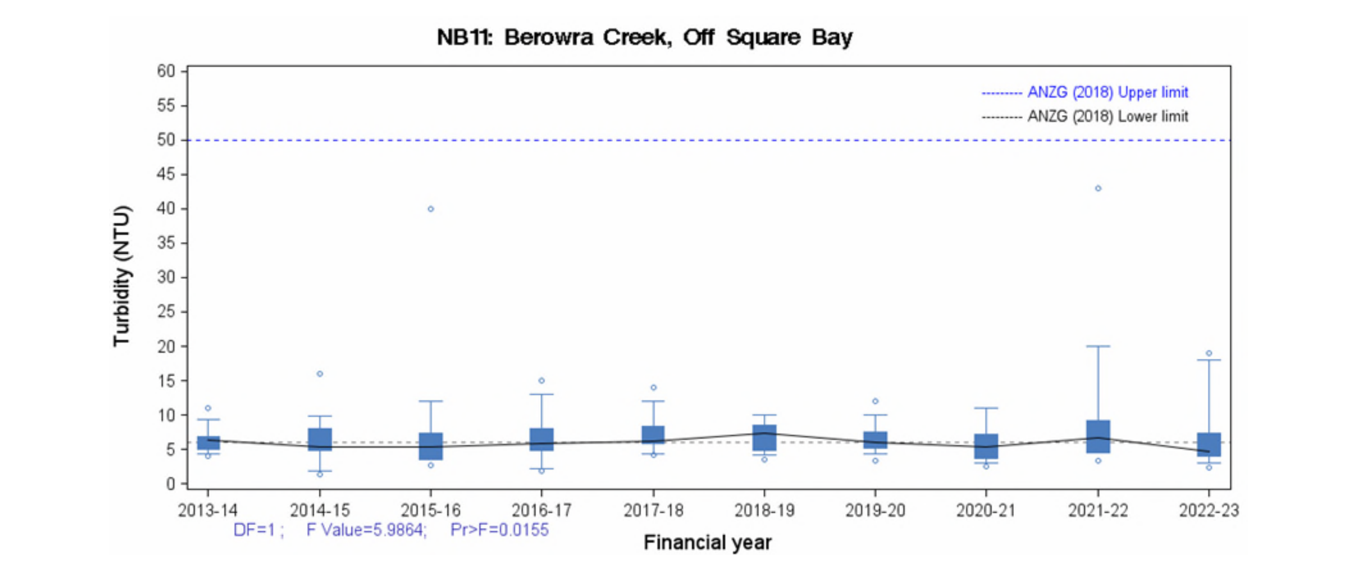


Figure 4-87 Nutrients and physico-chemical water quality exception plots, Berowra Creek off Square Bay (NB11)

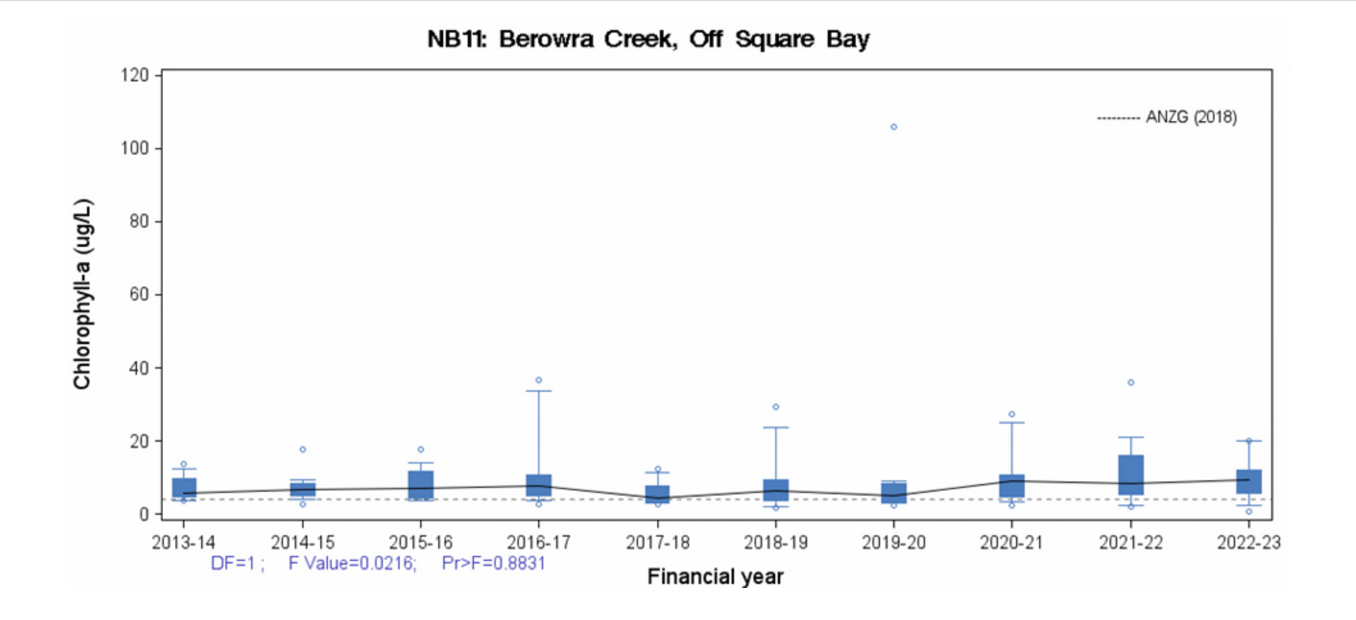


Figure 4-88 Phytoplankton as chlorophyll-a exception plot, Berowra Creek off Square Bay (NB11)

4.3.2 Other urban rivers and reference sites – Ecosystem health

Sites within the Port Jackson rivers upstream of Lane Cove Weir (PJLC) and Parramatta Weir (PJPR) were within the 'moderate water pollution' category (Volume 2 Appendix C-2). Additionally, sites in the Georges River for 2022-23 were between the moderate to mild water pollution categories (Volume 2 Appendix C-2). The Georges River results were typical of the stream health that has been recorded for these sites over the previous 1995 to 2023 period.

4.4 Nearshore marine environment

The treated wastewater discharged from the nearshore marine environment discharging WRRFs in 2022-23 and the population serviced by these WRRFs are shown in Table 4-57.

This section contains a summary of exceptions for nearshore marine environment discharging WRRFs.

Trend plots of discharge volume and catchment specific rainfall are presented first, and then reuse volume where applicable. This is followed by load limit plot where there was an exceedance during the 2022-23 monitoring period.

Trend plots showing the concentration of analytes in the discharge were only presented where they exceeded the respective EPL limit for a WRRF during the 2022-23 monitoring period, or there was a significant increase/decrease in concentrations in 2022-23 in comparison to earlier years.

All trend plots showing the analyte concentration and load data for nearshore marine WRRFs, including applicable concentration and load limits, can be found in Volume 2 Appendix D.

An electronic appendix file which includes a summary of results for all nearshore marine WRRFs by year has been provided to the EPA.

Table 4-57 Nearshore marine environment WRRFs operated by Sydney Water

WRRFs	Treatment level	Discharge 2022-23 (ML/year)[a]	Projected population 2022-23[b]	Discharge location
Warriewood	Secondary with disinfection	7,756	73,000	Ocean outfall Turimetta Head
Vaucluse & Diamond Bay (Bondi)	No treatment	1,537	0*	Cliff face outfalls
Cronulla	Tertiary with disinfection	24,114	241,590	Ocean outfall Potter Point, Kurnell
Wollongong	Tertiary with disinfection	19,314	210,310	Ocean outfall Coniston Beach
Bellambi**	Primary	1,235	0*	Near shore
Port Kembla**	Primary	948	0*	Shoreline
Shellharbour	Secondary with disinfection	8,298	79,500	Ocean outfall 130 m from Barrack Point with diffuser zone
Bombo	Secondary, denitrification with disinfection	2,311	15,610	Ocean outfall Bombo Point

[a] Discharge volume excludes onsite and offsite reuse.

[b] Projected populations (at 30 June 2023) are based on forecasts by the Australian Bureau of Statistics and the DPE.

*WRRFs not directly servicing any households.

**Part of Wollongong system. Treated wastewater is discharged during wet weather only.

4.4.1 Warriewood WRRF

- All parameters (concentrations and loads) in the discharge from Warriewood WRRF were within EPL limits. There were increasing trends in toxicity and copper concentration in the discharge.

Pressure – Wastewater discharge

Table 4-58 Gate 1 Analysis outcome summary – Warriewood WRRF

Analytes / Warriewood WRRF	Nutrients		Conventional analytes				EC_{50} Toxicity	Trace Metals		Other chemicals / organics	
	Total Nitrogen	Total Phosphorus	Biochemical Oxygen Demand	Faecal Coliforms	Oil and Grease	Total Suspended Solids		Aluminium	Copper	Cyanide	Nonyl phenol ethoxylate
Concentration				→		→	↗	→	↗	→	→
Load											

Cell shading: Concentration row – Faecal Coliforms, Total Suspended Solids, EC_{50} Toxicity, Aluminium, Copper, Cyanide, Nonyl phenol ethoxylate within the Environment Protection Licence limit; Total Nitrogen, Total Phosphorus, Biochemical Oxygen Demand, Oil and Grease not required in the EPL or no concentration limit. Load row – Total Nitrogen, Total Phosphorus, Biochemical Oxygen Demand, Oil and Grease, Total Suspended Solids within the Environment Protection Licence limit; Faecal Coliforms, EC_{50} Toxicity, Aluminium, Copper, Cyanide, Nonyl phenol ethoxylate not required in the EPL or no concentration limit.

↗	Upward trend	↘	Downward trend	→	No trend, p>0.05

(green)	Within the Environment Protection Licence limit
(yellow)	Environment Protection Licence limit exceedance
(grey)	Analytes not required in the EPL or no concentration limit

All concentration and load values in the Warriewood WRRF discharge were within the EPL limits during the 2022-23 reporting period.

Statistical analysis identified significantly increasing trends in toxicity and copper concentrations in 2022-23 compared to the previous nine years.

Metal removal at Warriewood WRRF is incidental as facility processes are not designed to remove metals. The increasing trend is believed to be related to storm flows with the continuation of a wet weather pattern during the 2022-23 reporting period. Only one result exceeded the average EPL limit during the 2022-23 reporting period which occurred during the extreme wet weather event across the greater Sydney catchment area between 2 – 7 July 2022. The reason for the increasing toxicity trend cannot be confirmed using available data. To determine the toxicity source requires performing a systematic toxicity identification evaluation which is challenging due to the range of chemicals that may be present in treated wastewater.

Warriewood WWRF is in the final commissioning stages of a major UV system refurbishment, which is expected to improve reliability and performance of the facility's disinfection process.

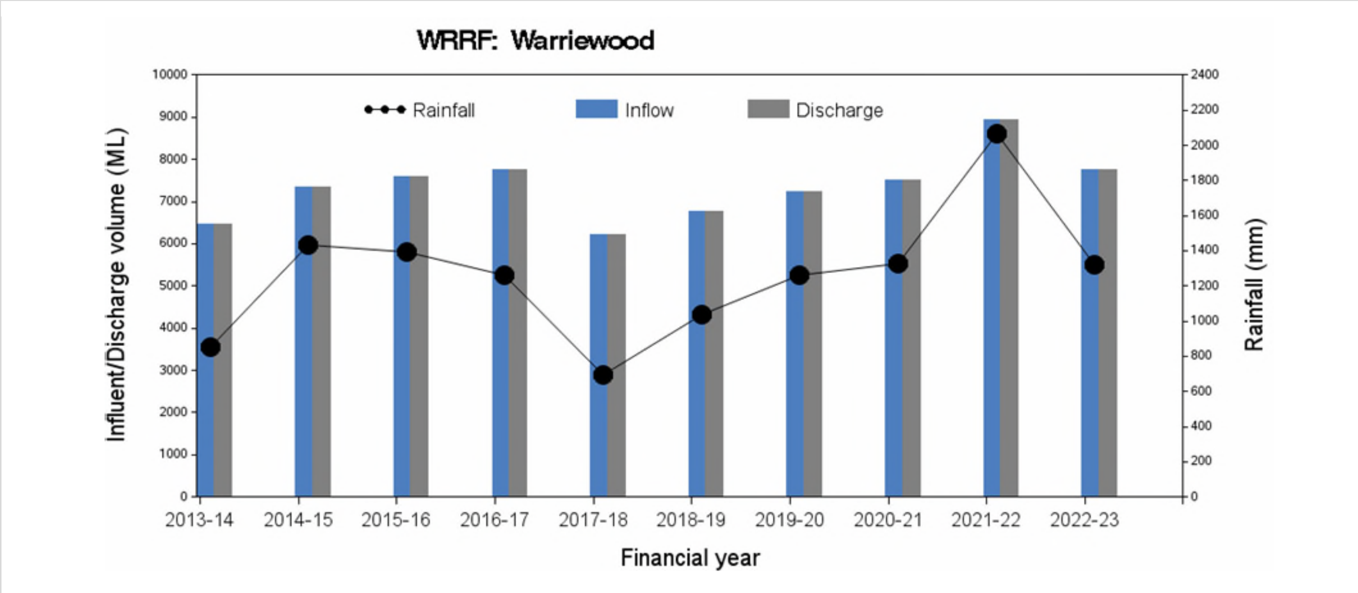


Figure 4-89 Warriewood WRRF inflow and discharge volume with catchment rainfall

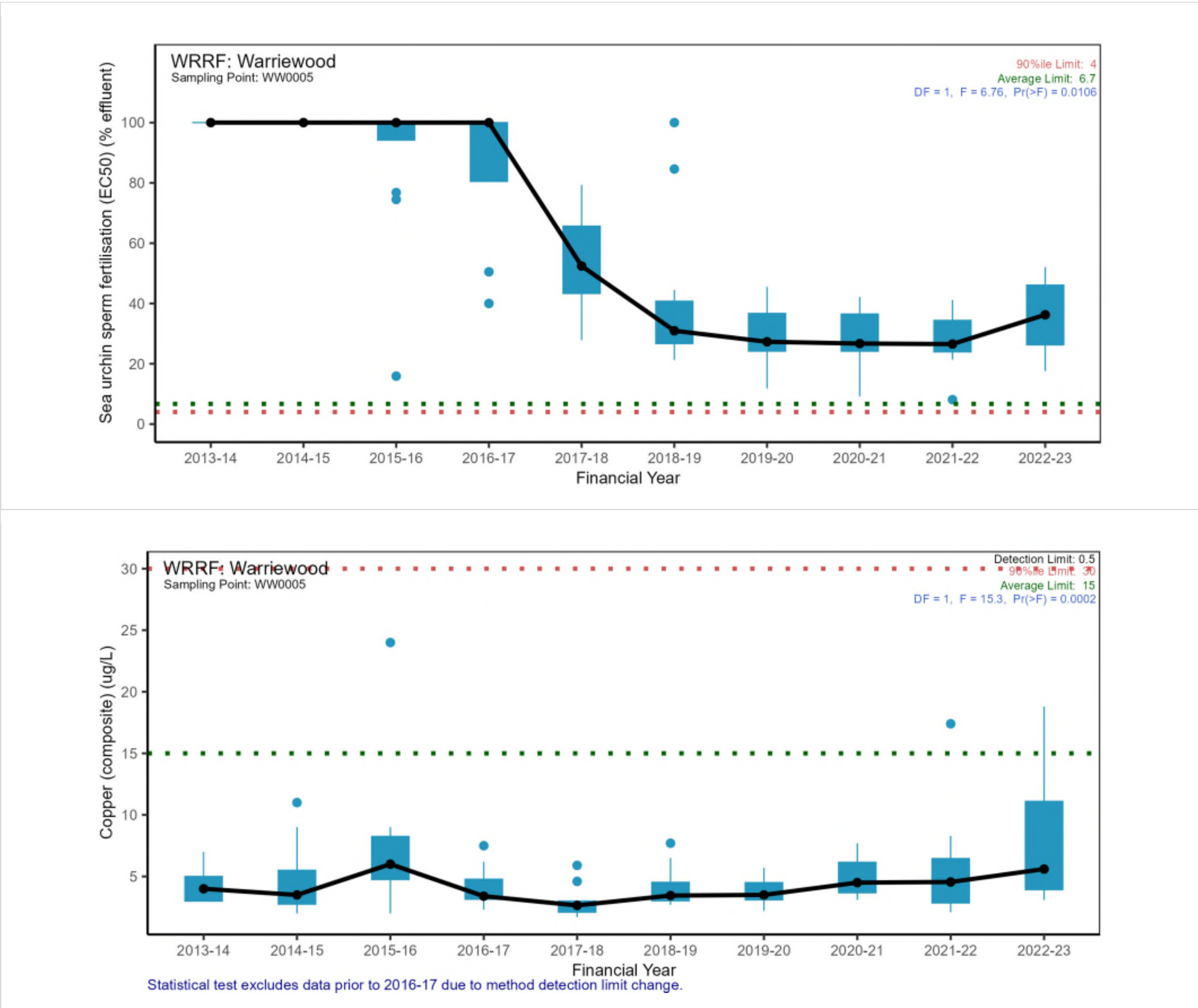


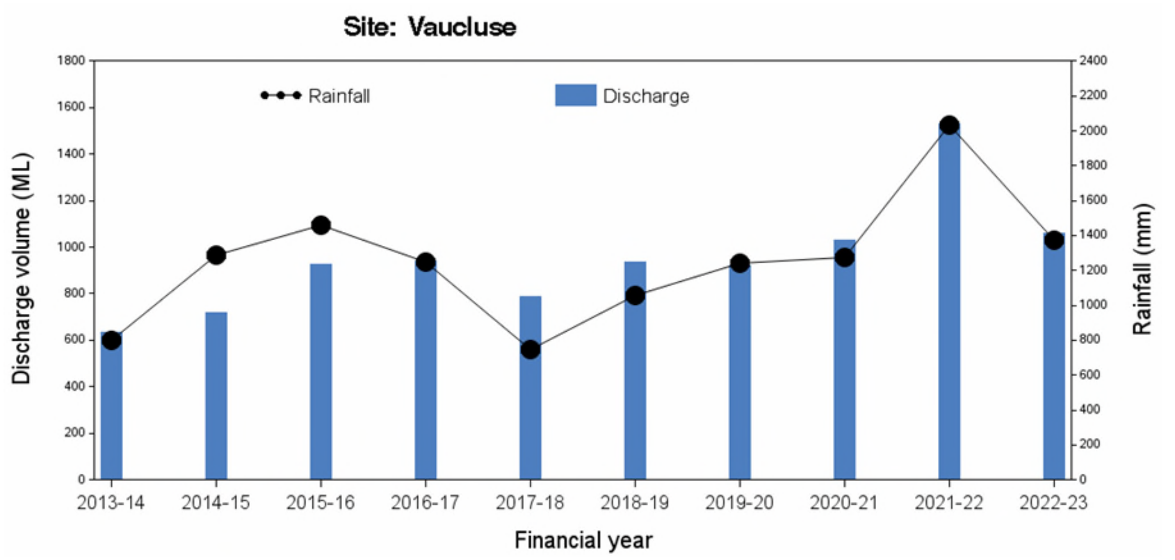
Figure 4-90 Warriewood WRRF discharge quality and toxicity exception plots

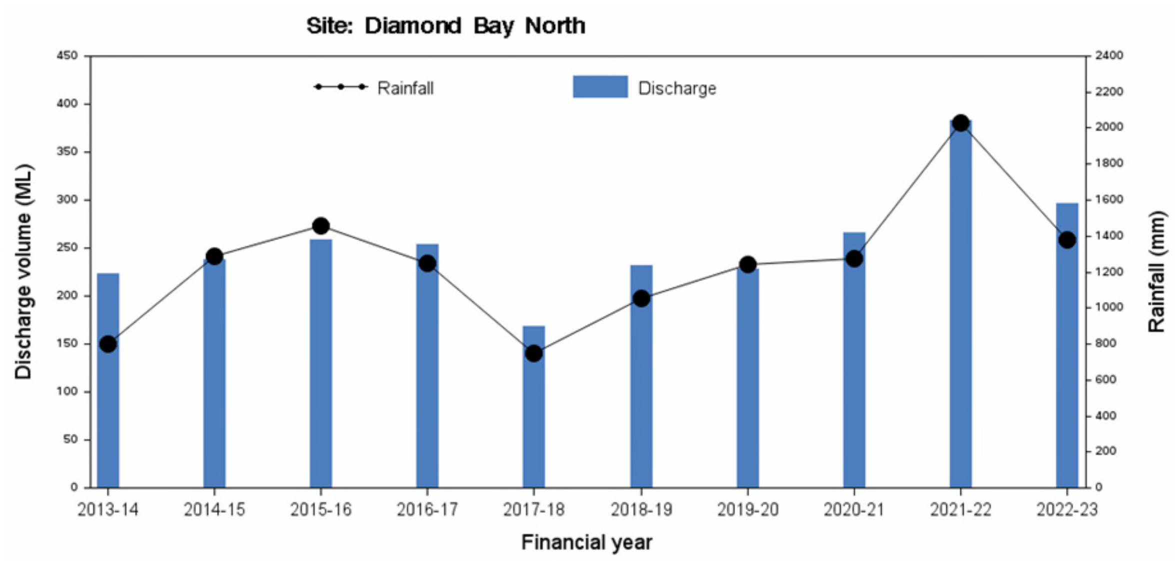
4.4.2 Bondi WRRF (nearshore discharges, Vaucluse & Diamond Bay)

Pressure – Wastewater discharge

99% of Sydney's wastewater is treated at water resource recovery facilities before it is released to the environment. Currently, untreated wastewater is discharged from cliff face outfalls at Vaucluse and Diamond Bay. Sydney Water are progressing with the planning stage to intercept and redirect wastewater for dry weather and the first 10 mm of rain events from Vaucluse (Parsley Bay) and Diamond Bay discharges to the existing Bondi network for treatment at Bondi WRRF and subsequent offshore discharge via the deepwater ocean outfall.

It is expected recreational use of the surrounding waters and aquatic ecosystem will be improved if the wastewater is diverted to Bondi WRRF which will bring this area in line with our other wastewater systems and cease the discharge of untreated wastewater from the Vaucluse and Diamond Bay cliff-face outfalls during dry weather.





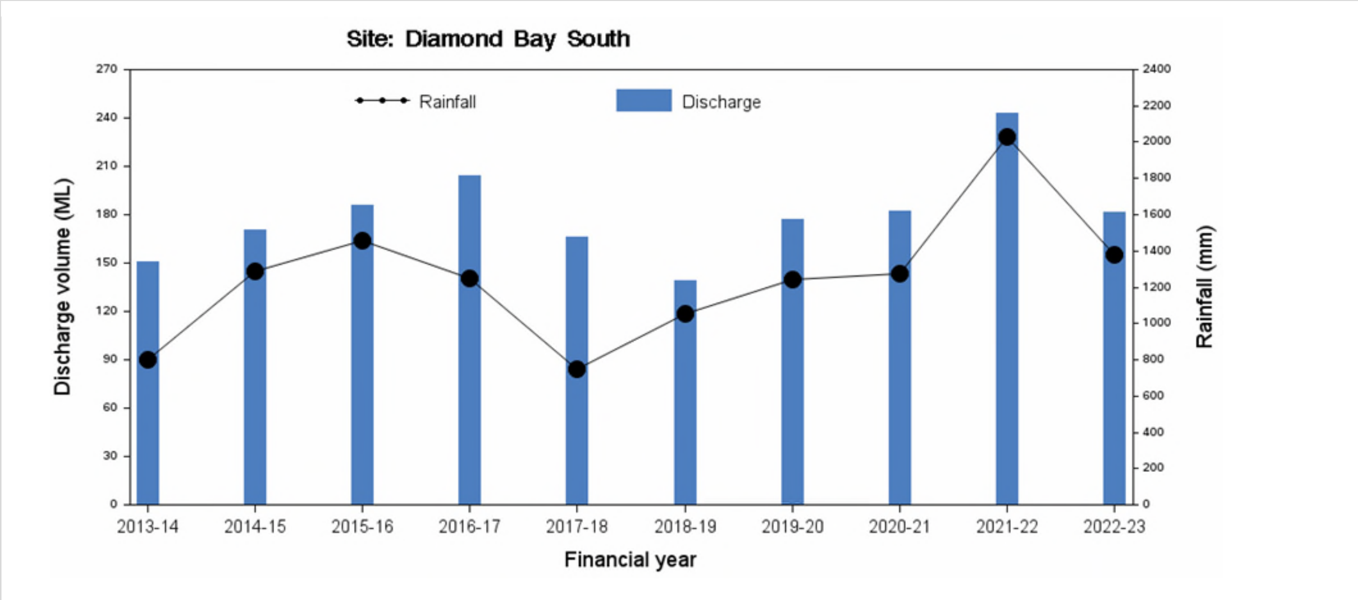


Figure 4-91 Bondi nearshore discharge volumes with catchment rainfall

4.4.3 Cronulla WRRF

- All parameters (concentration and loads) discharged from the Cronulla WRRF were within EPL limits. There was an increasing trend in ammonia nitrogen concentration and decreasing trend in zinc concentration in the discharge.

Pressure – Wastewater discharge

Table 4-59 Gate 1 Analysis outcome summary – Cronulla WRRF

Analytes / Cronulla WRRF	Nutrients			Conventional analytes				
	Ammonia Nitrogen	Total Nitrogen	Total Phosphorus	Biochemical Oxygen Demand	Faecal Coliforms	Oil and Grease	Total Suspended Solids	EC_{50} Toxicity
Concentration	↗			→	→	→	→	→
Load								

Analytes / Cronulla WRRF	Trace Metals								Other chemicals / organics					
	Aluminium	Cadmium	Chromium	Copper	Lead	Mercury	Selenium	Zinc	Chlorpyrifos	Cyanide	Diazinon	Hydrogen sulfide (un-ionised)	Nonyl phenol ethoxylate	Pesticides and PCBs
Concentration	→			→				↘	→	→	→	→	→	
Load														

↗	Upward trend	↘	Downward trend	→	No trend, p>0.05

(green)	Within the Environment Protection Licence limit
(yellow)	Environment Protection Licence limit exceedance
(grey)	Analytes not required in the EPL or no concentration limit

All concentration and load parameters measured in the Cronulla WRRF discharge were within the EPL limits during the 2022-23 reporting period.

Statistical analysis identified a significantly increasing trend in ammonia nitrogen concentration and a significant decreasing trend in zinc concentration in 2022-23 compared to the previous nine years.

The increasing trend in ammonia nitrogen can be linked to catchment growth and the continuation of extreme wet weather events resulting in subsequent increased inflows into the facility. Trend can also be linked to process interruptions during major maintenance and upgrades carried out on secondary and tertiary processes at the facility over the past few reporting periods. The tertiary filters were overhauled between 2018 – 2021 and overhauls to the four secondary clarifiers commenced in 2021. Clarifier 1 is now complete and clarifier 3 is currently in progress, with the remaining 2 clarifiers to follow thereafter. The facility has been operating with three clarifiers online for most of the time since the commencement of the maintenance program.

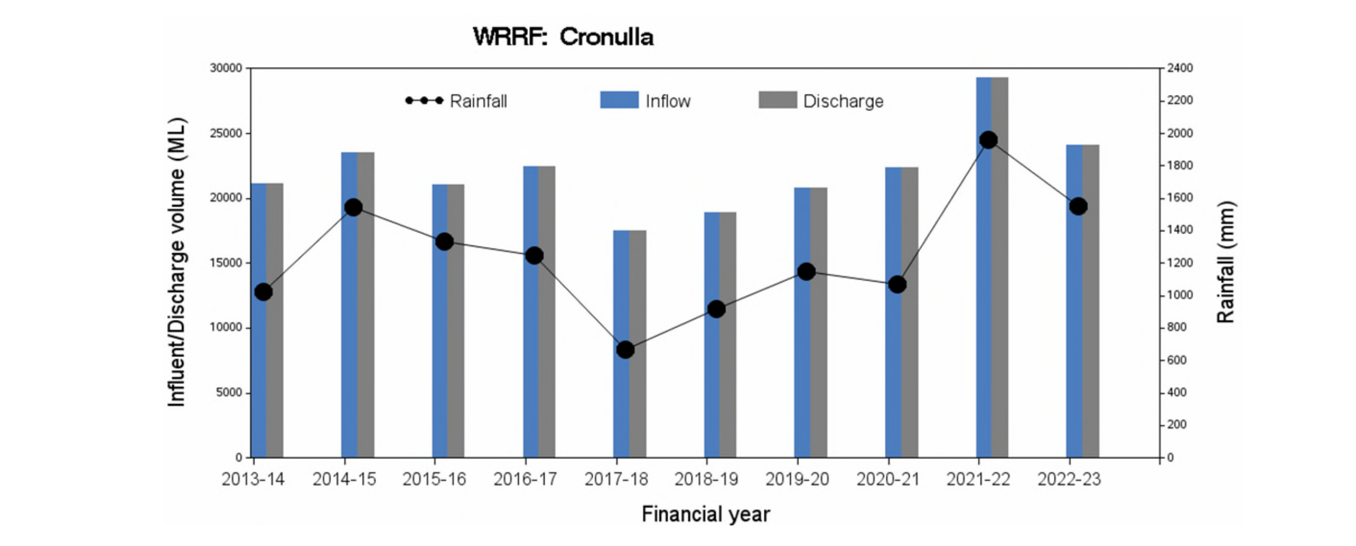


Figure 4-92 Cronulla WRRF inflow and discharge volume with catchment rainfall

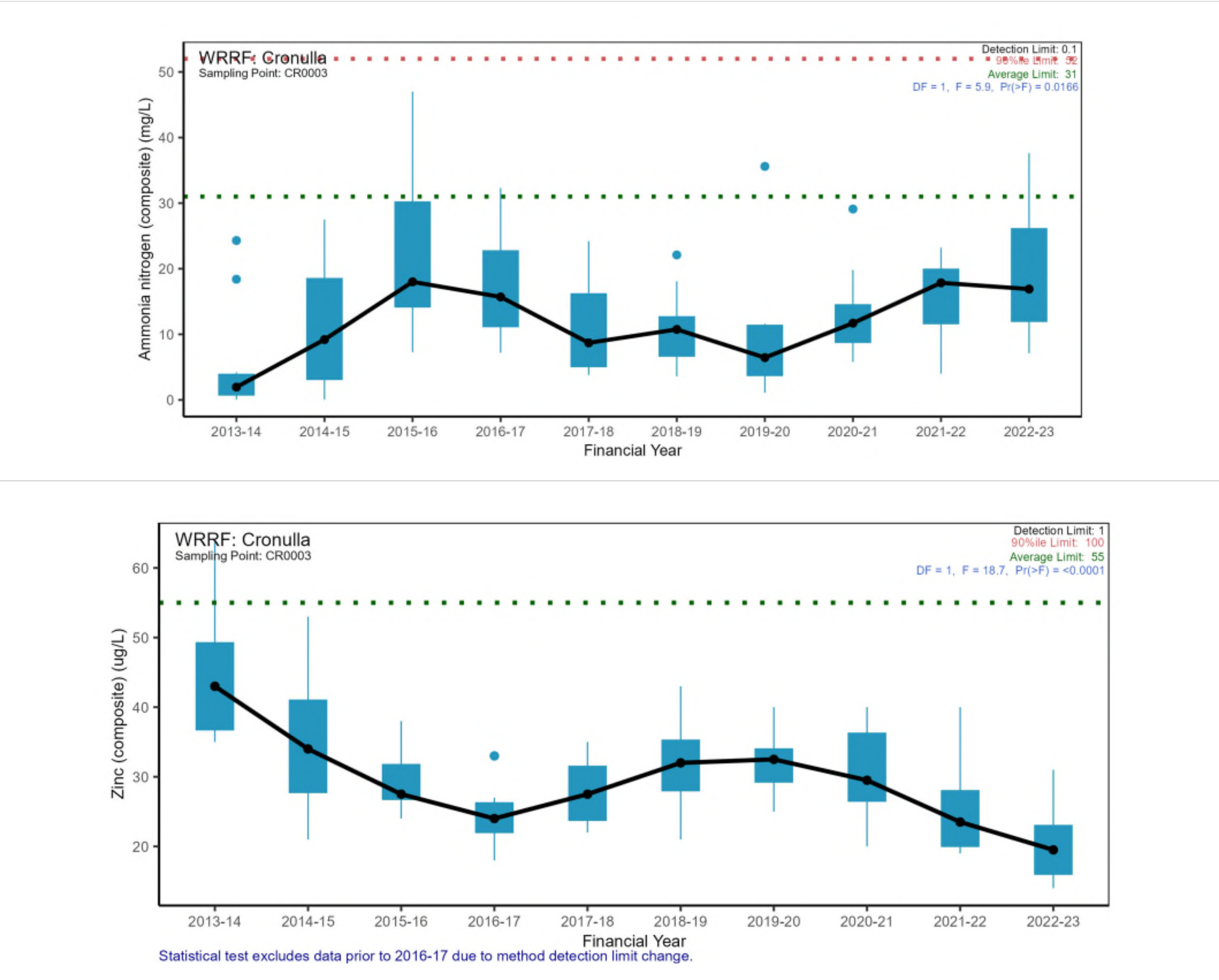


Figure 4-93 Cronulla WRRF discharge quality and toxicity exception plots

4.4.4 Wollongong WRRF

- Biochemical oxygen demand and total suspended solid EPL load limits were exceeded in the discharge from Wollongong WRRF during 2022-23. All other parameters (concentrations and loads) were within EPL limits. There was an increasing trend in total suspended solids concentration and a decreasing trend in copper concentration in the discharge.

Pressure – Wastewater discharge

Table 4-60 Gate 1 Analysis outcome summary – Wollongong WRRF

Analytes / Wollongong WRRF	Nutrients		Conventional analytes			Trace Metals		Other chemicals / organics	
	Total Nitrogen	Total Phosphorus	Biochemical Oxygen Demand	Oil and Grease	Total Suspended Solids	Aluminium	Copper	Diazinon	Hydrogen sulfide (un-ionised)
Concentration			→		↗	→	↘	→	→
Load									

↗	Upward trend	↘	Downward trend	→	No trend, p>0.05

(green)	Within the Environment Protection Licence limit
(yellow)	Environment Protection Licence limit exceedance
(grey)	Analytes not required in the EPL or no concentration limit

All concentrations in the discharge from Wollongong WRRF were within the EPL limits during the 2022-23 reporting period. The biochemical oxygen demand and total suspended solids load limits were exceeded during the 2022-23 reporting period. All other load values were within EPL limits.

Statistical analysis identified a significantly increasing trend in total suspended solids concentration and a significantly decreasing trend in copper concentration in 2022-23 compared to the previous nine years.

The exceeded annual load limits for biochemical oxygen demand and total suspended solids were largely due to the extreme wet weather events experienced between 2 – 7 July, 10 – 11 July, 28 September – 2 October, 6 –9 October, 24 – 25 October 2022 and 9 – 10 February 2023 within the Wollongong WTS catchment, and the subsequent high wet weather flows received at the treatment facilities (Wollongong WRRF, Bellambi and Port Kembla storm treatment facilities) during these periods.

Wollongong licence 218 accounts for emissions factors applied to unmonitored streams from Bellambi and Port Kembla storm treatment facilities which affect calculated loads under wet weather conditions. In 2022-23, 27% of the biochemical oxygen demand and 36% of the total suspended solids loads calculated as discharged from under the Wollongong EPL were generated by 10% of the total discharged volume. Both biochemical oxygen demand and total suspended solids loads were very high and subsequently annual limits were exceeded with a continuation of La Niña weather patterns during the 2022-23 reporting period.

No immediate actions could be undertaken as the facility was operating as designed under wet weather conditions during the periods of extreme wet weather. Performance against percentile limits at Wollongong WRRF was good during dry weather conditions, with results well below 50th percentile limits.

Sydney Water is engaging with the EPA on wet weather load calculations under extreme weather events due to a skewing effect on calculated loads during extreme wet weather. Further collaboration between Sydney Water and EPA is required to progress.

Current improvements include the renewal of tertiary filters and improvements to the Actiflo storm treatment plant at Wollongong WRRF to improve the wet weather performance for biochemical oxygen demand and total suspended solids removal. As of June 2023, five of ten tertiary filters have been completed. The Actiflo polymer dosing system was also replaced and commissioned in June 2023.

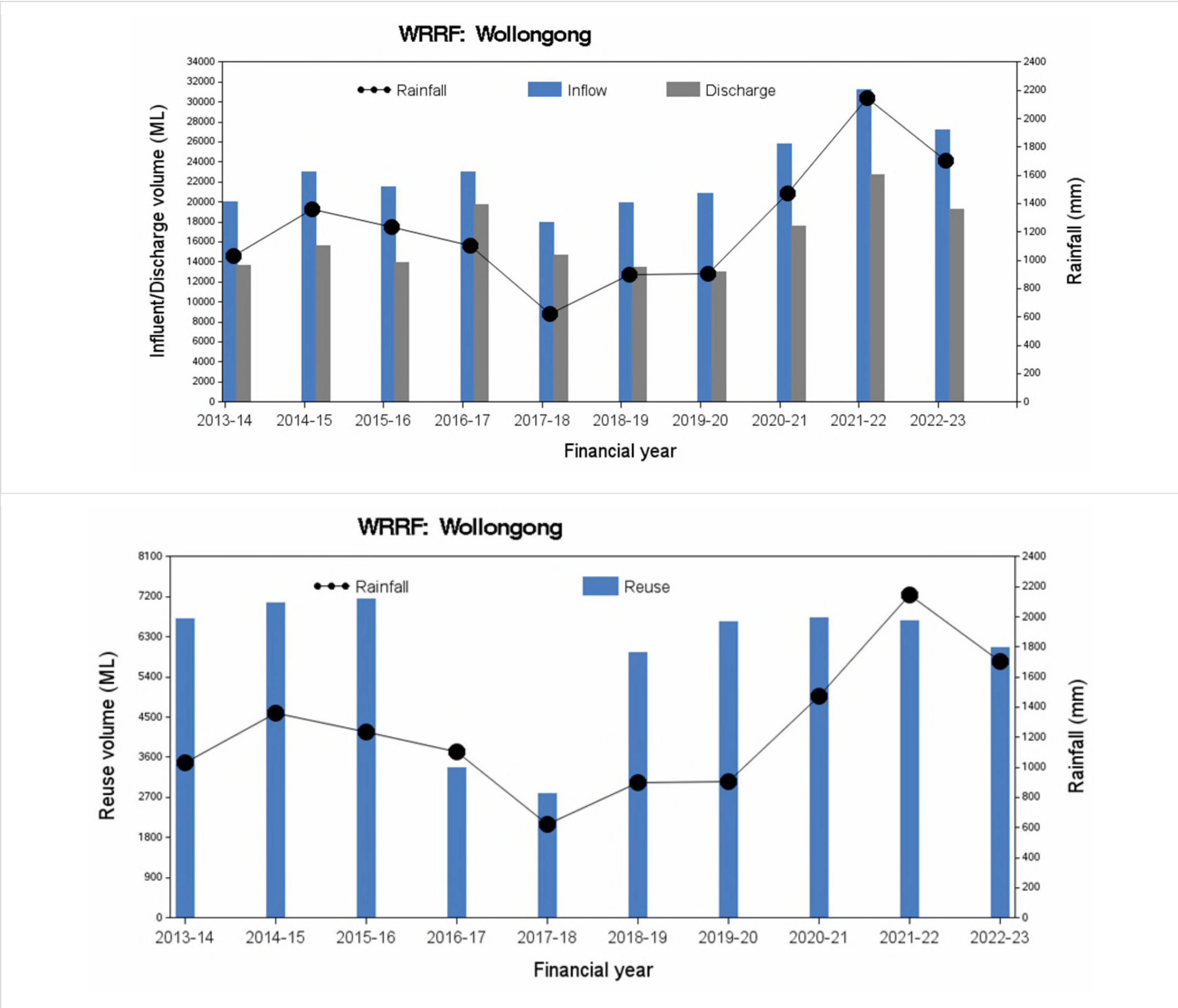


Figure 4-94 Wollongong WRRF inflow, discharge and reuse volume with catchment rainfall plots

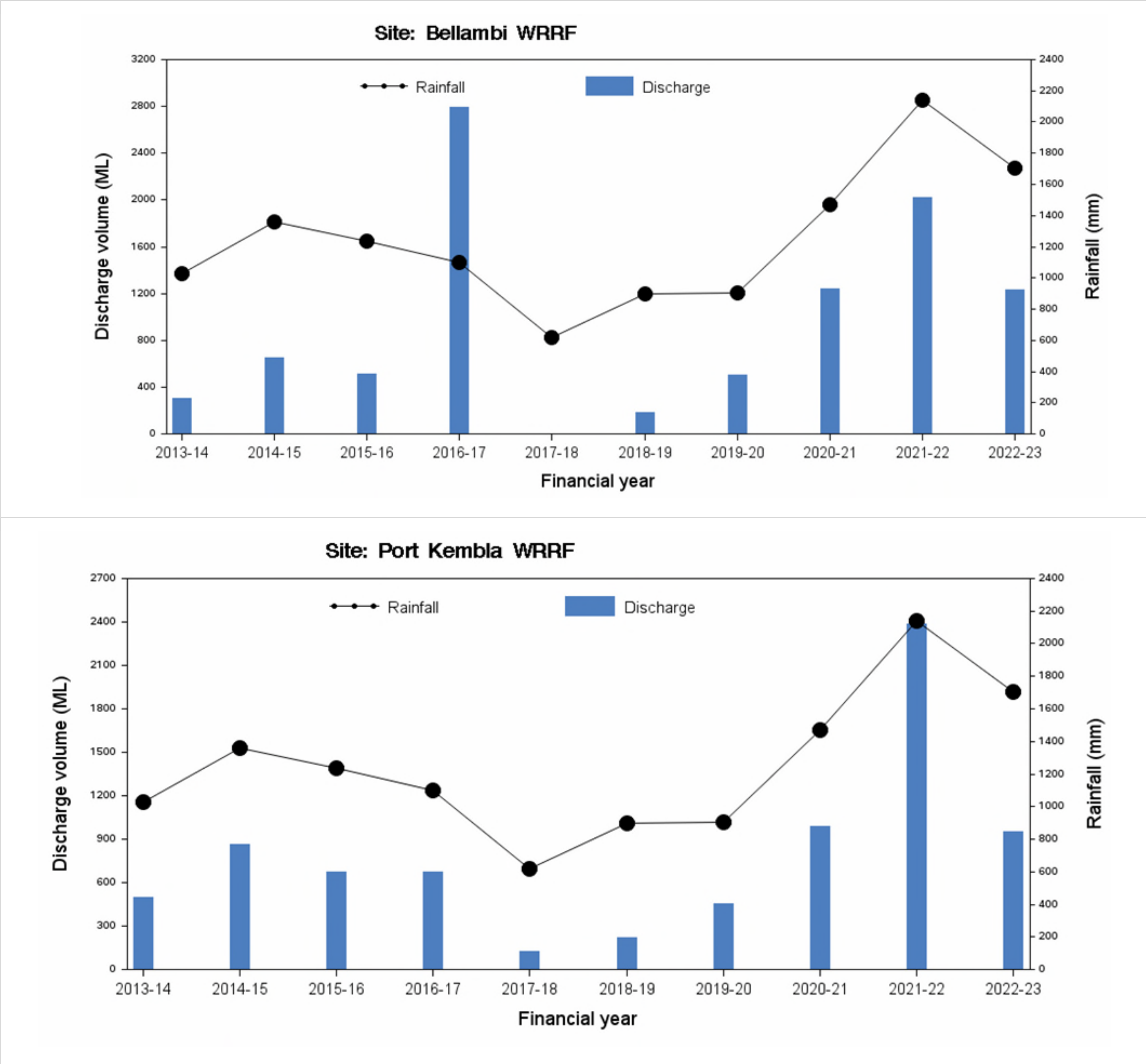


Figure 4-95 Bellambi and Port Kembla WRRF inflow and discharge volume with catchment rainfall plots

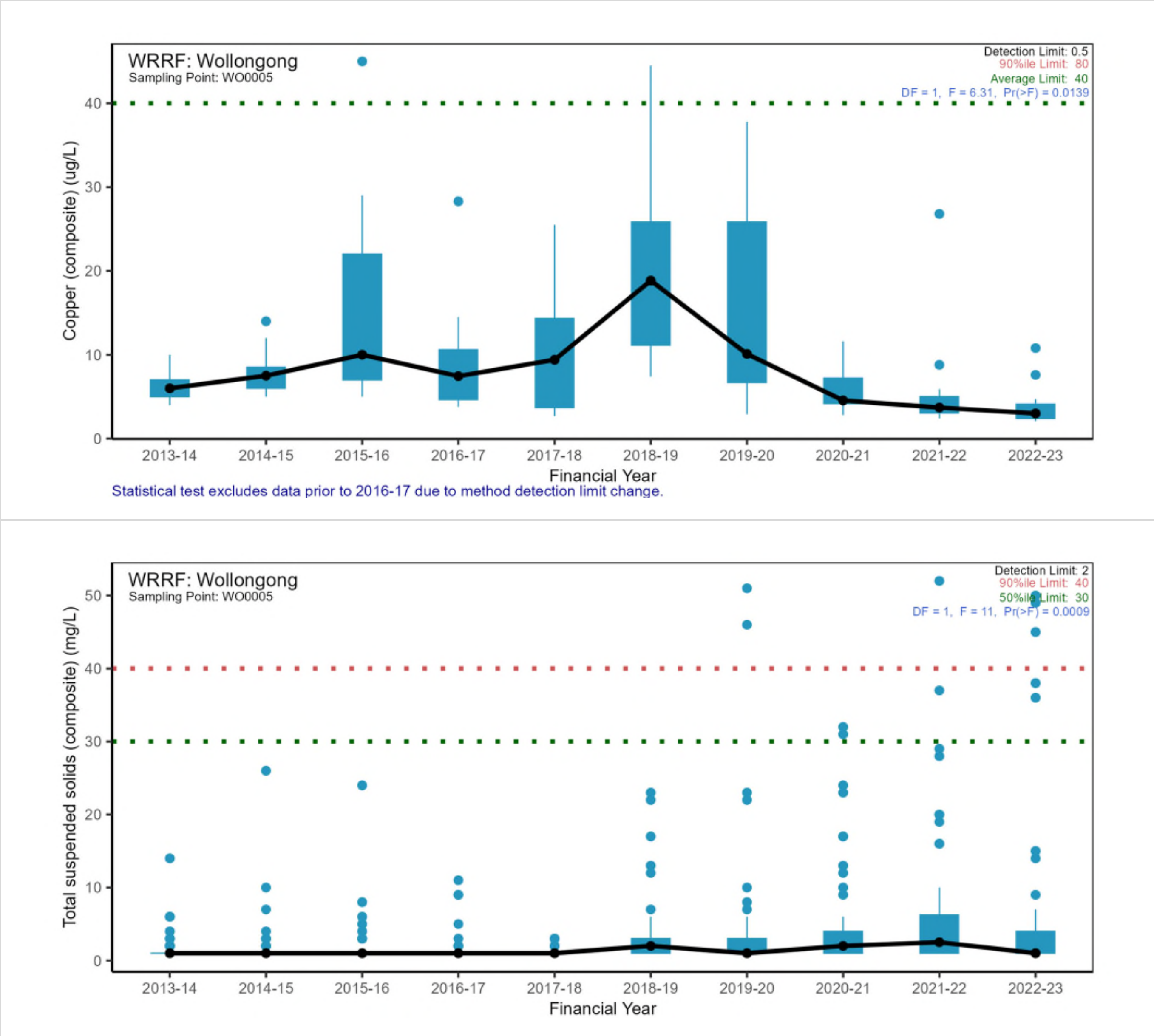


Figure 4-96 Wollongong WRRF discharge quality and toxicity exception plots

4.4.5 Shellharbour WRRF

- Aluminium average concentration and total suspended solid load in the discharge from Shellharbour WRRF exceeded the EPL limit during 2022-23. All other parameters (concentration and load) were within EPL limits. There were increasing trends in total suspended solids and aluminium concentrations, and a decreasing trend in copper concentration in the discharge.

Pressure – Wastewater discharge

Table 4-61 Gate 1 Analysis outcome summary – Shellharbour WRRF

Analytes / Bombo WRRF	Nutrients			Conventional analytes					Trace Metals		Other chemicals / organics		
	Ammonia Nitrogen	Total Nitrogen	Total Phosphorus	Biochemical Oxygen Demand	Faecal Coliforms	Oil and Grease	Total Suspended Solids	EC_{50} Toxicity	Aluminium	Copper	Diazinon	Hydrogen sulfide (un-ionised)	Nonyl phenol ethoxylate
Concentration	→			→	→		↗	→	↗	↘	→	→	→
Load													

↗	Upward trend	↘	Downward trend	→	No trend, p>0.05

(green)	Within the Environment Protection Licence limit
(yellow)	Environment Protection Licence limit exceedance
(grey)	Analytes not required in the EPL or no concentration limit

The Shellharbour WRRF aluminium average concentration limit was exceeded in the 2022-23 reporting period. In addition, the annual load limit for total suspended solids was exceeded during the reporting period. All other concentration and load values in the Shellharbour WRRF discharge were within the EPL limits.

Statistical analysis identified significantly increasing trends in total suspended solids and aluminium concentrations, whilst a significantly decreasing trend was observed in copper concentration in 2022-23 compared to the previous nine years.

The total aluminium exceedance was largely influenced by the extreme wet weather event in the Shellharbour catchment on 6 October 2022 when the elevated result was recorded. Suspected groundwater inflow/infiltration inputs with effluent performance impacted aluminium levels by reduced removal rates in extreme wet weather flows with compliant bypasses occurring concurrently.

No immediate action could be undertaken at the time of the exceedance as the facility was operating as designed under wet weather conditions when the elevated aluminium result was recorded. The elevated concentration was not known until after the event once samples were analysed in the laboratory. There were no re-occurrences during the remainder of the reporting period, with results well below the average limit for aluminium.

The total suspended solids load exceedance was largely influenced by the significant wet weather events received in the Shellharbour catchment between 1 – 7 July, 28 September – 10 October and 20 – 26 October 2022. No immediate actions could be undertaken as facility was operating as designed under wet weather conditions during the periods of extreme wet weather.

Sydney Water is engaging with the EPA on wet weather load calculations under extreme weather events due to a skewing effect on calculated loads during extreme wet weather. Further collaboration between Sydney Water and EPA is required to progress.

Current improvements include:

- Dewatering upgraded facility due for commissioning in late 2023 which will improve the reliability of the solids stream which will reduce process pressure on liquid stream flows and help reduce high suspended solids in storm flows. The work should also reduce side stream impacts like centrate quality.
- Current major periodic maintenance on the primary sedimentation tanks, air diffusers and clarifiers will improve process capability and suspended solids removal.

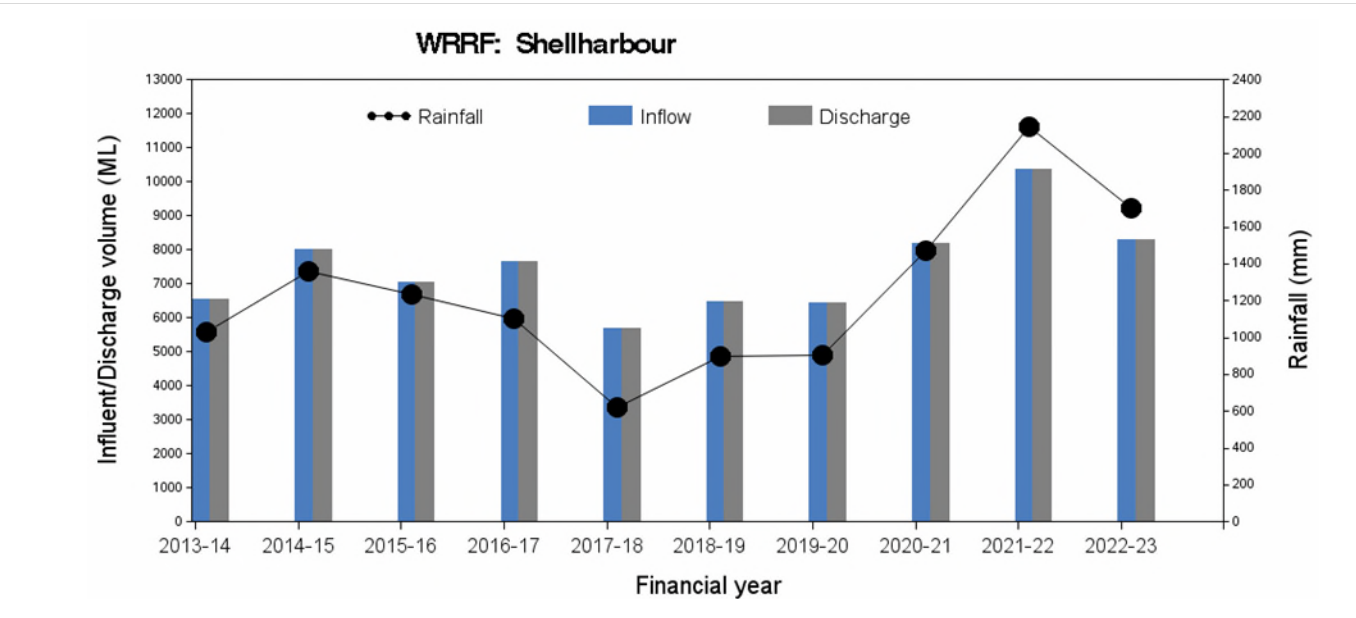
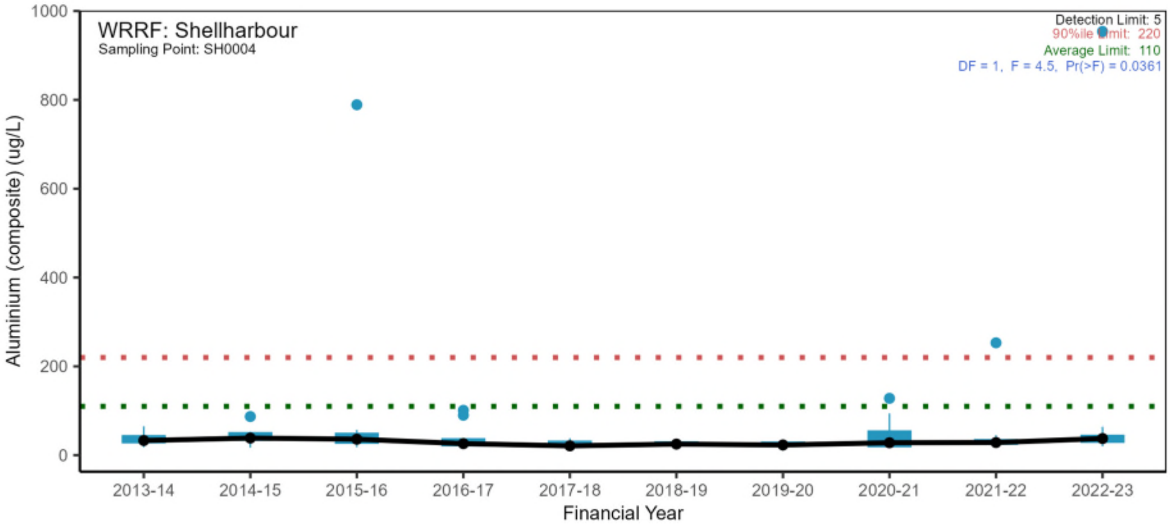
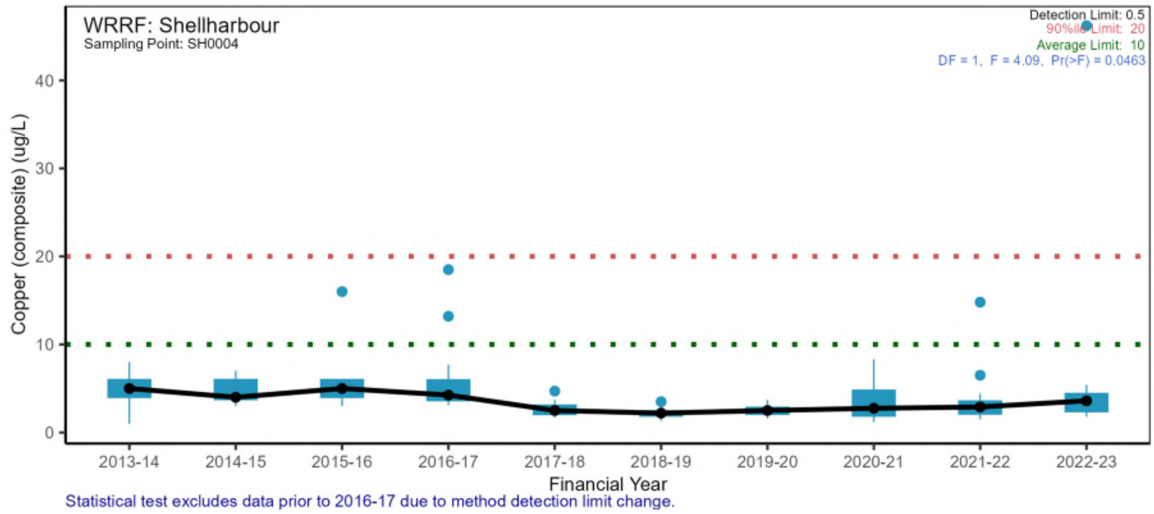


Figure 4-97 Shellharbour WRRF inflow and discharge volume with catchment rainfall





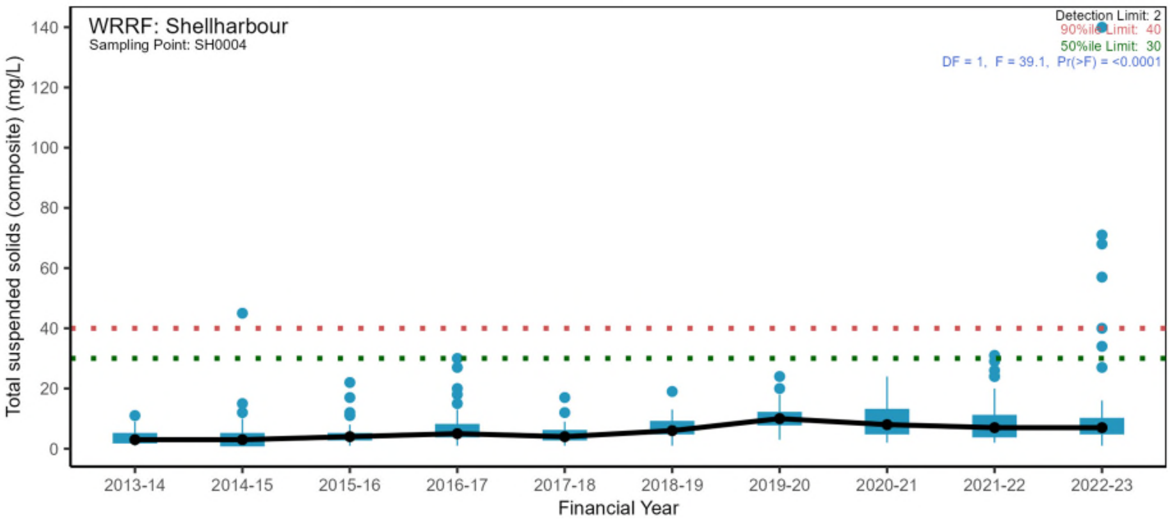


Figure 4-98 Shellharbour WRRF discharge quality and toxicity exception plots

4.4.6 Bombo WRRF

- The total suspended solids load in the discharge from Bombo WRRF exceeded the EPL limit during 2022-23. All other parameters (concentrations and loads) were within EPL limits. No significant trends were identified in the discharge quality.

Pressure – Wastewater discharge

Table 4-62 Gate 1 Analysis outcome summary – Bombo WRRF

Analytes / Bombo WRRF	Nutrients			Conventional analytes					Trace Metals		Other chemicals / organics		
	Ammonia Nitrogen	Total Nitrogen	Total Phosphorus	Biochemical Oxygen Demand	Faecal Coliforms	Oil and Grease	Total Suspended Solids	EC_{50} Toxicity	Aluminium	Copper	Diazinon	Hydrogen sulfide (un-ionised)	Nonyl phenol ethoxylate
Concentration	→			→	→		→	→	→	→	→	→	→
Load													

↗	Upward trend	↘	Downward trend	→	No trend, p>0.05

	Within the Environment Protection Licence limit
	Environment Protection Licence limit exceedance
	Analytes not required in the EPL or no concentration limit

All concentrations measured in the discharge from Bombo WRRF were within EPL limits during the 2022-23 reporting period. The annual load limit for total suspended solids was exceeded during the reporting period. All other load values in the Bombo WRRF discharge were within the EPL limits.

Statistical analysis did not identify any significant trends from the environmental discharge at Bombo WRRF during the 2022-23 reporting period.

The total suspended solids load limit exceedance was largely due to extreme wet weather events experienced 2 – 6 July, 29 September – 9 October, 21 – 26 October 2022, 9 – 10 February and 13 – 14 March 2023 within the Bombo WRRF catchment.

No immediate actions could be undertaken as facility was operating as designed under wet weather conditions. Actual total suspended solids concentration results from 6-day licence sampling were largely below the 50th percentile for the entire 2022-23 monitoring period. Most occurrences of elevated suspended solids were wet weather related with actual dry weather performance being below the 50th percentile limit for total suspended solids. Wet weather influence on the non-compliance is predominant.

Sydney Water is engaging with the EPA on wet weather load calculations under extreme weather events due to a skewing effect on calculated loads during extreme wet weather. Further collaboration between Sydney Water and EPA is required to progress.

Current improvements within the control of operations include:

- cleaning both sludge lagoons in the last cycle (grit cleanout after sludge dewatering). This has helped the reliability of the sludge lagoons to prevent impacts on the liquid stream processes.
- major periodic maintenance on Intermittently Decanting Aeration Lagoons (IDAL) to improve availability for process capability to ensure best suspended solids removal.

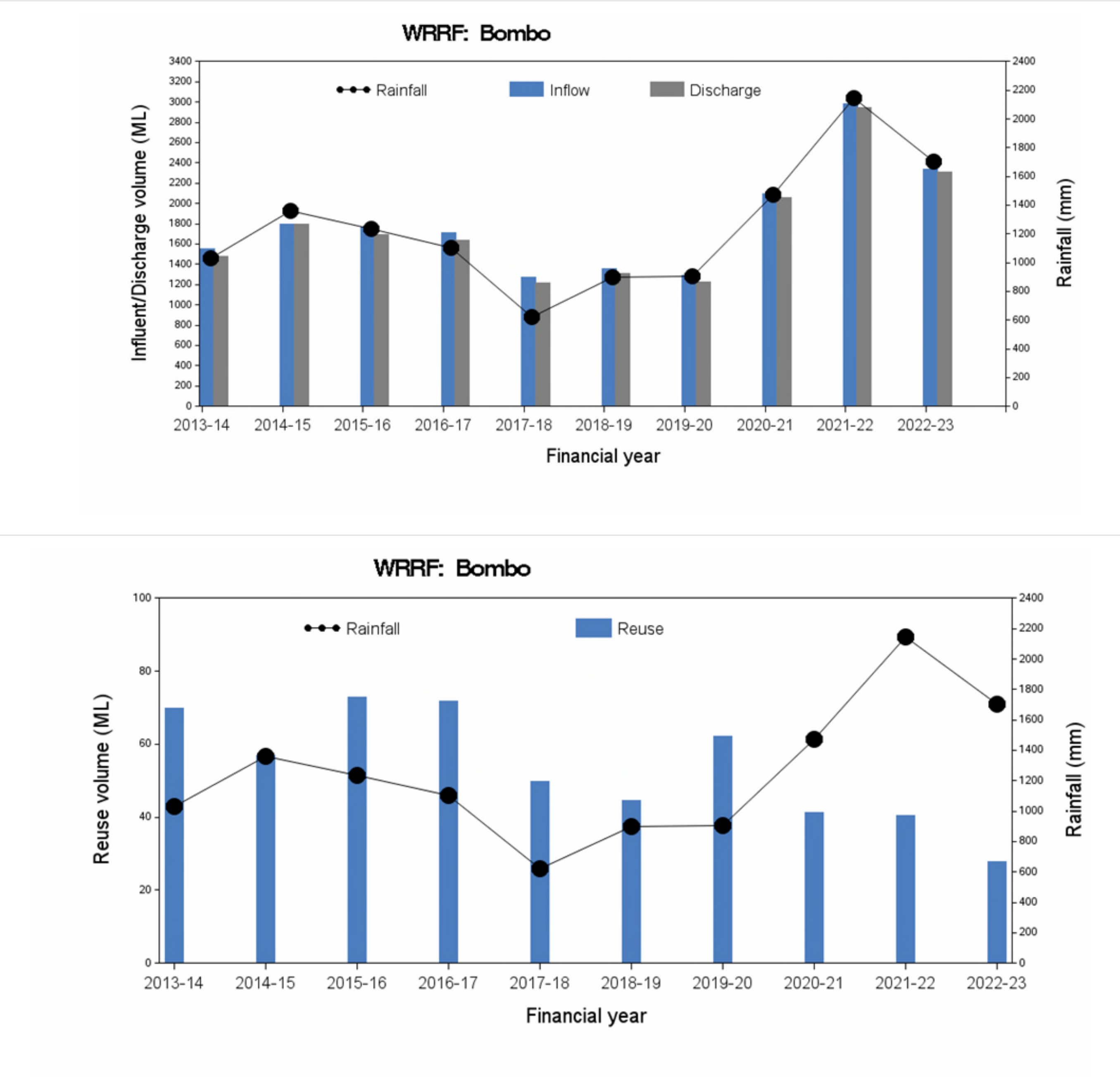


Figure 4-99 Bombo WRRF inflow, discharge and reuse volume with catchment rainfall

4.4.7 Nearshore marine environment

Stressor – Nearshore receiving water quality

Feasibility study required to inform an appropriate monitoring design and indicators (van Dam et al. 2023).

Ecosystem Receptor – Nearshore intertidal and subtidal macro-algae

Assessment of the 2008-09 to 2022-23 monitoring data from the Shellharbour WRRF and two control sites indicated a relatively stable equilibrium in the rocky-intertidal community structure (Volume 2 Appendix D-5-5). These results also suggest no measurable impact had developed in the intertidal rock platform community near the outfall at Barrack Point from wastewater discharges from the Shellharbour WRRF as the community assemblage at the outfall site was very similar to the control site 1 over the 2008-09 to 2022-23 period. The results from control site 2 represents natural variation in rocky-intertidal community structure that has been demonstrated to occur for closely spaced sites on the shoreline (Underwood and Chapman, 1995).

4.5 Offshore marine environment

The treated wastewater discharged from the offshore marine environment discharging WRRFs in 2022-23 and the population serviced by these WRRFs are shown in Table 4-63.

This section contains a summary of exceptions offshore marine environment discharging WRRFs.

Trend plots of discharge volume and catchment specific rainfall are presented first, and then reuse volume where applicable. This is followed by load limit plot where there was an exceedance during the 2022-23 monitoring period.

Trend plots showing the concentration of analytes in the discharge were only presented where they exceeded the respective EPL limit for a WRRF during the 2022-23 monitoring period, or there was a significant increase/decrease in concentrations in 2022-23 in comparison to earlier years.

All trend plots showing the analyte concentration and load data for offshore marine WRRFs, including applicable concentration and load limits, can be found in Volume 2 Appendix E.

An electronic appendix file summarising the results for all offshore marine WRRFs by year has been provided to the EPA.

Table 4-63 Offshore marine environment WRRFs operated by Sydney Water

WRRFs	Treatment level	Discharge 2022-23 (ML/year)[a]	Projected population 2022-23[b]	Discharge location
North Head	Primary	149,158	1,359,510	North Head Deepwater ocean outfall, 3.7 km from shoreline, 65 m maximum water depth, 762 m diffuser zone
Bondi	Primary	45,043	300,780	Bondi Deepwater ocean outfall; 2.2 km from shoreline, 63 m maximum water depth, 512 m diffuser zone
Malabar	Primary	199,794	1,629,960	Malabar Deepwater ocean outfall, 3.6 km from shoreline, 82 m maximum water depth, 720 m diffuser zone

[a] Discharge volume excludes onsite and offsite reuse.

[b] Projected populations (at 30 June 2023) are based on forecasts by the Australian Bureau of Statistics and the DPE.

4.5.1 North Head WRRF

- All parameters (concentrations and loads) in the discharge from North Head WRRF were within EPL limits. There was a decreasing trend in copper concentration in the discharge.

Pressure – Wastewater discharge

Table 4-64 Gate 1 Analysis outcome summary – North Head WRRF

Analytes / North Head WRRF	Nutrients		Conventional analytes			
	Total Nitrogen	Total Phosphorus	Biochemical Oxygen Demand	Oil and Grease	Total Suspended Solids	EC_{50} Toxicity
Concentration				→	→	→
Load						

Analytes / North Head WRRF	Trace Metals								Other chemicals / organics			
	Aluminium	Cadmium	Chromium	Copper	Lead	Mercury	Selenium	Zinc	Chlorpyrifos	Hydrogen sulfide (un-ionised)	Nonyl phenol ethoxylate	Pesticides and PCBs
Concentration	→			↘					→	→	→	
Load												

↗	Upward trend	↘	Downward trend	→	No trend, p>0.05

	Within the Environment Protection Licence concentration limit
	Environment Protection Licence concentration limit exceedance
	Analytes not required in the EPL or no concentration limit

All parameters (load and concentration) measured in the discharge from North Head WRRF were within the EPL limits during the 2022-23 period. Statistical analysis identified a decreasing trend in copper concentration in 2022-23 compared to the previous nine years.

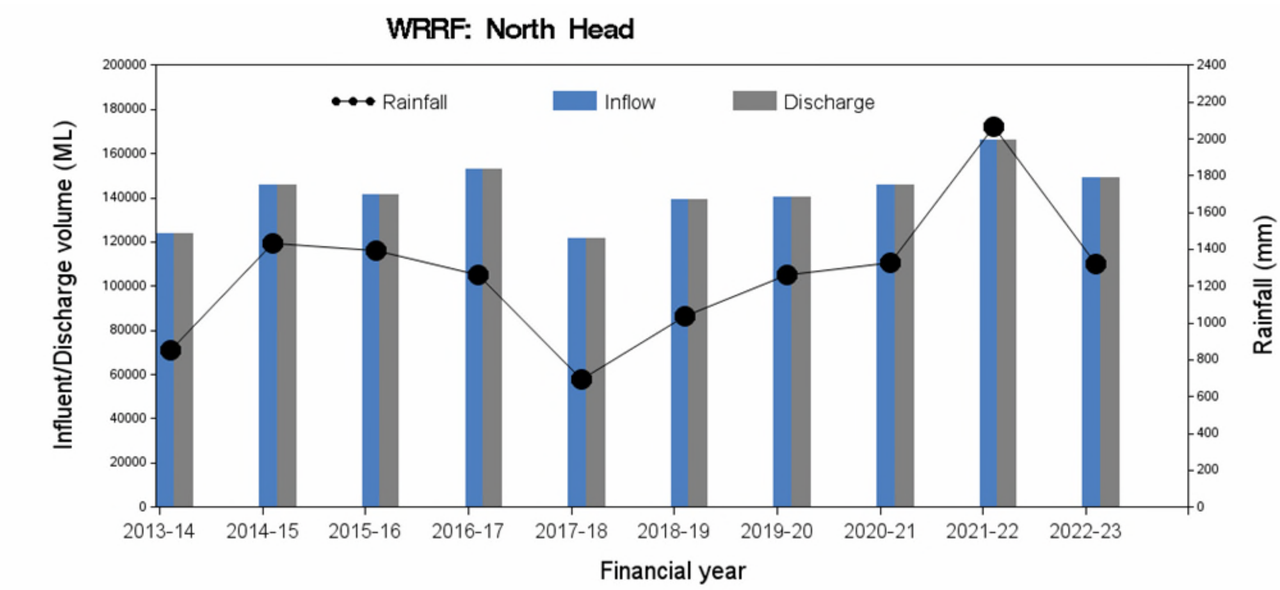


Figure 4-100 North Head WRRF inflow and discharge volume with catchment rainfalls

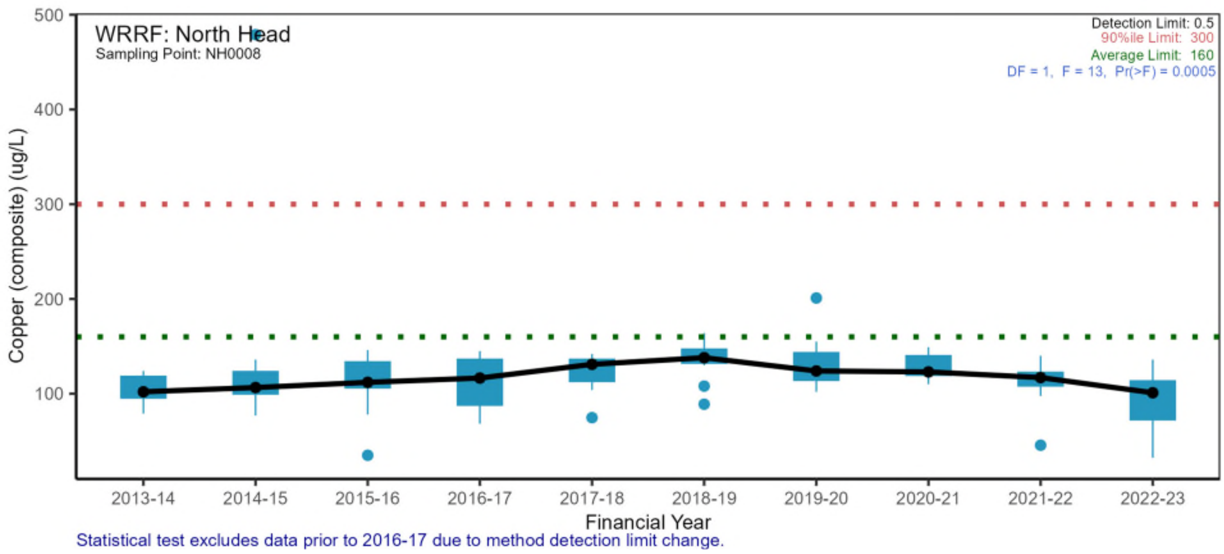


Figure 4-101 North Head WRRF discharge quality and toxicity exception plots

4.5.2 Bondi WRRF

- All parameters (concentrations and loads) measured in the discharge from Bondi WRRF were within EPL limits. There was an increasing trend in toxicity and decreasing trends in total suspended solids and oil and grease concentrations in the discharge.

Pressure – Wastewater discharge

Table 4-65 Gate 1 Analysis outcome summary – Bondi WRRF

Analytes / Bondi WRRF	Nutrients		Conventional analytes			
	Total Nitrogen	Total Phosphorus	Biochemical Oxygen Demand	Oil and Grease	Total Suspended Solids	EC_{50} Toxicity
Concentration				↘	↘	↗
Load						

Analytes / Bondi WRRF	Trace Metals								Other chemicals / organics		
	Aluminium	Cadmium	Chromium	Copper	Lead	Mercury	Selenium	Zinc	Hydrogen sulfide (un-ionised)	Nonyl phenol ethoxylate	Pesticides and PCBs
Concentration	→								→	→	
Load											

↗	Upward trend	↘	Downward trend	→	No trend, p>0.05

(green)	Within the Environment Protection Licence concentration limit
(yellow)	Environment Protection Licence concentration limit exceedance
(grey)	Analytes not required in the EPL or no concentration limit

All concentration and load limits for parameters measured in the final discharge from Bondi WRRF were within the EPL limits in 2022-23.

Statistical analysis identified a significant increasing trend in toxicity in 2022-23 compared to the past nine years. Significant decreasing trends in concentrations of oil and grease and suspended solids were also observed.

The cause of persistent and increasing effluent toxicity at Bondi WRRF has not been identified. There have been no major process changes at the facility that could account for increasing toxicity in the final discharge.

The oil and grease concentration in the discharge from Bondi WRRF has shown a decreasing trend for the last four annual reporting periods. This is likely due to COVID, wet weather, and continuing community educational programs aimed at reducing oil and grease discharges into the Sydney Water network within the Bondi WRRF catchment.

In September 2022, Sydney Water commenced a program engaging with numerous food retail businesses within the Bondi catchment to ensure they have a connection agreement with Sydney Water and an approval to discharge commercial trade waste into the network system to aid in the reduction of oil and grease entering the Bondi WTS. Around 900 suspected non-compliant retail food business customers were identified within the first 6 months of the program (September 2022 – March 2023). Further collaboration work with food retail businesses by Sydney Water is continuing as part of the education program to reduce oil and grease being discharged into the Bondi WTS.

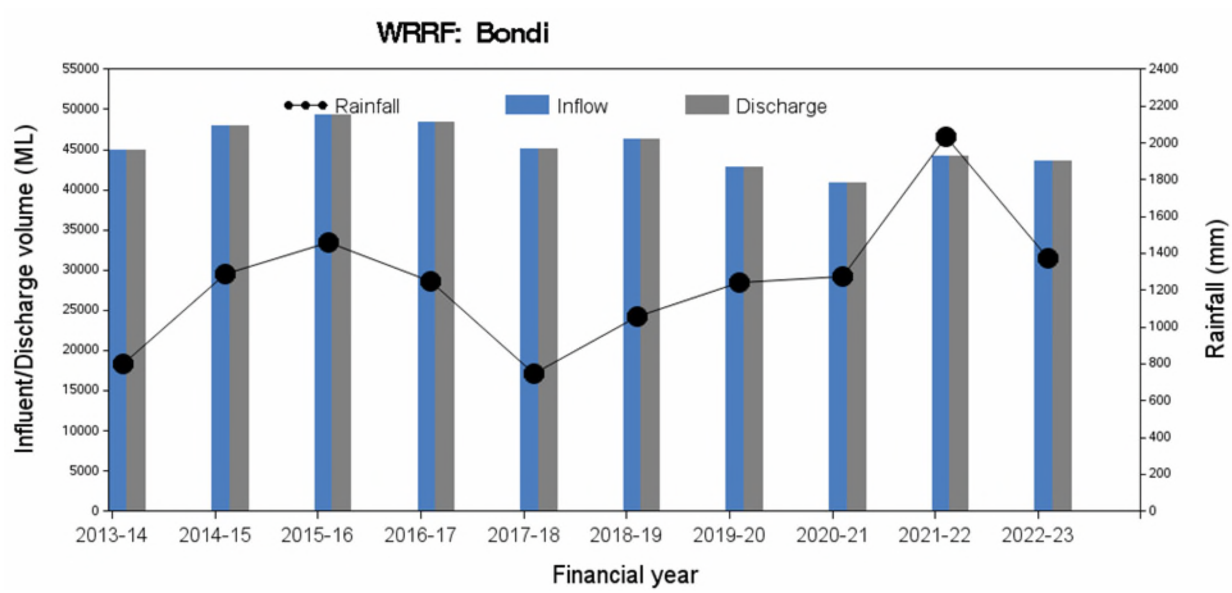
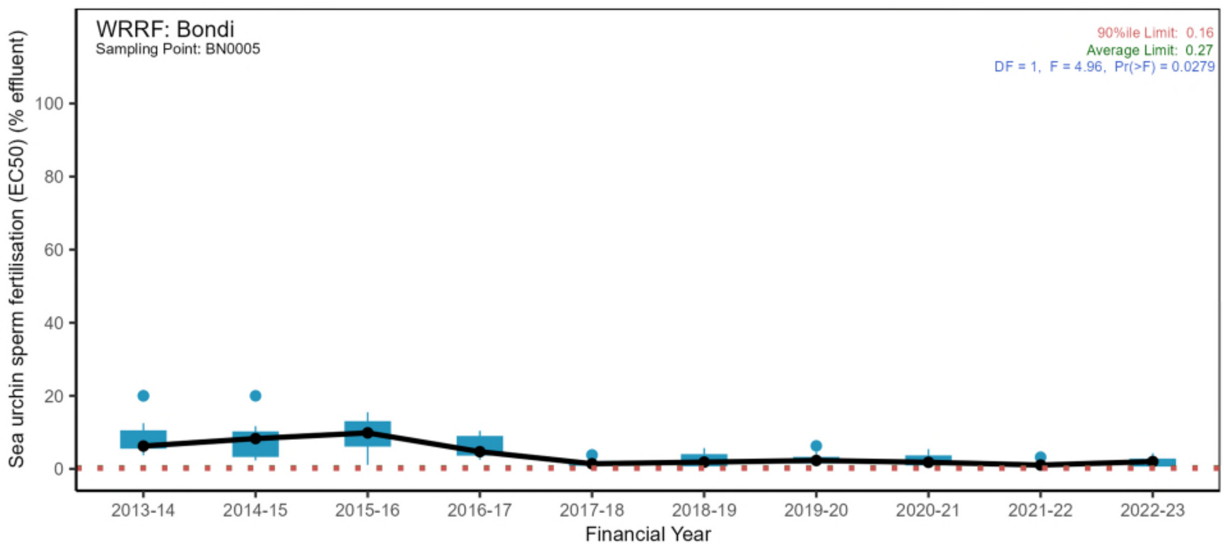


Figure 4-102 Bondi WRRF inflow and discharge volume with catchment rainfalls



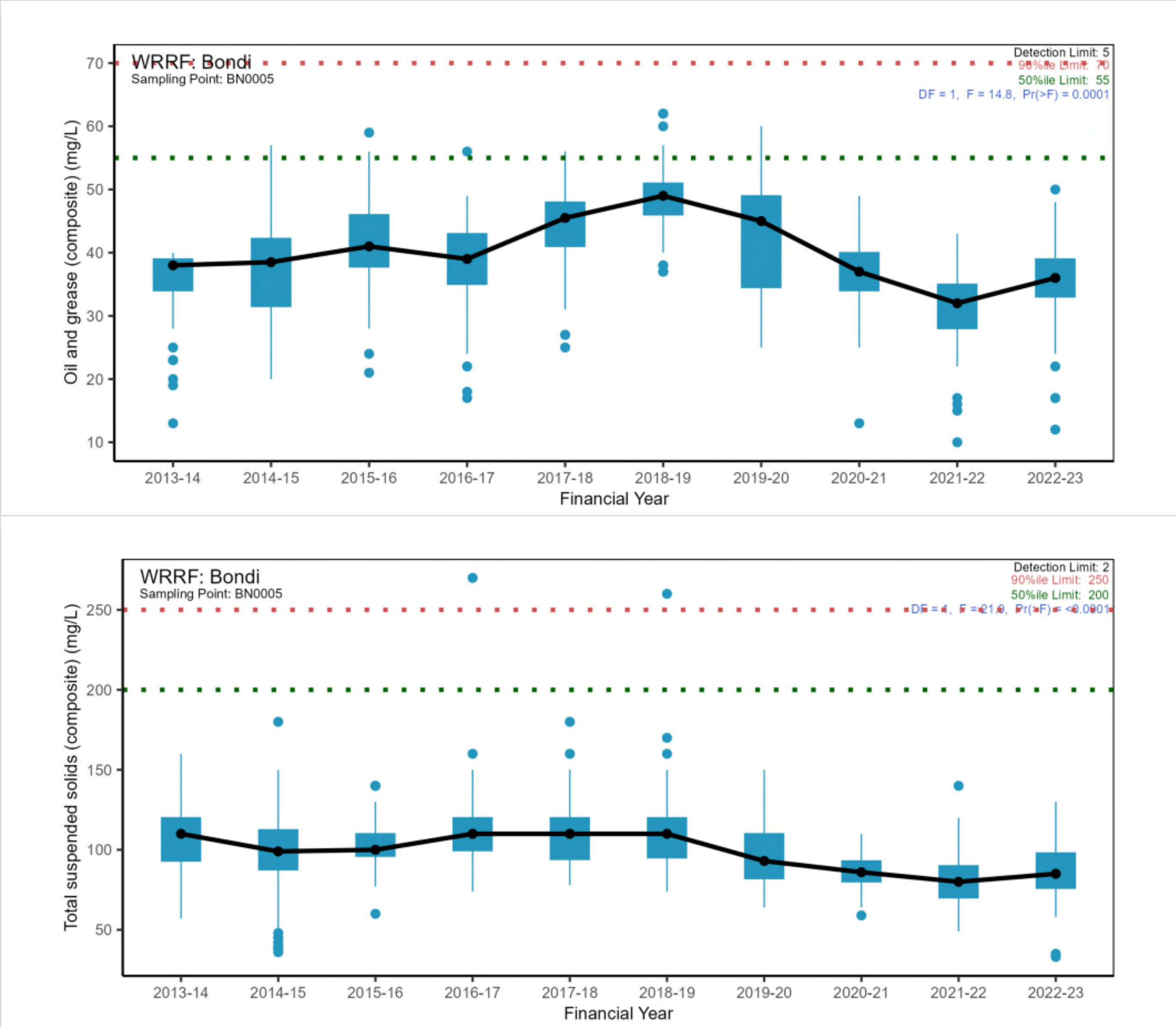


Figure 4-103 Bondi WRRF discharge quality and toxicity exception plots

4.5.3 Malabar WRRF

- All parameters (concentrations and loads) measured in the discharge from Malabar WRRF were within EPL limits. There were increasing trends in oil and grease, total suspended solids and aluminium concentrations in the discharge.

Pressure – Wastewater discharge

Table 4-66 Gate 1 Analysis outcome summary – Malabar WRRF

Analytes / Malabar WRRF	Nutrients		Conventional analytes			
	Total Nitrogen	Total Phosphorus	Biochemical Oxygen Demand	Oil and Grease	Total Suspended Solids	EC_{50} Toxicity
Concentration				↗	↗	→
Load						

Analytes / Malabar WRRF	Trace Metals								Other chemicals / organics		
	Aluminium	Cadmium	Chromium	Copper	Lead	Mercury	Selenium	Zinc	Hydrogen sulfide (un-ionised)	Nonyl phenol ethoxylate	Pesticides and PCBs
Concentration	↗								→	→	
Load											

↗	Upward trend	↘	Downward trend	→	No trend, p>0.05

	Within the Environment Protection Licence concentration limit
	Environment Protection Licence concentration limit exceedance
	Analytes not required in the EPL or no concentration limit

All parameters (concentrations and loads) measured in the final discharge from Malabar WRRF were within the EPL limits in 2022-23.

Statistical analysis identified a significant increasing trend in oil and grease, total suspended solids and aluminium concentrations in 2022-23 compared to the past nine years.

There has been a steady upward trend in oil and grease since 2012-13 which can be attributed to the increasing concentration in the influent.

The median concentration for oil and grease has been relatively stable since 2017-18. The longer-term trend is linked to a combination of population growth in the catchment, implementation of water saving measures that reduced volume of flow per person, and successful reduction of saltwater ingress into the wastewater network. The increasing suspended solids trend can be linked to a deterioration in the solids capture system capability. Sydney Water is addressing this issue by overhauling primary sedimentation assets.

Malabar WRRF was impacted by a few major trade waste incidents in 2021-22 that impacted the oil and grease and suspended solids removal efficiency of the primary sedimentation process. In response, Sydney Water have invested in additional monitoring in the upstream network using volatile organic carbon (VOC) monitors at pre-determined locations to provide an early warning detection system in the event of a trade waste incident. Sydney Water are also continuing to collaborate with trade waste customers and the EPA in reducing the probability of repeated incidents impacting treatment processes at Malabar WRRF.

In late 2021, Sydney Water launched a campaign called “It’s Best to Bin it”. The objective of this campaign is to influence the behaviours of our business customers to manage their wastewater better and ultimately reduce the amount of fats, oils and grease entering our system.

The cause of the increasing trend in aluminium can be linked to an increase in aluminium concentrations in the influent. Metal removal is incidental at Malabar WRRF as processes are not designed to remove aluminium.

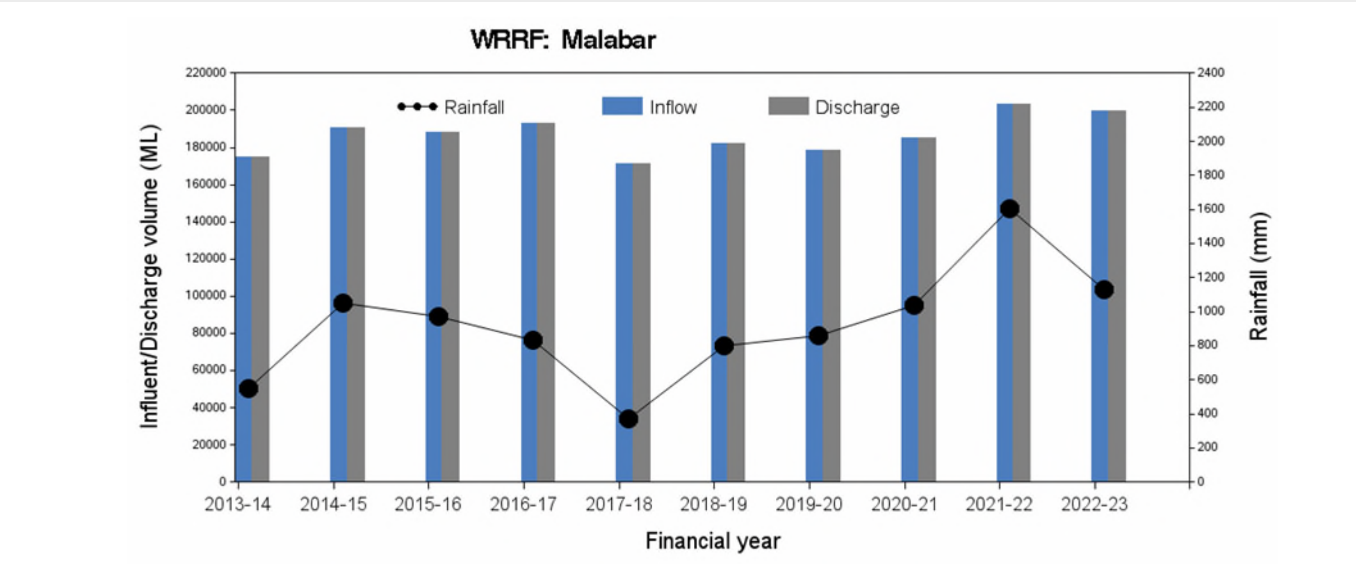


Figure 4-104 Malabar WRRF inflow and discharge volume with catchment rainfall

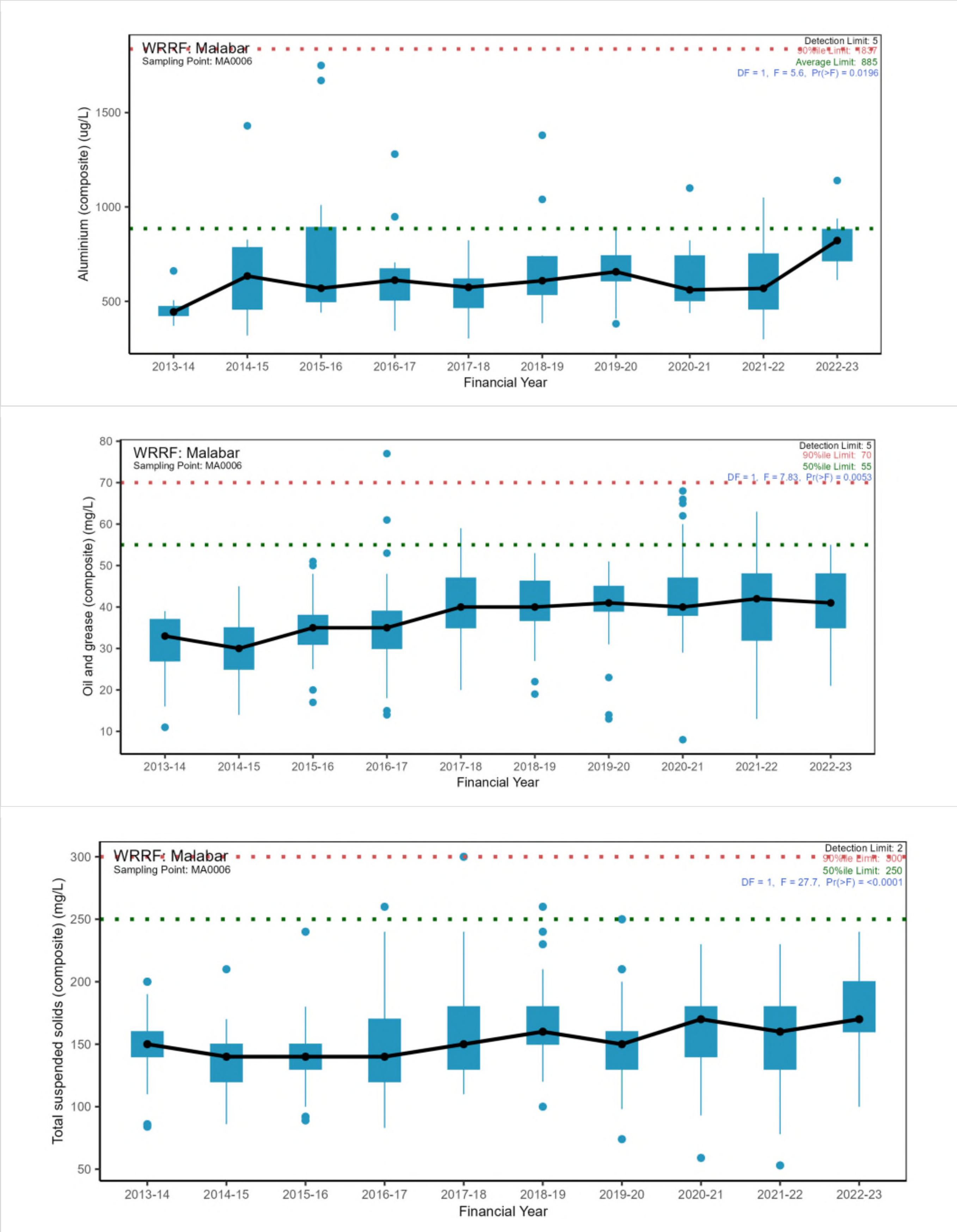


Figure 4-105 Malabar WRRF discharge quality and toxicity exception plots

4.5.4 Offshore marine environment

Stressor – Ocean receiving water quality

Out of eight chemicals assessed in 2022-23, only modelled copper concentrations in the receiving waters in the initial dilution zones of North Head and Malabar deepwater ocean outfalls exceeded the ANZECC (2000) guideline of 1.3 ug/L for protection of 95% of marine species. A summary of results can be found in Volume 2 Appendix E-5.

A literature review of sources of critical contaminants in domestic wastewater from household studies in Australia indicated major inputs were from lead, zinc and copper (Tjadraatmadja and Diaper, 2006). Inputs of lead appear to originate from the laundry and bathroom, while zinc mainly originates from the bathroom, and the major sources of copper were from plumbing and water supply (Tjadraatmadja and Diaper, 2006).

Assessment year measurements of sedimentary copper concentrations collected under the Ocean Sediment Program of the STSIMP were below the Simpson and Batley (2016) revised ANZECC (2000) lower sediment quality guideline value for protection of marine species at all nine study locations (which included outfall and control locations).

Stressor – Offshore marine sediment quality

Outcomes from the current 2022-23 surveillance year data is contained in Volume 2 Appendix E-6. A summary of the results is given below.

In 2022-23, the total organic carbon (TOC) content for all ten samples collected from the Malabar 0 km location were less than the NSW EPA specified 99th percentile trigger value of 1.2%. Although no specific trigger value has been set for either Bondi or North Head, TOC % content was less than 1.2% for all Bondi and North Head samples. The results from TOC laboratory analysis suggested elevated levels of anoxia were unlikely to have built-up in benthic sediment in 2022-23.

The average levels of fine sediments observed in 2022-23 were similar to those seen in past years, with no apparent build-up of fine particles (<0.063 mm). This suggests that sedimentary metal concentrations were unlikely to have increased in 2022-23 at the North Head, Bondi and Malabar 0 km deepwater outfall locations.

Ecosystem Receptor – Offshore marine sediment faunal communities

The current 2022-23 surveillance year data is contained in Volume 2 Appendix E-6. A summary of the results is given below.

The outcomes of abundance and richness measures in 2022-23 showed that the most common and abundant taxa were Polychaete worms, followed by Crustaceans. While a lower total number of individuals were observed in 2022-23 relative to the previous year, likely due to year-on-year biological variability, there is no evidence of a sustained decline in any taxonomic group over the 23 years of monitoring. Without any changes in sediment characteristics, the benthic community structure at the Malabar deepwater ocean outfall location was unlikely to have changed beyond the levels recorded in past assessment years.

5 Synthesis of impacts of Sydney Water's WRRF discharges

5.1 Hawkesbury-Nepean River

Wastewater discharges

With the increasing pressure from a growing population and climate change, Sydney Water is challenged with:

- treating and discharging an increasing volume of wastewater
- aligning or managing treatment activities with more frequent and extreme weather events.

During the 2022-23 monitoring period, there were a total of nine concentration EPL limit exceedances across five WRRFs (two 50th and 90th percentiles for ammonia nitrogen, one 50th and 90th percentiles for total nitrogen, one 80th percentile for faecal coliforms, one average and 90th percentile for copper and one average aluminium). In addition, there were a total of four load EPL limit exceedances across three WRRFs (two total phosphorus, one total nitrogen and one total suspended solids). This is a decrease from eight concentration exceedances recorded from four facilities and eleven load exceedances recorded from six facilities respectively from the previous 2021-22 monitoring period.

Based on statistical analysis comparing the 2022-23 monitoring period to the previous nine monitoring periods, the following observations were made:

- ammonia nitrogen concentrations continued to increase across the upper Nepean River WRRF discharges. An increase was also observed in two of the lower Hawkesbury-Nepean River WRRF discharges (Castle Hill and Rouse Hill)
- total nitrogen and total phosphorus concentrations showed an increasing trend across the majority of the Nepean River WRRF discharges
- all nutrient and conventional analytes concentrations in the discharge from North Richmond WRRF showed an increasing trend
- there was a decreasing to no significant trend identified for the majority of metal concentrations in Nepean River WRRF discharges. The exceptions were copper concentration in the St Marys WRRF discharge and aluminium concentration in the Castle Hill WRRF discharge
- there was a decreasing to no significant trend in total nitrogen and total phosphorus concentrations in the lower Hawkesbury-Nepean River WRRF discharges.

Sydney Water is committed to reducing pollutant concentrations being discharged into the Hawkesbury-Nepean River through key initiatives and programs, including:

- A major $220M amplification of West Camden WRRF, including the construction of a new Membrane Bioreactor (MBR) plant. This amplification will increase the treatment capacity to cater for population growth in the Camden district and reduce nutrient concentrations in the final discharge. With a completion date expected to be mid-2024. An additional $1.1M investment in further interim capacity upgrades are being undertaken at the facility, with an expected operational completion date end of 2023.

- An amended Picton EPL 10555 approved by the EPA on 24 May 2023, allowing for greater flexibility in discharges to Stonequarry Creek when preparing for anticipated extreme wet weather events. Various pollution studies and reduction programs were also added to the amended EPL, including opportunities for additional recycling and reuse of treated effluent, proposal to reduce load and concentration of pollutants discharged and identify opportunities to reduce inflows into the premises. Sydney Water has commenced planning of the delivery of these studies and programs to improve effluent quality and increase reuse from Picton WRRF.
- Refurbishment works to the Stage 7 Biological Nutrient Removal (BNR) process will be undertaken at Penrith WRRF to improve reliability and performance of nutrient removal. Completion is expected by July 2024.
- Winmalee WRRF is undergoing a $50M upgrade to fulfil the requirements of the Pollution Reduction Program (PRP) 800 under Environment Protection Licence (EPL) 1963. The upgrade includes the construction of a membrane bioreactor which will increase biological process capability and facilitate a reduction in nutrient concentrations being discharged from Winmalee WRRF. Upgrades are due to be completed by December 2023.
- Sydney Water has committed to upgrading Richmond WRRF. Following upgrade completion, flows from the North Richmond catchment will be transferred to the Richmond WRRF through a newly constructed pipeline, and the North Richmond WRRF will be decommissioned. Project is expected to be completed by the end of 2026.
- The St Marys and Quakers Hill WRRFs are going through treatment upgrades to improve reliability and service growth. Construction will continue to the end of 2023 with an anticipated further 12 months of process optimisation.
- Upgrades to improve the nutrient performance at Castle Hill and Rouse Hill WRRFs will commence in 2025 with expected completion by the end of 2029.
- Treatment upgrades and amplification of Riverstone WRRF in 2019 has increased the treatment capacity and improved performance of the facility as illustrated in the decreasing trends in total nitrogen and total phosphorus over the past few years. Further upgrades are planned for Riverstone WRRF to service growth in the catchment. Sydney Water is in the final stages of commissioning an ultrafiltration system to improve solids removal and amplify filter capacity. The expected completion is the end of 2023. Further upgrades to Riverstone WRRF are being planned to continue servicing growth along the transit corridors and growth precincts in the northwest of Sydney (2025 – 2029).
- Construction has commenced on the Upper South Creek Advanced Water Recycling Centre (AWRC) which is a new treatment plant to service growth in the South Creek catchment. The AWRC will have advanced treatment for dry weather discharge. Expected completion is 2026.
- We will continue to undertake major periodic maintenance on key process assets to improve treatment efficiency and reliability.

- We plan to expand production and distribution of recycled water.

Receiving water quality and phytoplankton

The receiving water quality and phytoplankton data for 36 upstream/downstream monitoring sites associated with 14 Hawkesbury-Nepean River WRRFs were assessed:

- to determine temporal trends (increasing, decreasing or steady) in 2022-23 year
- to compare the 2022-23 median results against national guidelines where available
- to make a general comparison between upstream and downstream monitoring results and identify possible link with the upstream factor eg WRRF discharges

The 2022-23 year was dominated by wet weather throughout the Hawkesbury-Nepean River catchment but eased from a peak in 2021-22. The total rainfall ranged from 907 mm (Lower Nepean River catchment) to 1,325 mm (Berowra Creek catchment) at various Sydney Water gauging stations. The impact of wet weather, along with the increasing/decreasing trends in the concentration of nutrient analytes in some of Sydney Water's WRRF might have influenced the nutrient concentrations at downstream receiving water sites.

A summary of data analysis outcomes to compare key nutrients concentrations in WRRF discharges along with the respective concentration of these nutrients in receiving water and resulting impact on chlorophyll-a concentrations for the downstream receiving water sites is presented in Table 5-1.

Overall the analysis/comparison outcome is mixed and highly variable. Although, an increase/decrease in nutrient concentrations in WRRF discharges is reflected in the concentration of nutrients in a few downstream receiving water sites, this was not reflected in the impact/benefit on phytoplankton as chlorophyll-a.

- Ammonia nitrogen and total nitrogen concentrations increased significantly downstream of West Camden WRRF in both the tributary and river in 2022-23 year, in line with the increased concentrations of these analytes in the WRRF discharge.
- Total nitrogen and total phosphorus concentration in the Warragamba River downstream of Wallacia WRRF also aligned with the increasing concentrations of these analytes in the discharge.
- The impact of the increasing trend in total nitrogen and total phosphorus concentrations from North Richmond WRRF was not evident at the downstream tributary site, where these concentrations actually decreased in 2022-23 year. But an increase in total nitrogen and stable total phosphorus at downstream River site was identified.
- A significant decrease in the concentration of total nitrogen in Penrith and West Hornsby discharges may have contributed to the decreasing total nitrogen concentration at the corresponding downstream tributary sites.
- A significant increase or decrease in key nutrient concentrations in discharges had no respective impact or resultant trend at many of the downstream tributary or river sites, where the nutrient concentrations remained stable eg total nitrogen and total phosphorus for the Picton, Penrith, Riverstone, Quakers Hill and Castle Hill WRRFs.

- The chlorophyll-a concentration was steady at 16 of the 18 downstream monitoring sites. The Nepean River downstream of Matahil Creek and the West Camden WRRF discharge, was the only site where chlorophyll-a concentrations increased significantly in 2022-23 year possibly linked with the increasing nitrogen concentration in the discharge. The chlorophyll-a concentration decreased significantly downstream of the Rouse Hill WRRF discharge despite an increase in nitrogen concentration in the discharge.
- The median ammonia nitrogen concentration exceeded the ANZG (2018) guideline at the majority of the tributary sites immediately downstream of discharges. The exceptions were at tributaries downstream of Picton, Wallacia and West Hornsby WRRFs where the ammonia concentration was within the guideline. Median ammonia concentrations exceeded guideline at two of four downstream river sites (West Camden and Penrith WRRFs).
- Median total nitrogen exceeded the guideline at all 18 downstream monitoring sites (tributary or river).
- The 2022-23 median total phosphorus concentrations exceeded the guideline at 11 of the 14 downstream tributary sites. The exceptions were at tributary sites downstream of Picton, Wallacia and Penrith WRRFs, where the guidelines were met. The median total phosphorus concentrations were within the guideline at three of four downstream river sites (downstream of West Camden, Penrith and North Richmond WRRFs)
- The 2022-23 median chlorophyll-a concentrations exceeded the ANZG (2018) guideline at half the downstream tributary monitoring sites. The median chlorophyll-a concentration exceeded the guideline at three of four downstream river monitoring sites. The exception was Nepean River downstream of Stonequarry Creek where Picton WRRF discharge met guideline.
- The median toxic blue-green counts exceeded the NHMRC (2008) Amber Alert level at Stonequarry Creek site downstream of Picton WRRF in 2022-23. Potentially toxic blue-green counts reached NHMRC (2008) Red Alert levels on two occasions in May 2023.

Table 5-1 Trends in key nutrients chlorophyll-a concentrations, WRRF discharges versus downstream receiving water sites.

Site	Ammonia nitrogen	Total nitrogen	Total phosphorus	Chlorophyll-a
Picton WRRF	↗	↘	↗	
Downstream tributary (N911)	→	→	→	→
Downstream river (N91)	→	→	↗	→
West Camden WRRF	↗	↗	→	
Downstream tributary (N7824)	→	↗	→	→
Downstream river (N75)	↗	↗	→	↗
Wallacia WRRF	↗	↗	↗	
Downstream tributary (N641)	→	↗	↗	→
Penrith WRRF	→	↘	↗	
Downstream tributary (N541)	→	↘	→	→
Downstream river (N53)	→	→	→	→
Winmalee WRRF	→	↗	↗	
Downstream river (N464)	→	→	→	→
North Richmond WRRF	↗	↗	↗	
Downstream tributary (N411)	→	↘	↘	→
Downstream river (N39)	→	↗	→	→
Richmond WRRF	→	→	→	
Downstream tributary (N388)	→	→	↘	→
St Marys WRRF	→	→	→	
Downstream tributary (NS23A)	→	→	→	→
Riverstone WRRF	→	↘	↘	
Downstream tributary (NS081)	→	→	→	→
Quakers Hill WRRF	↘	↘	↗	
Downstream tributary (NS087)	→	→	→	→
Rouse Hill WRRF	↗	↗	→	
Downstream tributary (NC516)	→	→	→	↘
Castle Hill WRRF	↗	↘	↘	
Downstream tributary (NC75)	→	→	→	→
West Hornsby WRRF	→	↘	→	
Downstream tributary (NB825)	→	↘	→	→
Hornsby Heights WRRF	→	→	→	
Downstream tributary (NB42)	→	→	→	→

↗	Upward trend	↘	Downward trend	→	no trend, p>0.05

(green)	2022-23 Concentration value within EPL limit or Median value within the guideline limit
(yellow)	2022-23 Concentration value outside EPL limit or Median value outside the guideline limit
(white)	No monitoring data

Macroinvertebrates

In 2022-23, stream ecological health in the Hawkesbury-Nepean catchment was assessed using macroinvertebrate index, Signal-SG (Sydney genus) as well as through multivariate community analysis:

- Monitoring results suggested localised ecosystem impacts in tributaries downstream of West Camden, Winmalee, Castle Hill, West Hornsby and Hornby Heights WRRFs. There was no evidence these impacts had any effect on the Hawkesbury-Nepean River system to which these creeks flow.
- The 2022-23 monitoring results suggested a decline in stream health at the site downstream of Wallacia WRRF. The upstream site could not be sampled due to persistent high flows. Using a proxy upstream site on the Nepean River (SoE site N67), there was no evidence that the downstream Warragamba site differed in community assemblage relative to the Nepean River upstream. A definitive impact from wastewater discharges of Wallacia WRRF could not be determined, and the decline in stream health at the downstream site was likely attributed to impacts from wet weather flows in 2022-23, which resulted in the macrophytes and habitat at the downstream site scoured out.

5.2 Nearshore marine environment

Wastewater discharge

Similar to the Hawkesbury-Nepean River WRRF discharges, Sydney Water is challenged with increasing pressure from a growing population and climate change in WRRF discharges to the nearshore marine environment.

During the 2022-23 monitoring period, there was one concentration EPL limit exceedance (aluminium average) and four load EPL limit exceedances (one biochemical oxygen demand and three suspended solids) from three facilities.

This is an increase from no concentration EPL limit exceedances and three load EPL limit exceedances from two facilities from the previous 2021-22 monitoring period.

Wet weather influence on the load and concentration non-compliances for the 2022-23 monitoring period from nearshore marine environment discharges was prominent, with a continuation of La Niña weather patterns during this period.

Based on statistical analysis comparing the 2022-23 monitoring period to the previous nine monitoring periods, the following observations were made:

- toxicity increased in the Warriewood WRRF discharge
- suspended solids concentrations increased in Shellharbour and Wollongong WRRF discharges
- copper concentrations decreased to no statistical trend across all nearshore discharges, except for Warriewood WRRF, where the copper concentration is increasing.

Sydney Water is committed to reducing pollutant concentrations being discharged into the nearshore marine environment through key initiatives and programs, including:

- intercept and redirect wastewater for dry weather and the first 10 mm of rain events from Vaucluse (Parsley Bay) and Diamond Bay discharges to the existing Bondi network for treatment and offshore discharge via the deepwater ocean outfalls
- a major refurbishment of the ultraviolet disinfection system at Warriewood WRRF. This is expected to improve the reliability and performance of the facility’s disinfection process
- major periodic maintenance of key processes, including but not limited to:
  - tertiary filters (completed in 2021) and secondary clarifiers (commenced in 2021) at Cronulla WRRF to improve solid settling and removal
  - tertiary filters and improvements to the Actiflo storm treatment plant at Wollongong WRRF, aiming to improve the wet weather performance for biochemical oxygen demand and suspended solid removal
  - primary sedimentation tanks, air diffusers and clarifiers at Shellharbour WRRF, expected to improve process capability and suspended solid removal
  - intermittently Decanting Aeration Lagoons (IDAL) at Bombo WRRF to improve availability for process capability to ensure optimal suspended solids removal.

- dewatering upgrade at Shellharbour WRRF due for commissioning in late 2023. This is expected to improve reliability of the solids stream, reducing process pressure on liquid stream flows and help reduce high suspended solids in storm flows. It should also reduce side stream impacts like centrate quality.
- cleaning out Bombo sludge lagoons in the last cycle (grit cleanout after sludge dewatering) to help the reliability of the sludge lagoons to prevent impacts on the liquid stream processes.

Assessment of the 2008-09 to 2022-23 monitoring data from the Shellharbour WRRF and two control sites indicated a relatively stable equilibrium in the rocky-intertidal community structure (Volume 2 Appendix D). These results also suggest no measurable impact had developed in the intertidal rock platform community near the outfall at Barrack Point from wastewater discharges from the Shellharbour WRRF as the community assemblage at the outfall site was very similar to the control site 1 over the 2008-09 to 2022-23 period. The results from control site 2 represents natural variation in rocky-intertidal community structure that has been demonstrated to occur for closely spaced sites on the shoreline (Underwood and Chapman, 1995).

5.3 Offshore marine environment

Wastewater discharges

There were no concentration or load EPL limit exceedances from the offshore WRRF discharges during the 2022-23 monitoring period. This is a decrease from two concentration EPL limit exceedances from one facility and no load EPL limit exceedances from the previous 2021-22 monitoring period.

Based on statistical analysis comparing the 2022-23 monitoring period to the previous nine monitoring periods, the following observations were made:

- increasing toxicity at Bondi WRRF
- increasing oil and grease and suspended solids concentrations in the final effluent from Malabar WRRF, however a decreasing trend for these analytes at Bondi WRRF.

Sydney Water is committed to reducing pollutant concentrations being discharged into the offshore marine environment through key initiatives and programs, including:

- undertaking a source control and education program for oil and grease to reduce the volume of oil and grease discharged into the Bondi WTS (as per special condition E4 under EPL 1688)
- community engagement across the wider system area under a campaign called “It’s Best to Bin it”, launched in late 2021. The objective of this campaign is to influence the behaviours of our business customers to manage their wastewater better and ultimately reduce the amount of fats, oils and grease entering wastewater system.
- ongoing silt removal works in the NSOOS Northside storage tunnel and SWSOOS1 to reduce solid load entering the wastewater system
- undertaking major periodic maintenance on key process assets to improve treatment efficiency and reliability.

Ocean receiving water & sediment

- Out of eight chemicals assessed in 2022-23, only modelled copper concentrations in the receiving waters in the initial dilution zones of North Head and Malabar deepwater ocean outfalls exceeded the ANZECC (2000) guideline of 1.3 ug/L for protection of 95% of marine species.
- The total organic carbon content (%) of the sediment was less than 1.2% for all samples collected from Malabar, North Head and Bondi outfall locations, below the NSW EPA specified 99th percentile trigger value.
- Average levels of fine sediments in 2022-23 were similar to those recorded in past years, with no apparent build up of fine particles. This indicates metals concentrations in the sediment were unlikely to have increased at the deepwater outfall locations

Macroinvertebrates

- The benthic community structure was assessed at the Malabar deepwater outfall location in the 2022-23 surveillance year
- Taxonomic compositions suggested that Polychaetes and Crustaceans continued to dominate the number of taxa collected at this site. While the total number of individuals was lower than the previous year, there has not been a sustained decline or increase in the main taxonomic groups over the 23 years of monitoring.

6 Results and discussion – Wastewater overflows

6.1 Wet and dry weather overflows and leakage

6.1.1 Wet weather overflows

Wet weather overflow performance

A summary of wet weather overflow performance on key EPL conditions is presented in Table 6-1. All the 23 wastewater treatment system models Sydney Water maintains were assessed as compliant with condition L7.1 during 2022-23. It was recommended that all models transition to a more detailed breakdown to smaller subsystems to improve accuracy. Details of these upgrade recommendations are provided in the *Independent Criteria Review Committee report on Sewerage Trunk System Licence Models* (Urban Water Solutions, 2022). Fourteen models from four systems were recalibrated in 2022-23.

Thirteen systems complied with key EPL conditions (L7.2, O4.8I, O4.9 and O4.10). The complying systems were Bombo, Bondi, Castle Hill, Cronulla, Hornsby Heights, Penrith, Quakers Hill, North Head, Richmond, Wallacia, Warriewood, Winmalee and West Hornsby. Two systems (Picton and Brooklyn-Dangar Island systems) don't have conditions and hence were not assessed for EPL compliance conditions.

The frequency of wet weather overflows from the reticulation system of seven systems exceeded the L7.2 limits ie maximum number of overflows per 10 years (Table 6-1).

The predicted wet weather overflow frequency for the Malabar system in 2022-23 was 294 overflow events in 10 years, exceeding the benchmark value of 238 overflow events in 10 years (Condition O4.8c).

The partial treatment capacity of the Fairfield stormwater plant in the Malabar system exceeded the benchmark limits of allowable discharges (maximum of 50 overflows in 10 years, Condition O4.9). There were 85 overflows from this stormwater plant in the last 10 years to 2022-23.

The non-compliances have been investigated and actions put in place to help identify and deliver works to bring systems back into compliance. Details of these mitigation measures and progress was reported via the *Annual Sewage Treatment System Performance Report – Wet Weather Overflow* (Sydney Water 2022c).

Table 6-1 List of wet weather overflow non-compliances by EPL clause (2022-23)

Wastewater system EPL Clause	Non-compliant systems
L7.1 Ongoing use and development of a high-quality Hydraulic System Sewer model	Nil
L7.2 Wet weather overflow limits	North Richmond, Riverstone, Rouse Hill, Shellharbour, St Marys, West Camden and Wollongong
O4.8 I Comparison of modelled wet weather overflows	Malabar
O4.10 Wet weather partial treatment discharges	Fairfield (Malabar)

Modelled occurrence and volume of wet weather overflows

Each year, the wastewater system's wet weather overflow performance (system performance) is compared against the benchmark year system performance or target system performance, to determine if any deterioration has occurred.

Sydney Water has developed hydraulic sewer models that are updated yearly due to growth, changes in the geometry and operation of the system. The model is then validated and if necessary recalibrated using rainfall and sewer flow and level data collected during the reporting year. The validated model is then used to simulate the performance for the base 10-year period, which is a fair representation of long-term climatic variation to predict long term average performance.

The modelled overflow volume from 14 inland wastewater systems was 1,478 ML in 2022-23 (Figure 6-1).The modelled wet weather overflows from eight ocean wastewater treatment systems were 24,948 ML in 2022-23 (Figure 6-1). Further details on recent year's wet weather overflow data including 2022-23, by each inland and ocean wastewater system are presented in Volume 2 Appendix F (Table F-1 and Table F-2).

The 2022-23 reporting year returned to more typical rainfall levels, following an extraordinary wet year in 2021-22. This resulted in a decrease in wet weather overflow volume by 58% in the ocean systems compared to the 2021-22 year. The volume of wet weather overflows from the inland systems decreased by 59% compared to the 2021-22 year.

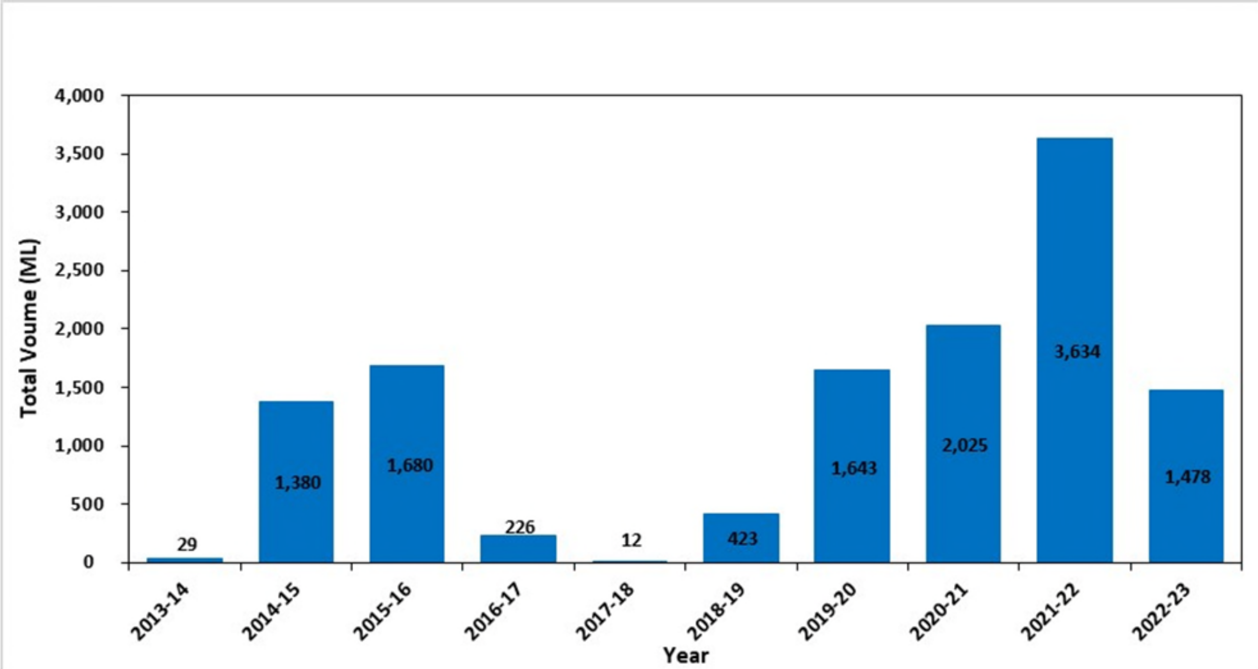


Figure 6-1 Previous 10 years of modelled wet weather overflow volumes by all inland wastewater systems

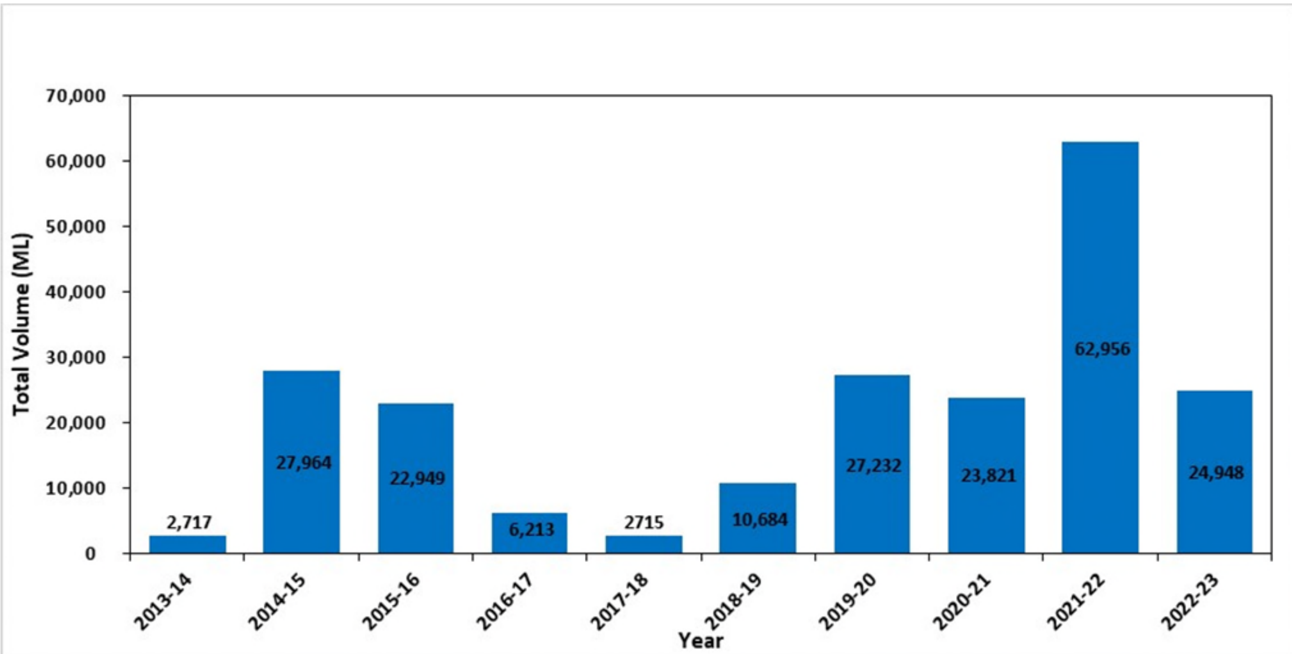


Figure 6-2 Previous 10 years of modelled wet weather overflow volumes by all ocean wastewater systems

6.1.2 Dry weather overflows

Dry weather overflow trends

Twelve large inland wastewater system networks were responsible for a total dry weather overflow volume of 0.9 ML in 2022-23 (Figure 6-3). There were no dry weather overflows recorded from the remaining three small wastewater system networks (Wallacia, North Richmond and Brooklyn). Further details on recent dry weather overflow data including 2022-23, by each inland wastewater system is presented in Volume 2 Appendix F (Table F-3).

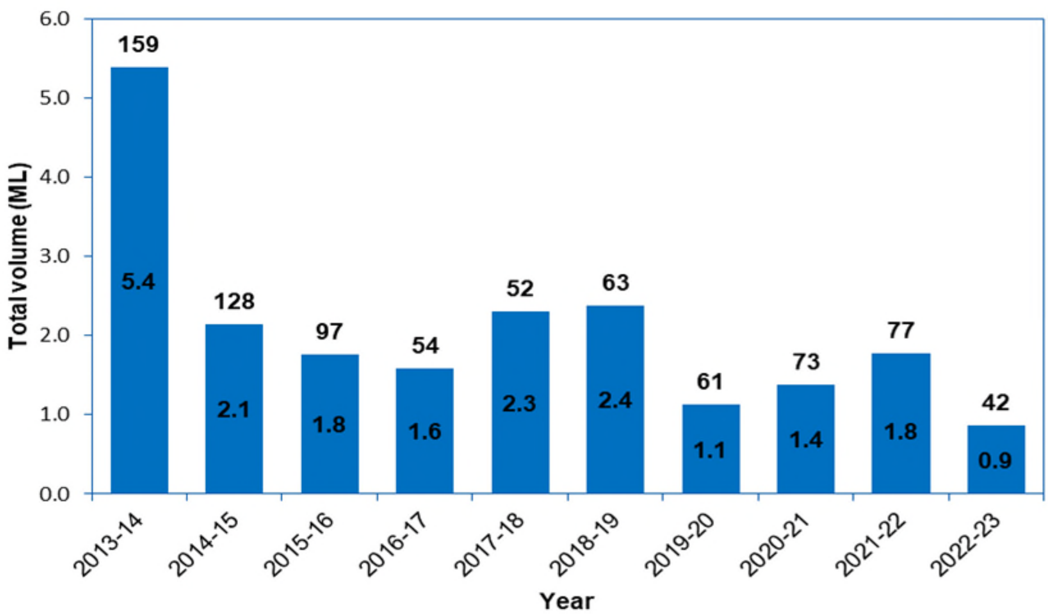
The total volume of dry weather overflows in 2022-23 from the inland catchments decreased by 51% compared to 2021-22. The four largest inland wastewater systems contributed to 83% of the total dry weather overflow volume (Penrith, Winmalee, St Marys and West Hornsby).

Since 2015-16 the overflow frequency from the inland wastewater systems has been less than 100 incidents each year. The overflow frequency from the inland systems in 2022-23 was the lowest (42 events) within the last ten years and was a 45% decrease compared to 2021-22.

Eight wastewater treatment systems draining to the ocean WRRFs were responsible for a total dry weather overflow volume of 13.3 ML in 2022-23 (Figure 6-4). Further details on recent year's dry weather overflow data including 2022-23, by each ocean wastewater system is presented in Volume 2 Appendix F (Table F-4).

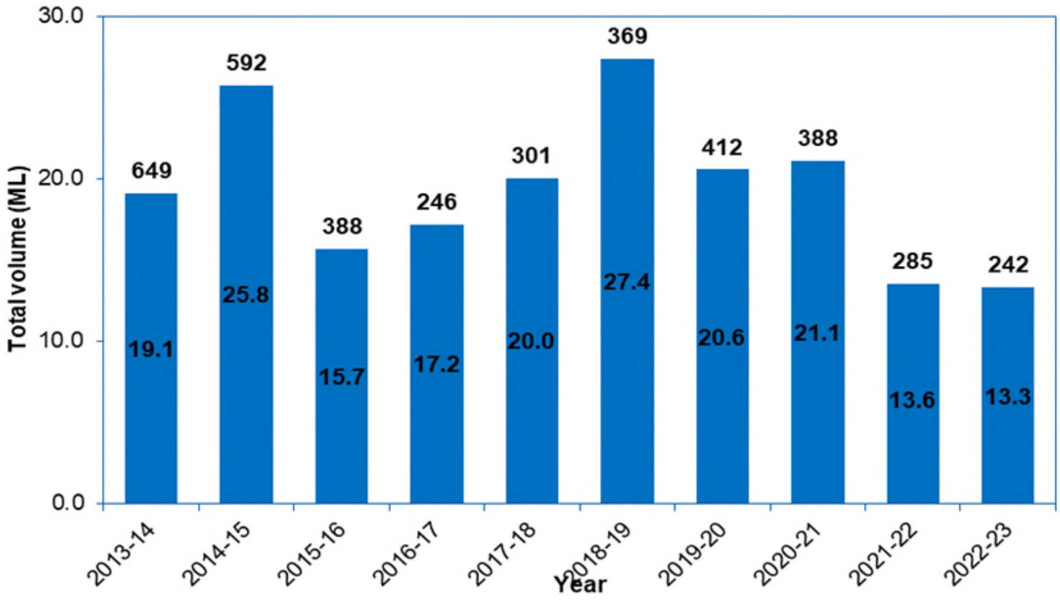
The total volume of dry weather overflows in 2022-23 from the ocean catchments decreased marginally by 2% compared to 2021-22. The two largest systems of North Head and Malabar were responsible for 75% of the total volume of dry weather overflows (North Head 22%, Malabar 53%).

The overflow frequency from the ocean catchments was the lowest (242 events) within the last ten years and was a 15% decrease compared to last year (2021-22).



Note: number of overflows that reach waterways per year is shown at the top of each bar, volume (ML) at the middle of bar

Figure 6-3 Previous 10 years of dry weather overflow volumes that reach waterways in inland WRRF catchments



Note: number of overflows that reach waterways per year is shown at the top of each bar, volume (ML) at the middle of bar

Figure 6-4 Previous 10 years of dry weather overflow volumes that reach waterways in ocean WRRF catchments

Dry weather overflow performance (EPL)

Dry weather overflow volumes are calculated using the date and time when an incident is reported to Sydney Water, the leak/overflow cease date and time, the assumed flow rate and the number of properties upstream of the overflow. The total number of overflows and the overflow volume for each EPL and SCAMP is recorded, and the portion that reaches the receiving waters is reported via annual returns under EPL condition L7.4 for each EPL where applicable.

Twelve out of 23 wastewater systems have EPL specified limits on the number of dry weather overflow incidents reaching the waterways (Clause 7.4). Among these, eight were under or equal to their limits in 2022-23 (Cronulla, Malabar, North Head, Penrith, Quakers Hill, Warriewood, Winmalee and Wollongong) and four other systems exceeded their respective limits (Bondi, Shellharbour, St Marys and West Camden).

Each SCAMP has an EPL target on the number of dry weather overflows reaching the waterways. Of the 216 SCAMPs with an EPL target, 175 (81%) were under or equal to their target. The remaining 41 (19%) areas exceeded their respective licence targets.

In 2022-23, Sydney Water experienced 7,644 blockages across all of its wastewater networks in relation to dry weather overflows (Sydney Water, 2022d). This was a 31% reduction in network blockages compared to 2021-22 due to recent wet weather conditions and resultant deep soil moisture condition. The total number of wastewater overflows reaching waterways from these blockages was 284 (3.7% of total overflows). This was a 22% reduction when compared to 362 overflows reaching waterways in 2021-22.

In 2022-23, most of the blockages occurred in small diameter pipes resulting from a combination of factors. Most of the blockages (42%) were caused by tree roots entering through cracks, joints and private sewers. Other major causes of blockages were soft chokes due to residual solids/ wet wipes/sanitary products (22%), debris from construction activity, broken pipes and non-flushable products (17%), and consolidation of fats in pipe walls from residential and commercial sources (10%). A more detailed analysis and performance of dry weather overflow volume and frequency by each of the SCAMPs and wastewater systems in relation to compliance limits is presented in a separate report (Sydney Water, 2022d).

The key Initiatives or Improvement strategies that were in place in 2022-23 to reduce the volume and frequencies of dry weather overflows reaching waterways were:

- reactive response to network blockages which involves establishing pollution controls, clearing of blockages (mainly using high-pressure water jetting equipment) and clean-up
- increased CCTV surveillance to inspect pipes after overflows reaching a waterway to identify maintenance, repair or renewal works to minimise repeat occurrence from the same asset
- early identification of blockages using online instruments to raise alarms when the level of wastewater in maintenance hole rises, and a crew can be sent to clear the sewers before the overflow occurs
- surveillance monitoring of abnormally low inflow rates at pumping stations to identify chokes and clear blockages before overflows occur
- continuous lining, where practical, of small diameter sewers that are most prone to tree root chokes caused by the high density of trees
- notification of property owners where CCTV finds tree roots entering Sydney Water's asset
- residential and business customer education campaigns which directly or indirectly helps to reduce dry weather overflows:
  - Wipes out of pipes: what should and shouldn't be flushed down the toilets
  - Other non-degradable items such as fats, oils & grease (FOG), bathroom products and sanitary wipes
  - Clean up not Down
  - It's Best to Bin It!
  - The Unflushables
  - FOG Source Control Project with business customers, initially in the Bondi WTS, which has been expanded to all food industry businesses
  - Construction industry campaign to prevent concrete from entering the sewer
- investigations, work and other activities are ongoing as a part of dry weather overflow abatement pollution reduction program (PRP) at Cronulla and North Head wastewater systems.

6.1.3 Dry weather leakage detection program

The Dry Weather Leakage Detection Program (DWLP) is a condition of Sydney Water's EPLs and has been conducted since 2006. The program is designed to identify leakage from the reticulated wastewater system and locate and repair any damaged assets. The program requires annual monitoring at 226 locations near the major stormwater outlets draining each SCAMP, and investigating the source of faecal coliforms where concentrations exceed the current EPL threshold (10,000 cfu/100mL). In 2022-23, there were 15 new SCAMPs added to the DWLP, which represent new residential areas and areas that have recently been connected to the sewer reticulation system.

SCAMP sites are generally visited annually, however when a site exceeds the EPL threshold for three consecutive routine sampling events, sampling frequency increases to quarterly. Conversely if a SCAMP on a quarterly sampling regime is below the EPL threshold for three consecutive routine sampling events, it reverts to an annual sampling frequency.

In previous years, a desktop investigation was completed following every routine exceedance, to identify overflows or surcharges in the SCAMP that could cause the high faecal coliform result. It was deemed more effective to the DWLP to address an exceedance immediately, rather than delay until a desktop investigation was completed. Following EPA approval in July 2018 to improve the DWLP, desktop investigations were discontinued unless value can be added to rectifying the issue from the time involved to complete the investigation.

In 2022-23 there were 234 routine site visits for the DWLP across Sydney, Blue Mountains and the Illawarra. Of the 226 SCAMPs, six annually monitored sites were dry or ponded at the time of sampling indicating no dry weather leaks. Eleven sites (5%) exceeded the >10,000 cfu/100 mL faecal coliform threshold at least once during the year, while 209 sites (93%) had faecal coliform results consistently below the threshold. Figure 6-5 shows the pattern of compliance for the last 10 years. All years have been compared against the EPL faecal coliform threshold (10,000 cfu/100 mL). Over the past 10 years, the percentage of sites exceeding the threshold has ranged from 5% (2022-23) to 21% (2018-19).

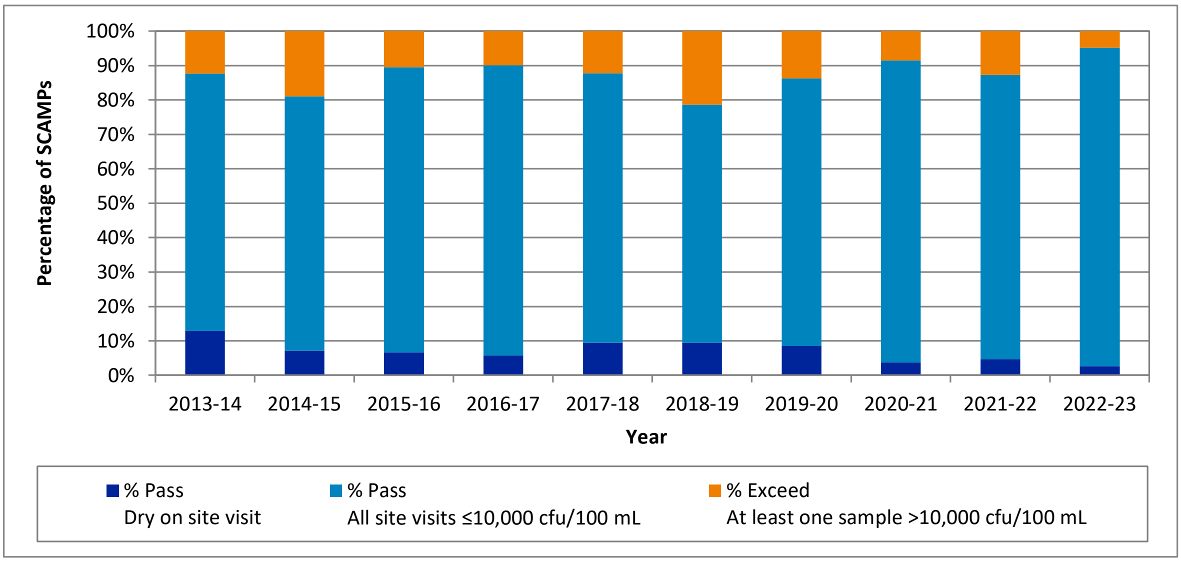


Figure 6-5 Percentage of SCAMP samples that were below (passed) or exceeded the faecal coliform threshold of 10,000 cfu/100 mL between 2013-14 and 2022-23

Figure 6-6 displays a map of ranked SCAMP performances for the last 10 years of the program. SCAMP regions are colour-coded to represent the frequency that routine samples were observed to exceed the faecal coliform threshold of 10,000 cfu/100mL. The map shows that inner city and Inner West areas largely to the south of the harbour tend to have the highest percentage of faecal exceedances. Intrinsically higher wastewater leakage is associated with old and ageing wastewater infrastructure. The SCAMP that exceeded most often was Freemans Reach (100%), identified by the dark red area, was one of the new SCAMPs added to the DWLP for 2022-23. This result represents one sampling event and is not indicative of a temporal trend. Other SCAMPs with increased exceedances ranked above 60% include Camperdown (79%), Ashfield (73%), Edgecliff (73%), Summer Hill (72%) and South Sydney (68%), identified by the dark orange regions. Seven SCAMPs exceeded 40-60% of the time (pale orange regions) Homebush (56%), Woolooware (55%), Liverpool (54%), Glenfield (50%), Riverwood (40%), Epping (40%) and South Wentworthville (40%). Thirty-six SCAMPs exceeded 20-40% of the time (pale yellow regions), sixty-one sites exceeded 1- 20% of the time (pale green regions) and 116 SCAMPs were consistently below the threshold (dark green regions) and have never recorded an exceedance in this period. This includes fourteen of the new SCAMPs that were added to the DWLP in 2022-23.

Figure 6-7 ranks the performance of SCAMPs over the most recent 3 years of the program. In general, the inner west and west regions of Sydney remained the key focus areas for the program and recorded the most exceedances. The SCAMPs that exceeded most often were Freemans Reach (100%) and Wollooware (100%), which are identified by the dark read areas. Freemans Reach is a new SCAMP that was added to the DWLP in 2022-23. This result represents one sampling event and is not indicative of a temporal trend. The Woolooware SCAMP investigation has shown that the consistently high faecal coliform results are not from a human source. The location of the Woolooware routine sampling point will be moved, pending EPA approval. SCAMPs with increased exceedances ranked above 60% include Camperdown (73%), Yagoona (67%) and Edgecliff (64%), identified as dark orange regions. Less significant increases were also evident at SCAMPs across Sydney, including the south-west, inner-west and inner city areas of Sydney (pale orange and pale yellow regions). Similar to the 10-year exceedance trends, the areas experiencing the greatest exceedances tend to be the areas with older wastewater infrastructure. In the last 3 years, 181 SCAMPs have recorded no exceedances at all, including fourteen of the new SCAMPs that were added to the DWLP in 2022-23. The SCAMPs that have increased exceedances in the last 3 years generally represent the catchments with current and ongoing source detection investigations.

Source detection work in 2022-23 identified approximately 39 individual leakage issues associated with Sydney Water assets and private faults. The significant findings from the SCAMPs where these faults were identified are detailed in Table 6-2. Additionally, special investigations completed outside of the DWLP routine monitoring program identified and rectified several faults. Investigations in the Camperdown, Edgecliff, Ashfield, Bankstown, Beverly Hills, Greenacre, Homebush and Strathfield SCAMPs are ongoing. Potential sources of contamination have been identified, however subsequent sampling identified ongoing issues requiring further rectification and investigation.

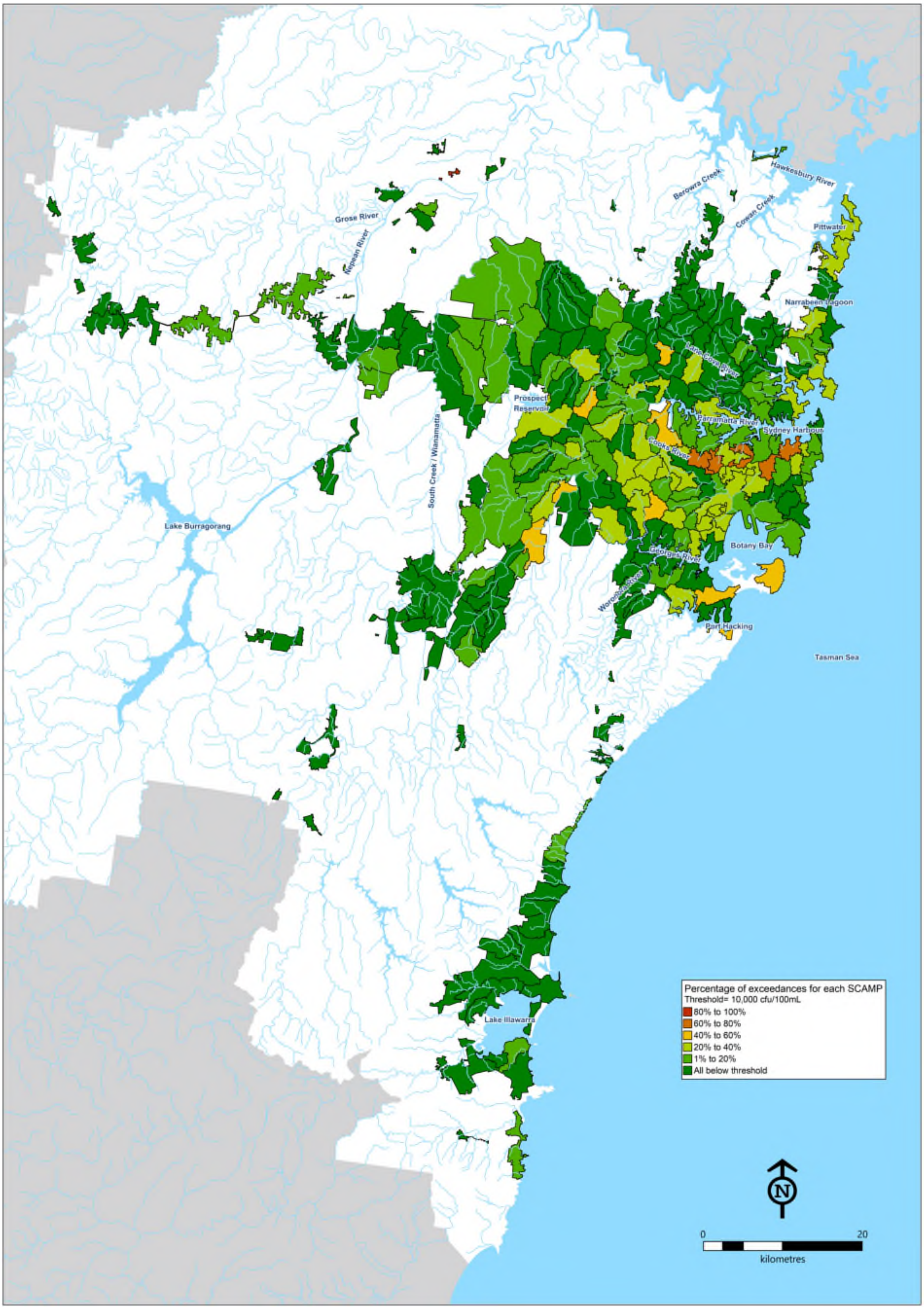


Figure 6-6 Percentage of exceedances for each SCAMP over the last 10 years of the DWLP, including 2022-23 data

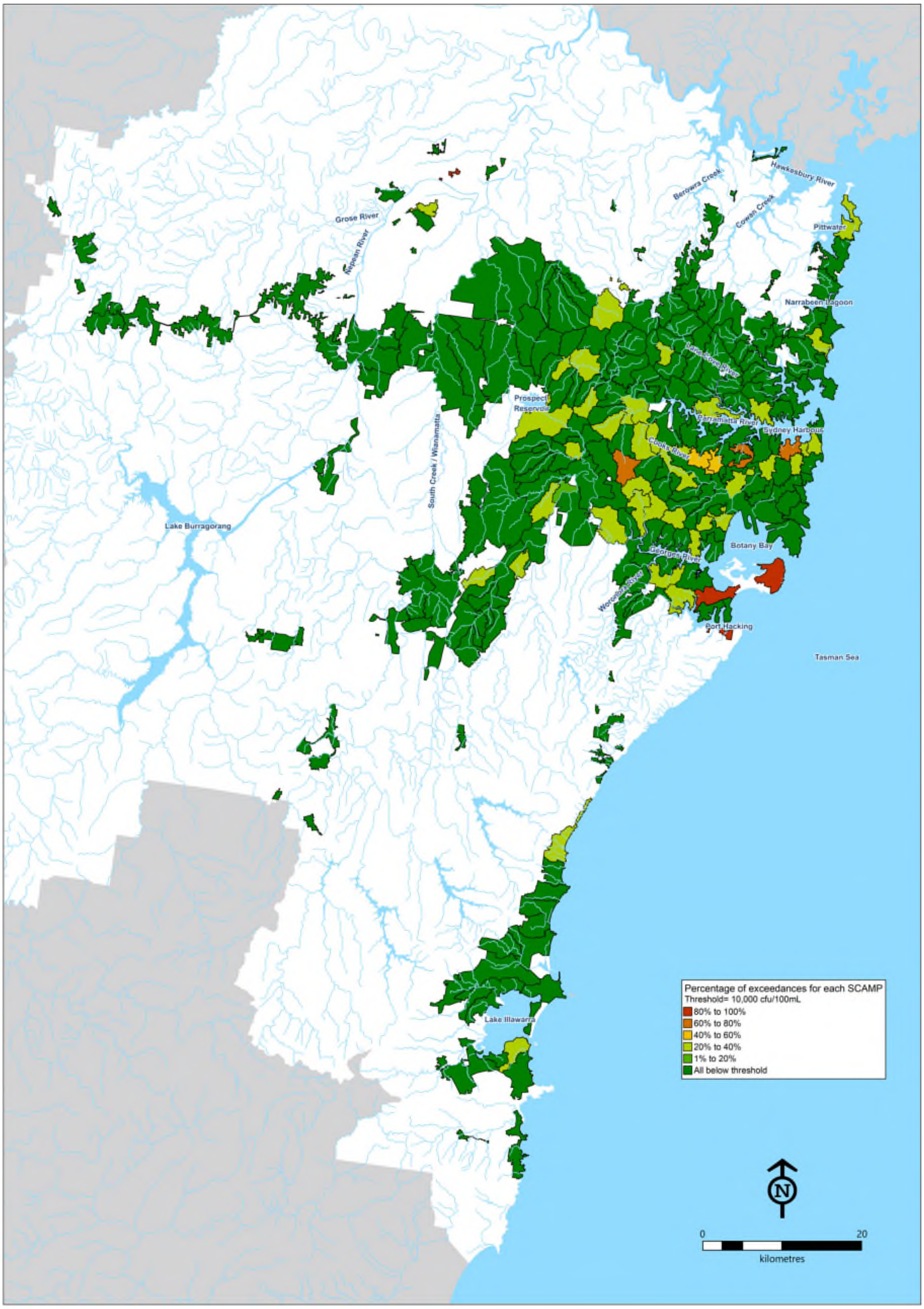


Figure 6-7 Percentage of exceedances for each SCAMP over last 3 years of the DWLP, including 2022-23 data

Table 6-2 SCAMP catchment investigation findings and status for the 2022-23 period

SCAMP	Outcome of investigations	Fault status
Camperdown	This catchment investigation has been ongoing since 2012. The routine quarterly samples for the 2022-23 fiscal period had threshold exceedances in quarter one and quarter four (58,000 cfu/100mL and 14,000 cfu/100mL respectively). Sydney Water conducted dye testing in July 2022 around Lennox St, Newtown with two dye tests showing dye in the stormwater. An investigation in August 2022 returned two bacteriological results only slightly above the threshold, with sites downstream of Lennox St returning results below the threshold. The Lennox St area was the location of a private fault and multiple rectification works in 2021-22. An investigation in October 2022 returned elevated results at one site in Cardigan St & Cardigan Lane, Stanmore. Investigations in November 2022 confirmed elevated results around Cardigan St Stanmore, however further investigations in December 2022 returned results under the threshold in the same location. The routine monitoring point returned results above the threshold in December. In January 2023, the routine monitoring site returned results under the threshold, however sites near Mallett St were elevated. In early March 2023, multiple sites returned elevated results, including around Gehrig Lane, Denison St and several sites around Roberts Lane. Later in March, dye testing was conducted on the Sydney Water sewer main in Roberts Lane and two nearby properties. The dye test from Roberts Lane was observed in the downstream stormwater. Also in March, an investigation returned further indicators of potential leakage in the vicinity of Gehrig Lane. In April 2023, dye testing and CCTV was conducted in the sewer assets along Roberts Lane. Multiple areas of damage requiring rectification were observed and work orders were created for repairs. Later in April, dye testing of the Sydney Water sewer main in Gehrig Lane was undertaken, with no dye observed in stormwater. Subsequent sampling events in late April returned multiple areas with elevated results including the routine monitoring site and sites in the stormwater branch that flows through Denison St & Gibbens St. Investigations continued around Gehrig Lane in May and early June. Two stormwater pits in Gehrig Lane returned elevated results at different times but further dye testing gave no conclusive results. This investigation remains open and is ongoing.	WO 88254839 – Dig & repair customer junction – asset 3051029 WO 88254618 – Dig & repair customer junction – asset 3051029 WO 88241590 – repair damage to base of manhole – asset 1113156 WO 88241220 – Dig & repair customer junction – asset 3048305 WO 88240672 – repair damage to base of manhole – asset 1113160 WO 88232740 – Patch liner over damage section of sewer – asset 3048301* WO 88232570 – Patch liner over damage section of sewer – asset 3048301* WO 88232414 – Patch liner over damage section of sewer – asset 3048301* WO 88201670 – Dig & repair customer junction – asset 3048301 * These WO's were subsequently cancelled and a WO for a full liner was created – WO 88765477.
Edgecliff	This catchment investigation has been ongoing since 2013. The routine quarterly samples for the 2022-23 fiscal period had threshold exceedances in quarters one, two and three (12,000 cfu/100mL, 14,000 cfu/100mL and 41,000 cfu/100mL respectively).	No rectification actions undertaken.

SCAMP	Outcome of investigations	Fault status
	At the start of the 2022-23 FY, the DWL program was awaiting the closure of an Environmental Response incident in this catchment before continuing the investigation. An investigation in November 2022 returned results slightly above the threshold at a site on Boundary Street. In March 2023, multiple field tests and observations indicated the likelihood of an overflow or surcharge upstream. Multiple sampling sites from this investigation returned elevated bacteriological results. An investigation in April 2023 returned results above the threshold at two locations upstream of Boundary St. In May 2023, two investigations returned elevated results at the routine site and one site on Boundary St, however a manhole overflow had been reported prior to the sampling and may have been contributing to the elevated bacteriological counts. An investigation in June 2023 returned slightly elevated bacteriological results at two sites. This investigation remains open and is ongoing.	
Rose Bay	The routine sample collected in March 2023 exceeded the faecal coliform threshold (28,000 cfu/100mL). The resample had a faecal coliform concentration of 820 cfu/100mL, below the threshold value. This investigation was subsequently closed.	No rectification actions undertaken.
Woolooware	This catchment investigation had been ongoing since 2021. The routine sampling moved from annual to quarterly frequency after the sample collected in February 2023 exceeded the faecal coliform threshold (84,000 cfu/100ml), the third routine annual exceedance in a row. The quarterly routine sample collected in April 2023 exceeded the faecal coliform threshold (44,000 cfu/100mL). The resample had a faecal coliform concentration of 7,900 cfu/100mL, below the threshold value. Subsequently, an investigation was not commenced. An investigation in July 2022 returned results indicating only the routine monitoring site was elevated. Further investigations in August 2022 again returned results at the routine monitoring site exceeding the threshold. In March 2023, investigations indicated that the source of bacteriological counts was not upstream of President Avenue, suggesting that the source could be non-human, for example, from the birds in Camellia Gardens. Additional samples were collected in March 2023 and analysed using Microbial Source Tracking (MST). The MST results indicated that the elevated bacteriological counts were not from a human source. Consequently, the investigation was closed.	No rectification actions undertaken.
Ashfield	This catchment investigation has been ongoing since 2012. The routine quarterly samples for the 2022-23 fiscal period had threshold exceedances in quarter two and quarter three (both results were 12,000 cfu/100mL). In July 2022, Inner West Council confirmed that work to rectify a private leak on College St, Croydon (reported through the DWL	WO 86726877 – Full lining of assets 3014721 & 3017461 WO 86726852 – D&R to install end cap on damaged junction no longer in use Private faults (reported to local council in previous FY):

SCAMP	Outcome of investigations	Fault status
	program) had been completed. Later in the month, CCTV was undertaken to investigate the source of elevated bacteriological counts around Alt St, Ashfield. Two assets with multiple damaged sections were located and a work order was created for a full lining of these assets. A work order was also created to install a cap on a damaged junction no longer in use. In August 2022, Sydney Water met with Inner West Council at Heighway Avenue to assist with dye testing properties at the location of a suspected private leak. A positive dye test result was observed, and council was to contact the property owners to get the faults rectified. Precautionary CCTV of sewer assets close to the Heighway Ave suspected private fault. No damage was found, and no rectification actions undertaken. In September 2022, inspection of a previous private fault on College St found no indicators of ongoing leakage. Later in the month, an investigation returned bacteriological results above the threshold at several sites in the vicinity of Elizabeth St & Etonville Pde. A sample collected from a site on Heighway Ave confirmed that a private fault previously reported to Inner West council had not yet been rectified. An Investigation In October 2022 confirmed elevated results at a site on Elizabeth St, however multiple sites upstream of this location returned results under the threshold, including just downstream of the previously reported private fault on College St. In November 2022, the routine site returned elevated results, but was under the threshold later in the month. One investigation returned elevated results at John St and Cheltenham Rd. These counts were traced up to Elizabeth St & Clarence St, Burwood during an additional investigation on a later date. Multiple investigations in December 2022 focussed on the elevated bacteriological counts around Elizabeth St and Church St, Burwood. A dye test from a commercial property on Burwood Rd was not a positive test. Several sites in this area returned elevated results during this time. A potential sewer surcharge on Elizabeth St, Ashfield, was investigated under the Environmental Response program. Dye testing continued around Church St, Burwood on multiple occasions in January 2023, with no dye appearing in the stormwater. In late January, a networks investigation provided no indication of an ongoing sewage leak. An investigation in February 2023 had elevated results at sites in the stormwater branch that flows along Elizabeth St and Brown St, Ashfield. A site just downstream of where a private sewer leak had previously been reported to Inner West Council (at Etonville Pde) returned results above the threshold. Later in February, multiple dye tests were conducted in the vicinity of Shaftsbury Rd, Belmore St & Burleigh St, Burwood, with no dye being observed in the stormwater. In March 2023, investigations returned elevated results around Church St, Burwood once again. However, a few days later, previously affected sites returned results under the threshold. In	• College St, Croydon • Heighway Ave, Croydon • Etonville Pde, Ashfield

SCAMP	Outcome of investigations	Fault status
	late March, results from a site in Iron Cove Creek near Elizabeth St were above threshold. Sampling in April 2023 indicated the source of elevated bacteriological counts in Iron Cove Creek was not upstream of Norton St, Croydon. In May 2023, dye testing continued around Burwood Rd, Clarence St & Belmore St, Burwood, with no dye appearing in the stormwater. The routine monitoring site returned results above the threshold during this time. In June 2023, sampling results were elevated in Iron Cove Creek at John St, Croydon. Elevated results were also found from outlets at Elizabeth St and Thomas St, Ashfield, indicating multiple sources of bacteriological counts. Later in the month, multiple sites upstream of Thomas St returned below the threshold, with one site slightly exceeding. A site just downstream of Thomas St and Iron Cove Creek at John St both returned elevated results. This investigation remains open and is ongoing.	
Bexley	This catchment investigation had been ongoing since 2016. The routine sample collected in December 2022, after the investigation was closed, did not exceed the faecal coliform threshold (1,900 cfu/100mL). Investigations in August 2022 returned all results under the threshold. This investigation was subsequently closed.	No rectification actions undertaken.
Bankstown	This catchment investigation has been ongoing since 2021. The annual routine sample collected in January 2023 did not exceed the faecal coliform threshold (9200 cfu/100mL). Sampling in July 2022 indicated the trade waste runoff from a business on Warren Ave, Bankstown was ongoing. This was reported to the Sydney Water Business Customer team who have been working with the business to improve their trade waste system. Investigations at Restwell Street continued in October of 2022 with multiple cross connections from the private sewer lines of a property on Restwell St being found connecting into the stormwater network. Follow up sampling at Restwell St in March 2023 returned results below the threshold indicating no ongoing leakage or cross connections. Follow up sampling at a business on Gow St, Padstow in July indicated runoff from their trade waste system was no longer entering the stormwater network, however there was still runoff observed pooled in the gutter in front of the building. Sydney Water's Business Customer team investigated again and rectified the issue. In March 2023, elevated faecal counts were traced upstream to Brancourt Ave, Bankstown. A chicken coup with an open grate was observed above the canal with chicken faeces in the canal below. Substantial amounts of dog faeces were also observed in the canal. Sydney Water's Customer Advocate team contacted the owners of both properties. Elevated faecal counts were also	Private faults located & reported to local council: • Restwell St, Bankstown • Chertsey Ave, Bankstown

SCAMP	Outcome of investigations	Fault status
	traced to Chertsey Ave where a private fault was located and reported to the council, with follow up sampling in May indicating the fault had been rectified. This investigation remains open and is ongoing.	
Belmore	This catchment investigation had been ongoing since 2019. The routine sample collected in July 2022 did not exceed the faecal coliform threshold (6,600 cfu/100mL). An investigation in August 2022 returned all results under the threshold. This investigation was subsequently closed.	No rectification actions undertaken.
Brighton	The routine sample collected in December 2022 exceeded the faecal coliform threshold (13,000 cfu/100mL). The resample had a faecal coliform concentration of 28,000 cfu/100mL, so an investigation was commenced. An investigation in December 2022 returned all results under the threshold. This investigation was subsequently closed.	No rectification actions undertaken.
Beverly Hills	This catchment investigation is continuing from 2020. The annual routine sample collected in August 2022 did not exceed the faecal coliform threshold (1,600 cfu/100mL). An investigation in August 2022 found a stormwater pit near Mercury St holding liquids with bacteriological counts exceeding the threshold. In the previous financial year, Georges River Council were requested to pump out/clean the pit. In April 2023, the council notified Sydney Water that this was completed. Investigations in December 2022 identified elevated results in a stormwater branch upstream of Merv Lynch Reserve. Further investigations in March & April 2023 identified multiple affected stormwater branches. Investigations in May 2023 identified a suspected private fault at the rear of a property on Dennis Pl, utilising dye testing. A private fault was subsequently reported to Georges River Council, who are liaising with the owner. Additional investigations & dye testing around Mercury St and Stoney Creek Rd in June 2023 returned no positive dye tests, however multiple bacteriological results exceeded the threshold. This investigation remains open and is ongoing.	Pit at Mercury St with elevated bacteriological counts reported to Georges River Council. Private fault on Dennis Pl reported to Georges River Council.
Greenacre	This investigation is continuing from 2018. The routine sample collected in July 2022 was below the exceedance threshold (1400 cfu/100mL). In December 2022, investigations led to a property on Urunga Pde. The owners of the property recently had rectification work carried out on their plumbing due to frequent blockages. Subsequent sampling of this area returned results below the threshold, indicating no ongoing leakage. In March of 2023, the scent detection dogs were used to investigate the stormwater canals between Punchbowl Rd and	Private faults reported to local council: • Defoe St, Wiley Park • Robinson St N, Wiley Park

SCAMP	Outcome of investigations	Fault status
	Urunga Pde, locating several potential leakage issues, including a property on Defoe St. Attempts to dye test were unsuccessful due to issues with access to property. In June 2023, an investigation traced the source of bacteriological counts to a suspected private fault on Robinson St. This investigation remains open and is ongoing.	
Homebush	This investigation is continuing from 2018. The annual routine sample collected in October 2022 was below the exceedance threshold (200 cfu/100mL). In July 2022, samples collected from seepage at a property on Parramatta Rd, Homebush exceeded the threshold. Council was notified of a private fault. Also in July, elevated faecal counts were traced to a stormwater pit behind a property on The Crescent, Homebush. There was evidence of a previous overflow from a nearby boundary trap and an overflowing grease trap which were reported to Sydney Water Business Customers in July 2022, and the council in November 2022. Follow up sampling in this area in January 2023 returned results below the threshold. In January & February 2023, sampling from an outlet near Sydney Markets returned elevated faecal counts. Networks notified Sydney Markets management for investigation. This investigation remains open and is ongoing.	Private fault on Parramatta Rd, Homebush reported to local council. Private fault on The Crescent, Homebush reported to local council.
Kensington	This investigation was continuing from 2020. The routine sample collected in January 2023 was below the exceedance threshold (8,200 cfu/100mL). Multiple rounds of sampling were conducted at Roma Ave, Randwick to assist Randwick Racecourse with upgrading their trade waste to prevent runoff from the horse stables entering the stormwater system. The investigation was closed in June based on MST sampling results, indicating the majority of the faecal counts were not from human sources.	No rectification actions undertaken.
Kogarah	This investigation was continuing from the 2018. The routine sample collected in January 2023 was below the exceedance threshold (3,800 cfu/100mL). Sampling undertaken in September 2022 returned all sites below the exceedance threshold and investigation was subsequently closed.	No rectification actions undertaken.
Marrickville	This investigation was continuing from 2019. The routine sample collected in August 2022 was below the exceedance threshold (2,700 cfu/100mL). Investigations in September 2022 narrowed down the elevated faecal counts to a stormwater pit near Centennial St. A suspected private fault at a property on Centennial St was reported to Inner West Council. In August 2022, Networks met	Private fault on Centennial St reported to local council.

SCAMP	Outcome of investigations	Fault status
	council on site to conduct dye testing with no dye appearing in the stormwater. The Investigation was closed in November 2022 based on all sites being below the threshold.	
Padstow	The routine sample collected in February 2023 exceeded the faecal coliform threshold (30,000 cfu/100mL). The resample had a faecal coliform concentration of 2000 cfu/100ml, below the threshold value. This investigation was subsequently closed.	No rectification actions undertaken.
Strathfield	This investigation is continuing from 2021. The routine sample collected in October 2022 was below the exceedance threshold (410 cfu/100mL). In September 2022 elevated faecal counts were traced to Morwick St where a private fault was located. Precautionary CCTV was carried out on nearby sewer assets and multiple Work Orders were created. Sampling of the stormwater pit at a property on Station St, Homebush in November 2022 returned results below the threshold, after being previously elevated. Also in November 2022, elevated counts were traced to the vicinity of Carrington Ave. Extensive dye testing was conducted by with no dye appearing in the stormwater. An extensive CCTV investigation was conducted in January 2023 in the vicinity of Carrington Ave, Nichol Pde and Vernon St, with multiple rectification Work Orders being created. Further sampling of the stormwater pit and outlet at a property on Station St, Homebush in June 2023 returned elevated faecal counts after a sewer leak detection dog indicated on the outlet to the stormwater canal. This investigation remains open and is ongoing.	Private fault on Morwick St, Strathfield originally reported to Sydney Water emergency response hotline due to sewage flowing into the gutter (WO 87145516). Further investigation found the fault to be private - local council and building strata were notified. 87792827 – D&R on junction 4532710 87792810 – D&R on junction 4529978 87792771 – D&R @ ~52m to 56m U/S of MH 1320614 on multiple junctions 87792725 – T-seal for junction at asset 4529982 87792682 – Patch Liner on displaced joint~3.36m u/s of MH 1320614 87773022 – JJ @ Junction Asset 4529123 87772981 – Patch @ 22.27m U/S of MH 1318246 87772965 – Patch from 66m to 69m U/S of MH 1318246 87770132 – inspect MH – all 3 connecting assets are damaged 87770109 – D&R @ 0.3m upstream of MH 1320970 87770080 – D&R on drop @ 49.2m downstream of MH 1318246 87769995 – D&R starting @ 1.3m upstream of MH 1318238 87769938 – JJ on junction @ 1.19m upstream of MH 1318238 87763751 – D&R on damaged junction asset 4532722

SCAMP	Outcome of investigations	Fault status
		87762908 – D&R on damaged junction (asset 8601317) 87762823 – D&R on damaged junction (asset 4531839) 87761758 – D&R from 15m to 16m u/s of MH 1318242 including junction 4529107 87752694 – Patch liner for damaged section of line from 24.75m to 26.28m u/s of MH 1318242 87751827 – MH rehab on asset 1320970 for exfiltration 87751670 – MH rehab on asset 1320614 for exfiltration 87751560 – MH rehab on asset 1318242 for exfiltration 87750086 – Junction jet ~55.90m u/s of mh 1318246 87749975 – Patch liner over damaged section of sewer ~47.67m u/s MH 1318246
Summer Hill	This investigation was continuing from 2014. The routine samples collected in August 2022 (1500 cfu/100mL), October 2022 (2600 cfu/100ml) and March 2023 (2300 cfu/100mL) were all below the threshold. This routine monitoring point transitioned to annual sampling from quarterly sample after these three results. Multiple investigations into fluctuating counts upstream of Smith St and Gelding Lane between August 2022 and December 2022 did not result in any located faults or rectification works being carried out. In November 2022, Networks investigated counts upstream of Smith St, including inspecting emergency relief structures and underground pump-outs. Sampling in January 2023 returned results under threshold downstream of the A site (superseded into this investigation from an Environmental Response incident). Sampling conducted in April 2023 returned results below the exceedance threshold and the investigation was subsequently closed.	No rectification actions undertaken.
Wetherill Park	The routine sample collected in March 2023 exceeded the faecal coliform threshold (11,000 cfu/100mL). The resample had a faecal coliform concentration of 1,400 cfu/100mL, below the threshold value. This investigation was subsequently closed.	No rectification actions undertaken.

SCAMP	Outcome of investigations	Fault status
Holroyd	This investigation was continuing from 2019. The routine sample in September 2022 was below the threshold (120 cfu/100mL). In November 2022 elevated ammonia and other field indicators were traced to Clarence St, where a private fault was being cleared by a plumber. Sampling conducted later in November 2022 returned results below the exceedance threshold and the investigation was subsequently closed.	No rectification actions undertaken.
Lidcombe	This investigation was continuing from 2021. The routine sample in September 2022 was below the threshold (4,600 cfu/100mL). In October 2022, sampling that was undertaken at multiple sites around Woodburn Rd, Berala, the site at the rear of a business continued to have elevated faecal coliform and field indicators. This is the site of a previously reported suspected private fault. The local council confirmed that investigations were not conclusive. In November 2022, dye testing of Sydney Water sewer assets and properties on Woodburn Road, including the business, and neighbouring properties was conducted, with no dye being visible in the stormwater. In December 2022, the site at the rear of the business appeared to be holding pulp and sewage liquids in it. Results at this site were elevated, however none of the downstream stormwater sites returned elevated results. In February 2023, the same site was inspected and pooled, grey liquid that had a foul odour was noted. Subsequently, CCTV was conducted on Sydney Water sewer assets around Woodburn Rd and Crawford St, Berala, with multiple rectification work orders being created. Sampling in May 2023 found the only remaining elevated site was a small pit at the rear of the business, this pit was reported to local council and Sydney Water Business Customers team. The CCTV investigation, completed rectification works and dye testing of Sydney Water's assets indicated the faecal counts are likely from a private fault. The Sydney Water Business Customer team have also inspected the trade waste system of a property on Woodburn Rd and found no damage or necessary improvements. Sampling of the downstream stormwater indicates there is no impact from the faecal counts at this site and the investigation was subsequently closed.	87907912- D&R on damaged section of line ~22.37m d/s of MH 1308465 87907704 Patch liner over fracture @ 7.17m u/s of MH 1311189 87897457 T-seal over cracks around junction @ 16.21m d/s MH 1311189 (asset 4504648) 87897422 Patch on broken pipe @ 2.26-2.92m u/s of MH 1311497 87897412 Patch liner on displaced joint @ 10.40m u/s of MH 1308769 87897409 Patch liner on displaced joint @ 6.88m u/s of MH 1308769
North Sydney	This investigation was continuing from 2022. The routine sample collected in November 2022 was below the threshold (3,600 cfu/100mL). In August 2022, a private fault was confirmed to have not been rectified at a property on Bay Rd by Sydney Water's Environmental Liaison Officers and Customer Advocate teams. Waverton Council was contacted to follow up on rectification. In September 2022, the private fault on Bay Rd had been rectified.	Private fault on Bay Road reported to Waverton Council

SCAMP	Outcome of investigations	Fault status
	Dye testing of a Sydney Water sewer asset was undertaken in November 2022 following elevated results at Woolcott St, with no dye appearing in the stormwater. Subsequent sampling returned results below the exceedance threshold and the investigation was closed.	
Rosehill	Previously, the routine monitoring site was temporarily moved to the next accessible upstream location, due to construction. The interim routine site sampled was in Clay Cliff Creek at the rear of a property on Oak St. This is approximately 421m upstream of the original routine site. The routine sample collected In September 2022 exceeded the faecal coliform threshold (23,000 cfu/100mL). The resample in November 2022 had a faecal coliform concentration of 1,600 cfu/100mL, below the threshold. Subsequently, the investigation was closed.	No rectification actions undertaken.
Seven Hills	This investigation was continuing from 2021. There was no routine sample collected in November 2022 as the routine site was ponded and had no flow. The investigation was subsequently closed in December 2022 when the routine site was dry, and all other sites were under the threshold.	No rectification actions undertaken.
Wentworthville	The investigation was continuing from 2018. In November 2022, the investigation was closed as all samples were under the threshold. The routine sample collected in December 2022 was below the threshold (3,300 cfu/100ml).	No rectification actions undertaken.
Freemans Reach	The routine sample collected in January 2023 exceeded the faecal coliform threshold (48,000 cfu/100ml). The resample had a faecal coliform concentration of 5,600 cfu/100ml, below the threshold value. This investigation was subsequently closed.	No rectification actions undertaken.
Richmond	This investigation was continuing from 2020. The routine sample collected in January 2023 was below the threshold (2,400 cfu/100mL). Sampling conducted in August 2022 returned results below the exceedance threshold and the investigation was subsequently closed.	No rectification actions undertaken.
Lake Illawarra	The routine sample collected in August 2022 exceed the threshold (16,000 cfu/100mL). The resample had a faecal coliform concentration of 10 cfu/100mL, below the threshold. This investigation was subsequently closed.	No rectification actions undertaken.
Blackett	This investigation was continuing from 2020. The routine sample in August 2022 returned a faecal coliform concentration of 1,400cfu/100mL, below the threshold. Sampling conducted in August 2022 returned results below the exceedance threshold and the investigation was subsequently closed.	No rectification actions undertaken.

6.2 Other monitoring – Estuary, lagoon and beaches

6.2.1 Chlorophyll-a in estuarine sites

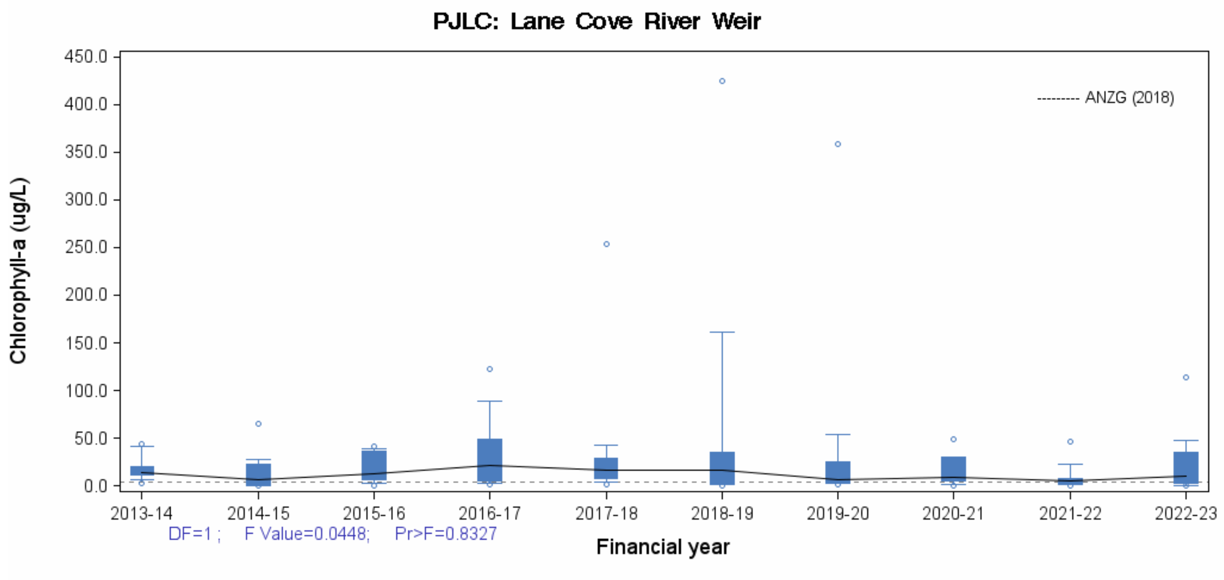
The yearly trends in chlorophyll-*a* at all estuarine monitoring sites are presented in Volume 2 Appendix G-1 Chlorophyll-a trend plots for the sites with an increasing or decreasing trend in 2022-23 or where yearly median results exceeded the ANZG (2018) guideline limit are presented below.

Statistical analysis confirmed that the 2022-23 chlorophyll-a at upper Georges River (downstream of Harris Creek, GR19A) was significantly higher than the results in previous nine years (2013-22). The trends in chlorophyll-a concentrations were steady at all other 15 estuarine sites.

The 2022-23 median chlorophyll-a concentrations at six monitoring sites were higher than the respective freshwater or estuarine guideline limit (ANZG 2018). These are the sites in upstream river that had higher chlorophyll-a concentrations than the sites closer to the mouth of each estuary.

Elevated chlorophyll-a concentration was recorded at Lane Cove River Weir (PJLC) with maximum of 113.4 μg/L on 16 September 2022. The 2022-23 median chlorophyll-a concentration was also high at this site (10.7 μg/L). The maximum of chlorophyll-a concentration of 56.9 μg/L on 13 January 2023 was recorded at Parramatta River Weir (PJPRA). The Parramatta River at Ermington (PJ015) has recorded maximum of chlorophyll-a concentration of 29.1 μg/L on 10 February 2023. Higher chlorophyll-a concentration of 83.3 μg/L was also recorded on 13 April 2023 at Alexandria Canal (CR04A). The 2022-23 median chlorophyll-a concentration was also highest at this site (12.8 μg/L). The upstream Georges River at Liverpool Weir (GR22) had a maximum of chlorophyll-a concentration of 38.4 μg/L on 9 December 2022. The upper Georges River (downstream of Harris Creek (GR19A)) had maximum of chlorophyll-a concentration of 31.0 μg/L on 16 September 2022.

The chlorophyll-a concentrations were lower at PJCB1, PJTB, PJCB2, PJDFP, GR01, GROB, GRRB, GRFB, PHLPB compared to the other estuarine sites in 2022-23. Median chlorophyll-a concentrations at these sites were much lower than the guideline limit. The lowest median chlorophyll-a concentration was at Lilli Pilli Baths (PHLPB) in Port Hacking, 0.8 μg/L.


PJLC: Lane Cove River Weir
ANZG (2018)
Chlorophyll-a (ug/L)
450.0
400.0
350.0
300.0
250.0
200.0
150.0
100.0
50.0
0.0
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
2020-21
2021-22
2022-23
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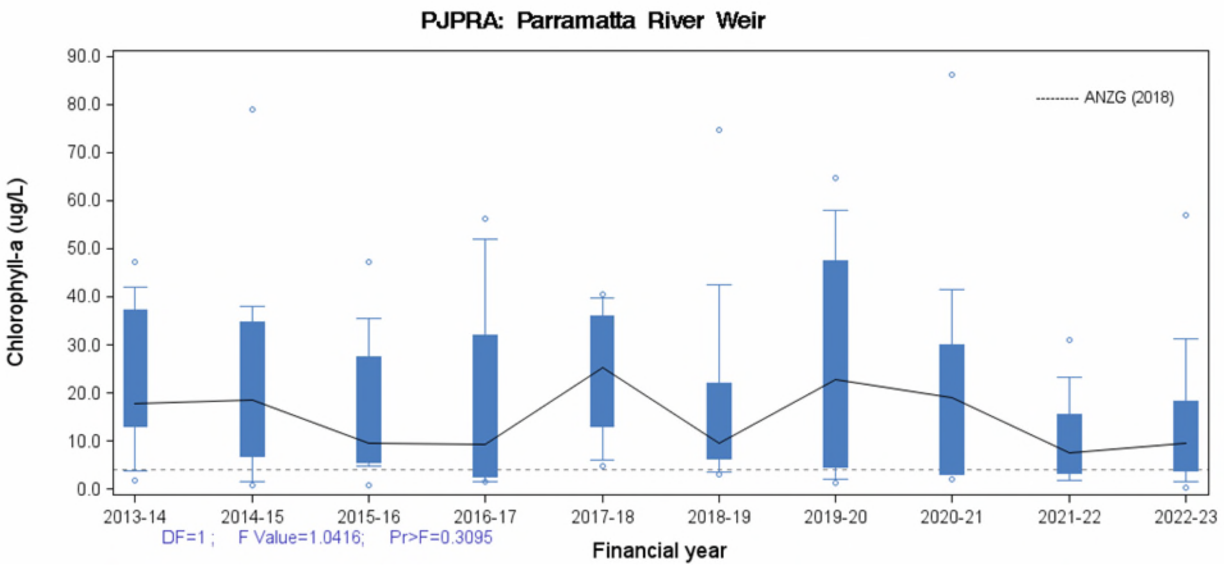
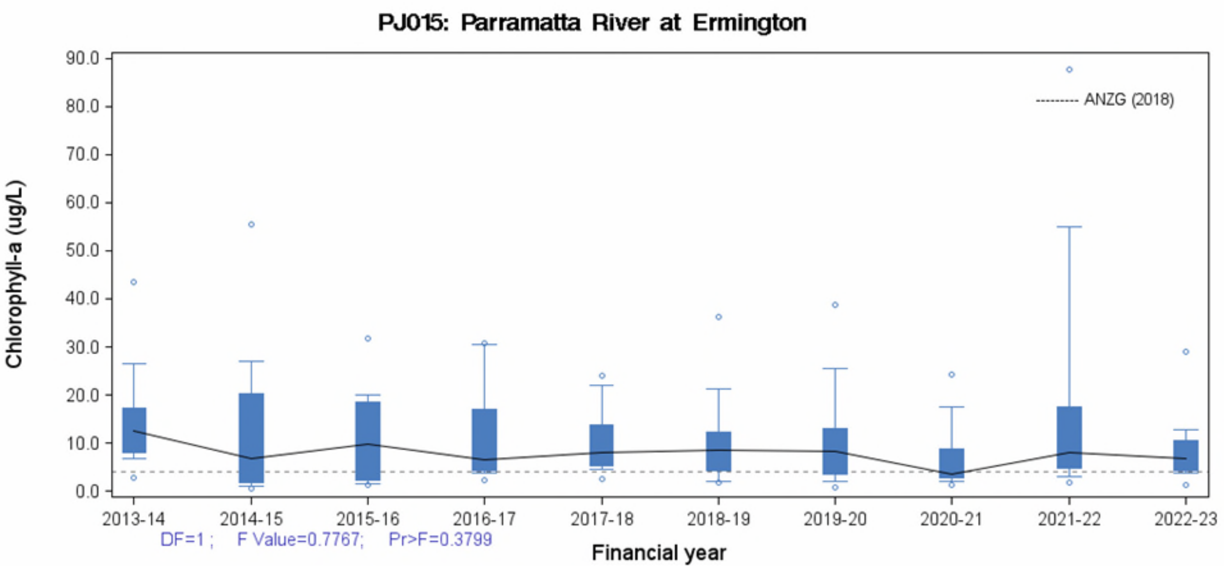
Financial year


PJPRA: Parramatta River Weir
ANZG (2018)
Chlorophyll-a (ug/L)
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
2020-21
2021-22
2022-23
DF=1 ; F Value=1.0416; Pr>F=0.3095
Financial year


PJ015: Parramatta River at Ermington
ANZG (2018)
Chlorophyll-a (ug/L)
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
2020-21
2021-22
2022-23
DF=1 ; F Value=0.7767; Pr>F=0.3799
Financial year

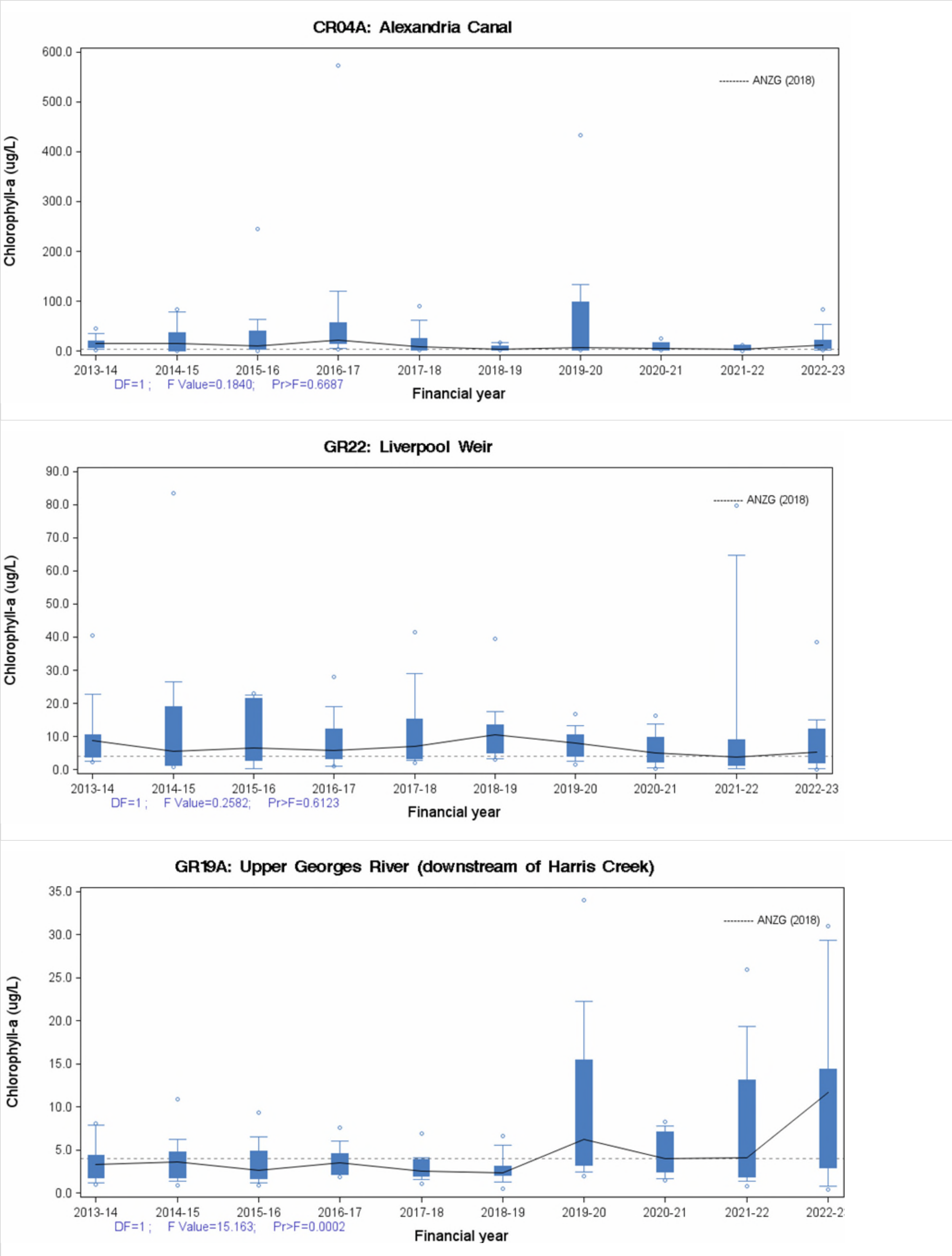


Figure 6-8 Chlorophyll-a exception plots for all estuarine sites

6.2.2 Water quality trends in lagoons

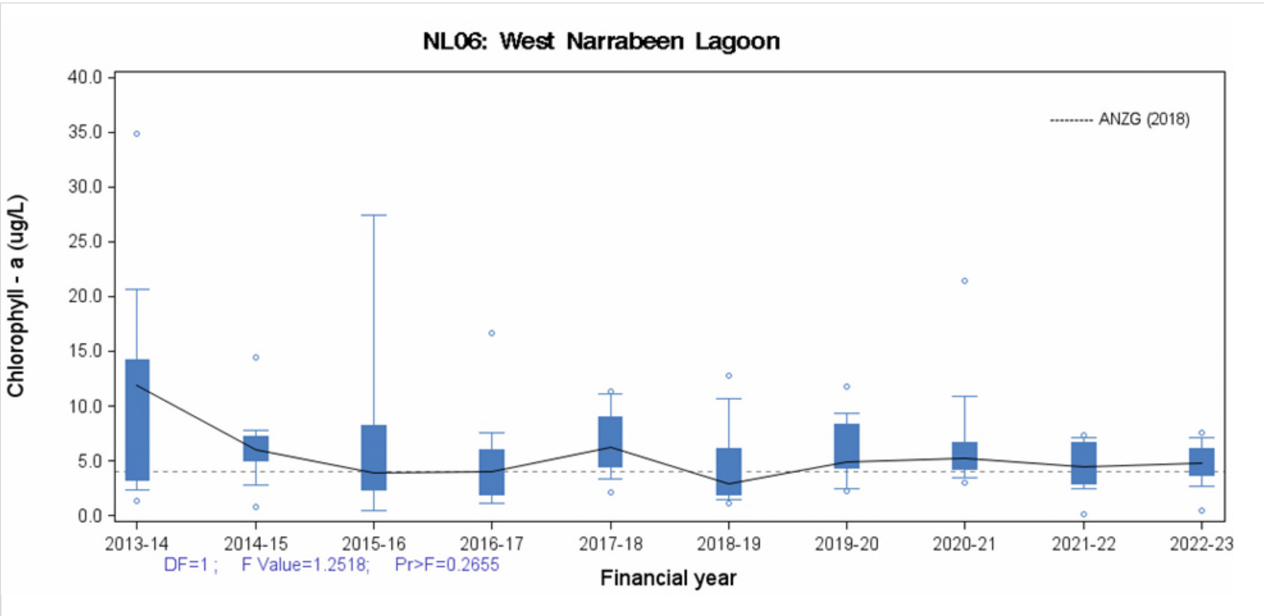
The yearly trends in conductivity, chlorophyll-a and *Enterococci* results of all lagoon monitoring sites are presented in Volume 2 Appendix G-2. The trend plots for the sites with an increasing or decreasing trend in 2022-23 or the yearly median results exceeding the relevant guideline limit are presented below.

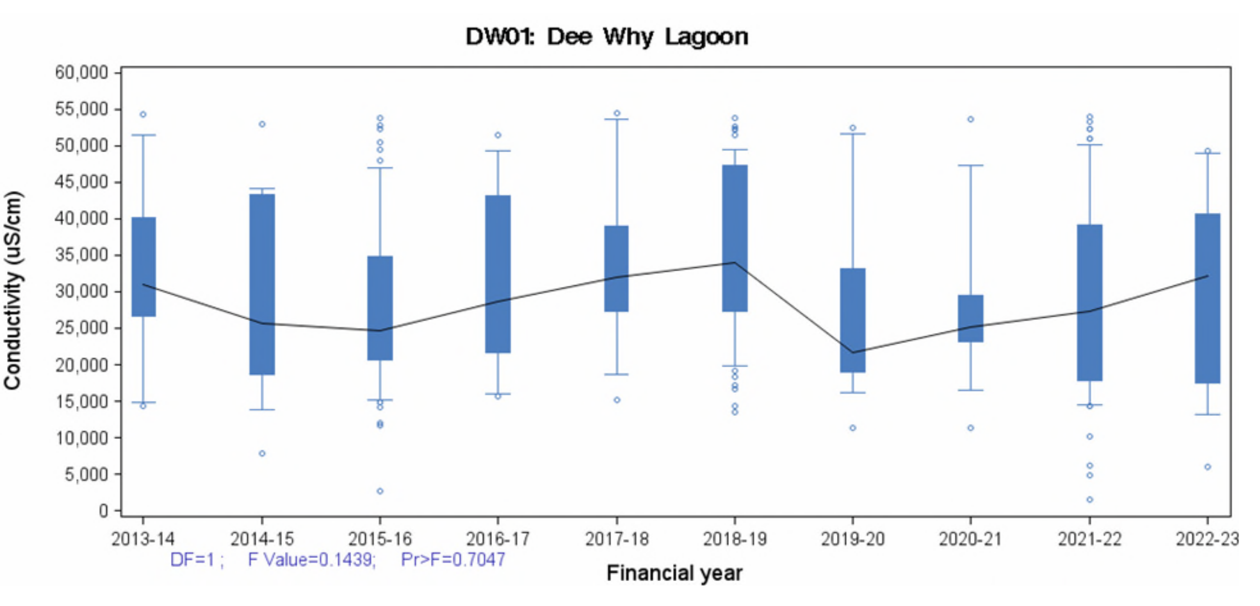
There was no significant increase or decrease in trends of chlorophyll-a concentrations and *Enterococci* densities in 2022-23. Conductivity was significantly higher at Wattamolla Lagoon (WL83) in 2022-23.

The 2022-23 median chlorophyll-a concentrations exceeded the ANZG (2018) guideline at West Narrabeen Lagoon (NL06), Curl Curl Lagoon (CC01) and Upper Manly Lagoon (ML03). The median chlorophyll-a concentrations were lower than the guideline at the other four lagoon sites.

Occasionally, chlorophyll-a reached higher concentrations at other lagoon sites depending on mixing with the sea or marine water. Closed lagoon conditions with no connection to the open sea for prolonged periods tended to have accelerated phytoplankton growth if other conditions were also favorable (eg temperature, light and nutrients). The chlorophyll-a reached a maximum of 34.7 mg/L at Curl Curl Lagoon (CC01) on 9 December 2022 and 38.2 at Dee Why Lagoon (DW01) on 14 July 2022.

The median *Enterococci* level exceeded the ANZECC (2000) secondary contact recreation guideline at Upper Manly Lagoon (ML03). The median *Enterococci* exceeded the primary contact recreation guideline at four other lagoon sites (East Narrabeen lagoon NL01, West Narrabeen Lagoon NL06, Curl Curl lagoon CC01 and Mouth Manly lagoon ML01).





DW01: Dee Why Lagoon
Conductivity (uS/cm)
60,000
55,000
50,000
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
2020-21
2021-22
2022-23
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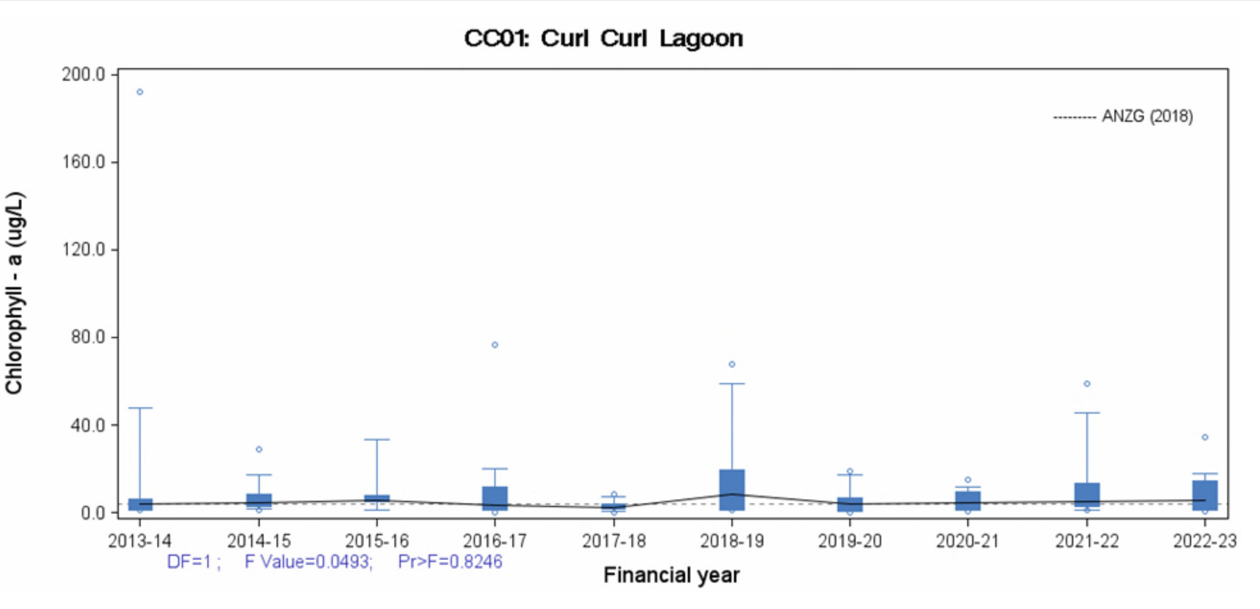
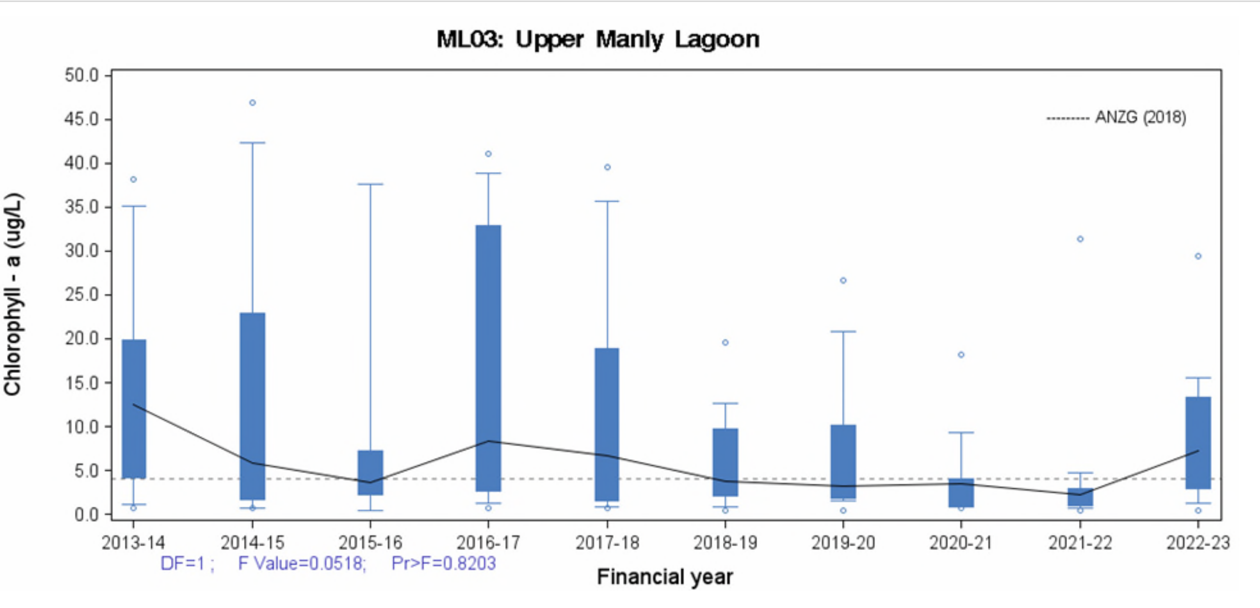
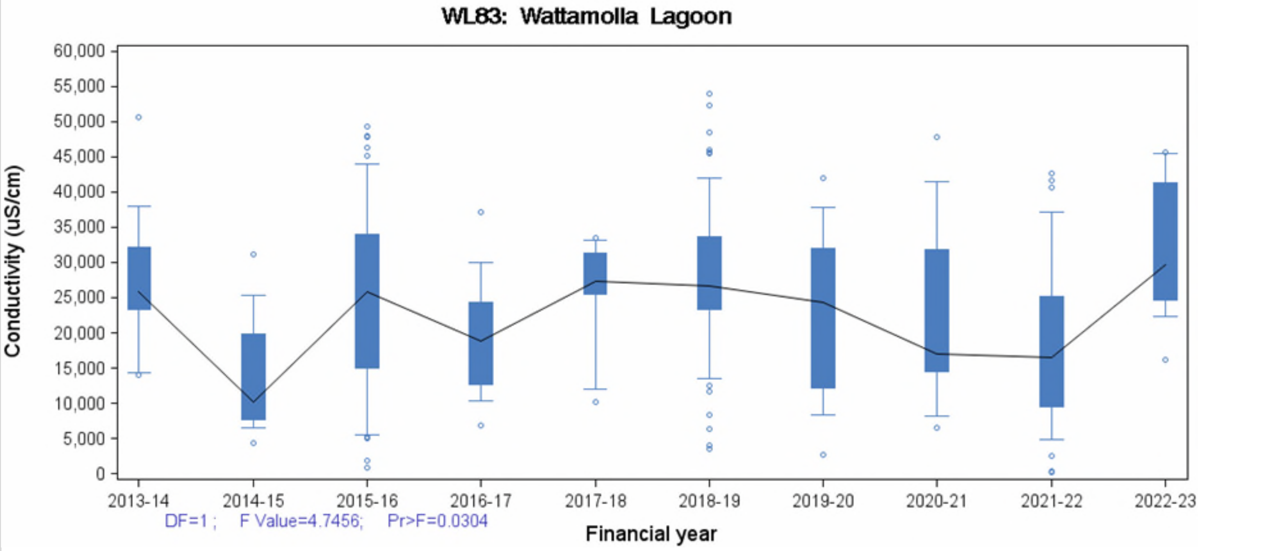
Financial year



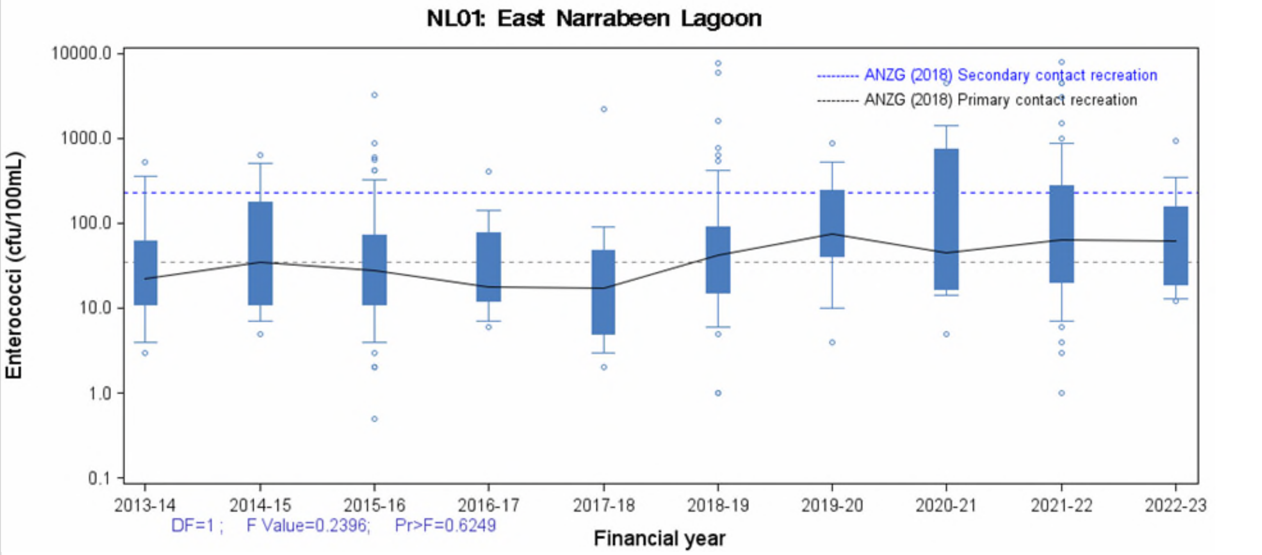
CC01: Curl Curl Lagoon
ANZG (2018)
Chlorophyll - a (ug/L)
200.0
160.0
120.0
80.0
40.0
0.0
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
2020-21
2021-22
2022-23
DF=1 ; F Value=0.0493; Pr>F=0.8246
Financial year



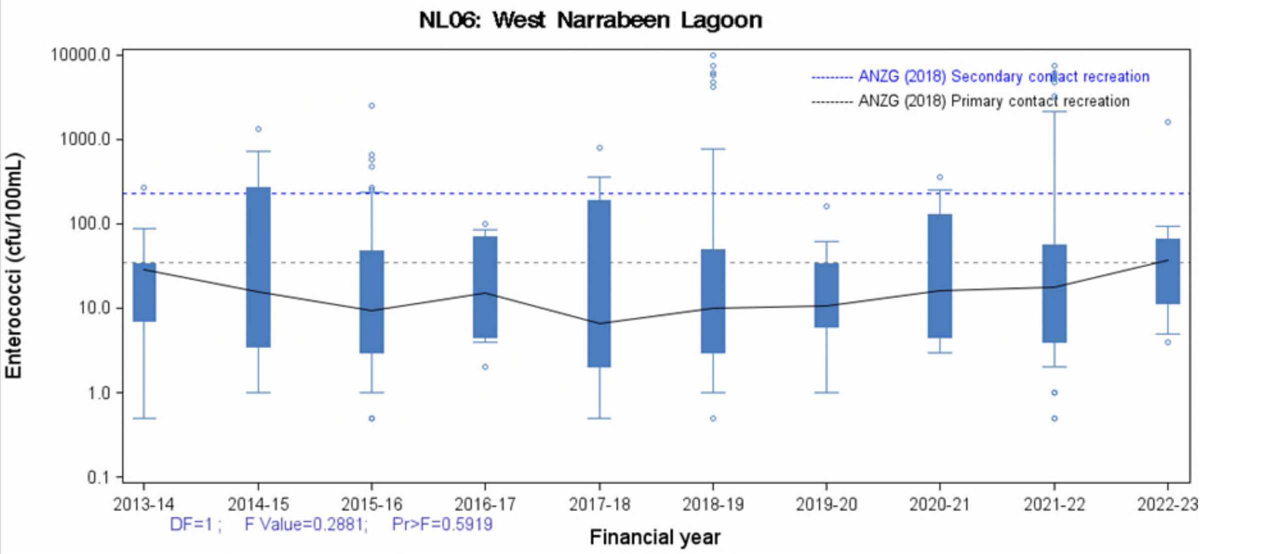
ML03: Upper Manly Lagoon
ANZG (2018)
Chlorophyll - a (ug/L)
50.0
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
2020-21
2021-22
2022-23
DF=1 ; F Value=0.0518; Pr>F=0.8203
Financial year



WL83: Wattamolla Lagoon
Conductivity (uS/cm)
60,000
55,000
50,000
45,000
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
2020-21
2021-22
2022-23
DF=1 ; F Value=4.7456; Pr>F=0.0304
Financial year



NL01: East Narrabeen Lagoon
Enterococci (cfu/100mL)
10000.0
1000.0
100.0
10.0
1.0
0.1
ANZG (2018) Secondary contact recreation
ANZG (2018) Primary contact recreation
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
2020-21
2021-22
2022-23
DF=1 ; F Value=0.2396; Pr>F=0.6249
Financial year



NL06: West Narrabeen Lagoon
Enterococci (cfu/100mL)
10000.0
1000.0
100.0
10.0
1.0
0.1
ANZG (2018) Secondary contact recreation
ANZG (2018) Primary contact recreation
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
2020-21
2021-22
2022-23
DF=1 ; F Value=0.2881; Pr>F=0.5919
Financial year

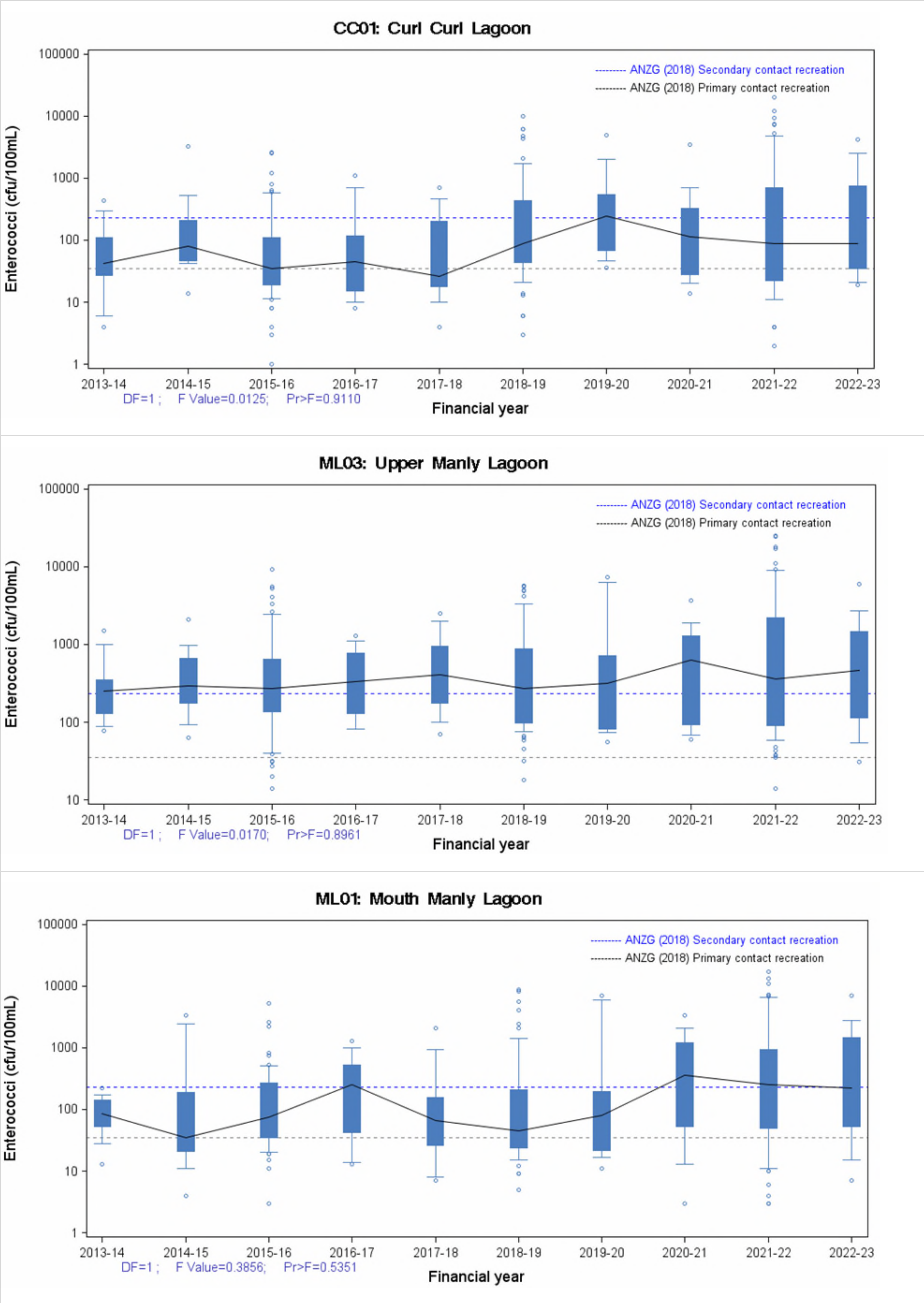


Figure 6-9 Chlorophyll-a and *Enterococci* exception plots for all lagoon sites

6.2.3 Intertidal communities – Sydney estuaries

Intertidal rock platform communities

The comparison of control sites to other intertidal rock platform sites indicated test sites had similar results in 2022 to the last few years. The intertidal community at test sites in the higher salinity zone was similar or within the range of variation recorded for the higher salinity control sites. Test sites in the lower salinity zone had an intertidal community that in most cases was different to that recorded for the lower salinity control sites. This suggests the 2022 community structure in the lower salinity zone at most sites was impaired with the exception of the improving trends for the Hawthorn Canal arm within Iron Cove (PJ082), Wolli Creek Cooks River (CR06) and at Woolwich Baths Lane Cove River (PJ05) (Volume 2 Appendix G-3).

Settlement panels

Barnacles were the dominant animal that settled on panels and included a mixture of small types like *Elminius* and *Chamaesipho*, as well as some larger animals like *Balanus*. Analysis by Sydney Water (2012) showed higher levels of barnacle cover to be a possible indicator of wastewater overflows in wave-sheltered areas of the estuaries around Sydney. In wave exposed areas of the coast and outer estuaries where there is regular wave occurrence, barnacles naturally grow on hard substrates and are not an indicator of the presence of wastewater.

In 2022-23, PJ33 (Rushcutters Bay) and GR085 (Quibray Bay-Kurnell) were significantly different from the remaining sites in the higher salinity zone, while the Georges River site GR115 (Kyle Bay) had statistically higher barnacle settling in the lower salinity zone (Volume 2: Appendix G-3).

6.2.4 Recreational water quality – Harbour and beaches

Altogether there were 775 observations when *Enterococci* levels were above the ANZECC (2000) primary contact recreational guideline (>35 cfu/100mL) at 114 Beachwatch and Harbourwatch sites during the 2022-23 reporting year. Austinmer Beach from Wollongong was the only site where the pr imary contact guideline was maintained throughout the year. There were one or more *Enterococci* e xceedances above the secondary contact recreation guideline (>230 cfu/100 mL) at 85 sites (74% of all sites, Table 6-3).

Based on the assessment of high conductivity (>30,000 µS/cm) and dry weather criteria (72 hours rainfall <2 mm), 168 of these individual primary contact exceedances were identified for further investigation to determine if they had been impacted by dry weather overflows (Volume 2, Appendix G, Table G-4).

These 168 dry weather Beachwatch exceedances were from 68 beaches (59% of all sites). The investigation focused on assessing the data collected at sites sampled under the Environmental Response (ER) and Dry Weather Leakage Program (DWLP) programs. All sampling data for these projects was extracted and then filtered by sites that exceeded primary contact guidelines. This site list was rationalised to only include wastewater inflow points (the point at which a surcharge reaches any waterway) or any site sampled that is deemed to be a primary or secondary contact waterway. This sampling information was then mapped against the 168 Beachwatch exceedances. Any site sampled under the ER or DWLP that met the above criteria and occurred within 7 days before and 7 days after the Beachwatch exceedance was deemed to have a potential impact.

Using the above methodology for 2022-23 data, wastewater overflows from Sydney Water's networks may have contributed to elevated *Enterococci* at 14 of the 115 Beachwatch sites (12% of all sites) on 19 occasions. Eleven of these sites had only one incident. There were two incidents at Dolls Point Baths and three incidents at Carss Point Baths during 2022-23 when Sydney Water's network may have contributed to these exceedances.

Twenty-eight wastewater overflow impacted sites from the last 2 years and respective beach suitability grades as determined by the Department of Planning and Environment (DPE 2022 and DPE 2023) were compared in Table 6-5. The beach suitability grades were deteriorated at three of these sites and stable at the remaining sites compared to last year's (2021-22) results.

- Four of the sites were consistently impacted by wastewater overflows for last two consecutive years. These were Foreshore Beach, Hayes Street Beach, Jew Fish Bay Baths and Parsley Bay.
- None of the three sites where beach suitability grades deteriorated were impacted by wastewater overflows in 2022-23 (Gunnamatta Bay Baths, Woolwich Baths and Lake Illawarra Entrance Lagoon). All three sites were impacted in 2021-22.

Sydney Water is currently conducting programs of work to reduce overflows to Rose Bay Beach and Foreshore Beach (see Chapter 5 for more information).

Table 6-3 Summary of the number of beach monitoring sites that exceeded the primary or secondary contact guidelines that may have been impacted by wastewater overflows during 2022-23

Catchment	Sub-catchment	Number of sites						Overflow incidents impacting waterways
		Total monitoring sites	One or more secondary contact exceedance	One or more primary contact exceedance	One or more dry weather exceedance (primary contact)	Sewage overflow impacted sites	Number of incidents	Name of the beach/ site
Sydney Coastal Beaches	Northern Sydney	22	13	22	8	0	0	None
	Central Sydney	11	11	11	7	0	0	None
	Southern Sydney	8	1	8	7	0	0	None
Sydney Harbour	Botany Bay and Georges River	15	14	15	14	7	12	Carss Point Baths, Dolls Point Baths, Foreshores Beach, Jew Fish Bay Baths, Kyeemagh Baths, Monterey Baths, Sandringham Baths
	Port Hacking	5	4	5	4	2	2	Gymea Bay Baths, Horderns Beach
	Port Jackson	15	15	15	13	4	4	Dawn Fraser Pool, Hayes Street Beach, Murray Rose Pool, Parsley Bay
	Middle Harbour	11	8	11	1	0	0	None
	Pittwater	10	7	10	6	1	1	Bayview Baths
Illawarra	Wollongong	11	7	10	5	0	0	None
	Shellharbour	3	3	3	1	0	0	None
	Bombo	4	2	4	2	0	0	None
Total number of sites		**115**	**85**	**114**	**68**	**14**	**19**	**-**
Percent of all sites (%)		**-**	**74%**	**99%**	**59%**	**12%**	**-**	**-**

Table 6-4 Short-listed beaches, harbour and estuarine monitoring sites with possible pollution from wastewater overflows during 2022-23

Site name	Sampling date	*Enterococci* (>35 cfu/100mL)	Conductivity (µS/cm)	Incident date	Comments
Sydney harbours and estuaries					
Bayview Baths	2/12/2022	240	51900	4/12/2022	Overflow incident had the potential to impact *Enterococci* levels. Sample collected at Winnererremy Bay, 70 m northeast of Flying Fox Café 04/12/2022 exceeded the primary contact threshold.
Carss Point Baths	16/02/2023	200	49100	15/02/2023	Overflow incident had the potential to impact *Enterococci* levels. Sample collected at Kogarah Bay, in front of Wharf Road Reserve, 40 m south-east of 33 Wharf Road 15/02/2023 has exceeded the primary contact threshold.
Carss Point Baths	27/02/2023	46	42400	6/03/2023	Overflow incident had the potential to impact *Enterococci* levels. Sample collected at Kogarah Bay, in front of Wharf Road Reserve, 40 m south-east of 33 Wharf Road 06/03/2023 has exceeded the primary contact threshold. Overflow incident had the potential to impact Enterococci levels. Sample collected at Carss Point Baths, 90 m south of Carrs Park life saving hall has exceeded the primary contact threshold.
Carss Point Baths	18/04/2023	90	54100	12/04/2023	Overflow incident near Torrens St, Blakeurst had the potential to impact *Enterococci* levels. Sample collected at Stormwater canal, 50m North East of 28 Torrens St, downstream of footbridge on 12/04/2023 exceeded the primary contact threshold.
Dolls Point Baths	16/02/2023	68	48500	15/02/2023	Overflow incident had the potential to impact *Enterococci* levels. Sample collected at Kogarah Bay, in front of Wharf Road Reserve, 40 m south-east of 33 Wharf Road 15/02/2023 has exceeded the primary contact threshold.
Dolls Point Baths	27/02/2023	100	43500	21/02/2023 23/02/2023	Overflow incident had the potential to impact *Enterococci* levels. Sample collected at Georges River at Vanston Baths, 40 m East of 7 Vanston Parade 21/02/2023 has exceeded the primary contact threshold. Overflow incident had the potential to impact *Enterococci* levels. Sample collected at Dolls Point Beach, 250 m South of 27 Malua St Dolls Point 23/02/2023 has exceeded the primary contact threshold.

Site name	Sampling date	*Enterococci* (>35 cfu/100mL)	Conductivity (µS/cm)	Incident date	Comments
Sydney harbours and estuaries					
Dawn Fraser Pool	12/12/2022	260	50900	9/12/2022	Overflow incident had the potential to impact *Enterococci* levels. Sample collected at Iron Cove Creek, 1 m downstream of Elizabeth St road bridge, 10 m west of 183 Elizabeth St. 09/12/2022 exceeded the primary contact threshold.
Foreshore Beach	3/02/2023	630	51400	10/02/2023	Overflow incident had the potential to impact *Enterococci* levels. Sample collected at Mill Stream lookout on 10/2/23 exceeded primary contact threshold.
Foreshore Beach	27/02/2023	250	48200	23/02/2023	Overflow incident had the potential to impact *Enterococci* levels. Sample collected at Right pathway of Banksmeadow boat ramp 23/02/23 exceeded the primary contact threshold.
Foreshore Beach	18/04/2023	46	53100	17/04/2023	Overflow incident at Mill Stream had the potential to impact *Enterococci* levels at Forshores beach. A sample collected on 17/4/23 from Mill Stream near Mill Stream Lookout exceeded the primary contact threshold.
Gymea Bay Baths	27/02/2023	150	39900	25/02/2023	Overflow incident had the potential to impact *Enterococci* levels. Sample collected at Gymea bay baths 25/02/2023 has exceeded the primary contact threshold.
Hayes Street Beach	14/03/2023	200	52700	16/03/2023	Overflow incident had the potential to impact *Enterococci* levels. Sample collected at confluence between Neutral Bay and stormwater channel 16/03/2023 has exceeded the primary contact threshold.
Horderns Beach	30/12/2022	51	52000	31/12/2022	Overflow incident had the potential to impact *Enterococci* levels. Sample collected at Port Hacking Bay ~30 m south east 1 Bell Place has exceeded the primary contact threshold.
Jew Fish Bay Baths	3/02/2023	72	40100	2/02/2023	Overflow incident had the potential to impact *Enterococci* levels. Sample collected at Lime Kiln Wetlands 205 m south west of 29 Beaumaris Crescent, adjacent Hurstville Golf Course 02/02/2023 has exceeded the primary contact threshold.
Kyeemagh Baths	18/04/2023	320	53400	11/04/2023	Overflow incident at Muddy Creek had the potential to impact *Enterococci* levels. Sample collected at Muddy Ck adjacent to 112 Francis Ave, Brighton Le Sands on 11/4/23 exceeded the primary contact threshold.

Site name	Sampling date	*Enterococci* (>35 cfu/100mL)	Conductivity (µS/cm)	Incident date	Comments
Sydney harbours and estuaries					
Monterey Baths	3/02/2023	110	53100	7/02/2023 10/02/23	Overflow incident had the potential to impact *Enterococci* levels. Sample collected at Kogarah Bay, in front of Wharf Road Reserve, 40 m south-east of 33 Wharf Road 07/02/2023 has exceeded the primary contact threshold. Overflow incident had the potential to impact *Enterococci* levels. Sample collected at Georges River, unnamed beach at end of Tuffy Ave, 210 m East of St George Sailing Club 10/02/23 has exceeded the primary contact threshold.
Murray Rose Pool	8/02/2023	37	52300	6/02/2023	Overflow incident had the potential to impact *Enterococci* levels. Sample collected at Double Bay, approximately 50 m north east of 91 Ocean Avenue at confluence with stormwater outlet 06/02/2023 has exceeded the primary contact threshold.
Parsley Bay	21/12/2022	200	54100	21/12/2022	Overflow incident had the potential to impact *Enterococci* levels. Sample collected at Parsley Bay Beach, 50 m west of 8 The Crescent in the centre of the beach has exceeded the primary contact threshold.
Sandringham Baths	27/02/2023	68	46600	21/02/2023 23/02/2023	Overflow incident had the potential to impact *Enterococci* levels. Sample collected at Georges River at Vanston Baths, 40 m East of 7 Vanston Parade 21/02/2023 has exceeded the primary contact threshold. Overflow incident had the potential to impact *Enterococci* levels. Sample collected at Dolls Point Beach, 250 m South of 27 Malua St Dolls Point 23/02/2023 has exceeded the primary contact threshold.

Table 6-5 Summary of the wastewater overflow impacted sites, beach suitability grades and comparison between 2021-22 and 2022-23

Region and site names	2021-22	2022-23	Trend
Sydney beaches			
Bronte Beach	Yes		Stable
Coogee Beach	Yes		Stable
Sydney harbours and estuaries			
Bayview Baths		Yes	Stable
Cabarita Beach	Yes		Stable
Chinamans Beach	Yes		Stable
Clontarf Pool	Yes		Stable
Carss Point Baths		Yes	Stable
Dolls Point Baths		Yes	Stable
Dawn Fraser Pool		Yes	Stable
Foreshore Beach	Yes	Yes	Stable
Frenchmans Bay	Yes		Stable
Gunnamatta Bay Baths	Yes		Deteriorated
Gymea Bay Baths		Yes	Stable
Hayes Street Beach	Yes	Yes	Stable
Horderns Beach		Yes	Stable
Jew Fish Bay Baths	Yes	Yes	Stable
Kyeemagh Baths		Yes	Stable
Little Manly Cove	Yes		Stable
Lilli Pilli Baths	Yes		Stable
Monterey Baths		Yes	Stable
Murray Rose Pool		Yes	Stable
Parsley Bay	Yes	Yes	Stable
Rose Bay Beach	Yes		Stable
Sandringham Baths		Yes	Stable
Tambourine Bay	Yes		Stable
Woodford Bay	Yes		Stable
Woolwich Baths	Yes		Deteriorated
Illawarra beaches			
Lake Illawarra Entrance Lagoon	Yes		Deteriorated
Total number of impacted sites	**18**	**14**	

Legend:

Yes	Potential impact from wastewater overflows
	DPE Beach suitability grade: Good or Very Good
	DPE Beach suitability grade: Fair
	DPE Beach suitability grade: Poor or Very Poor

7 Glossaries and references

7.1 Glossaries

Acronyms/ Abbreviations	Full meanings
ADCP	Acoustic Doppler Current Profile
Amm	Ammonia nitrogen
APHA	American Public Health Association
ANOSIM	Analysis of similarities
ANOVA	Analysis of variance
ANZECC	Australian and New Zealand Environment and Conservation Council.
ANZG	Australian and New Zealand Guidelines for Fresh and Marine Water Quality
AWI	Antecedent Wetness Index
AWRC	Advanced Water Recycling Centre (Upper South Creek)
AWTP	Advanced Water Treatment Plant
BNR	Biological Nutrient Removal
BOD	Biochemical Oxygen Demand
BOM	Bureau of Meteorology
BOOS	Bondi Ocean Outfall Sewer
bluegr_bv	Blue-green biovolume (phytoplankton)
CAP	Canonical Analysis of Principal coordinates
CBOD	Carbonaceous Biochemical Oxygen Demand
CCTV	Closed-Circuit Television
cfu/100mL	Colony forming units per 100 millilitres
Chla	Chlorophyll-a
Cond	Conductivity
COOS	Cronulla Ocean Outfall Sewer
CRM	Certified reference material
CTD	A CTD or Sonde is an oceanography instrument used to measure the conductivity, temperature, and pressure of seawater (the D stands for ‘depth’, which is closely related to pressure
DO	Dissolved oxygen concentration
DOMS	Deepwater Outfall Modelling System
DPE	Department of Planning and Environment
DOsat	Dissolved oxygen saturation
DWLP	Dry weather leakage program
EC_{50}	Effect Concentration for immobilization of 50% of exposed target biota
EPA	Environment Protection Authority

Acronyms/ Abbreviations	Full meanings
EPL	Environment Protection Licence
ER	Environmental Receptor
FOG	Fats, Oils and Grease
FTP	Filterable total phosphorus
hr	Hours
HRC	Healthy River Commission
IDAL	Intermittently Decanted Aerated Lagoons
IMOS	Integrated Marine Observing System
IPART	Independent Pricing and Regulatory Tribunal
IQR	Interquartile Range
KL	Kilolitre
km	kilometre(s)
LSCTUP	Lower South Creek Treatment Upgrade Program
m	metre
max	Maximum value of a set of observations
MBR	Membrane Bioreactor
MDL	Method detection limits
MOF	Maximum overflow frequency
Mean	Mean value of a set of observation
Median	Median or 50th percentile value
mg/L	milligrams per litre
Min or Minimum	Minimum value of a set of observations
mL	Millilitre
ML	Megalitre
ML/d	Megalitre per day
mm	millimetre(s)
mm^3/L	Phytoplankton biovolume millimetre cube per litre
NATA	National Association of Testing Authorities
N/A	Not applicable
NHMRC	National Health and Medical Research Council
nMDS	Non-metric multidimensional scaling
No. of Obs	Number of observations
Nox	Oxidised nitrogen
NSOOS	Northern Suburbs Ocean Outfall Sewer
NSW	New South Wales
NTU	Nephelometric Turbidity unit

Acronyms/ Abbreviations	Full meanings
ORS	Ocean Reference Station
OSP	Ocean Sediment Program
P	Pressure
p10	10^{th} percentile value of a set of observations
p20	30^{th} percentile value of a set of observations
p50	50^{th} percentile value of a set of observations
p80	80^{th} percentile value of a set of observations
PAHs	Polyaromatic hydrocarbons
PERMDISP	Distance-based test for homogeneity of multivariate dispersions
PCB	Polychlorinated Biphenyls
PCO	Principal Coordinates Ordination
PCs	Principal Component axes
PERMANOVA	Permutational Analysis of Variance
P-S-ER	Pressure, Stressor and Ecosystem Receptor (P-S-ER)
QA/QC	Quality assurance/Quality control
R	Regression co-efficient
RBA	Rapid Biological Assessment
S	Stressor
SCAMP	Sewer Catchment Area Management Plan
SIGNAL-SG	Stream Invertebrate Grade Number Average Level – Genus taxonomic level for the greater Sydney region. This is a biotic index based on freshwater macroinvertebrate diversity, abundance and tolerance to organic pollution
SIMPER	Similarity percentage
SoE	State of the Environment
SOV	System overflow volume
SRA	State Recreation Area
Stats	Statistics
SD or Stddev	Standard deviation of a set of observations
STSIMP	Sewage Treatment System Impact Monitoring Program
SWAM	Sydney Water Aquatic Monitoring (program)
SWOOS	Southern and Western Suburbs Ocean Outfall Sewer
Temp	Temperature
TN	Total nitrogen
TOC	Total organic carbon
tot_bv	Total phytoplankton biovolume
tox_bluegr_cnt	Toxic blue-green species counts (phytoplankton)
TP	Total phosphorus

Acronyms/ Abbreviations	Full meanings
Turb	Turbidity
USEPA	United States Environmental Protection Agency
UV	Ultraviolet disinfection system
WET	Whole Effluent Toxicity
WoE	Weight of Evidence
WQMF	Water Quality Management Framework
WRP	Water Recycling Plants
WRRF	Water Resource Recovery Facility
WTS	Wastewater Treatment System
WWOAP	Wet Weather Overflow Abatement Program
µg/L	micrograms per litre
µS/cm	micro Siemens per centimetre (unit of conductivity)

7.2 References

ANZECC, 2000. *Australian and New Zealand Water Quality Guidelines for Fresh and Marine Waters*, Australian and New Zealand Environment and Conservation Council.

ANZG 2018. *Guidelines for Fresh and Marine Water Quality*. Australian and New Zealand Governments and Australian state and territory governments, Canberra ACT, Australia. https://www.waterquality.gov.au/anz-guidelines

APHA, 2017. *Standard Methods for the Examination of Water and Wastewater*, 23rd Edition. American Public Health Association (APHA), American Water Works Association (AWWA) and Water Environment Federation (WEF) Washington DC

Anderson, M.J., Gorley, R.N., and Clarke, K.R., 2008. *PERMANOVA+ for PRIMER: Guide to software and statistical methods.* PRIMER-E, Plymouth, UK.

Anderson, M.J. and Walsh, D.C.I., 2013. *PERMANOVA, ANOSIM, and the Mantel test in the face of heterogeneous dispersions: What null hypothesis are you testing?* Ecological Monographs 83(4): 557-574.

AS/NZS, 2007. *Water Microbiology – Enterococci – membrane filtration method* (ISO 7899-2 :2000 MOD). Australian/New Zealand Standard Water Microbiology Method 09 (AS/.NZS 4276.9 : 2007).

Bailey, H.C., Krassoi, R., Elphick, J.R., Mulhall, A-M., Hunt, P., Tedmanson, L. and Lovell, A., 2000. ‘Application of *Ceriodaphnia dubia* for whole effluent toxicity tests in the Hawkesbury-Nepean watershed, New South Wales, Australia: Method development and validation’, *Environmental Toxicology and Chemistry:* Vol. 19, No. 1, pp. 88–93.

Besley C.H. and Chessman B.C., 2008. Rapid biological assessment charts the recovery of stream macroinvertebrate assemblages after sewage discharges cease. *Ecological Indicators* **8**, 625-638.

Bunn, S. E., 1995. Biological monitoring of water quality in Australia: Workshop summary and future directions. *Australian Journal of Ecology*, 20, 220-227

Bunn, S.E. and Davies, P.M. 2000. Biological processes in running waters and their implications for the assessment of ecological integrity. *Hydrobiologia*, 422/423, 61-70

Burgman, M., Lowell, K., Woodgate, P., Jones, S., Richards, G., and Addison, P., 2012. *An endpoint hierarchy and process control charts for ecological monitoring* in (eds) Lindenmayer, D., and Gibbons, P. Biodiversity Monitoring in Australia. CSIRO Publishing, Collingwood, Australia.

Chapman, M.G., Underwood, A.J. and Skilleter, G.A., 1995. Variability at different spatial scales between a subtidal assemblage exposed to the discharge of sewage at two control locations. *Journal of Experimental Marine Biology and Ecology* 189: 103-122.

Chessman, B.C., 1995. Rapid assessment of rivers using macroinvertebrates: a procedure based on mesohabitat-specific sampling, family-level identification and a biotic index. *Australian Journal of Ecology*, 20, 122-129.

Chessman, B.C., Growns, J.E., Kotlash, A.R., 1997. Objective derivation of macroinvertebrate family sensitivity grade numbers for the SIGNAL biotic index: application to the Hunter River system, New South Wales. *Mar. Freshwater Research.* 48: 159–172.

Chessman, B.C., 2003. New Sensitivity grades for Australian river macroinvertebrates. *Marine and Freshwater Research*, 54: 95-103.

Chessman B.C., Williams S.A. and Besley C.H., 2007. Bioassessment of streams with macroinvertebrates: effect of sampled habitat and taxonomic resolution. *Journal of North American Benthological Society 26 (3): 546-565.*

Clarke, K. R., 1993. Non-parametric multivariate analyses of changes in community structure. *Australian Journal of Ecology* 18: 117-143.

Clarke, K.R., Gorley, R.N., Somerfield, P.J. and Warwick, R.M., 2014. *Change in Marine Communities: An Approach to Statistical Analysis and Interpretation,* 3rd ed. PRIMER-E, Plymouth, U.K.

Crowe, T. P., Thompson, R. C., Bray, S. and Hawkins, S.J., 2000. Impacts of anthropogenic stress on rocky intertidal communities. *Journal of Aquatic Ecosystem Stress and Recovery* 7: 273-297.

Dakin, W.J., 1987. *Australian Seashores*. Angus & Robertson, Sydney.

Dean, K.D., 2008. The use of polychaetes (Annelida) as indicator species of marine pollution: a review. *International journal of tropical biology and conservation,* 56: 11-38.

Department of Environment and Climate Change (DECC), 2009. Load Calculation Protocol for use by holders of NSW environment protection licences when calculating assessable pollutant loads. DECC, NSW.

Doyle, C.J., Pablo, R., Lim, P.R. and Hyne, R.V., 2003. 'Assessment of metal toxicity in sediment pore water from Lake Macquarie, Australia', *Archives of Environmental Contamination and Toxicology,* 44: 343-350.

DPE, 2023. State of the Beaches 2022-23. Department of Planning and Environment, NSW Government. Annual State of the beaches reporting | NSW Environment and Heritage

DPE, 2022. State of the Beaches 2021-22. Department of Planning and Environment, NSW Government. Annual State of the beaches reporting | NSW Environment and Heritage

Edgar, G.J., 1997. *Australian Marine Life, The plants and animals of temperate waters* Reed Books, ISBN 0 07301 04745, pp 544

EP Consulting, 2003. *Shellharbour Sewage Treatment Plant Optimisation and Amplification. Intertidal and Subtidal Rocky Reef Summer and Winter Survey.* Final Report for Sydney Water Corporation. EP Consulting Group Pty Ltd. February 2003.

EPA, 1998. *Study Design for Long-Term Monitoring of Benthic Ecosystems near Sydney's Deepwater Ocean Outfalls. NSW Environment Protection Authority (EPA)* Technical Report No. 98/105.

Fairweather, P.G., 1990. Sewage and biota on seashores: assessment of impact in relation to natural variability. *Environmental Monitoring and assessment* 14:197-210.

Growns, J.E, Chessman, B.C., McEvoy, P.K. and Wright, I.A., 1995. Rapid assessment of rivers using macroinvertebrates: Case studies in the Nepean River and Blue Mountains, NSW. *Australian Journal of Ecology, 20, 130-141*

Growns, J.E., Chessman, B.C., Jackson, J.E., and Ross, D.G., 1997. Rapid assessment of Australian rivers using macroinvertebrates: cost efficiency of 6 methods of sample processing. *Journal of North American Benthological Society*, 16, 682-693.

Hawking, J.H., 2000. Key to Keys. *A guide to keys and zoological information to identify invertebrates from Australian inland waters.* Identification Guide No. 2. Second edition. Cooperative Research Centre for Freshwater Ecology, Albury.

HRC, 1998. Healthy River Commission. *Independent Inquiry into the Hawkesbury-Nepean River System. Final Report.* Healthy Rivers Commission of NSW.

Humphrey, C., Storey, A., and Thurtell, L., 1998. LWRRDC Final Report: Development and implementation of QA/QC protocols for sample processing components of the MRHI bioassessment program. *Internal report 299 Supervising Scientist, Canberra.* Unpublished paper.

Kingsford, M and Battershill, C., 1998. *Studying Temperate Marine Environments,* A handbook for ecologists, Canterbury University Press, ISBN 0 908812 54 X, pp 335.

Metzeling, L., Chessman, B., Hardwick, R. and Wong, V. 2003. Rapid assessment of rivers using macroinvertebrates: the role of experience, and comparisons with quantitative methods. *Hydrobiologia*, 510, 39-52.

Naaim, M., Ibrahim A. and Wheals, B.B., 1996. Determination of alkylphenol ethoxylate non-ionic surfactants in trade effluents by sublation and high-performance liquid chromatography. *Analyst, Vol. 121 pp. 239-42.*

NHMRC, 2008. National Health and Medical Research Council. *Guidelines for Managing Risks in Recreational Water*. Australian Government Publication Services, ISBN 1864962666

Quarry 2020. Next redevelopment phase begins for century-old quarry. Quarry 2020. https://www.quarrymagazine.com/2020/03/19/next-redevelopment-phase-begins-for-century-old-quarry

Simon, J. and Laginestra, E. 1997. '*Bioassay for testing sublethal toxicity in effluents, using gametes of the sea urchin Heliocidaris tuberculata',* National Pulp Mills Research Program, Technical Report No. 20 CSIRO, Canberra.

Simpson, S. and Batley, G., 2016. Sediment Quality Assessment. A Practical Guide (second edition) Appendix A Sediment Quality Guideline values. CSIRO 2016.

Summerhayes, S.A., Kelaher B.P., and Bishop, M.J. 2009a. Spatial patterns of wild oysters in the Hawkesbury River, NSW, Australia. *Journal of Shellfish Research* 28:447-451

Summerhayes, S.A., Bishop, M.J., Leigh, A., and Kelaher B.P., 2009b. Effects of oyster death and shell disarticulation on associated communities of epibiota. *Journal of Experimental Marine Biology and Ecology* 379:60-67.

Sydney Water, 2008. *Sewage Treatment System Impact Monitoring Program.* Sydney Water, July 2008.

Sydney Water, 2010. *Sewage Treatment System Impact Monitoring Program.* Sydney Water, December 2010.

Sydney Water, 2012. *Sewage Treatment System Impact Monitoring Program Interpretive Report 2010-11*. Sydney Water.

Sydney Water, 2020. *Ocean Sediment Program 2020 assessment year report*. Sydney Water.

Sydney Water, 2023. *Sydney Water Aquatic Monitoring (SWAM) Program*, version 1, March 2023

Sydney Water, 2023a. Water Resource Recovery Facilities: Compliance Monitoring Plan 2023-24.

Sydney Water, 2023b. *Annual Sewage Treatment System Performance Report 2022-23 - Environment Protection Licences Condition R5.5 b) and c) Reticulation System Dry Weather Overflows and Cronulla EPL U3.6, North Head EPL U9.6*. Sydney Water, September 2023.

Sydney Water, 2023c. *Sewage Treatment System Licence, Annual Sewage Treatment System Performance Report - Wet Weather Overflow, 2022–23*, Sydney Water, September 2023.

Tate, P.M., Holden, C.J. and Tate, D.J. 2019. Deepwater ocean outfalls: a sustainable solution for sewage discharge for mega-coastal cities (Sydney, Australia): Influence of plume advection and particle settling on wastewater dispersion and distribution. *Marine Pollution Bulletin*, 145, pp. 678-690.

Tjadraatmadja G and Diaper C 2006.Sources of critical contaminants in domestic wastewater – a literature review. CSIRO: Water for a Healthy Country National Research Flagship.

van Dam R, Badcock C-A, Dafforn K & Howden C 2023. Recommendations report – Findings from the independent review of Sydney Water's Sewage Treatment System Impact Monitoring Program (STSIMP). Final report prepared for Sydney Water, February 2023.

Warwick, R.M. and Clarke, K.R., 1993. Increased variability as a symptom of stress in marine taxonomic communities. *Journal of Experimental Marine Biology and Ecology* 172: 215-226

Whittaker, R.H., 1952. A study of summer foliage insect communities in the Great Smoky Mountains. *Ecological Monograms*, 22, 1-44.

Underwood, A.J. and Chapman, M.G., 1995. *Coastal Marine Ecology of Temperate Australia*. UNSW Press.

Urban Water Solutions, 2022. *Independent Criteria Review Committee to review Sewerage Trunk System Licence Models*. May 2022.

USEPA, 1998. *Organophosphorus Compounds by Gas Chromatography*. United States Environment Protection Agency, Washington, DC. Draft Update IVA, January 1998. Method 8141B.

USEPA, 2000. *Polychlorinated Biphenyls (PCBs) by Gas Chromatography*. United States Environment Protection Agency, Washington, DC. Draft Update IVB, November 2000. Method 8082a.

USEPA, 2002a. *Short-term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Freshwater Organisms*. 4th Ed. United States Environmental Protection Agency, Office of Water, Washington DC.

USEPA, 2002b. *Short-term methods for measuring the chronic toxicity of effluents and receiving waters to marine and estuarine organisms.* Third Edition. United States Environmental Protection Agency, Office of Water, Washington DC, EPA-821-R-02-014.

USEPA, 2005. *Mercury in Water by Cold Vapor Atomic Fluorescence Spectrometry*. Revision 2.0. EPA-821-R-05-001. February 2005.

USEPA, 2014. *Method 6020b inductively coupled plasma—mass spectrometry*. Rev. 2, July 2014.