Sewage Treatment System Impact Monitoring Program

Volume 1

Data Report 2019-20

Sydney WATER

Commercial-in-Confidence

Sydney Water

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Executive summary

Background

Sydney Water operates 23 wastewater treatment 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 that is required.

The Sewage Treatment System Impact Monitoring Program (STSIMP) commenced in 2008 to satisfy condition M5.1a of our EPLs. The results are reported to the NSW EPA every year. The STSIMP aims to monitor the environment within Sydney Water's area of operations to determine general trends in water quality over time, monitor Sydney Water's performance and to determine where Sydney Water's contribution to water quality may pose a risk to environmental ecosystems and human health.

The format and content of 2019-20 Data Report predominantly follows four earlier reports (2015-16 to 2018-19). Sydney Water's overall approach to monitoring (design and method) is consistent with the Australian and New Zealand Environment and Conservation Council (ANZECC 2000 and ANZG 2018) guidelines.

The STSIMP Data Report 2019-20 has been prepared to satisfy condition M5.1d of the EPLs and to provide a summary of monitoring data collected under the program. It consists of the following two volumes:

Volume 1 STSIMP Data Report 2019-20: this is the main volume of the 2019-20 report that provides a summary of all monitoring programs, monitoring methods, data analysis techniques and significant trends and/or exceedances of guidelines or EPL licence limits. It also provides a summary of wastewater overflows.

Volume 2 STSIMP Data Report 2019-20 (Appendices): includes all wastewater and environmental monitoring data, data summaries and ten yearly trend plots of all analytes measured under the EPLs. This volume is also supported by multiple electronic appendices of data summaries and raw data.

Summary of key indicator trends

A summary of EPL limit exceedances together with statistically significant increasing and decreasing trends from across the coastal and inland discharging Wastewater Treatment Plants is provided in Table ES-1. A similar summary across Hawkesbury-Nepean River sites is provided in Table ES-2 based upon ANZECC (2000 or National Health and Medical Research Council (NHMRC, 2008) guideline values.

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Table ES-1Summary of EPL limit exceedances, together with statistically significant increasing and decreasing trends of coastal and inland discharging WWTPs

Analytes ===➔	Nutrients			Conventional analytes						Trace Metals														Other chemicals/organics					
WWTPs	Ammonia nitrogen	Total nitrogen	Total phosphorus	Carbonaceous BOD	Chlorine residual (total)	Faecal coliforms	Oil and Grease	Suspended solids	EC50 Toxicity	Aluminium	Arsenic	Cadmium	Chroomium	Cobalt	Copper	Iron	Lead	Manganese	Mercvury	Molybdenum	Nickel	Selenium	Zinc	Chlorpyirfos	Cyanide	Diazinon	Hydrogen sulphide	Nonyl phenol ethoxylate	Pesticides and PCBs
Ocean plants																													
Warriewood		L																											
North Head							L																						
Bondi							C																						
Malabar							C																						
Cronulla																													
Wollongong								L																					
Shellharbour																													
Bombo																													
Storm plants (Malabar system)																													
Fairfield																													
Glenfield																													
Liverpool																													
Inland plants																													
Picton		L				C		L																					
West Camden																													
Wallacia																													
Penrith																													
Winmalee																													
North Richmond																													
Richmond						C																							
St Marys																													
Quakers Hill																													
Riverstone																													
Castle Hill																													
Rouse Hill																													
Hornsby Heights																													
West Hornsby																													
Brooklyn																													

Legend

	No statistically significant trend in 2019-20		Analytes not required in the EPL for that particular WWTP
	Statistically significant decreasing trend in 2019-20		Only monitored for load estimation. No trend analysis was carried out
	Statistically significant increasing trend in 2019-20	C	Discharge concentration outside the EPL limit
	No trend analysis conducted, most results (≥90%) below method detection limit	L	Discharge load outside the EPL limit

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Table ES-2 Summary of Hawkesbury-Nepean River water quality trends and comparison with guidelines (ANZECC 2000 or NHMRC 2008)

Site code	Description (Analytes →)	Nutrients: Ammonia nitrogen[a]	Nutrients: Oxidised nitrogen[a]	Nutrients: Total nitrogen[a]	Nutrients: Filterable total phosphrus*	Nutrients: Total phosphorus[a]	Chlorophyll-a and algae: Chlorophyll-a[a]	Chlorophyll-a and algae: Total algal biovolume*	Chlorophyll-a and algae: Blue-green algal biovolume[b]	Chlorophyll-a and algae: Toxic blue-green algal biobolume[b]	Chlorophyll-a and algae: Toxic blue-green algal count[b]	Physico-chemical analytes: Conductivity[a]	Physico-chemical analytes: Dissolved oxygen*	Physico-chemical analytes: Dissolved oxygen saturation[a]	Physico-chemical analytes: pH[a]	Physico-chemical analytes: Temperature*	Physico-chemical analytes: Turbidity[a]
N92	Nepean River at Maldon Weir		H	H													L
N75	Nepean River at Sharpes Weir	H	H	H													L
N67	Nepean River at Wallacia Bridge		H	H			H										
N57	Nepean River at Penrith Weir		H	H			H										L
N51	Nepean River opposite Fitzgeralds Creek		H	H			H										L
N48A	Nepean River at Smith Road	H	H	H			H										L
N44	Nepean River at Yarramundi Bridge	H	H	H			H										L
N42	Hawkesbury River at North Richmond		H	H			H										L
N39	Hawkesbury River at Freemans Reach		H	H			H										L
NS04A	Lower South Creek at Fitzroy Bridge	H	H	H		H	H							L			
N35	Hawkesbury River at Wilberforce	H	H	H		H	H										
NC11A	Lower Cattai Creek at Cattai Road	H	H	H		H	H							L			
N3001	Hawkesbury River at Cattai SRA		H	H		H	H										
N26	Hawkesbury River at Sackville Ferry		H	H		H	H										
N2202	Lower Colo River at Putty Road																L
N18	Hawkesbury River at Leets Vale		H	H		H	H					H					
NB13	Berowra Creek at Calabash Bay		H	H			H					H					L
NB11	Berowra Creek Off Square Bay			H			H					H					

Legend

	No significant trend	*	No guideline applicable to these analytes
	Statistically significant improving trend in 2019-20	a	ANZECC (2000) guideline applied
	Statistically significant deteriorating trend in 2019-20	b	NHMRC (2008) amber alert guideline applied
H	2019-20 median value higher than the guideline limit	L	2019-20 median value lower than the lower guideline limit

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1 Introduction

1.1 Background

One of Sydney Water's principal objectives is to minimise the impact of its operational activities on the environment. Sydney Water is 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 currently operated across the greater Sydney, Blue Mountains and Illawarra region (Figure 1-1). Generally, each wastewater treatment system consists of a Wastewater Treatment Plant (WWTP) or a Water Recycling Plant (WRP) and its reticulation system. The Malabar wastewater treatment system includes three Georges River stormwater plants (Fairfield WWTP, Glenfield WRP and Liverpool WRP), while the Wollongong wastewater treatment system includes the Bellambi and Port Kembla WWTPs. Altogether, these 16 WWTPs and 12 WRPs provide an integrated and effective wastewater treatment service to more than five million people.

The physical environment in which Sydney Water conducts its discharge operations varies widely across its area of operations. Monitoring activities cover a broad range of receiving water environments including marine, shoreline, estuarine and freshwater riverine environments. These systems are distinct in terms of the nature of the discharge operations, the nature of environmental processes and the management objectives. This distinctiveness is reflected in the design of the monitoring programs targeting the respective systems.

The Sydney, Blue Mountains and Illawarra region is a major centre of economic, industrial and agricultural activities 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 ocean, estuarine and riverine ocean environments. The challenge for Sydney Water is to identify the effects of its wastewater operations against the background of diverse human activities. Sydney Water aims to address this challenge by implementing well-designed monitoring that targets key impact indicators sensitive to Sydney Water's activities.

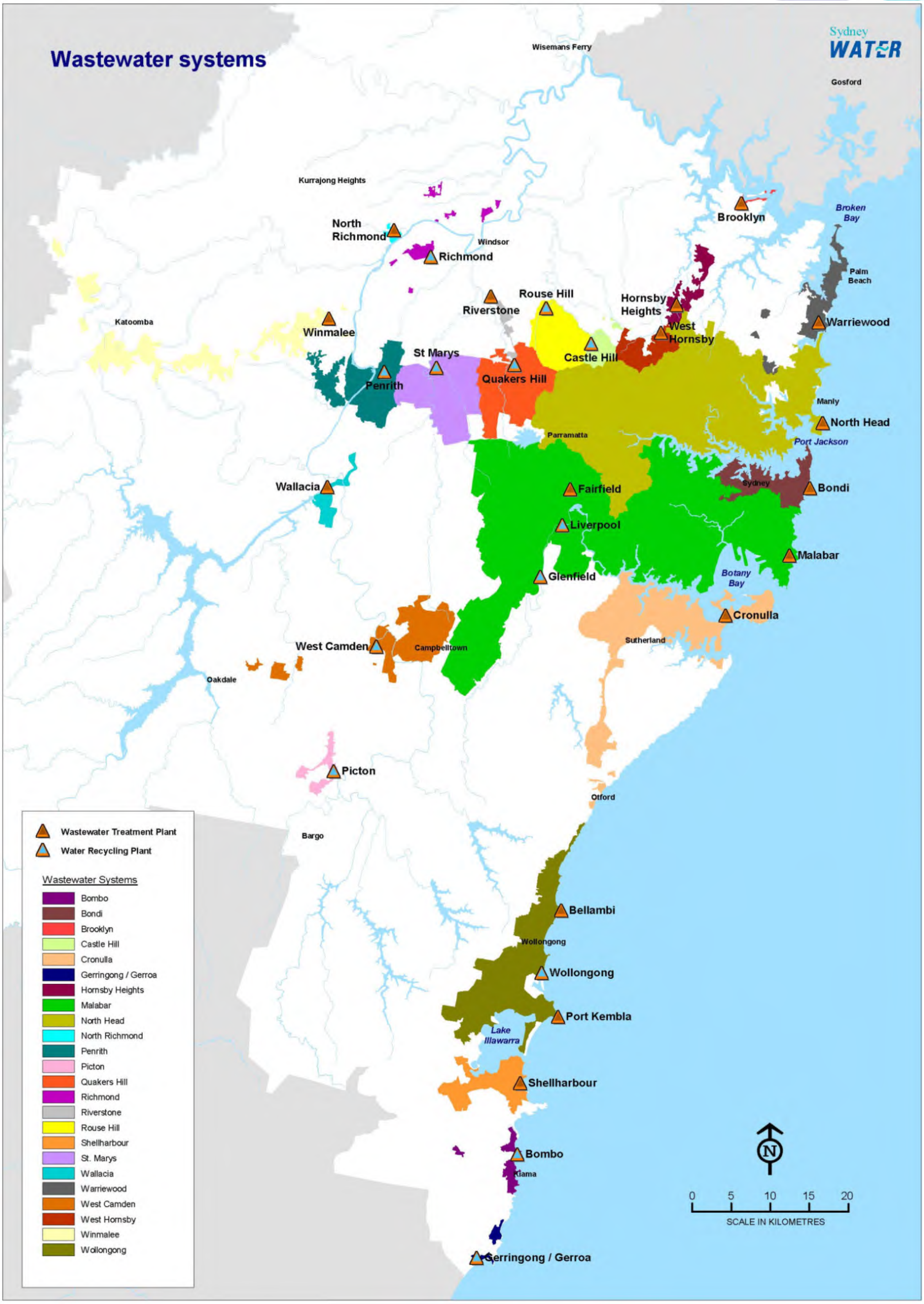
1.2 Sewage Treatment System Impact Monitoring Program

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

The STSIMP aims to monitor the environment within Sydney Water's area of operations to determine general trends in water quality over time, monitor Sydney Water's performance and to determine where Sydney Water's contribution to water quality may pose a risk to environmental ecosystems and human health. The indicators selected are based on current knowledge of the relationship between pollutants and ecological or human health impacts. The program is consistent with national water quality guidelines (ANZECC 2000/ANZG 2018), NSW State of the Environment reporting, and the objectives of previous monitoring programs undertaken by Sydney Water, NSW DPIE and other agencies.

The EPLs have referenced the STSIMP to specify environmental monitoring and reporting requirements for Sydney Water's wastewater operations. Each EPL directly specifies the types of monitoring requirements such as wastewater discharge quantity and quality, as well as performance standards. Sydney Water is required to prepare annual reports on monitoring from all these programs to assess our 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.



Note: Gerringong/Gerroa system is included for completeness. The EPL is held by Veolia Water

Figure 1-1 Wastewater treatment systems showing location of WWTPs/WRPs

Table 1-1 Summary of the monitoring program

Wastewater catchment or receiving water	Sydney Water activities	Operating WWTPs/WRPs	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 plant performance, compliance limits on discharge volumes and pollutant loads	*In-situ* online monitoring: volume of discharges (treated and partially treated). Wastewater quality: carbonaceous BOD, oil and grease, suspended solids, every six 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 plant 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 (55 sites) Some sites every six days throughout the year, others every six days during October to April and monthly during rest of the year Sydney Water only monitors 18 sites in the Illawarra region. Other data is collected by Environment, Energy and Science (EES) Branch of NSW DPIE

Wastewater catchment or receiving water	Sydney Water activities	Operating WWTPs/WRPs	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: Twenty-six 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: Eleven 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*	Wastewater quantity, quality and toxicity: To measure plant 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 WWTPs with disinfection systems), faecal coliforms, suspended solids and carbonaceous BOD, every six days; toxicity testing with *Ceriodaphnia dubia*, every month (excluding Picton); metal and organic contaminants, every month Minor plant specific variations and other requirements as per EPL

Wastewater catchment or receiving water	Sydney Water activities	Operating WWTPs/WRPs	Monitoring program and rationale	Monitoring requirements
		Quakers Hill* Riverstone Castle Hill* Rouse Hill* Hornsby Heights West Hornsby Brooklyn	Hawkesbury-Nepean River: water quality and algae Estimate trophic status, nutrient and algal dynamics, combined impact from all catchment sources	Hawkesbury-Nepean River and tributaries: Eighteen sites, every three weeks; chlorophyll-*a*, algal identification and counting triggered by elevated chlorophyll-*a* (7 µg/L), associated nutrients and physico-chemical measurements
			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 WWTPs
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 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 222 sewer catchments for sewer leakage at least once per year

* These plants are called as 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 both WWTPs and WRPs are termed as WWTPs from here and afterword.

1.1 Report structure and objectives

The STSIMP Data Report is prepared to meet condition M5.1d of the EPLs. It provides a summary of wastewater discharge quality, quantity and load data for key pollutants with respect to regulatory limits. It also provides summaries on wastewater overflows and recycled water data. Comparing environmental data (biota, water quality and algae) to established guidelines or protocols allows Sydney Water to determine the general status of each monitoring site as part of our environmental assessment of our wastewater operations. Significant trends in the latest year's data with respect to the previous nine years also allows identification of site-specific issues requiring further investigation.

The format and content of the 2019-20 Data Report is consistent with the reports submitted since 2015-16. These extended data reports were designed in consultation with NSW EPA and NSW DPIE.

The monitoring data and trends in analytes are presented following a widely used framework, the 'Pressure-State-Response (PSR)' model originally developed by the Organisation for Economic Cooperation and Developments (OECD, 1993). The PSR model is based on the linkage between human activities, the state of the environment and the social and economic responses to the environmental change.

Using this PSR approach, monitoring indicators and other information are classified according to the following three groups:

- Pressure to the environment resulting from natural and human causes eg weather, global warming, changes in land uses, pollutant loads from various human activities. The 'pressure' presented in this data report is specifically related to wastewater discharge and overflows.
- State of current quality of environment or quantity of natural resources eg river flow, receiving water quality, ecosystem health condition.
- The Response is the ultimate change or impact on the environment and how society responds to these problems eg environmental conservation activities by human beings. For this data report, the 'response' refers to Sydney Water's management actions.

A more detailed context of the PSR model and how STSIMP monitoring programs are grouped, ordered and presented in this report is summarised in Table 1-2.

The 2019-20 data report is primarily focused on the first two groups of monitoring indicators (Pressure and State) and data that were routinely collected by the STSIMP. Discussion on 'The Response' component of the framework is included as a high-level summary of Sydney Water's initiatives to minimise the impact of wastewater discharges or overflows on the environment.

All STSIMP monitoring programs, methods and relevant results are first grouped into these three broader PSR categories (pressure-state-response) and then the usual order is followed:

- Ocean catchment first and then inland catchments
- Ocean WWTPs ordered from North to South coast
- Inland WWTPs ordered from their location in upstream to downstream Hawkesbury-Nepean River catchments

- The analytes grouped first in the order of significance and then presented alphabetically.

Table 1-2 Components of PSR framework and relevant STSIMP programs/results

Model components	STSIMP monitoring programs/results	Report chapters	
		Volume 1	Volume 2
Pressure			
Wastewater discharges	Discharge volume and characteristics	2.1, 4.1 and 4.2	Appendix C and Appendix D
	Trends in wastewater quantity, quality and pollutant loads		
Wastewater overflows	Dry weather overflows	2.2.1 and 4.3.1	Appendix E
	Wet weather overflows	2.2.2 and 4.3.2	
Wastewater leakage	Dry weather leakage detection monitoring program	2.2.3 and 4.3.3	
State			
Ocean environment	Ocean receiving water	2.3.1 and 4.4.1	Appendix F
	Ocean sediment program	2.3.2 and 4.4.2	Appendix G
Coastal environment	Beachwatch – Harbour and beaches	2.4.1 and 4.5.1	Appendix H
	Chlorophyll-*a* at estuarine sites	2.4.2 and 4.5.2	Appendix I
	Water quality in lagoons	2.4.3 and 4.5.3	Appendix J
	Intertidal communities – Shoreline outfalls	2.4.4 and 4.5.4	Appendix K
	Intertidal communities of Sydney's estuaries	2.4.5 and 4.5.5	Appendix L
Riverine environment	Hawkesbury-Nepean River water quality and algae	2.5.1 and 4.6.1	Appendix M
	Hawkesbury-Nepean River –Stream health	2.5.2 and 4.6.2	Appendix N
	Other Sydney urban rivers – Stream health	2.5.3	Appendix O
Response			
Management initiatives to address the pressure	Sydney Water initiatives – WWTP upgrades, water reuse etc.	5	

The 2019-20 STSIMP data report consists of the following two volumes:

Volume 1 STSIMP Data Report 2019-20: this is the main volume of data report that provides a summary of all monitoring programs, methods of monitoring and data analyses outcomes on significant data trends and exceptions. 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 (ANZECC 2000, ANZG 2018 and NHMRC 2008).

Volume 2 STSIMP Data Report 2019-20 (Appendices): includes <u>all</u> wastewater and environmental monitoring data, data summaries and ten yearly trend plots of all analytes measured under the EPLs. This volume is also supported by multiple electronic appendices of data summaries and raw data.

The key objectives of the 2019-20 Data Report are to:

- detail the monitoring programs, sites, methods of sampling and analyses
- present the yearly wastewater discharge quantity, quality and pollutant loads data with reference to EPL limits and the previous nine years
- present wastewater overflow, leakage and recycled water data
- present data on water quality, algae and macroinvertebrates with respect to the previous nine years
- identify exceptions where results were outside the EPL limits/water quality guidelines or a significant upwards or downwards trend identified

2 Monitoring programs 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 with quality of data ensured through quality control measures.

Sydney Water Laboratory Services are part of the Integrated Management System certified to AS/NZS ISO 9001:2015 Quality management systems – Requirements under BSI number FS 663513. All analytical work is performed to the requirements of AS ISO/IEC 17025:2015 General requirements for the competence of testing and calibration laboratories. Laboratory Services is also part of Sydney Water's Environmental Management System to ISO 14001:2015 Environmental Management Systems – Requirements with guidance for use.

2.1 Wastewater discharge volume and characteristics

A summary of the monitoring program for wastewater discharge volumes and characteristics is presented in Chapter 1 (Table 1-1).

Tests conducted on the wastewater are specified under EPLs issued by the NSW EPA for WWTPs. Tests conducted vary under each EPL. Details of each EPL can be accessed via links to individual NSW EPA EPLs on the Sydney Water wastewater treatment plants web page. A summary of the tests conducted on wastewater and details of the specific method used in respective laboratory analyses is presented in Table 2-1.

Table 2-1 List of analytes and methods for wastewater quality monitoring

Analytes	Detection limit	Unit of measurement	Reference
Nutrients			
Ammonia (low level)	0.01	mg/L	APHA (2017) 4500-NH3 H
Ammonia (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			
CBOD	2	mg/L	APHA (2017) 5210B
Total chlorine (HACH)	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

Analytes	Detection limit	Unit of measurement	Reference
			collected *Ceriodaphnia dubia* by Bailey et al. (2000).
Ecotoxicological Endpoint: 1 hrs. 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
Arsenic	0.2*	µg/L	USEPA (2014) 6020B
Cadmium	0.1	µg/L	USEPA (2014) 6020B
Chromium	0.2*	µg/L	USEPA (2014) 6020B
Cobalt	0.1	µg/L	USEPA (2014) 6020B
Copper	0.5*	µg/L	USEPA (2014) 6020B
Iron	5*	µg/L	USEPA (2014) 6020B
Lead	0.1*	µg/L	USEPA (2014) 6020B
Manganese	0.5*	µg/L	USEPA (2014) 6020B
Mercury	0.01	µg/L	USEPA (2005) 245.7(Rev2.0)
Molybdenum	0.1*	µg/L	USEPA (2014) 6020B
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)

2.2 Wastewater overflows and leakage

2.2.1 Dry weather overflows

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

Dry weather overflow volumes are measured when an incident is reported to Sydney Water. The total number of overflows and the overflow volume are estimated by each Sewer Catchment Area Management Plan (SCAMP) and the proportion that reaches the receiving waters is reported via annual returns for each EPL.

2.2.2 Wet weather overflows

Wastewater overflows under wet weather conditions occur when the hydraulic capacity of the sewers or treatment capacity of WWTPs are exceeded. The primary cause of wet weather overflows includes the ingress of water via incorrectly plumbed downpipes that cause flooding of sewers, or infiltration of rainwater into a sewer via a public or private line. Saltwater ingress, particularly during large tide events is also known to affect assets located within the intertidal zone. Groundwater is similarly known to infiltrate the sewer network.

Sydney Water estimates the volume of wet weather overflows via a model 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 2020b). Each year the model is updated if significant growth or changes in the geometry or operation of the system has occurred. The model is then recalibrated using rainfall and sewer flow and level data collected during the reporting.

2.2.3 Dry weather leakage detection monitoring program

Sydney Water has divided its wastewater network into 222 individual SCAMPs, each equivalent to approximately 100 km of sewer. Dry and wet weather overflows and dry weather wastewater leakage from these catchments have the potential to impact on recreational water quality at designated swimming areas and impact 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 11 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. These areas are mostly located to the south of the city (Gerringong, Gerroa, Jamberoo etc) or in underdeveloped areas (ie Duffy's Forest). 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 at present.

The current 211 dry weather leakage detection monitoring sites are identified in Table 2-3, Figure 2-1, Figure 2-2, Figure 2-3, Figure 2-4, Figure 2-5, Figure 2-6 and Figure 2-7.

Dry weather leakage monitoring consists of three phases:

- Routine Surveillance: All 211 SCAMP sites are sampled at least once every 12 months as per the EPL requirements and are compared against the revised faecal coliform 10,000 cfu/100mL threshold (the threshold was increased from 5,000 cfu/100mL to 10,000 cfu/100mL 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.

  When a SCAMP's faecal coliform result exceeds the threshold value three years in a row, the sampling frequency automatically 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/100mL 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.

- Source Detection: 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 most facilitated following a resample exceedance.

The source detection process involves a 'catchment walk', utilising a semi instantaneous field-based ammonia test (HACH ammonia test strips) taken 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 responsible are notified and repairs requested.

All sampling and the source detection process are undertaken 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 an Antecedent Wetness Index (AWI) of less than 5 mm. The AWI is calculated using the following equation:

$$\text{AWI (today)} = 0.7 * (\text{RAIN(24hr)} + (\text{AWI(yesterday)}))$$

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 runoff 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 rain gauge. For all sites affected by tidal influence samples are collected at low tide to ensure stormwater is representative of the catchment and is not affected by incoming tides. 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 2-2 contains the list of analytes monitored for the dry weather leakage detection monitoring program. Faecal coliform laboratory analysis is completed on a composited sample, made up of two equally portioned grab samples collected five minutes apart. The faecal coliform bacterial indicator is cost effective in detecting the presence of wastewater in SCAMPS and for leakage detection investigations.

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

Water quality analyte	Detection limit	Unit	Method/Reference	Place of measurement
Faecal coliforms	<1	cfu/100mL	APHA (2017) 9222D	Laboratory
Ammonia (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	-	^{o}C	APHA (2017) 2510 B, 4500-O G, 4500-H B	Field
Field observation and assessment of wastewater indicators	-	-	-	Field

Table 2-3 List of Dry Weather Leakage Detection Program monitoring sites

System	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	No-Name Creek	-33.713491	150.700428
	PRPNR1	Penrith	1409	Peach Tree Creek	-33.749299	150.684740
	WGWAR1	Warragamba	12235	Meggaritys Creek	-33.87447	150.611411
	WLWAL2	Wallacia	12235	Scotcheys Creek	-33.8973627	150.6234339
	WMHAZ1	Hazelbrook	1963	Hazelbrook Creek	-33.71272	150.45457
	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	No-Name Creek	-33.865914	151.176522
	BNRSB1	Rose Bay	1688	Rose Bay Channel	-33.877040	151.263864
	BNSYE1	Sydney East	1688	Woolloomooloo Bay	-33.871290	151.219929
	BNSYW2	Sydney West	1688	Cockle Bay	-33.885858	151.206841
	BNVAU2	Vaucluse	1688	No-Name Creek	-33.852357	151.278351
COOS	CRBAG1	Bangor	1728	Still Creek	-34.0056477	151.0164489
	CRCRN2	Cronulla	1728	No-Name Creek	-34.054445	151.145222

System	Site Code	SCAMP	EPL	Waterway	Latitude	Longitude
	CRCRS1	Caringbah South	1728	No-Name 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
	CRMEN1	Menai	1728	No-Name Creek	-33.9880645	151.023147
	CRMIR1	Miranda	1728	Gwawley Creek	-34.0211773	151.1008282
	CRSUT1	Sutherland	1728	No-Name Creek	-34.0190038	151.0756332
	CRWOL1	Woolooware	1728	No-name Creek	-34.042972	151.112255
Illawarra	BOKIA1	Kiama	2269	No-Name Creek	-34.6773117	150.8532904
	SHALP2	Albion Park	211	No-Name 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
	WOGWY1	Gwynneville	218	No-Name Creek	-34.4163954	150.8887018
	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	No-name 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

System	Site Code	SCAMP	EPL	Waterway	Latitude	Longitude
	NHBGH1	Balgowlah Heights	378	No-Name 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	No-Name Creek	-33.745528	151.291260
	NHCMR1	Cromer	378	South Creek	-33.732287	151.276400
	NHCRM1	Cremorne	378	No-Name 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
	NHGIW1	Girraween	378	Girraween Creek	-33.783487	150.952245
	NHGLF1	Guildford	378	Duck Creek	-33.835973	151.011882
	NHGRW1	Greenwich	378	No-Name Creek	-33.826493	151.159794
	NHHOL1	Holroyd	378	A'Becketts Creek	-33.827284	151.010063
	NHHOR1	Wahroonga	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	Chatswood West	378	Swaines Creek	-33.798949	151.161888

System	Site Code	SCAMP	EPL	Waterway	Latitude	Longitude
	NHMNY2	Manly Beach	378	Manly Beach	-33.7958739	151.2878308
	NHMOS1	Mosman	378	No-name Creek	-33.8268207	151.2515979
	NHMQP1	Macquarie Park	378	Shrimptons Creek	-33.774865	151.122591
	NHNEP1	North Epping	378	No-Name Creek	-33.750955	151.084174
	NHNPR1	North Parramatta	378	Hunts Creek	-33.781766	151.024995
	NHNRB1	Naremburn	378	No-Name Creek	-33.813078	151.199429
	NHNRD1	North Ryde	378	No-Name Creek	-33.806494	151.137870
	NHNSY1	North Sydney	378	No-Name Creek	-33.841224	151.198286
	NHPAR1	Parramatta	378	Parramatta River	-33.811823	151.007205
	NHPNH1	Pendle Hill	378	Pendle Creek	-33.784264	150.955375
	NHRSH1	Rosehill	378	No-Name Creek	-33.817711	151.020613
	NHRSV1	Roseville	378	Moores Creek	-33.770158	151.195439
	NHRYD1	Ryde	378	Strangers Creek	-33.810789	151.129099
	NHRYL1	Rydalmere	378	No-Name Creek	-33.817501	151.040676
	NHSEA1	Seaforth	378	Burnt Bridge Creek	-33.787393	151.266574
	NHSIL1	Silverwater	378	No-name Creek	-33.849943	151.052336
	NHSVH1	Seven Hills	378	No-Name 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	Chatswood West	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

System	Site Code	SCAMP	EPL	Waterway	Latitude	Longitude
	NHWTH1	Winston Hills	378	No-name Creek	-33.783138	150.972779
	NHWTU1	West Turramurra	378	No-Name 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	No-name Creek	-33.9074255	151.193935
	MAARN1	Arncliffe	372	No-Name Creek	-33.932051	151.154151
	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	No-Name Creek	-33.983475	151.120173
	MABKN1	Bankstown	372	Salt Pan Creek	-33.932122	151.036489
	MABKS1	Banksia	372	No-name Creek	-33.945399	151.148868
	MABLM1	Belmore	372	No-Name Creek	-33.903962	151.094790
	MABLS1	Belmore South	372	Cup and Saucer Creek	-33.916499	151.119752
	MABOT1	Botany	372	No-name 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	No-name Creek	-33.93276	150.97659
	MACGE1	Coogee	372	Coogee Beach	-33.919310	151.259620
	MACHF2	Malabar beach	372	Malabar Beach	-33.960834	151.249372

System	Site Code	SCAMP	EPL	Waterway	Latitude	Longitude
	MACMP1	Campsie	372	No-name Creek	-33.9036447	151.0991055
	MACNE1	Concord East	372	No-Name Creek	-33.856988	151.107213
	MACNW1	Concord West	372	No-name Creek	-33.840861	151.092278
	MACPN1	Chipping Norton	372	Drain to Amaroo Wetland	-33.908043	150.982269
	MACTB1	Canterbury	372	No-Name Creek	-33.8991517	151.1046665
	MADRU2	Drummoyne	372	No-name Creek	-33.852161	151.135765
	MADUL1	Dulwich Hill	372	No-name Creek	-33.910280	151.138630
	MAEAR1	Earlwood	372	No-name Creek	-33.916518	151.132011
	MAEGV1	Eagle Vale	372	Thompson Creek	-34.021200	150.839360
	MAFAR1	Fairfield	372	No-Name Creek	-33.8785305	150.9538165
	MAFVD1	Five Dock	372	No-name 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	No-Name 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	No-Name Creek	-33.925091	151.221139
	MAKGB1	Kogarah Bay	372	No-Name Creek	-33.990013	151.137847
	MAKOG1	Kogarah	372	No-Name 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	No-Name Creek	-33.931867	150.924800
	MALNV1	Lansvale	372	Long Creek	-33.888413	150.957380
	MALUG1	Lugarno	372	Boggywell Creek	-33.979833	151.050782

System	Site Code	SCAMP	EPL	Waterway	Latitude	Longitude
	MAMAR1	Maroubra	372	No-Name Creek	-33.958894	151.224938
	MAMAS1	Mascot	372	No-Name 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	No-name Creek	-33.946403	151.258109
	MAMRV2	Marrickville	372	No-name Creek	-33.9193193	151.1540963
	MAPAD1	Padstow	372	No-name Creek	-33.933018	151.042154
	MAPAN1	Panania	372	Kelso Creek	-33.947767	150.995946
	MAPHS1	Penhurst	372	To Poulton Creek	-33.984288	151.096078
	MAPKH1	Peakhurst	372	No-name 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	No-Name 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	Marrickville	372	No-Name Creek	-33.921699	151.156777
	MAVIL1	Villawood	372	Prospect Creek	-33.876239	150.962858
	MAWAK1	Wakeley	372	Orphan School Creek	-33.874598	150.916618
	MAWOD1	Woodbine	372	Bow Bowing Creek	-34.034790	150.831703
	MAWPK1	Wetherill Park	372	Orphan School Creek	-33.867378	150.912881
	MAYEN1	Yennora	372	Prospect Creek	-33.871080	150.960428
Warriewood	WWAVA1	Avalon	1784	Careel Creek	-33.627118	151.333409

System	Site Code	SCAMP	EPL	Waterway	Latitude	Longitude
	WWELH1	Elanora Heights	1784	Mullet Creek	-33.691922	151.282893
	WWNEW1	Newport	1784	McMahons Creek	-33.657814	151.315693
Brooklyn	BKBKL1	Brooklyn	12438	Hawkesbury River	-33.548675	151.228709
West Camden	WCCMD1	Camden	1675	No-Name 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
Western Sydney	CHCHS1	Castle Hill STS	1725	Cattai Creek	-33.7122818	150.9837967
	HHHHT1	Hornsby Heights	750	Walls Gully	-33.670957	151.102368
	NRNRC1	North Richmond	190	Redbank Creek	-33.572819	150.730599
	PRMRV1	Mount Riverview	1409	No-name Creek	-33.731120	150.651241
	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
	RHRHL1	Rouse Hill	4965	Smalls Creek	-33.687804	150.943774
	RMRIC2	Richmond	1726	No-Name Creek	-33.596998	150.763076
	RSRVS1	Riverstone	1796	No-Name Creek	-33.675420	150.857906
	SMBCT1	Blackett	1729	Little Creek	-33.722022	150.798306
	SMMDR1	Mount Druit	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
	WHCHB1	Cherrybrook	1695	Pyes Creek	-33.704180	151.053207
	WHTHO2	Thornleigh	1695	Waitara Creek	-33.702315	151.080528

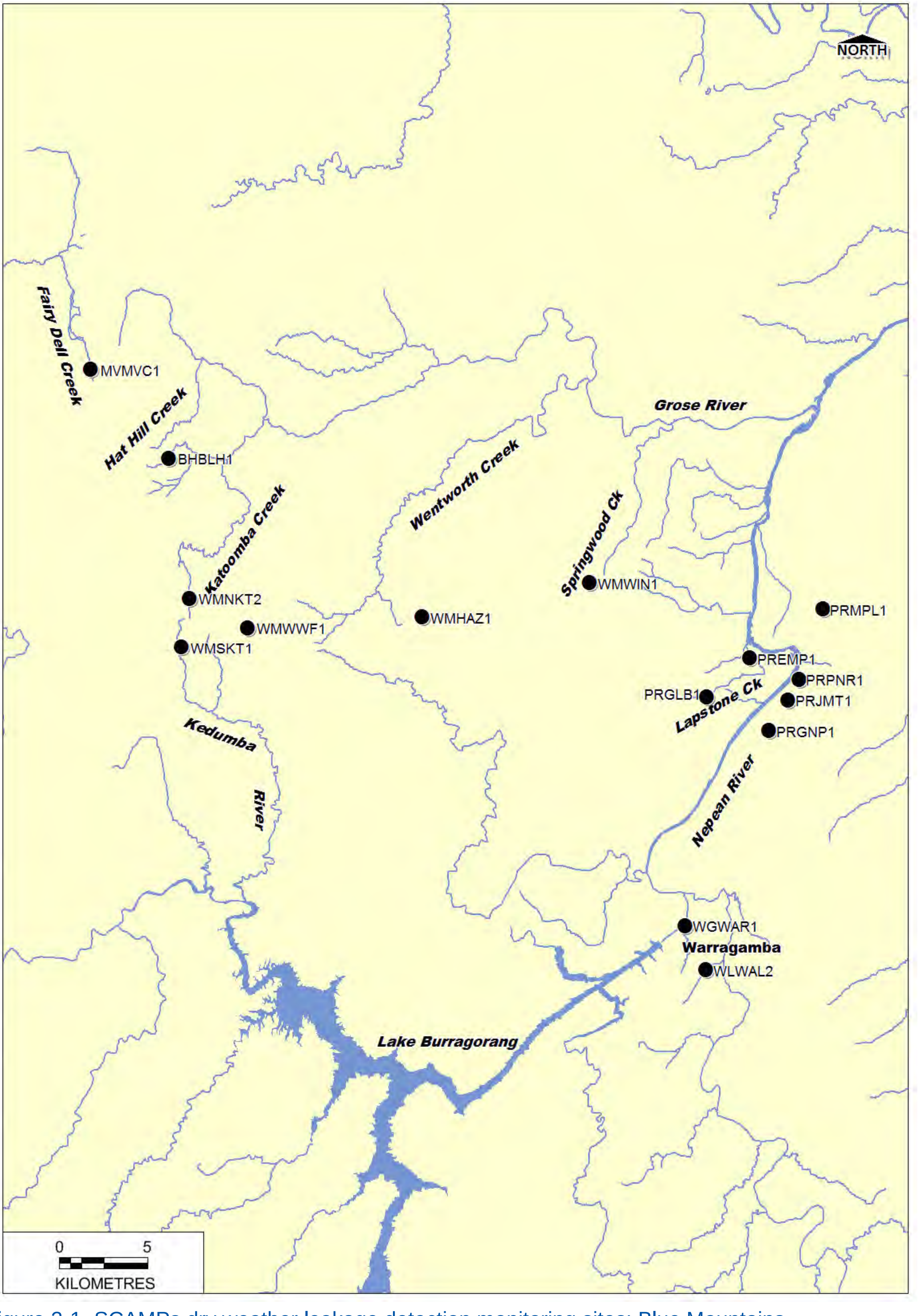


Figure 2-1 SCAMPs dry weather leakage detection monitoring sites: Blue Mountains

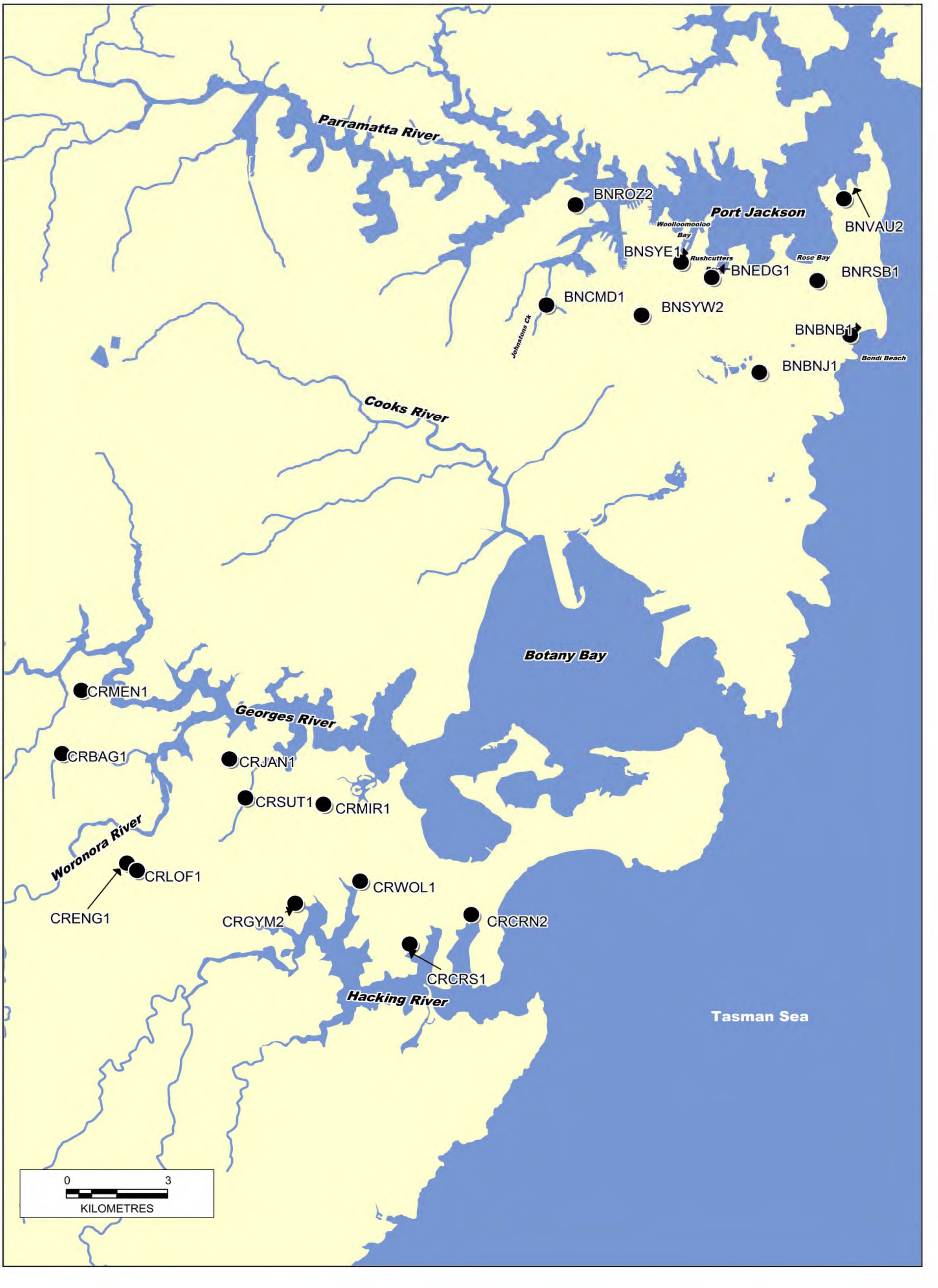


Figure 2-2 SCAMPs dry weather leakage detection monitoring sites: Bondi Ocean Outfall System and Cronulla Ocean Outfall System

Figure 2-3 SCAMPs dry weather leakage detection monitoring sites: Illawarra

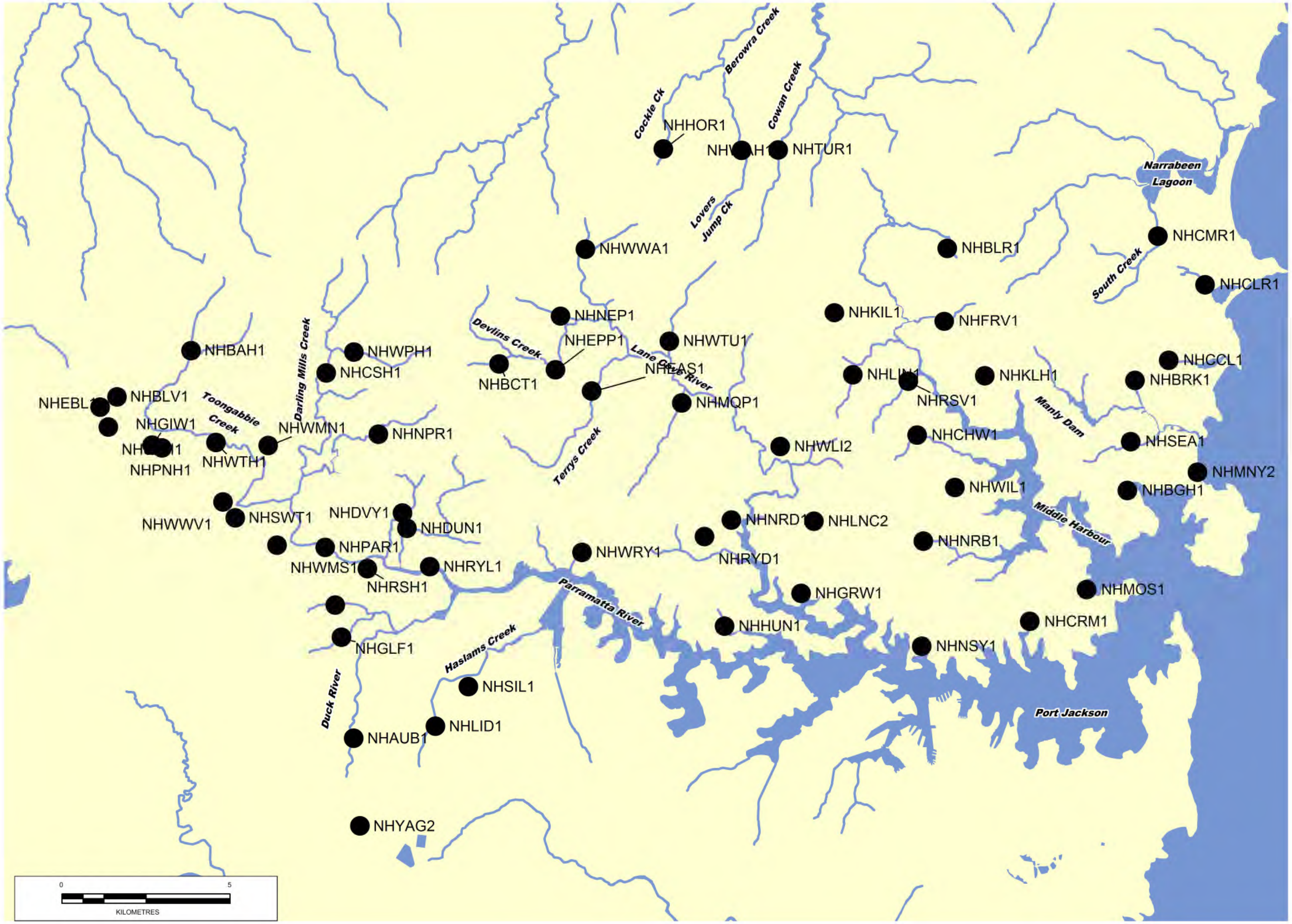


Figure 2-4 SCAMPs dry weather leakage detection monitoring sites: Northern Suburbs Ocean Outfall System

Figure 2-5 SCAMPs dry weather leakage detection monitoring sites: South Western Ocean Outfall System

Figure 2-6 SCAMPs dry weather leakage detection monitoring sites: Warriewood and Brooklyn

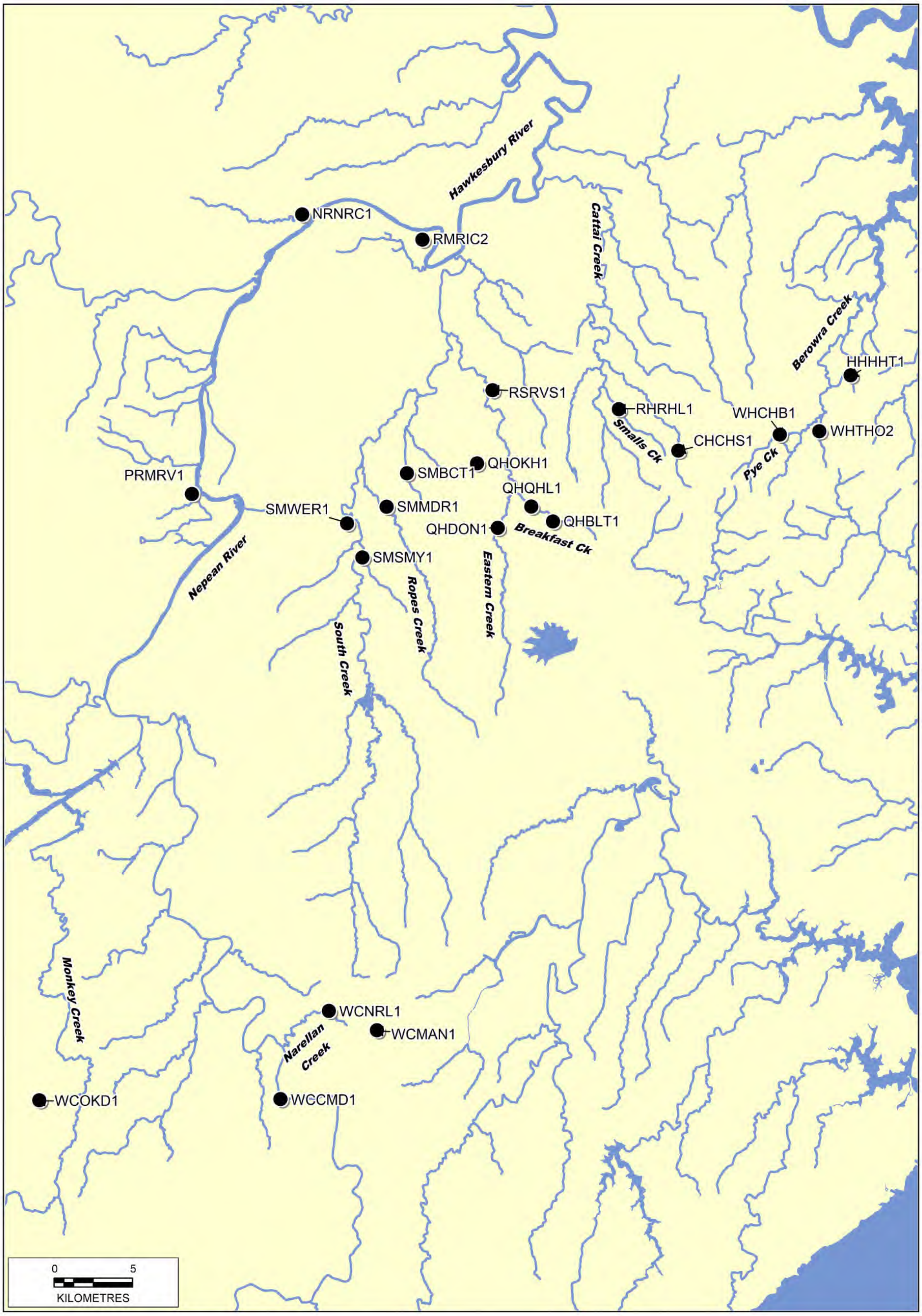


Figure 2-7 SCAMPs dry weather leakage detection monitoring sites: Western Sydney and West Camden

2.3 State of ocean environment

This section describes the two key monitoring programs implemented by Sydney Water to understand the state of ocean environment in relation to deepwater ocean outfalls.

2.3.1 Ocean receiving water

Sydney Water has collected oceanographic data from the Ocean Reference Station (ORS) mooring, located approximately 3 km east of Bondi Beach in waters approximately 67 m deep, since 1990. The ORS underwent a major re-configuration in May 2006. Since 2006, the ORS instrumentation includes:

- a bottom mounted Acoustic Doppler Current Profiler (ADCP) returning 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
- two conductivity, temperature and depth (CTD) sensors located about 10 m above the sea floor and about 10 m below the sea surface.

All data are recorded at 5 min intervals. The ORS is serviced (nominally monthly) to upload data from the instruments.

The ORS measures current speed and direction throughout the water column while a series of temperature sensors estimate the water density profile. Wind data are obtained from the Bureau of Meteorology's weather station located at Sydney Airport. Wastewater flow volume is obtained from gauging stations at the North Head, Bondi and Malabar WWTPs.

These data are used:

- to assess the oceanographic processes that affect the advection and dispersion of Sydney Water discharges to the marine environment
- as input to a suite of numerical models to estimate the location and dilution of the wastewater plumes and particle settle setting.

Transfer functions were developed to ensure continuity between data collected from earlier configurations of the ORS and the post 2006 setup.

Data are provided to the EPA within approximately two weeks of servicing of the system.

Provisions for data loss

Based on experience with similar non-real-time systems, Sydney Water expects to achieve a data recovery rate more than 90%. Small data gaps (approximately 2 hours in duration) occur each month due to the servicing and data download processes. These data gaps can be patched using standard oceanographic techniques such as splines, spectral methods or neural networks.

Equipment failure

Most oceanographic equipment presently available is highly reliable and equipment failure is unlikely. The most likely fault is battery failure, although the use of lithium batteries reduces this risk. Such a failure is normally not recognised until the system is serviced. For such a scenario, up to one month of data may be lost. With monthly servicing, the loss of an entire month of data still provides 92% data recovery, well in excess of the 85% recovery criteria by the EPA. The present system has been operating for approximately 14 years with no major data loss.

Implications for the modelling if data are lost

Data losses for short periods (eg a few hours during servicing) have virtually no implication for modelling. If large volumes of data such as an entire month of data is lost, data patching will be required. These include building a statistical profile for each month (based on historical data) and inserting this into the data set, with appropriate warnings or using another alternative data substitution technique such as a neural network.

Modelling pollutant dispersion from Deepwater Ocean Outfalls

Predictive models are used to determine the location and dilution of the deepwater ocean outfall plumes using data from the ORS. As more than 90% of the dispersion of the wastewater from the deepwater ocean outfalls occurs in the near-field, near-field models are used.

The near-field model (PLOOM) was developed specifically for Sydney's deepwater ocean outfalls and has been appropriately calibrated and validated. The PLOOM3 version of the model has been used to estimate the behaviour of the three deepwater ocean outfalls at North Head, Bondi and Malabar since 2006.

The near-field model is run annually, undertaking simulations every hour. Output from the near-field model include:

- the distance to the boundary of the initial dilution zone
- the 3D trajectory of the wastewater plume
- the dilution of the wastewater plumes. These data are combined with data on the concentrations of a range of contaminants in the wastewater resulting in the concentration of contaminants at the boundary of the initial dilution zone.

The distance from the discharge point to the boundary of the initial dilution zone varies considerably, depending on ocean and discharge conditions. It is defined to occur when the vertical momentum and buoyancy of the wastewater are the same as that of the surrounding water. The near-field model automatically outputs this distance. The initial dilution zone is also referred to as the initial mixing zone or the end of the near-field.

Modelled wastewater concentrations are raised for the initial dilution zone and compared to ANZG (2018) water quality guidelines to assess the environmental performance of the deepwater ocean outfalls in protection of marine species. This information allows Sydney Water to assess the environmental performance of the deepwater ocean outfalls of North Head, Bondi and Malabar.

2.3.2 Ocean sediment program

Rationale

Sydney Water undertakes the Ocean Sediment Program (OSP) as a condition of the EPL for the North Head, Bondi and Malabar wastewater treatment systems. The OSP was developed through discussions between the EPA and Sydney Water and is based on recommendations in Study Design for Long-term Monitoring of Benthic Ecosystems near Sydney's Deepwater Ocean Outfalls (EPA, 1998).

The objectives of the program are to determine:

- any chronic impact of discharging wastewater from Sydney's deepwater ocean outfalls; and
- if the impact of discharging wastewater from the Malabar outfall is increasing in spatial extent.

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 1999, 2002, 2005, 2008, 2011, 2014 and 2016. This year (2020) is an assessment year in line with the STSIMP interpretive reporting schedule.
- '**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, 2018, 2019, 2021 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.

Between 1999 and 2010, sampling was undertaken at 11 locations (22 sites) between Terrigal in the north and Shoalhaven Bight in the south (Table 2-4) as set out under the 1998 design (EPA 1998).

The OSP was revised by the EPA in July 2010. The new program comprised a reduced number of locations to nine (18 sites) between Long Reef and Marley (Figure 2-8) and collecting a reduced number of samples during the surveillance years (Table 2-5). This change to the program saw removal of the two distant control sites (Terrigal and Shoalhaven Bight) with the three closer control sites being retained (Long Reef, Port Hacking and Marley Beach).

The 2019-20 is an assessment year when a separate STSIMP interpretive report is produced on the Ocean Sediment Program data. That report explores data trends with those recorded under other earlier assessment years (2002 to 2016). Outcomes of the 2002 to 2016 assessment years were published in the August 2019 Marine Pollution Bulletin (Besley and Birch, 2019a, 2019b, 2019c; Manning et al 2019; Tate et al. 2019).

Table 2-4 Ocean sediment program sampling sites

Site code	Site description	Easting (grid centre)	Northing (grid centre)
T-1C*	Terrigal 1, 60m	364288.53	6292802.11
T-2C*	Terrigal 2, 60m	365981.63	6298198.85
LR-1C	Long Reef 1, 60m	349791.41	6266903.05
LR-2C	Long Reef 2, 60m	349315.23	6264892.5
NH-1C	North Head 1, 60m	347436.95	6257934.94
NH-2C	North Head 2, 60m	347463.41	6256056.66
B-1C	Bondi 1, 60m	343415.85	6248226.1
B-2C	Bondi 2, 60m	344024.31	6250792.2
MO-1C	Malabar 0km S 1, 80m	342807.4	6238966.99
MO-2C	Malabar 0km S 2, 80m	343468.76	6239125.72
M3-1C	Malabar 3km S 1, 80m	341378.85	6236506.71
M3-2C	Malabar 3km S 2, 80m	341590.48	6236612.53
M5-1C	Malabar 5km S 1, 80m	340638.12	6234628.44
M5-2C	Malabar 5km S 2, 80m	340902.67	6234469.71
M7-1C	Malabar 7km S 1, 80m	339527.03	6233041.16
M7-2C	Malabar 7km S 2, 80m	339394.75	6232723.7
PH-1C	Port Hacking 1, 80m	336749.29	6228649.7
PH-2C	Port Hacking 2, 80m	336749.29	6228411.6
MB-1C	Marley Beach 1, 80m	331643.55	6221348.22
MB-2C	Marley Beach 2, 80m	331722.92	6221163.04
SB-1C*	Shoalhaven Bight 1, 80m	310030.14	6138174.95
SB-2C*	Shoalhaven Bight 2, 80m	310056.6	6137810.41
SB-3C*	Shoalhaven Bight 3, 80m	310400.51	6137672.32
SB-4C*	Shoalhaven Bight 4, 80m	310532.78	6137360.68

* sampling and analysis discontinued from July 2010

Table 2-5 Ocean sediment program sampling and analytical requirements

Site codes	Assessment years										Surveillance years							
	Number of sites (one sample per site)										Number of sites (one sample per site)							
	Collection/ subsampling		Analysis						Benthos counts		Collection/ subsampling		Analysis				Benthos counts	
			TOC and GS		Chem1		Chem2						TOC and GS		Chem1 and Chem2			
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
T-1C*	10		5		5		0		5		10		5		0		0	
T-2C*	10		5		5		0		5		10		5		0		0	
LR-1C	10	5	5	5	5	5	0	0	5	5	10		5		0		0	
LR-2C	10	5	5	5	5	5	0	0	5	5	10		5		0		0	
NH-1C	10	5	5	5	5	5	5	5	5	5	10	5	5	5	0		0	
NH-2C	10	5	5	5	5	5	5	5	5	5	10	5	5	5	0		0	
B-1C	10	5	5	5	5	5	0	0	5	5	10	5	5	5	0		0	
B-2C	10	5	5	5	5	5	0	0	5	5	10	5	5	5	0		0	
M0-1C	10	10	5	5	5	5	5	5	10	10	10	10	5	5	0		10	10
M0-2C	10	10	5	5	5	5	5	5	10	10	10	10	5	5	0		10	10
M3-1C	10	5	5	5	5	5	0	0	5	5	10		5		0		0	
M3-2C	10	5	5	5	5	5	0	0	5	5	10		5		0		0	
M5-1C	10	5	5	5	5	5	0	0	5	5	10		5		0		0	
M5-2C	10	5	5	5	5	5	0	0	5	5	10		5		0		0	
M7-1C	10	5	5	5	5	5	0	0	5	5	10		5		0		0	
M7-2C	10	5	5	5	5	5	0	0	5	5	10		5		0		0	
PH-1C	10	5	5	5	5	5	0	0	5	5	10		5		0		0	
PH-2C	10	5	5	5	5	5	0	0	5	5	10		5		0		0	
MB-1C	10	5	5	5	5	5	0	0	5	5	10		5		0		0	
MB-2C	10	5	5	5	5	5	0	0	5	5	10		5		0		0	
SB-1C*	10		5		5		0		5		10		5		0		0	
SB-2C*	10		5		5		0		5		10		5		0		0	
SB-3C*	10		5		5		0		5		10		5		0		0	
SB-4C*	10		5		5		0		5		10		5		0		0	

Notes:

*not sampled since 2008

A = Pre June 2010

B = July 2010 onwards

Shading = samples not required

TOC = Total organic carbon

GS = grain size (%gravel; %sand: %fines)

Chem1 = metals/metalloids; naphthalene; m-cresol

Chem 2 = PAHs; o-cresol; 2-chlorophenol; organochlorine pesticides; PCBs; total Kjeldahl nitrogen; phosphorus

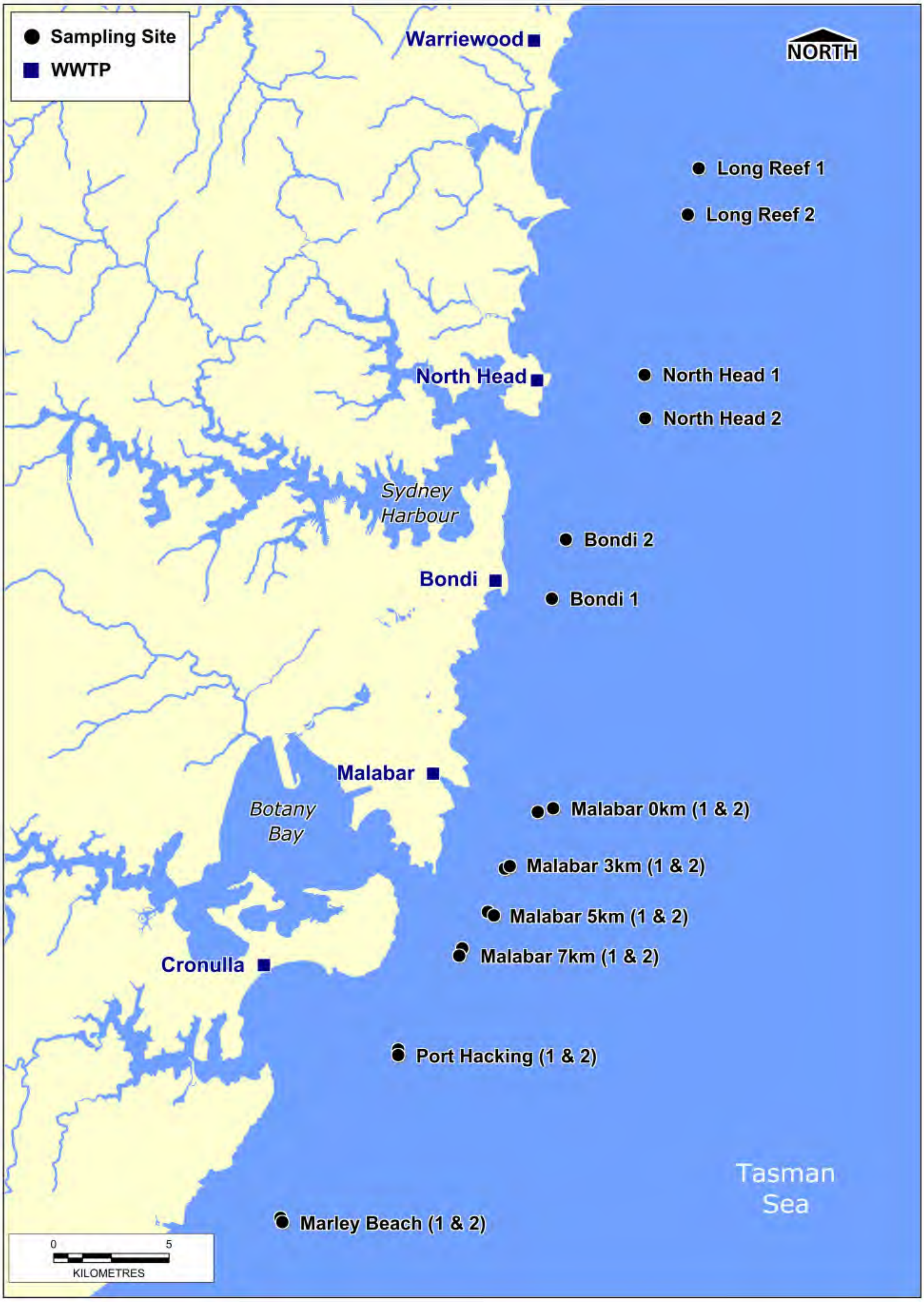


Figure 2-8 Ocean sediment program sampling sites from July 2010

2.4 State of coastal environment

This section describes five major monitoring programs to understand the overall ambient condition of Sydney and Illawarra's coastal environment. These programs are tailored to know the general state of environment and to find (where possible) any linkage between wastewater overflows from Sydney Water's networks reaching the environment.

2.4.1 Beachwatch

Rationale

Sydney Water contributes to DPIE's Beachwatch Monitoring Program by collecting samples and taking conductivity measurements from the Illawarra beaches. Sydney Water also provides instruments and support to DPIE for conductivity monitoring at all other Beachwatch sites monitored by DPIE. In turn, results from DPIE's Beach Monitoring Program are made available to Sydney Water for assessment of potential dry weather wastewater leakage issues.

Beachwatch monitoring program overview

Enterococci and conductivity data are collected predominantly by DPIE for the Beachwatch program. Forty one Sydney coastal beaches and 55 harbour beaches of Botany Bay, lower Georges River, Port Hacking, Port Jackson, Middle Harbour and Pittwater are monitored by DPIE at locations listed in Table 2-6 and Table 2-7 as part of the Beachwatch Program. Location maps for these Beachwatch sites are provided in Figure 2-9 to Figure 2-12. Sydney Water monitors 18 Illawarra coastal beach monitoring sites on behalf of DPIE (Table 2-8).

Sydney and Illawarra coastal beach sites are monitored for *Enterococci* and conductivity (Table 2-9) at six-day intervals throughout the year, except Austinmer, Thirroul and Kiama, which are only monitored from October to April. Harbour beaches are monitored for *Enterococci* at six-day intervals from October to April and monthly outside of this period.

Please see the Beachwatch website for more information on this program (https://www.environment.nsw.gov.au/topics/water/beaches/beachwatch-water-quality-program).

Table 2-6 List of Sydney coastal beach monitoring sites, monitored by DPIE

Northern Sydney	Central Sydney	Southern Sydney
Palm Beach	Bondi Beach	Boat Harbour
Whale Beach	Tamarama Beach	Greenhills
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		

Northern Sydney	Central Sydney	Southern Sydney
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 2-9 Sydney coastal beach monitoring sites

Table 2-7 List of Beachwatch harbour monitoring sites, monitored by DPIE

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	Redleaf Pool or Murray Rose 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				

Figure 2-10 Beachwatch monitored harbour sites in Botany Bay, Georges River and Port Hacking

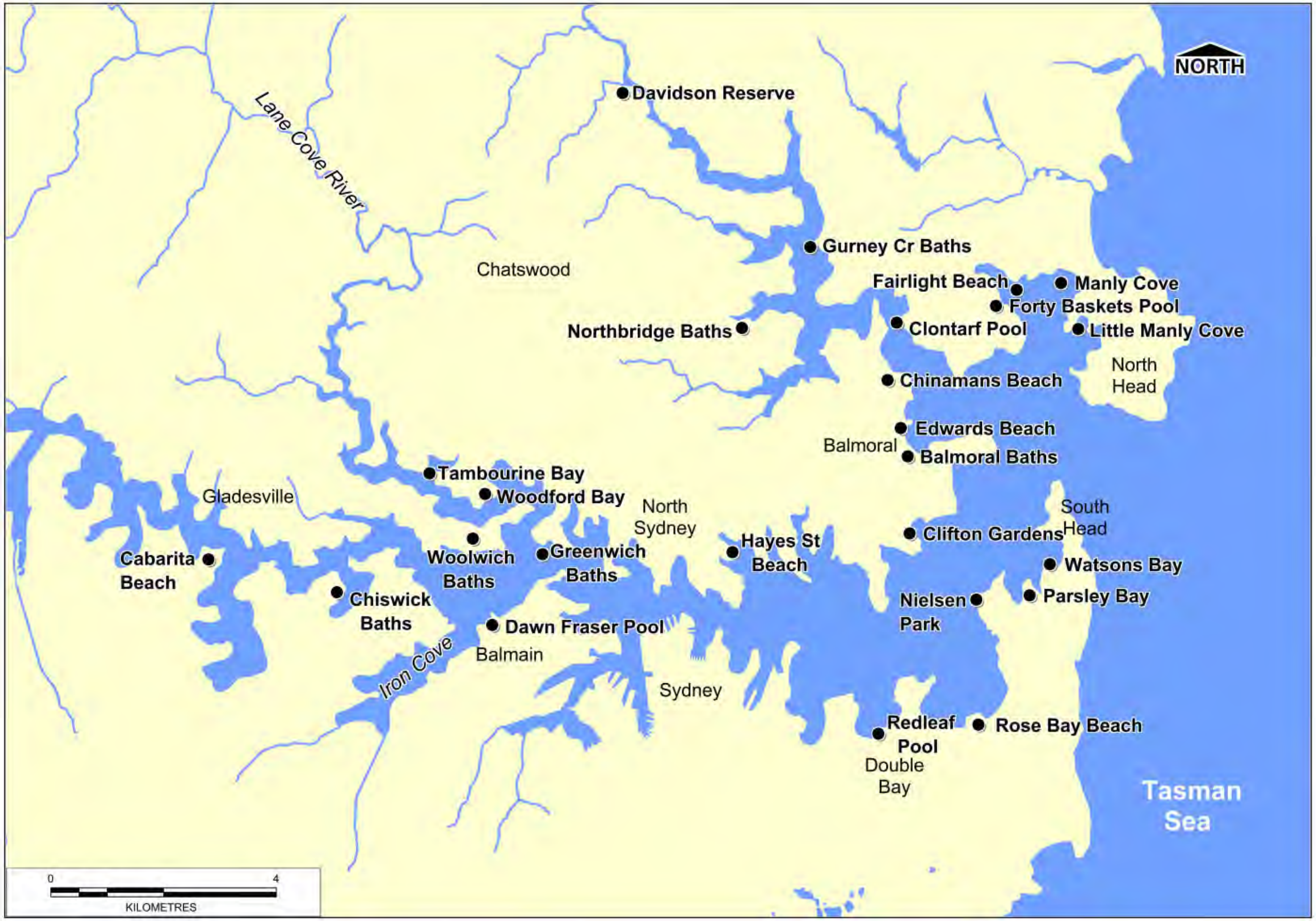


Figure 2-11 Beachwatch monitored harbour sites in Middle Harbour and Port Jackson

Figure 2-12 Beachwatch monitored harbour sites in Pittwater

Table 2-8 List of Illawarra beach monitoring sites monitored by Sydney Water on behalf of DPIE

Wollongong	Shellharbour	Bombo
Austinmer Beach	Entrance Lagoon Beach, Lake Illawarra Beach	Boyd's Beach
Thirroul Beach	Warilla Beach	Bombo Beach
Bulli Beach	Shellharbour Beach	Kiama beach
Wonoona Beach		Werri Beach
Bellambi Beach		
Corrimal Beach		
North Wollongong Beach		
Wollongong Beach		
Coniston Beach		
Fisherman's Beach		
Port Kembla Beach		

Table 2-9 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	0	cfu/100mL	AS/NZS 4276.9 :2007	Laboratory

Figure 2-13 Illawarra coastal beach monitoring sites

2.4.2 Chlorophyll-*a* at estuarine sites

Rationale

The estuarine water quality monitoring program was rationalised in 2008 based on the review and assessment on earlier monitoring data. Chlorophyll-*a* was chosen as a sole indicator for eutrophication impacts at key sites in estuaries. In many cases, and where possible, these sites have been chosen at or near existing Beachwatch sites in consideration of links to algal blooms and potential adverse public health outcomes.

Monitoring Program

The 16 estuarine sampling sites for chlorophyll-*a* monitoring are listed in Table 2-10 and shown in Figure 2-14, including the organisation responsible for sampling (DPIE collect samples from some of the sites as part of the Beachwatch program). It is noted, should any of these sampling sites be enclosed bathing areas, then sampling is to be undertaken in open waters in the vicinity of 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 2-10 List of chlorophyll-*a* monitoring sites

Estuary	Site code	Site description	Sample collection by
Port Jackson	PJDR	Davidson Reserve	DPIE
	PJCB1	Chinamans Beach	DPIE
	PJLC	Lane Cove River Weir	Sydney Water
	PJTB	Lane Cove River (near Tambourine Bay)	DPIE
	PJPRA	Parramatta River Weir	Sydney Water
	PJ015	Parramatta River at Ermington	Sydney Water
	PJCB2	Cabarita Beach	DPIE
	PJDFP	Dawn Fraser Pool	DPIE
Botany Bay	CR04A	Alexandria Canal	Sydney Water
	GR01	Cooks River (downstream Muddy Creek)	Sydney Water
	GR22	Liverpool Weir	Sydney Water
	GR19	Upper Georges River (downstream of Harris Creek)	Sydney Water
	GROB	Oatley Baths	DPIE
	GRRB	Ramsgate Baths	DPIE
	GRFB	Frenchman's Bay	DPIE
Port Hacking	PHLPB	Lilli Pilli Baths	DPIE

Figure 2-14 Estuarine chlorophyll-a monitoring sites

2.4.3 Water quality in lagoons

Monitoring Program

All water quality monitoring sites for the coastal lagoons are listed in Table 2-11 and shown in Figure 2-15. From 2008, routine and campaign style monitoring were introduced in coastal lagoons monitoring program. In routine years, conductivity, chlorophyll-*a* and *Enterococci* are monitored at monthly intervals (Table 2-12). Once every three years these are monitored more frequently at six day intervals. Last year was the Campaign year with intensive monitoring data (2018-19). These high frequency campaign monitoring data are used for a more comprehensive assessment on recreational water quality of these lagoons.

Table 2-11 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, 150m 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 2-12 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	0	cfu/100mL	AS/NZS 4276.9 :2007	Laboratory

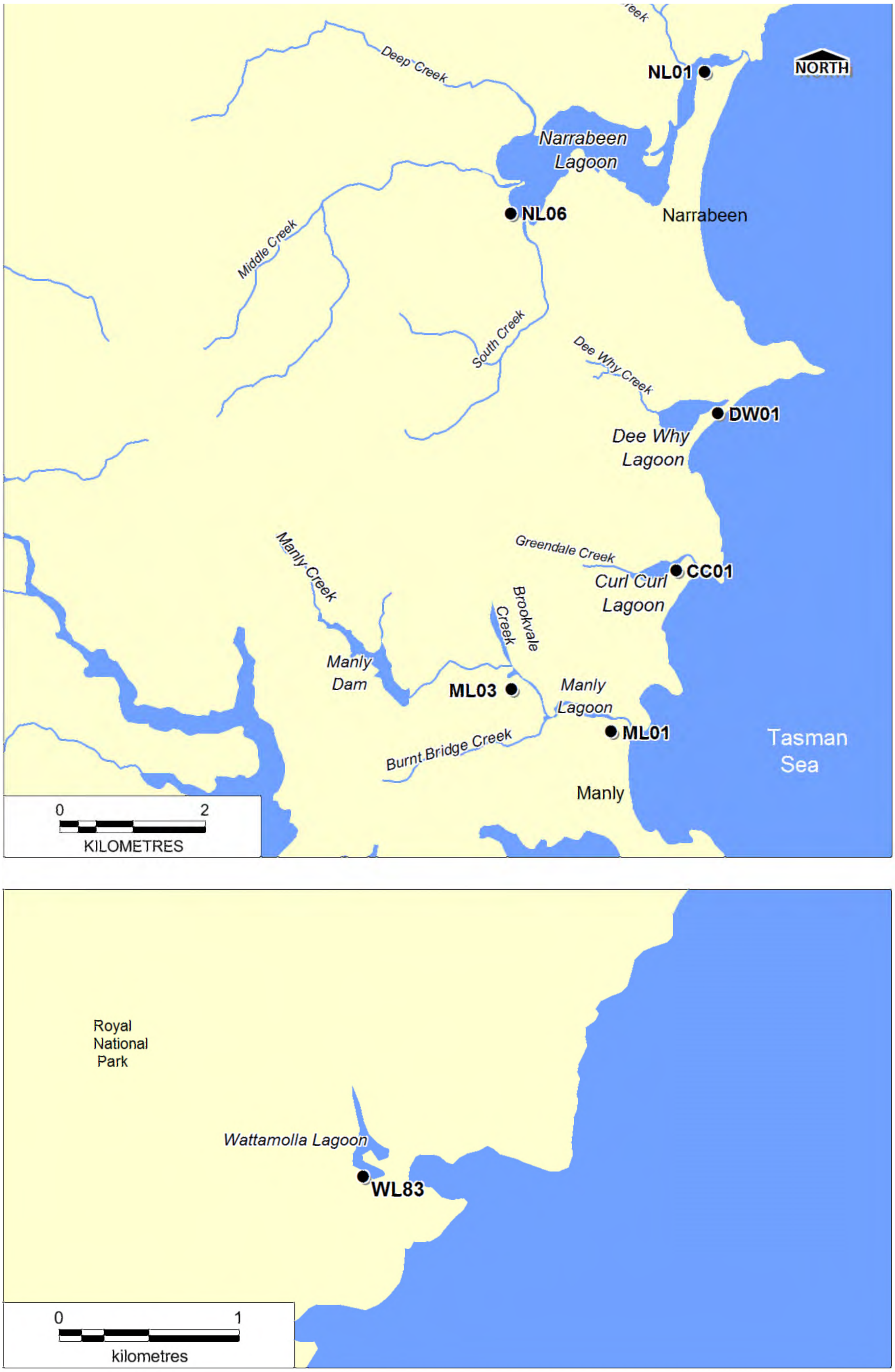


Figure 2-15 Chlorophyll-*a* monitoring sites, lagoons

2.4.4 Intertidal communities – Shoreline outfalls

Rationale

The aim of the shoreline outfall program is to assess any significant change in ecological communities from Sydney Water's WWTPs discharging into the nearshore ocean environment.

Sydney Water operates five WWTPs that discharge treated wastewater of differing quality into nearshore marine environments. Sydney Water's EPLs permit an impact within the wastewater mixing zone (a zone in which the salinity is below that of normal seawater). Nevertheless, Sydney Water's shoreline outfalls may impact the local aquatic ecology outside the mixing zone.

The upgrade of the Shellharbour WWTP in the mid-2000s ameliorated the former impact with green algal dominance in the intertidal shoreline community. Krogh (2000) has summarised the impacts of wastewater discharge from shoreline ocean outfalls in NSW. The most obvious and often quoted impact of wastewater outfalls in NSW is their effect on the proportion (% cover) of the green alga *Ulva lactuca* on rocks close to the outfall. Where this has been measured, the % cover of *Ulva lactuca* usually increases considerably at the outfall sites and for some distance from the outlet (Krogh, 2000). Krogh (2000) also states:

> 'In association with an increase in *Ulva lactuca* near outfalls, there has usually been a decrease reported in the diversity of other algal species. The diversity of brown and red algal species in particular, is often reduced in the vicinity sewerage outfalls (e.g. Borowitzka 1972, May 1981, 1985, Fairweather 1990, Brown et al. 1990, Banwell 1996, Campbell and Burridge 1998).'

Overseas studies (Littler and Murray 1975, 1978) have also reported a dominance of green algae (*Chlorophyta*) and a reduction in brown algae (*Phaeophyta*) surrounding the point of wastewater discharge. Prior to the upgrade of the Shellharbour WWTP in the mid-2000s, EP Consulting (2003) recorded a localised impact along 50 m of the shoreline at the Shellharbour outfall site where the intertidal community was characterised by an extensive cover of green macroalgae, a relative lack of brown macroalgal taxa and a low cover of a red macroalgal taxa.

The EP Consulting (2003) survey also showed an almost complete absence of the faunal community at the Shellharbour outfall site. That survey result was in line with a worst case cited by Krogh (2000) of Fairweather (1990) who found gross reductions in species diversity in intertidal areas around Potter Point, Malabar, Bondi and North Head outfalls, with an almost complete absence of animals.

The works of Krogh (2000) and EP Consulting (2003) help us understand what floristic and faunal impacts look like in the intertidal zone. This understanding of the former impact is used in assessing post-upgrade data collected for Shellharbour under the STSIMP.

Monitoring Program

In the mid-2000's, an assessment of accessibility to the five outfall sites identified a health and safety access issue to all but one outfall (Shellharbour). The rock platform at Turimetta Headland (Warriewood WWTP discharge area) is flat with frequent wave wash up to the vertical cliff. On the day of inspection, the waves were approximately only 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.

At Shellharbour 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 two 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. Monitoring is undertaken at Shellharbour and the two control sites in late winter to spring (Table 2-13 and Figure 2-16).

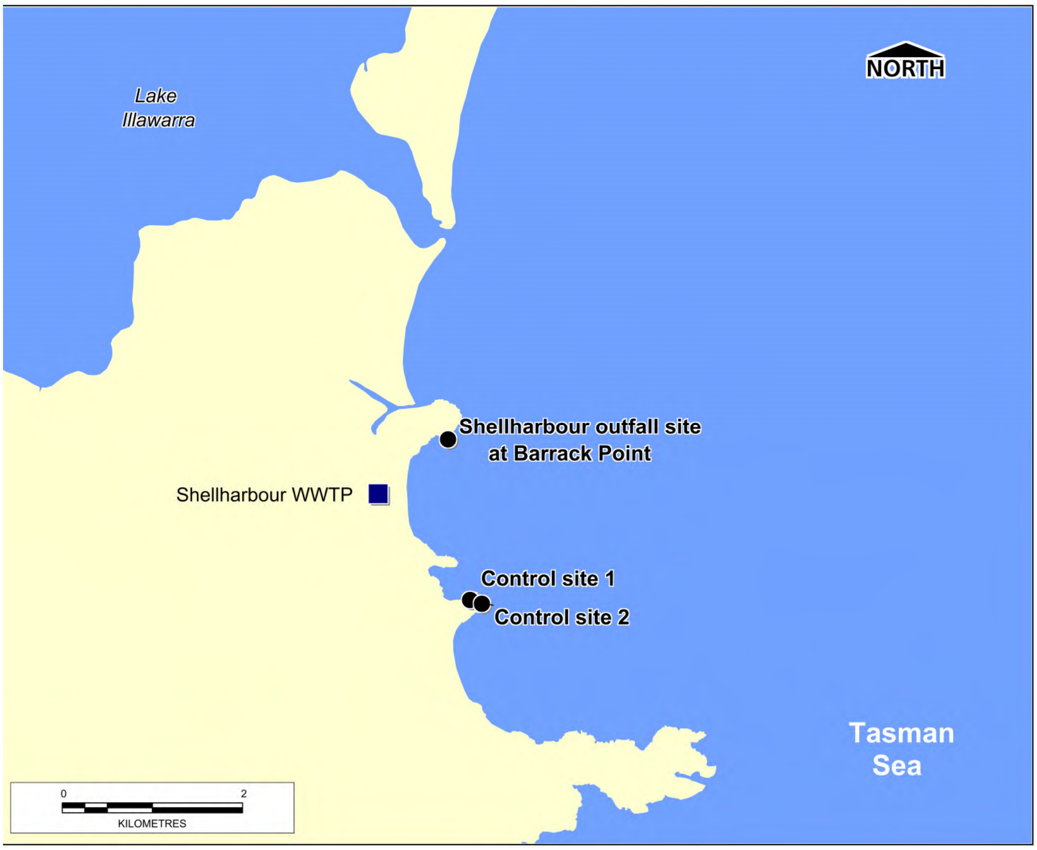


Figure 2-16 Shoreline outfall monitoring at Shellharbour

Table 2-13 Shoreline outfall monitoring sites

Monitoring site	Wastewater quality	Longitude	Latitude
Warriewood (WWTP)*	Secondary		
Diamond Bay (Vaucluse)*	Untreated		
Cronulla (WWTP)*	Tertiary		
Bombo (WWTP)*	Secondary		
Shellharbour (WWTP) at Barrack Point	Secondary	150.8736	34.5638
Control site 1: Northern side of Shellharbour Headland	No outfall	150.8758	34.5796
Control site 2: Eastern side of Shellharbour Headland	No outfall	150.8772	34.5800

* Included for completeness but Health and Safety risk prevents monitoring of these outfalls

2.4.5 Intertidal communities of Sydney's 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 2-14 and Figure 2-17). Monitoring in this period reduces the influence of annual recruitment of most species of settling larvae 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). Seven randomly allocated quadrats are measured at each site.

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

Four hardwood panels are deployed for four months of exposure (January to May and July to November each year) in the intertidal zone. The majority of 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 2-14 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	-33.8302
	PJ082	Iron Cove-Hawthorn Canal arm	151.15007	-33.87219
	PJ115	Lavender Bay	151.2074	-33.84414
	PJ33	Rushcutters Bay	151.23158	-33.87167
	PJ13	Little Sirius Cove	151.23773	-33.84083
	PJ28	Quakers Hat Bay	151.2391	-33.81562
	PJ05	Lane Cove River-Woolwich Baths	151.17029	-33.83905
	PJ295	Sugarloaf Bay-Castlecrag, control site	151.23058	-33.7912
	PJ315	Bantry Bay, control site	151.22978	-33.77867
	PJ245*	Balmoral	151.2524	-33.82292
Botany Bay	CR04	Alexandra Canal at Canal Bridge Road	151.1791	-33.91997
	CR06	Wolli Creek	151.1537	-33.92685
	GR01	Cooks River (d/stream Muddy Creek)	151.1605	-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	-33.9946
	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	151.1630093	-33.46997634
	NB115**	Kimmerikong Bay Hawkesbury River	151.155948	-33.549288
	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 two 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 two sites situated east of the Brooklyn Road bridge in 2012 to replace N06 and NB115

Figure 2-17 Estuarine intertidal communities monitoring sites

2.5 State of riverine environment

This section describes three monitoring programs designed to understand the state of the riverine environment notably the Hawkesbury-Nepean River where 15 inland WWTPs discharge treated wastewater routinely.

2.5.1 Hawkesbury-Nepean River water quality and algae

Rationale

Sydney Water operates 15 WWTPs in the greater Hawkesbury-Nepean River catchment. In addition to regular discharges from Sydney Water WWTPs, there are numerous point and diffuse sources of pollution to the river such as wastewater discharges from council WWTPs and agricultural and urban runoff. Sydney Water's Hawkesbury-Nepean River water quality and algae monitoring program is designed to monitor the direct impacts of Sydney Water's activities and additional ambient environmental conditions.

Algal blooms in the Hawkesbury-Nepean River have been acknowledged as a river management issue in the past. The key drivers for these blooms are a combination of flow, temperature, light penetration, water clarity and nutrient levels.

The intent of the water quality and algae monitoring program for inland waters is to measure the dynamics of algal growth, standing crop and diversity of algal species.

Monitoring Program

The receiving water quality and algae status is assessed at 13 sites along the Hawkesbury-Nepean River from the upstream freshwater reaches of the Nepean River at Maldon to downstream Hawkesbury River at Leets Vale. Another five sites are monitored in four major tributaries, namely South Creek, Cattai Creek, Colo River and Berowra Creek.

Field measurements and samples are collected on a three-weekly basis from 18 sites as listed in Table 2-15 and Figure 2-18. From each site, 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 approximately 100 m apart while the second method is to obtain samples from one site approximately five minutes apart. Each replicate is made up of a composite of the two samples collected, where possible, at a depth of 0.5 m below the surface.

Field measurements (Table 2-16) are taken at each site after sample collection on one of the replicate samples. Samples are analysed in Sydney Water Laboratories by NATA (National Association of Testing Authorities) accredited methods for the selected water quality analytes that can affect algal growth (Table 2-16).

Algal abundance and identification to genus level are determined when chlorophyll-*a* concentration exceeds 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).

Quality control samples are also collected and analysed as part of this program. A duplicate is collected on each run and a field blank / trip blank is collected on alternate runs. That is, if a field blank is collected one month, a trip blank should be collected the following month.

Table 2-15 List of Hawkesbury-Nepean River water quality and algae monitoring sites

Site code	Description	Longitude	Latitude
N92	Nepean River at Maldon Weir, control site, upstream of all Sydney Water WWTPs	150.630	-34.2036
N75	Nepean River at Sharpes Weir, downstream of Matahil Creek and West Camden WWTP	150.677	-34.0415
N67	Nepean River at Wallacia Bridge, upstream of Warragamba River	150.636	-33.8670
N57	Nepean River at Penrith Weir, upstream of Penrith WWTP	150.684	-33.7432
N51	Nepean River opposite Fitzgeralds Creek, downstream of Penrith WWTP	150.657	-33.7150
N48A	Nepean River at Smith Road, upstream of Winmalee WWTP	150.663	-33.6701
N44	Nepean River at Yarramundi Bridge, downstream of Winmalee WWTP	150.698	-33.6146
N42	Hawkesbury River at North Richmond, downstream of Grose River	150.723	-33.5868
N39	Hawkesbury River at Freemans Reach, downstream of North Richmond WWTP	150.747	-33.5700
NS04A	Lower South Creek at Fitzroy Bridge, Windsor	150.825	-33.6067
N35	Hawkesbury River at Wilberforce, downstream of South Creek	150.838	-33.5730
NC11A	Lower Cattai Creek at Cattai Road	150.908	-33.5576
N3001	Hawkesbury River at Cattai SRA, downstream of Cattai Creek	150.889	-33.5583
N26	Hawkesbury River at Sackville Ferry, downstream of Cattai Creek	150.876	-33.5007
N2202	Lower Colo River at Putty Road, control site	150.829	-33.4325
N18	Hawkesbury River at Leets Vale, downstream of Colo River	150.948	-33.4280
NB13	Berowra Creek at Calabash Bay	151.118	-33.5869
NB11	Berowra Creek, Off Square Bay	151.148	-33.5667

Table 2-16 List of analytes and methods for the Hawkesbury-Nepean River water quality and algae monitoring program

Water quality analyte	Detection limit	Unit of measurement	Method/Reference	Place of measurement
Nutrients				
Ammonia nitrogen	0.01	mg/L	APHA (2017) 4500-NH3-H	Laboratory
Oxidised nitrogen	0.01	mg/L	APHA (2017) 4500 NO3-I	Laboratory
Total nitrogen	0.05	mg/L	APHA (2017) 4500-Norg/NO3-	Laboratory
Filterable total phosphorus	0.002	mg/L	APHA (2017) 4500-P-H	Laboratory
Total phosphorus	0.002	mg/L	APHA (2017) 4500-P-H	Laboratory
Chlorophyll-*a* and algae				
Chlorophyll-*a*	0.2	µg/L	APHA (2017) 10200-H ½	Laboratory
Algal biovolume and cell count *	-	mm^3/L and cells/mL	APHA (2017) 10200-F	Laboratory
Other physico-chemical analytes				
Conductivity	-	µS/cm	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
pH	-	pH unit	APHA (2017) 2510 B, 4500-O G, 4500-H B	Field
Temperature	-	ºC	APHA (2017) 2510 B, 4500-O G, 4500-H B	Field
Turbidity	-	NTU	APHA (2017) 2130 B	Field

* when chlorophyll-*a* exceeds 7 µg/L

Figure 2-18 Hawkesbury-Nepean River water quality and algae monitoring sites

2.5.2 Hawkesbury-Nepean River – Stream health

Rationale

Sydney Water monitors freshwater macroinvertebrate communities upstream and downstream of WWTP discharge to determine if stream health is altered by treated wastewater (Volume 2: Appendix N).

Macroinvertebrates are small animals without a backbone that can be seen without a microscope. They live on the surface or in the sediments of water bodies. They include many insect larvae, for example mosquitoes, dragonflies and caddisflies. Other examples of common macroinvertebrates include crustaceans (such as crayfish), snails, worms and leeches. Macroinvertebrates can populate ponds or streams in large numbers, some of them up to thousands in a square metre.

A healthy stream is comprised of many different types of macroinvertebrate animals. The types present will vary according to natural factors such as stream type, altitude and geographic region. The types present will also vary according to human disturbance, particularly water pollution. Water pollution in a stream will change the macroinvertebrate assemblage in a predictable way. As the level of pollution increases, the more sensitive macroinvertebrate animals become excluded or lost. A natural waterway that is not impacted by human activity will include a large proportion of sensitive macroinvertebrate animals that represent high stream health. A more disturbed or polluted stream has a higher proportion of insensitive types of macroinvertebrate animals present, representative of lower stream health.

Sydney Water has assessed 'stream health' with the Stream Invertebrate Grade Number Average Level (SIGNAL-SG) biotic index tool. 'S' indicates Sydney region version and 'G' indicates taxonomy is at the genus taxonomic level. This tool provides a sensitivity score for a macroinvertebrate sample and can range from 1 to 10. The latest version of SIGNAL-SG has determined sensitivity grades of 367 genera over the greater Sydney region according to increasing organic pollution and takes into account stream type and altitude (Chessman et al. 2007). The SIGNAL-SG biotic index has been demonstrated as an easily communicated measure of wastewater impacts on macroinvertebrates in Blue Mountain streams (Besley and Chessman 2008).

Biotic indices used in other parts of the world include the ASPT index in Britain (Hawkes, 1997), the ASPT index of the South African Scoring System (SASS: Dickens and Graham, 2002), the Spanish average Biological Monitoring Water Quality (a-BMWQ) score (Camargo, 1993), the New Zealand Macroinvertebrate Community Index (MCI) and its quantitative and semi-quantitative equivalents (Stark, 1998; Stark and Maxted, 2007), and the North Carolina Biotic Index (Lenat, 1993). The conceptual basis underlying all of these indices is that in the presence of stressors such as organic pollution, taxa that are sensitive to the stressors tend to be eliminated or greatly reduced in abundance. Conversely, tolerant taxa persist, and may multiply as a result of less competition or predation, or because their food supply is increased by organic or nutrient enrichment. Consequently, stress results in a decline in the average sensitivity value of the taxa and individual organisms that are collected. Index scores therefore act as indicators of the presence and intensity of those stressors to which the index is attuned (Besley and Chessman 2008).

The primary degrading process to urban streams is suggested to be 'effective imperviousness' (Walsh et al. 2005a), provided sewer overflows, wastewater treatment WWTP discharges, or long-lived pollutants from earlier land uses are not operable as these can obscure stormwater impacts

(Walsh et al. 2005b). Walsh et al. (2005a) defines ‘effective imperviousness’ as the proportion of a catchment covered by impervious surfaces directly connected to the stream by stormwater pipes. Walsh (2004) determined macroinvertebrate community composition was strongly explained by the gradient of urban density and that most sensitive taxa were absent from urban sites with greater than 20% connection of impervious surfaces to streams by pipes. The direct connection of impervious surfaces, such as roofs, gutters, roads, paths and car parks to a stream allows small rainfall events to produce surface runoff that cause frequent disturbance to the stream through regular delivery of water and pollutants (Walsh et al. 2005a). Given this direct connection between a stream and sources of surface runoff in urban and rural streams, even small rainfall events can produce measurable impacts on stream health above WWTPs. As such, upper catchment stream health may limit downstream stream health in urban and rural streams. It is from this background we are assessing potential stream health changes from wastewater discharge.

Monitoring Program

Freshwater macroinvertebrates are monitored at upstream and downstream site pairs for 12 WWTPs (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.

Paired upstream-downstream sites are located near the WWTPdischarge (Table 2-17 and Figure 2-19) on the receiving stream. In the case of North Richmond, Penrith and West Camden 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 Winmalee, the unnamed stream to which Winmalee WWTP discharges is ephemeral, this prevents the upstream-downstream design applied to other WWTP discharge points. Below the Winmalee WWTP 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.

The collection of macroinvertebrates is based on relatively inexpensive but efficient rapid assessment methods (e.g. Chessman, 1995; Turak et al. 2004). Macroinvertebrates are collected in autumn and spring from up to four distinct habitats (pool edges, pool rock, macrophytes, and riffles) of the river or stream. Different groups of animals occur within these habitats and the most sensitive assessment is achieved by sampling as many habitats as possible at each study site. If only one habitat is available from a site a replicate sample is taken.

Freshwater macroinvertebrate samples are sorted in the field to obtain the range of animals present at each site. Sorted collections of freshwater macroinvertebrates are then returned to Sydney Water’s laboratory facility 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).

Figure 2-19 Hawkesbury-Nepean River freshwater macroinvertebrates monitoring sites

Table 2-17 List of Hawkesbury-Nepean River freshwater macroinvertebrates monitoring sites

Site codes	Site description	Longitude	Latitude
N7825	Matahil Ck, upstream of West Camden WWTP	150.679	34.0640
N7824	Matahil Ck, downstream of West Camden WWTP	150.684	34.0578
N78	Nepean R at Macquarie Grove Rd, upstream of West Camden WWTP	150.694	34.0430
N75	Nepean R at Sharpes Weir, downstream of West Camden WWTP	150.677	34.0415
N67	Nepean R at Wallacia Bridge, upstream of Warragamba River	150.637	33.8651
N642A	Warragamba R upstream riparian release pt., upstream of Wallacia WWTP	150.607	33.8761
N641	Warragamba R Norton Basin, downstream of Wallacia WWTP	150.611	33.8618
N57	Nepean R at Penrith Weir, upstream of Penrith WWTP	150.684	33.7432
N53	Nepean R at BMG Causeway, downstream of Penrith WWTP	150.679	33.7332
N542	Boundary Ck, upstream of Penrith WWTP	150.702	33.7444
N541	Boundary Ck, downstream of Penrith WWTP	150.692	33.7433
N48	Nepean R at Smith Rd, upstream of Winmalee WWTP	150.663	33.6701
N462	Unnamed Ck, downstream of Winmalee WWTP	150.638	33.6563
N461	Unnamed Ck 3km downstream N462, further downstream of Winmalee WWTP	150.656	33.6704
N44	Nepean R at Yarramundi Bridge, downstream of Winmalee WWTP	150.698	33.6146
N42	Nepean R at North Richmond, upstream of North Richmond WWTP	150.723	33.5868
N40	Nepean R, downstream of North Richmond WWTP	150.744	33.5705
N412	Redbank Ck, upstream of North Richmond WWTP	150.710	33.5777
N411	Redbank Ck, downstream of North Richmond WWTP	150.719	33.5774
N38	Hawkesbury River at Windsor Bridge, upstream of South Creek	150.816	33.6064
NS082	Eastern Ck, upstream of Riverstone WWTP	150.851	33.6695
NS081	Eastern Ck, downstream of Riverstone WWTP	150.846	33.6680
NS090	Breakfast Ck, upstream of Quakers Hill WWTP	150.884	33.7450
NS087	Breakfast Ck, downstream of Quakers Hill WWTP	150.872	33.7361
NS26	South Ck, upstream of St Marys WWTP	150.758	33.7428
NS23	South Ck, downstream of St Marys WWTP	150.760	33.7333
N35	Hawkesbury R at Wilberforce, downstream of South Ck, upstream Cattai Ck	150.838	33.5730
NC8	Cattai Ck, upstream of Castle Hill WWTP	150.982	33.7143
NC75	Cattai Ck, downstream of Castle Hill WWTP	150.982	33.7084
NC53	Second Pond Ck, upstream of Rouse Hill WWTP	150.912	33.6805
NC515	Second Pond Ck, downstream of Rouse Hill WWTP	150.923	33.6662
NC5*	Cattai Ck Annangrove Road, downstream of both Rouse Hill and Castle Hill WWTPs	150.929	33.6603
N26	Hawkesbury R at Sackville Ferry, downstream of Cattai Creek	150.876	33.5007
NB83	Waitara Ck, upstream of West Hornsby WWTP	151.079	33.7045
NB825	Waitara Ck, downstream of West Hornsby WWTP	151.080	33.7028

Site codes	Site description	Longitude	Latitude
NB43	Calna Ck, upstream of Hornsby Heights WWTP	151.101	33.6714
NB42	Calna Ck, downstream of Hornsby Heights WWTP	151.103	33.6688

* Site not monitored in 2019-20 due to safety issues from site contamination

2.5.3 Other Sydney urban rivers – stream health

Freshwater macroinvertebrate communities were also measured at 11 sites not associated with direct WWTP assessment. The objective of this program is to measure the general ambient condition of four 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. The sites assessed were in the freshwater reaches of Lane Cove, Parramatta and Georges Rivers as well as key control sites used to confirm calibration of the SIGNAL-SG biotic index (Table 2-18 and Figure 2-20).

The monitoring is undertaken twice per annum (autumn and spring). The methods of sampling and laboratory analysis are the same as those described for upstream-downstream sites sampled around inland WWTPs of Hawkesbury-Nepean River system (Section 2.5.2).

Table 2-18 Freshwater macroinvertebrates sampling sites, river feeding to estuaries

Site code	Site description	Longitude	Latitude
GE510	O'Hares Ck upstream confluence with Georges R, control site	150.835	-34.0944
GR22	Georges R, upstream of Liverpool Weir	150.928	-33.9255
GR23	Georges R, Cambridge Causeway	150.912	-33.9700
GR24	Georges R, at Ingleburn Reserve Weir, control site	150.888	-34.0067
PH22	Hacking R at McKell Avenue, control site	151.048	-34.1089
PJLC	Lane Cove R, upstream of Lane Cove Weir	151.154	-33.7911
PJPR	Parramatta R, upstream of Parramatta Weir	151.006	-33.8127
LC2421	Unnamed tributary of Devlin's Ck, Lane Cove R, control site	151.084	-33.7508
NP001	McCarrs Ck, control site	151.249	-33.6629
N628	Bedford Ck, control site	150.4990	-33.7721
N451	Lynchs Ck, control site	150.664	-33.6511

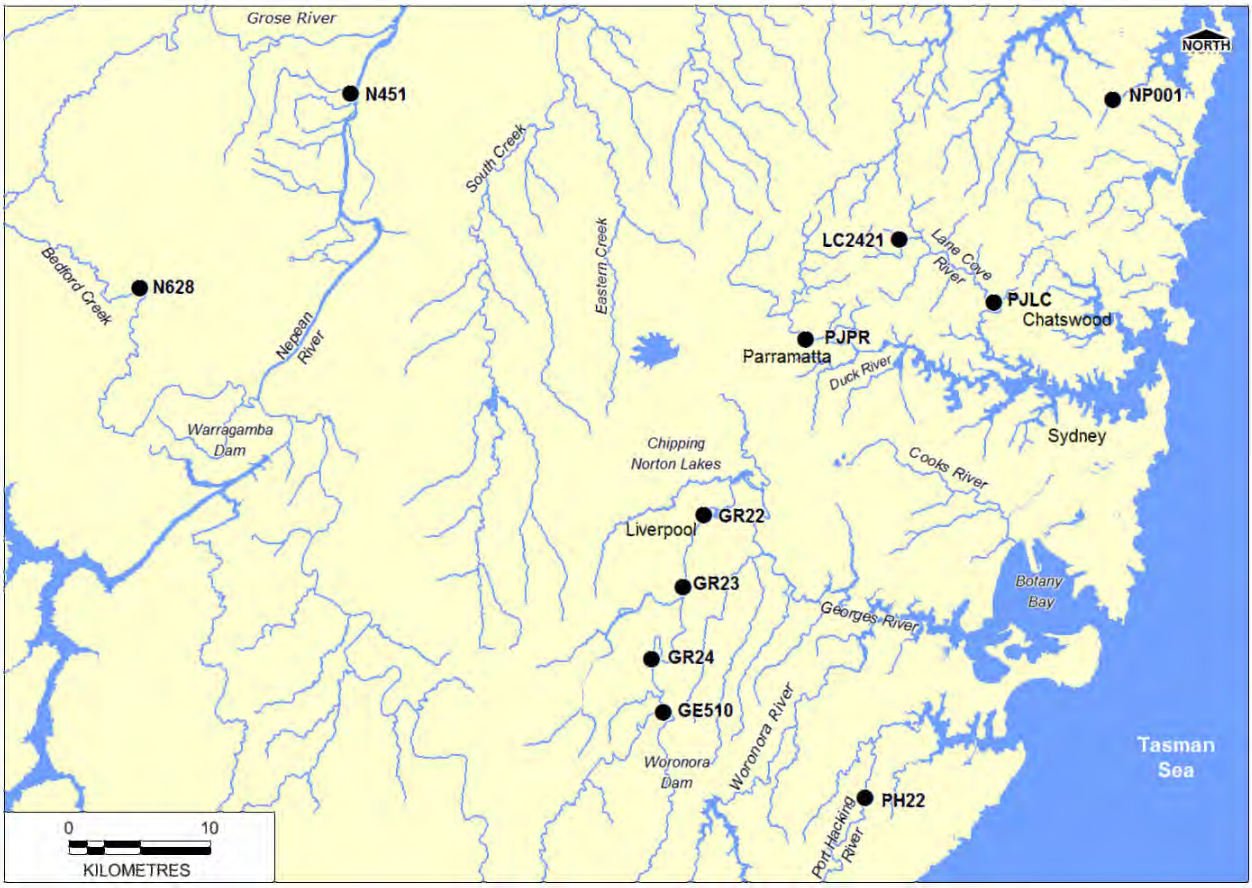


Figure 2-20 Freshwater macroinvertebrates monitoring sites in waterways feeding to estuaries

2.6 Quality control and quality assurance

Sydney Waters Laboratory Services is accredited by NATA for technical competence to operate in accordance with ISO/IEC17025 for sampling and testing Under the Scope of Accreditation No.63.

2.6.1 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. Decontamination is undertaken after sampling and prior to the sampling at the next site. Prior to collecting water samples, the sample containers are rinsed once with local water at the sample site.

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.

Chain of custody

Every sample collected in the field is labelled with a unique identifier code. At the end of each day of sampling, 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 and documented acceptance and handling 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.

2.6.2 Analytical quality control

The chemical analysis of samples is undertaken by a NATA accredited laboratory, generally Sydney Water Laboratory Services or a suitably qualified external laboratory. Each laboratory is required to analyse a range of quality control samples. The number, type and frequency of these samples varies depending on the size and range of chemical analyses required.

The types of quality control samples used are described below:

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.

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

In order 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) prior to 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.

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 percent difference between each separate result is within acceptable control limits. Percent 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.

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 National Association of Testing Authorities (NATA) and/or Australian Standards. For all analyses, initial calibration is conducted at the beginning of each analytical sequence or, as necessary, if the continuing calibration acceptance criteria are not met.

3 Data and data analysis methods

3.1 Data collation

In addition to presenting the various wastewater and environmental information collected by the STSIMP, this report also uses *Enterococci* and conductivity data of Sydney Beaches and estuaries collected by the NSW Department of Planning, Industry and Environment (DPIE). Rainfall data is also collated from relevant stations of Sydney Water and Bureau of Meteorology (BOM) where required.

Data collected between July 2019 and June 2020 was used to assess the current year's performance. However, historical data collected over the previous years (where available) was also used to compare 2019-20 performance to the last nine years or to a period available under the respective indicators.

3.2 Data analysis methods

3.2.1 Wastewater quantity, quality and pollutant loads

Data preparation and analysis

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 as legend such as the detection limit of that particular analyte, WWTP specific EPL concentrations limits etc.

Wastewater quantity and quality data sets were used to determine the performance of each WWTP during 2019-20 with respect to the EPLs. To understand how 2019-20 compared to recent years (previous nine years) all wastewater pollutant analytes were tested statistically for any significant differences under an ANOVA with a single fixed factor 'Period', with two levels. These levels were represented by data from 'the current 2019-20 year' compared against the 'previous nine years of data (2010-11 to 2018-19)'.

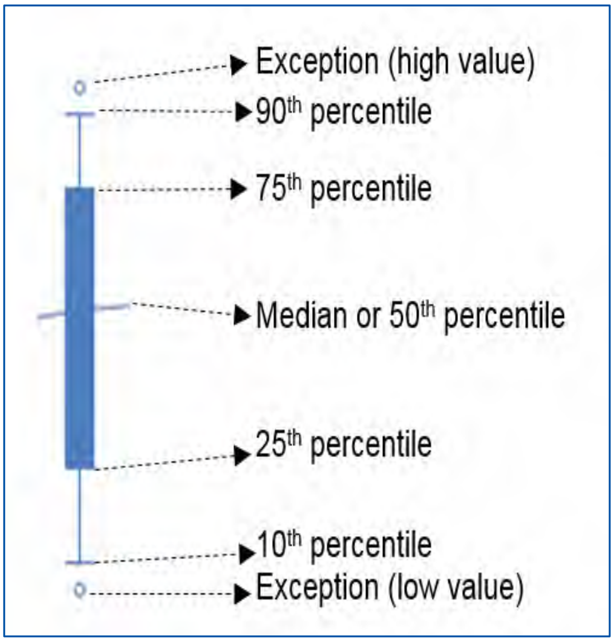


Figure 3-1 Example box plot

For CBOD, the laboratory analytical process was automated from July 2014, leading to less variability. So, the statistical test was based on 2019-20 data with the previous five years data (2014-2019). Method detection limits for nine other analytes were much lower before July 2016 (hydrogen sulphide, arsenic, chromium, copper, iron, manganese, molybdenum, nickel and zinc).

Statistical tests for these analytes were based on 2019-20 data with the previous three years (2016-19). Statistical tests for some of the analytes were performed when 90% or more results were greater than the detection limits (e.g. arsenic, chromium). Statistical test was performed for all analytes with licence concentration limits and results are shown in the plots.

Statistical tests were performed with the PROC GLM module of SAS 9.4.

The wastewater quality data are presented as box plots by each WWTP to show the trends and comparisons over the years. The box plots graphed the 25th percentile value, median/50th percentile (line) and 75th percentile values (Figure 3-1). The whiskers point to the 10th (bottom line) and 90th (top line) percentile values. The maximum and minimum values and exceptions are presented as a circle at the top and bottom of whiskers.

All box plots on wastewater quality are presented in Volume 2: Appendix C and D.

If the 2019-20 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 2009a).

The wastewater quantity, quality and load data were also separated into dry and wet weather categories based on catchment-specific rainfall related to each WWTP. Daily average rainfall data of one or multiple rain gauges from relevant WWTP catchments were used for this purpose (Appendix B).

Wet weather monitoring data were defined when any of the following specific conditions were met:

- 10 mm or more rainfall fell in the previous 24 hours (until 9 am on the day of sampling)
- 21 mm or more rainfall fell in the previous 72 hours (until 9 am on the day of sampling)

The remaining data was categorised as dry weather.

Summary statistics on all weather wastewater discharge volume and characteristics data by WWTPs (all analytes) and year are provided to EPA as electronic Appendices (EA_1 and EA_2). Summary statistics on load data (key analytes) by all weather, dry and wet weather are also provided as electronic appendices (EA_5 and EA_6).

3.2.2 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 (Sydney Water 2020a and Sydney Water 2020b). This STSIMP Data Report is mainly based upon these two reports to provide a condensed summary on wastewater overflows over the last ten years.

3.2.3 Dry weather leakage detection program

The wastewater network has been divided into 211 SCAMPs. 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. This follow-up work may result in multiple sampling events and exceedances for that SCAMP as these investigations remain ongoing until a source is identified, rectified and verification samples are below the threshold or if resamples under these investigations return below threshold values, follow-up is ceased. The findings and rectification work from these investigations are recorded and documented for the current financial year in Section 4.3.3.

The dry weather wastewater leakage data presented in this report is based on faecal coliform concentrations recorded over the last 10 years (2010 to 2020). Exceedances were compared against the EPA's 10,000 cfu/100mL trigger threshold. Sites without water at the time of sampling are considered to have passed, as no flow indicates no possibility of wastewater contamination.

Historically, two replicate grab samples collected five 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 only one replicate submitted for analysis. For consistency, only the highest recorded faecal coliform concentration from the paired duplicate samples (pre-October 2015) was used to generate the exceedance data represented in the Dry Weather Wastewater Leakage results in Section 4.3.3.

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 three-year and 10-year SCAMP 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.

3.2.4 Ocean sediment program

In surveillance years, only 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 undertaken with results for sediment fractions obtained for three categories of: < 0.063 mm (%); > 0.063 mm (%); and > 2.0 mm (%) categories. 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 2019 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 greater than 1% TOC content across the nine locations of the broader study program from 2001 to 2019 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 2019 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) with the outputted sample allocations inspected for fit of the 2019 samples to historical samples.

As 2020 was a scheduled assessment year a more extensive analysis of all assessment year data (2002, 2005, 2008, 2011, 2014, 2016 and 2020) were undertaken. Under STSIMP 2020 reporting a separate report (Ocean Sediment Program 2020 Assessment Year Report) contains these outcomes.

3.2.5 Beachwatch data analysis

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 H). These bubble plots highlighted the dry weather elevated *Enterococci* densities (as shown by larger bubbles at the top of a plot which represent dry weather conditions based on conductivity). Assumptions behind these plots were:

- *Enterococci* results without a respective conductivity value were excluded. Conductivity results for many sites were not available prior to 2013
- 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 are shown in plots for all extreme *Enterococci* values ≥ 230 cfu/100mL, which is the secondary contact recreation guideline (ANZECC 2000).

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 investigation

Site-specific investigations were carried out on all Beachwatch data with *Enterococci* values higher than the primary contact recreational guideline (35 cfu/100mL) during 2019-20. Firstly, these exceptions were merged with the site-specific rainfall data (Sydney Water or 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 H, Table H-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 display persistent, there is an opportunity to complete non-routine catchment investigations under the Dry Weather Leakage Detection Program to locate the potential source.

3.2.6 Chlorophyll-*a* at estuarine sites

Chlorophyll-*a* data from the latest year (2019-20) were compared with recent years (previous nine years, 2010-11 to 2018-19). Statistical analysis was performed using PROC GLM in SAS 9.4 to determine significant differences. Data were presented as box plots (as shown earlier in Figure 3-1) for each site to show the trends and comparisons over time. Instances when the 2019-20 data were significantly different from previous years and instances when guideline limits 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 I (Volume 2).

3.2.7 Water quality trends in lagoons

Lagoon chlorophyll-*a*, conductivity and *Enterococci* data were analysed using the same method as outlined above (Section 3.2.6), the exception plots are presented in the main body of the report (Volume 1) and all plots are in Appendix J (Volume 2).

3.2.8 Intertidal communities – shoreline outfall program

Results from the shoreline outfall program for the Shellharbour WWTP are presented in Appendix K.

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 two sites formed the ‘Control’ locations. A quadratic root transformation was applied to the data prior to a Bray-Curtis dissimilarity matrix being 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 to 2019 allowed the factor ‘Time’ to be included in the above asymmetrical permutational analysis of variance test (PERMANOVA). Time was comprised of 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018 and 2019 surveys, which were conducted at varying times through late winter to late spring each year.

Ordination plots were raised to visualize data patterns. The non-metric multidimensional scaling (nMDS) ordination routine of PRIMER was used to produce two and three-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 MDS 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 2019 site data to that from previous years (2008 to 2018), 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).

3.2.9 Intertidal communities of Sydney's 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 Principal Coordinates analysis (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 two or three 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 2018 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.

3.2.10 Hawkesbury-Nepean River water quality

Data preparation

Where the recorded measurement was below the detection limit, half the detection limit value was used as the recorded measurement 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 and algal data from all sites were statistically analysed to understand how 2019-20 compared to recent years (last nine years, 2010-11 to 2018-19). Significant differences were determined using PROC GLM in SAS 9.4. The water quality and algae data were presented as box plots (as shown earlier in Figure 3-1) by each site to show the trends and comparisons over the year. These box plots also annotated guidelines (Table 3-1) as horizontal lines for comparison when available. 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). For two key nutrients (total nitrogen and total phosphorus) and chlorophyll-*a*, HRC (1998) water quality objectives guidelines were shown in parallel for information. For blue-green algal analytes, green, amber and red alert level guidelines were used (NHMRC 2008).

All box plots on water quality and algae are presented in Appendix M (Volume 2).

If the 2019-20 data was significantly different from the previous nine years or exceeded guideline limits then these were identified as exceptions and presented in main body of this report (Volume 1). These exceptions include both improved water quality results, as well as a deterioration in water quality.

A comparison of the 2019-20 Hawkesbury-Nepean River water quality results with respect to the previous nine years results (2010-11 to 2018-19) was also explored using multivariate statistical analysis. Principal Component Analysis (PCA) was carried out for each site using PRIMER version 7.0.13. Prior to running PCA, data were normalised to have comparable dimensionless scales.

This produced a correlation based PCA output. The key water quality analytes used for this purpose were conductivity, dissolved oxygen, pH, temperature, turbidity, ammonia nitrogen, oxidised nitrogen, total nitrogen, total phosphorus, filterable total phosphorus and chlorophyll-*a*. The graphical and data analysis output on these analyses are included in Appendix M (Volume 2).

The water quality and algae were also separated into dry and wet weather categories based on catchment-specific rainfall related to each monitoring site. Daily average rainfall data of one or multiple rain gauges from relevant catchments were used for this purpose (Volume 2: Appendix B).

Wet weather monitoring data were defined when any of the following specific conditions were met:

- 10 mm or more rainfall fell in the previous 24 hours (until 9 am on the day of sampling)
- 21 mm or more rainfall fell in the previous 72 hours (until 9 am on the day of sampling).

The remaining data was categorised as dry weather.

Summary statistics on water quality and algae data by all weather and dry or wet weather is not presented in this report but provided electronically to the EPA (EA_10).

Table 3-1 Water quality and algae guidelines used in box plots

Water quality and algae analytes	Main stream Hawkesbury-Nepean River sites: Mixed rural use and sandstone plateau (N92, N75, N67, N51, N48A, N44, N39, N35, N3001, N26, N2202 and N18)	Main stream Hawkesbury-Nepean River sites: Predominantly urban (N57 and N42)	Tributary stream of Hawkesbury-Nepean River sites: predominantly urban (NS04A and NC11A)	Estuarine and brackish sites of the Hawkesbury-Nepean River (NB11 and NB13)	Freshwater sites: Non-Hawkesbury-Nepean River catchment (PJLC, PJPR and GR22)	Estuarine or saline sites: Non-Hawkesbury-Nepean River catchment (Lagoons and other saline sites)	Guideline references
Nutrients, chlorophyll-*a* and algal analytes							
Ammonia nitrogen (mg/L)	<0.020[d]			<0.015[c]	-	-	ANZECC (2000)
Oxidised nitrogen (mg/L)	<0.040[d]			<0.015[c]	-	-	ANZECC (2000)
Total nitrogen (mg/L)	<0.70	<0.50	<1.00	<0.40	-	-	HRC (1998)a
	<0.35[b]			<0.30[c]	-	-	ANZECC (2000)
Total phosphorus (mg/L)	<0.035	<0.030	<0.050	<0.030	-	-	HRC (1998)a
	<0.025[b]			<0.030[c]	-	-	ANZECC (2000)
Chlorophyll-*a* (μg/L)	<7.0	<15.0	<20.0	<7.0	-	-	HRC (1998)a
	<3.0[b]			<4.0[c]	<3.0[b]	<4.0[c]	ANZECC (2000)
Total blue-green algal biovolume (mm^3/L)	Green alert: >0.04; Amber alert ≥0.4; Red alert ≥10 for combined total blue-green algae				-	-	Blue-green algal alert levels for recreational water (NHMRC 2008)
Toxic blue-green algal biovolume (mm^3/L)	Green alert: >0.04; Amber alert ≥0.4; Red alert ≥4 for combined total blue-green algae						
Toxic blue-green algal counts (cells/mL)	Green alert >500; Amber alert ≥5,000; Red alert ≥ 50,000				-	-	
Physico-chemical analytes							
Conductivity (μS/cm)	125 to 2200						ANZECC (2000)
Dissolved oxygen saturation (%)	>85 and <110[d]			>80 and <110[c]	-	-	ANZECC (2000)
pH	>6.5 and <8.5[e]			>7 and <8.5[c]	-	-	ANZECC (2000
Turbidity (NTU)	6 to 50						ANZECC (2000)

a: Water quality objectives for nutrients b: Default trigger values for NSW and VIC east flowing coastal river c: Estuaries
d: Default trigger value for lowland river e: Default trigger values for NSW lowland river

3.2.11 Hawkesbury-Nepean River stream health

Assessment of freshwater macroinvertebrate data for each inland WWTP 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 WWTP point source discharges is conducted upstream-downstream of the WWTP 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 WWTP 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 WWTPs 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, which 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 2019-20) for the downstream site was assessed against the range of stream health recorded over all previous financial years (for example 1995-19) for the upstream site. Downstream mean stream health for the most recent financial year that the report covers (for example 2018–19) was also compared against the range of stream health collected from the upstream site in this same financial year (for example 2019-20). 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 above listed upstream stream health ranges.

Univariate t-tests were also undertaken and provided a more stringent assessment as statistical test ranges approximated generally tighter two standard errors of the mean. Pooled or Satterthwaite t-test methods were used subject to equality of variance test results. Where variances were shown to be equal, the Pooled results were appropriate to be adopted. If a t-test confirmed significant differences between sites then multivariate statistics were used to further examine the ecological response for the respective WWTP.

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 3-2). 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 3-2.

Table 3-2 Summary of monitoring periods omitted from multivariate analysis of freshwater macroinvertebrate data due to unbalanced sample habitats

WWTP	Stream	Periods with unbalanced sample habitats
North Richmond	Redbank Ck	N/A
North Richmond	Hawkesbury-Nepean River 'macrophyte'	spring 2005, autumn 2012, spring 2012 and spring 2013
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 and spring 2016
Hornsby Heights	Calna Creek 'edge'	spring 2012 and autumn 2018
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 and autumn 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 undertaken 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 WWTPs 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. In order 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 two or three axes such 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 3-2 where the first division shows a clear difference between upstream and downstream samples from the (before) period when the former Blackheath WWTP which ceased operation in 2008 was active. This WWTP 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 WWTPs Sydney Water operates have better control of the ammonia bi-product of wastewater treatment.

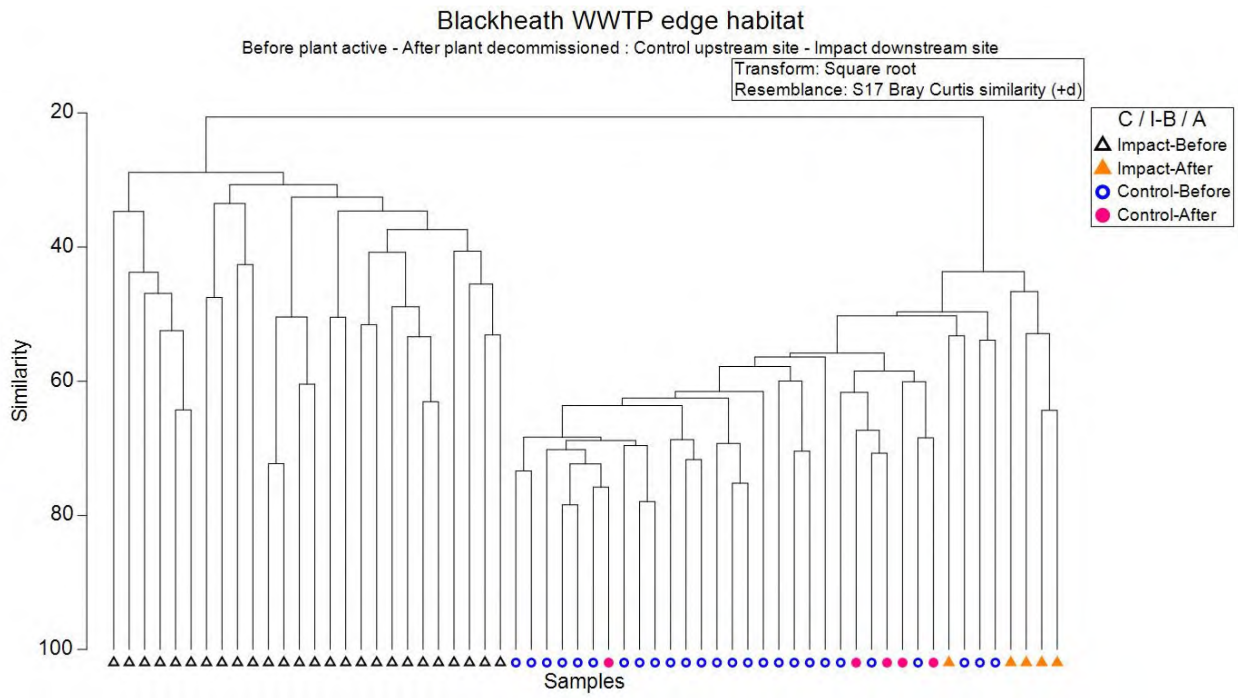


Figure 3-2 Example of classification plot showing a distinct organic pollution impact and recovery

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 WWTP 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 3-3.

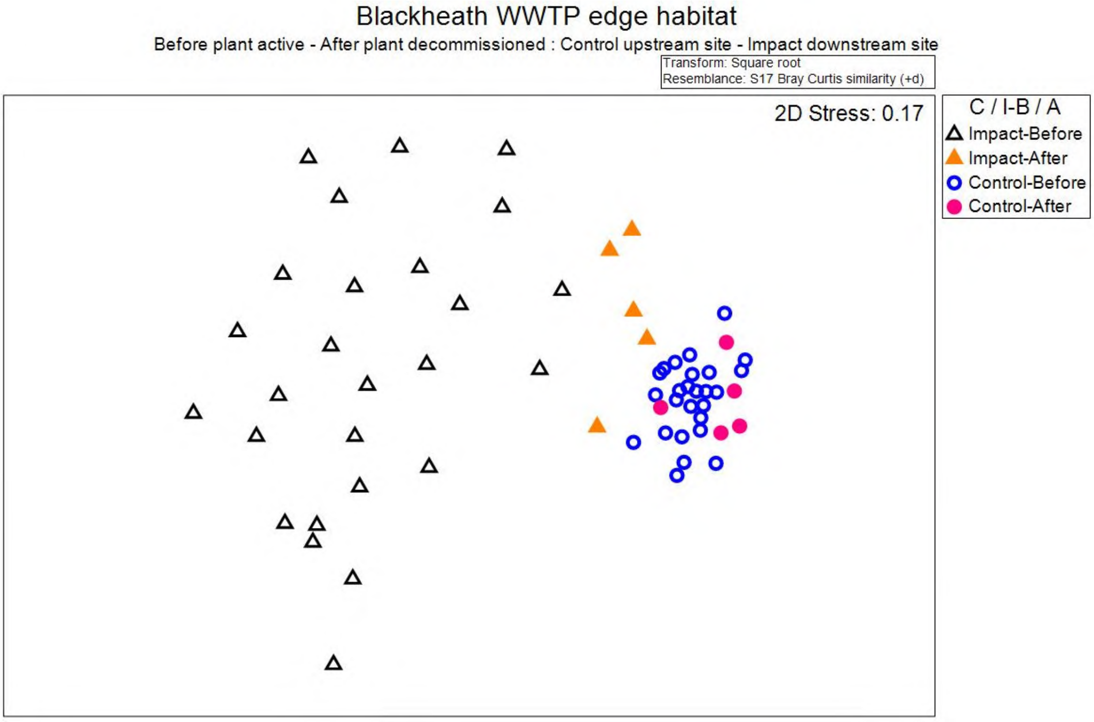


Figure 3-3 Example of nMDS ordination plot showing a distinct organic pollution impact and recovery

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 3-4).

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 3-5). 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 3-5). 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 two 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 (2014) suggests it is not too sensitive to dispersion.

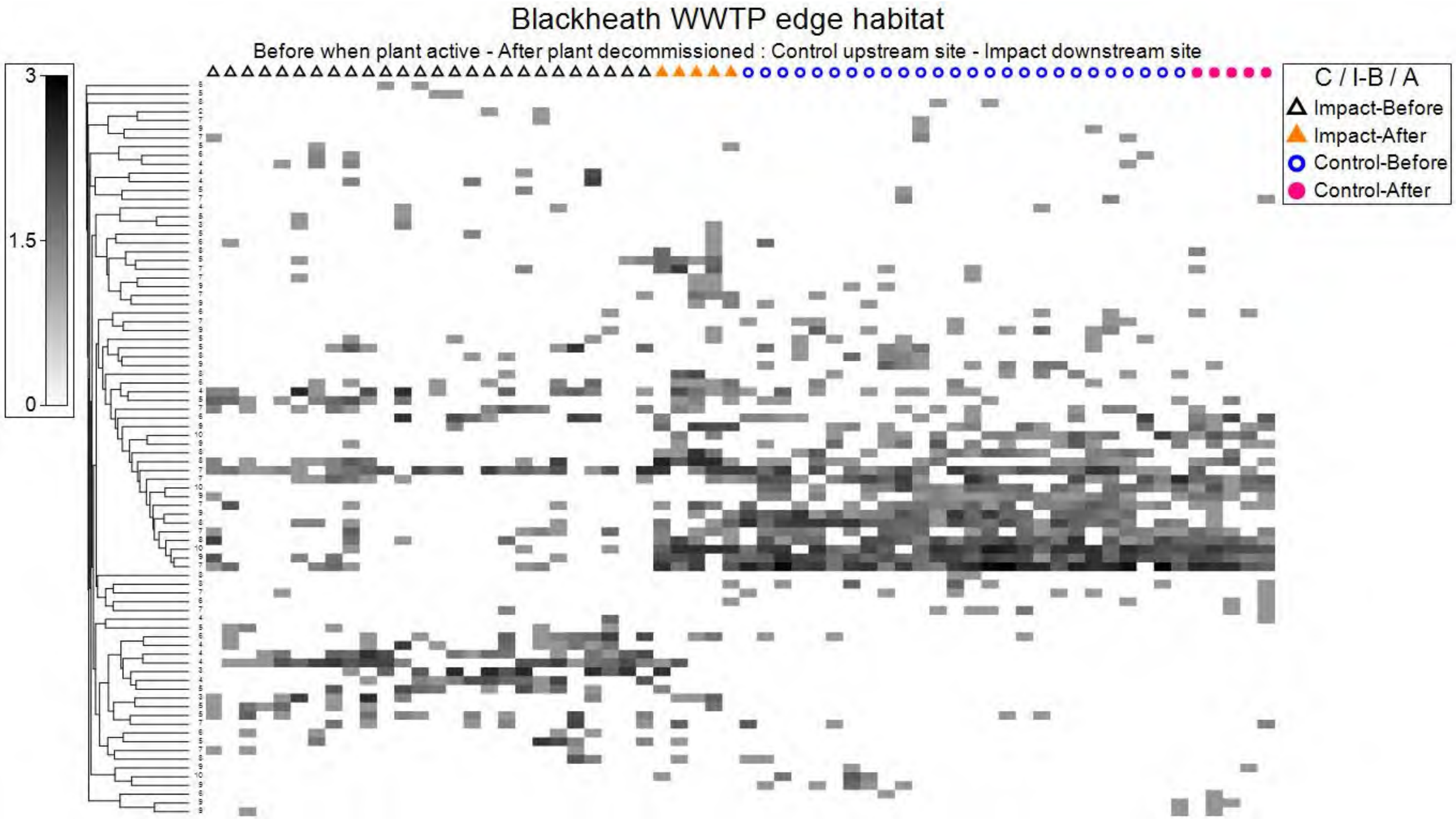
ANOSIM provides an absolute measure of how separated groups of samples are on a scale of - 1 to 1 (Clarke 1993). As the R-value approaches 1, this indicates all temporal samples from a site were more similar to each other than they were to temporal samples from another site; that is, groups are clearly 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 2019 and 2020 calendar years with the autumn 2020 sample from each site as a test group. Under this analysis approach, four or five measurements became available from each of the four WWTPs 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 3-2. 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 3-4 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 3-5 Shade plot of square root transformed count data serially reordered based on classification of genera

3.2.12 Other Sydney urban rivers – Stream 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 3-3. SIGNAL-SG scores back to 1995 were plotted by financial year (Appendix O).

Table 3-3 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

4 Results and discussion

4.1 Wastewater discharges from Coastal WWTPs

The treated wastewater discharged from ocean WWTPs in 2019-20 and the population serviced by these WWTPs are shown in Table 4-1.

This section contains a summary of exceptions for each of the coastal discharging WWTPs. All coastal WWTP trend plots on discharge volume and catchment specific rainfalls are presented first and then reuse volume where applicable. This is followed by a load limit plot where there was an exceedance during 2019-20.

Trend plots on concentrations of analytes in discharges were only presented where it exceeded the respective EPL limit for a WWTP or there was a significant increase/decrease in concentrations in 2019-20 in comparison to earlier years. All trend plots on concentrations of analytes and load data can be found in Volume 2 Appendix C.

Each analyte presented in this section or in Volume 2 has up to two plots. One plot shows data in relation to EPL percentile limit values. The second plot has a reduced analyte scale to provide a zoomed in view, if required.

An electronic appendix file is also provided on summary of results for all coastal WWTPs by year (EA_8).

Table 4-1 Ocean WWTPs operated by Sydney Water (in order from north to south)

WWTPs	Treatment level	Discharge 2019-20 (ML/year)	Projected population 2019-20#	Discharge type	Discharge location
Warriewood	Secondary with disinfection	7,222	74,270	Shoreline	Ocean outfall Turimetta Head
North Head	Primary	140,080	1,381,450	Deepwater	North Head Deepwater ocean outfall, 3.7 km from shoreline, 65 m maximum water depth, 762 m diffuser zone
Bondi	Primary	42,873	333,920	Deepwater	Bondi Deepwater ocean outfall; 2.2 km from shoreline, 63 m maximum water depth, 512 m diffuser zone
Malabar	Primary	178,585	1,678,590	Deepwater	Malabar Deepwater ocean outfall, 3.6 km from shoreline, 82 m maximum water depth, 720 m diffuser zone
Fairfield**	Primary	1,502	0*	Transfer to Malabar	Treated wastewater occasionally discharged to Orphan School Creek (to Georges River) during wet weather
Glenfield**	Secondary with disinfection	399	167,550	Transfer to Malabar	Treated wastewater occasionally discharged to Georges River in wet weather
Liverpool**	Secondary with disinfection	4,249	91,590	Transfer to Malabar	Treated wastewater occasionally discharged to Georges River in wet weather
Cronulla	Tertiary with disinfection	20,836	240,940	Shoreline	Ocean outfall Potter Point, Kurnell
Wollongong	Tertiary with disinfection	13,000	208,360	Near shore	Ocean outfall Coniston Beach
Bellambi***	Primary	502	0*	Near shore	Bellambi Point during wet weather
Port Kembla***	Primary	456	0*	Shoreline	Red Point during wet weather
Shellharbour	Secondary with disinfection	6,451	75,620	Near shore	Ocean outfall 130 m from Barrack Point with diffuser zone
Bombo	Secondary, denitrification with disinfection	1,230	15,680	Shoreline	Ocean outfall Bombo Point

* WWTPs not directly servicing any households.

** Part of Malabar system. Wastewater is discharged during wet weather only.

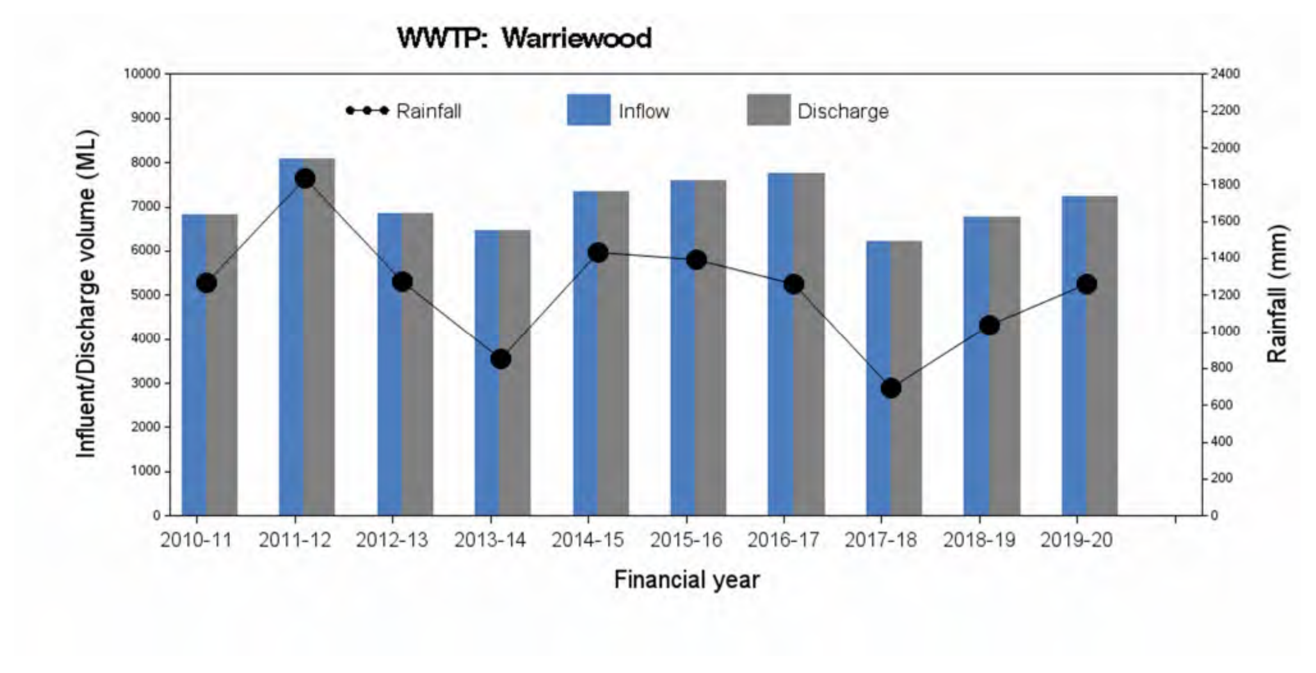
*** Part of Wollongong system. Treated wastewater is discharged during wet weather only.

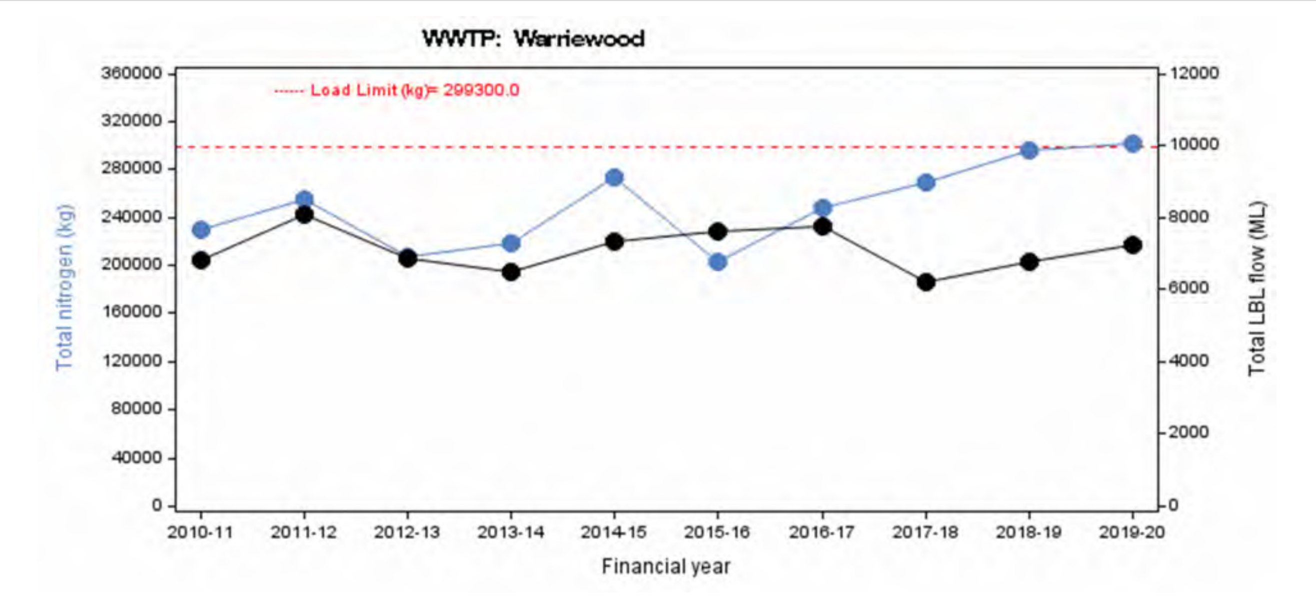
Projected populations are based on forecasts by the Australian Bureau of Statistics and the Department of Planning, Industry and Environment.

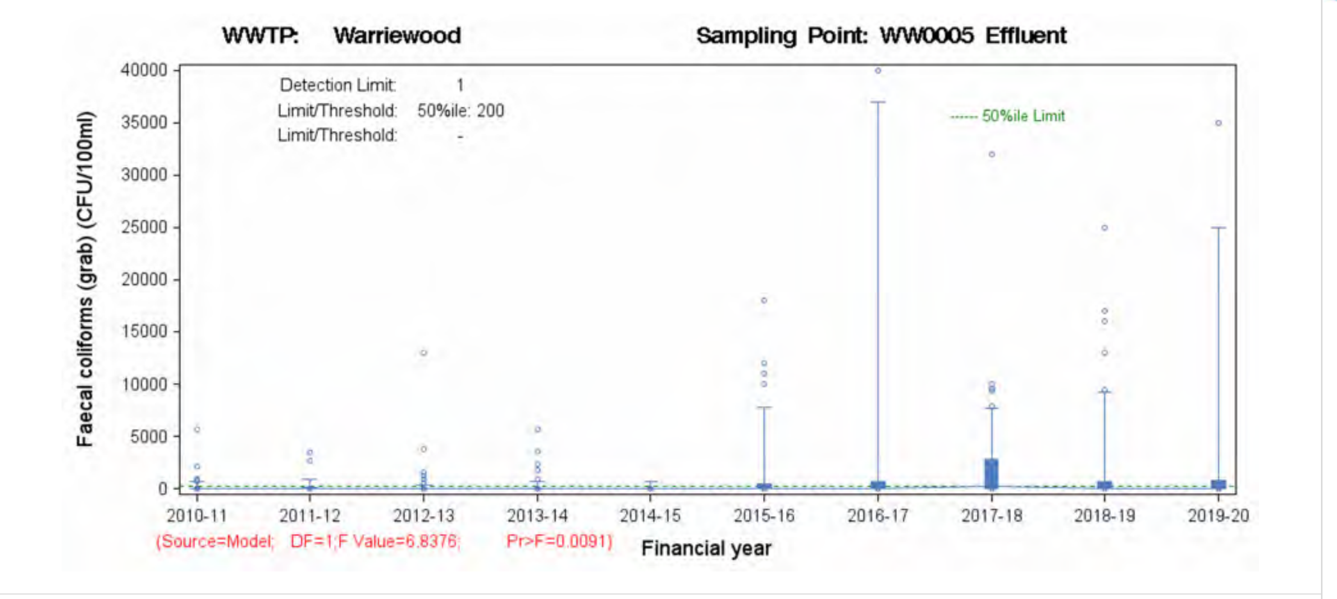
4.1.1 Warriewood WWTP

All concentration limits in the discharge from Warriewood WWTP were within the EPL limits during the 2019-20 period. The load limit for total nitrogen was exceeded in the discharge from Warriewood WWTP during the 2019-20 period. The load plot is presented below. During the recent drought conditions, higher than normal total nitrogen concentrations were being received at Warriewood WWTP, and then coming out of the drought conditions with the significant rain event in early February 2020. There was an increase in flows and subsequent loads during the second half of 2020, possibly due to the COVID-19 pandemic with more people working from home. Sydney Water are currently reviewing the nitrogen removal effectiveness at Warriewood WWTP.

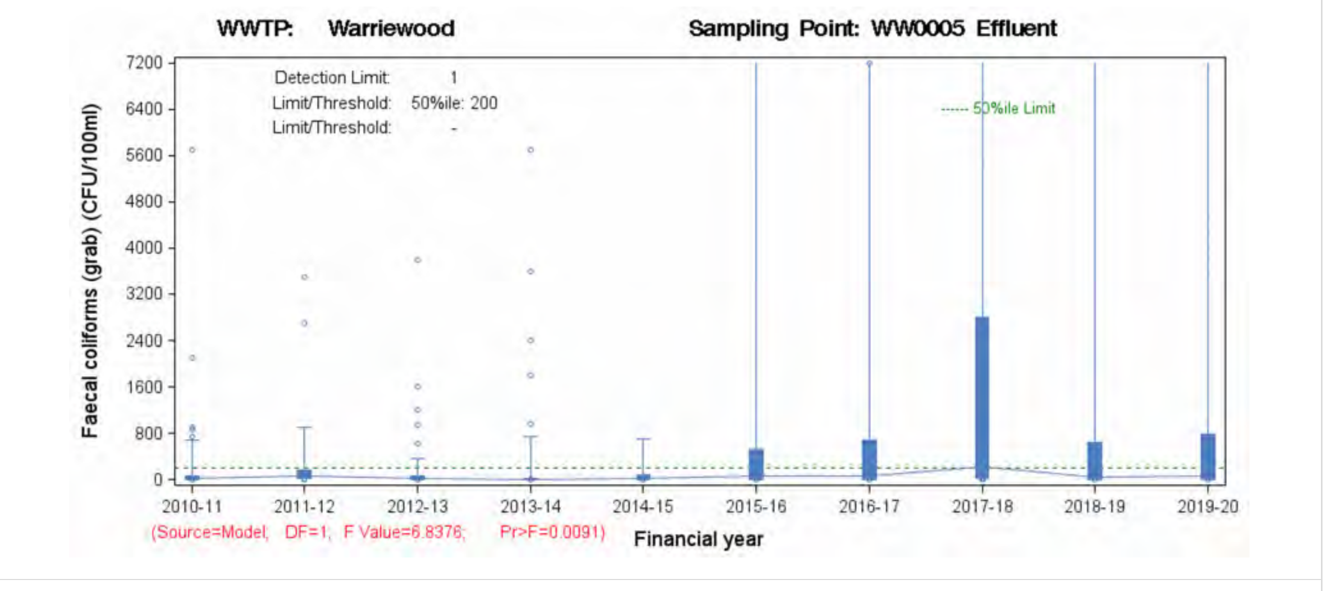
Statistical analysis identified a significant increasing trend in faecal coliforms and toxicity in Warriewood WWTP discharges during 2019-20 in comparison to the earlier nine years. Sydney Water are improving maintenance on the current UV system as well as targeting for replacement in the near future.



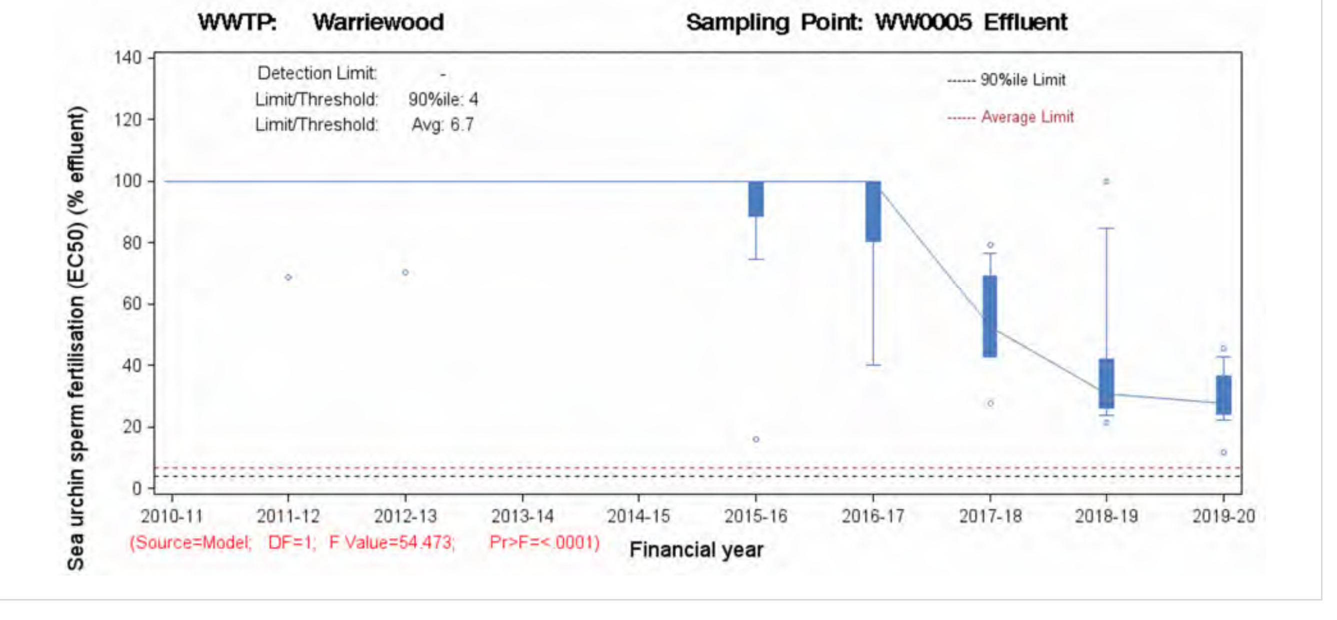




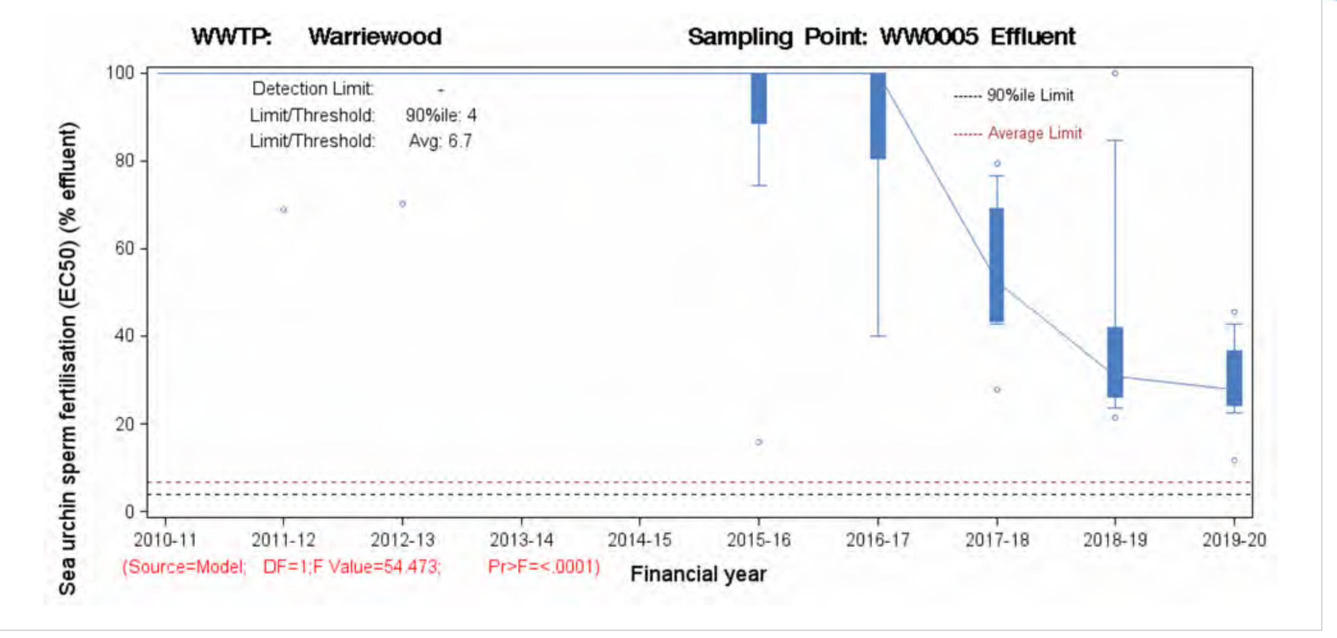
WWTP: Warriewood
Sampling Point: WW0005 Effluent
Detection Limit: 1
Limit/Threshold: 50%ile: 200
Limit/Threshold: -
------ 50%ile Limit
Faecal coliforms (grab) (CFU/100ml)
40000
35000
30000
25000
20000
15000
10000
5000
0
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1;F Value=6.8376; Pr>F=0.0091)
Financial year



WWTP: Warriewood
Sampling Point: WW0005 Effluent
Detection Limit: 1
Limit/Threshold: 50%ile: 200
Limit/Threshold: -
------ 50%ile Limit
Faecal coliforms (grab) (CFU/100ml)
7200
6400
5600
4800
4000
3200
2400
1600
800
0
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1; F Value=6.8376; Pr>F=0.0091)
Financial year



WWTP: Warriewood
Sampling Point: WW0005 Effluent
Detection Limit: -
Limit/Threshold: 90%ile: 4
Limit/Threshold: Avg: 6.7
------ 90%ile Limit
------ Average Limit
Sea urchin sperm fertilisation (EC50) (% effluent)
140
120
100
80
60
40
20
0
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1; F Value=54.473; Pr>F=<.0001)
Financial year


WWTP: Warriewood
Sampling Point: WW0005 Effluent
Detection Limit: -
Limit/Threshold: 90%ile: 4
Limit/Threshold: Avg: 6.7
------ 90%ile Limit
------ Average Limit
Sea urchin sperm fertilisation (EC50) (% effluent)
100
80
60
40
20
0
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1;F Value=54.473; Pr>F=<.0001)
Financial year

4.1.2 North Head WWTP

All concentration limits in the discharge from North Head WWTP were within the EPL limits during the 2019-20 period. The load limit for oil and grease was exceeded in the discharge from North Head WWTP during the 2019-20 period. Statistical analysis identified a significantly increasing trend in oil and grease concentration during 2019-20 in comparison to previous nine years. The oil and grease load plots are presented below. The load values for oil and grease in 2019-20 were less than the previous 2018-19 monitoring period with similar influent volumes.

A suspected cause of the oil and grease load exceedance is due to the prolonged period of diverting flow from the Northern Suburbs Ocean Outfall Sewer (NSOOS) to North Head WWTP via the Northside Storage Tunnel (NST). This flow diversion is part of Sydney Water's 15-year works program to rehabilitate 25.5 kilometres of the NSOOS tunnel, involving the removal of silt build up and rehabilitation of tunnel lining to improve the operational and hydraulic capacity of the NSOOS.

Pumping from the NST to the inlet works of North Head WWTP adds an extra agitation step which is thought to emulsify more oil and grease in the raw sewage, compared to no diversion state, as the NST wet well design was primarily intended for stormwater use.

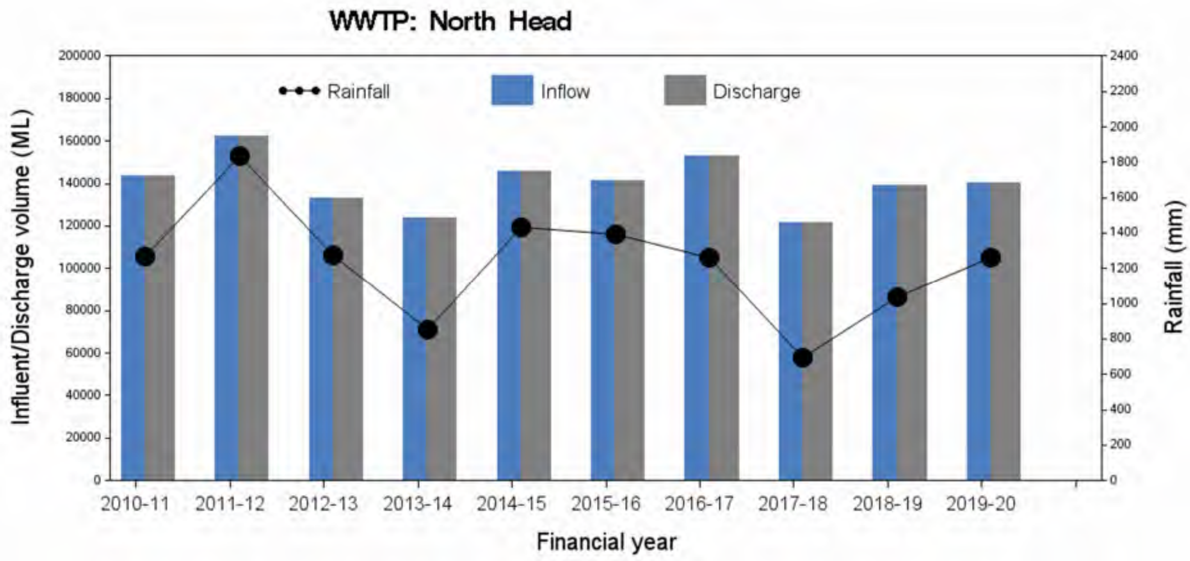
Work is being carried out by Sydney Water to reduce oil and grease at North Head WWTP. This includes:

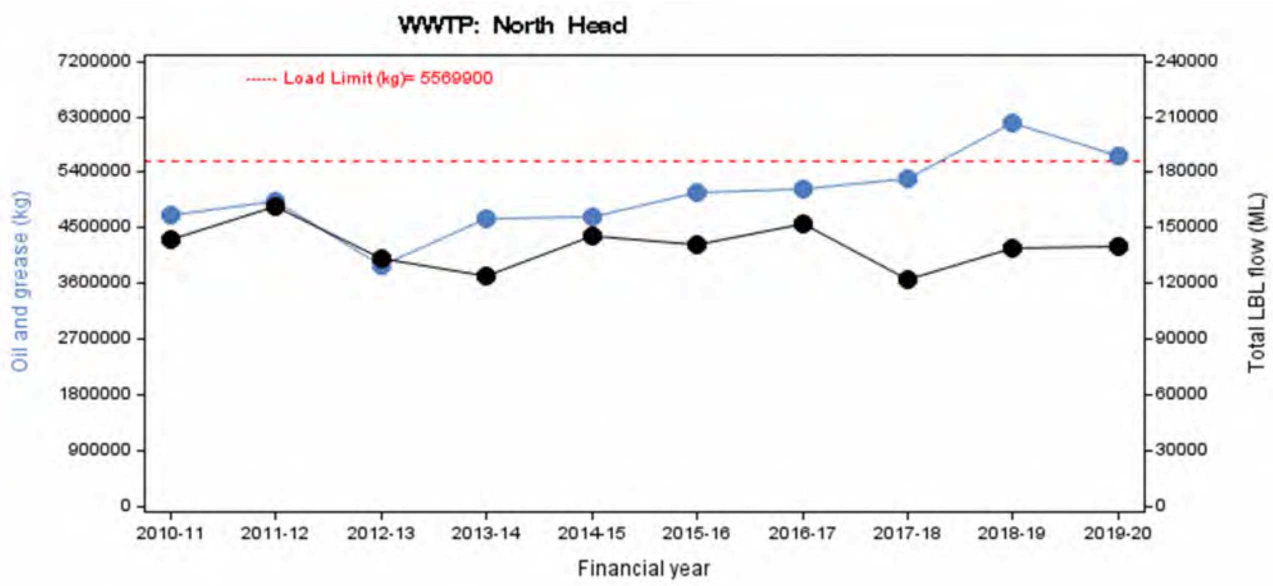
- Reduce surging and variation in Primary Sedimentation Tank (PST) wastewater level upon NST pump starting
- Review options to modify NST pump operation to reduce variation in level in the PST upon NST pump stop / start. NSOOS rehab works requires diversion of NSOOS to NST for worker safety. This extra pumping is thought to emulsify the oil and grease making it harder to separate in the PSTs
- Undertake sampling of side streams to assess temporal variation.

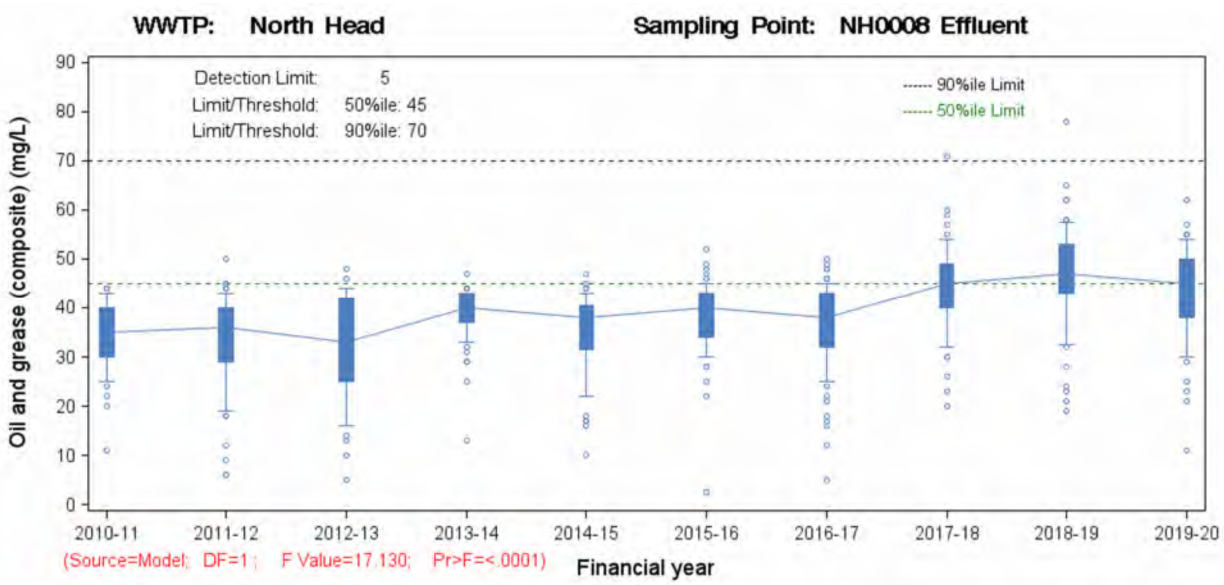
Other possible explanations for the elevated concentration values of oil and grease during 2019-20 could be related to:

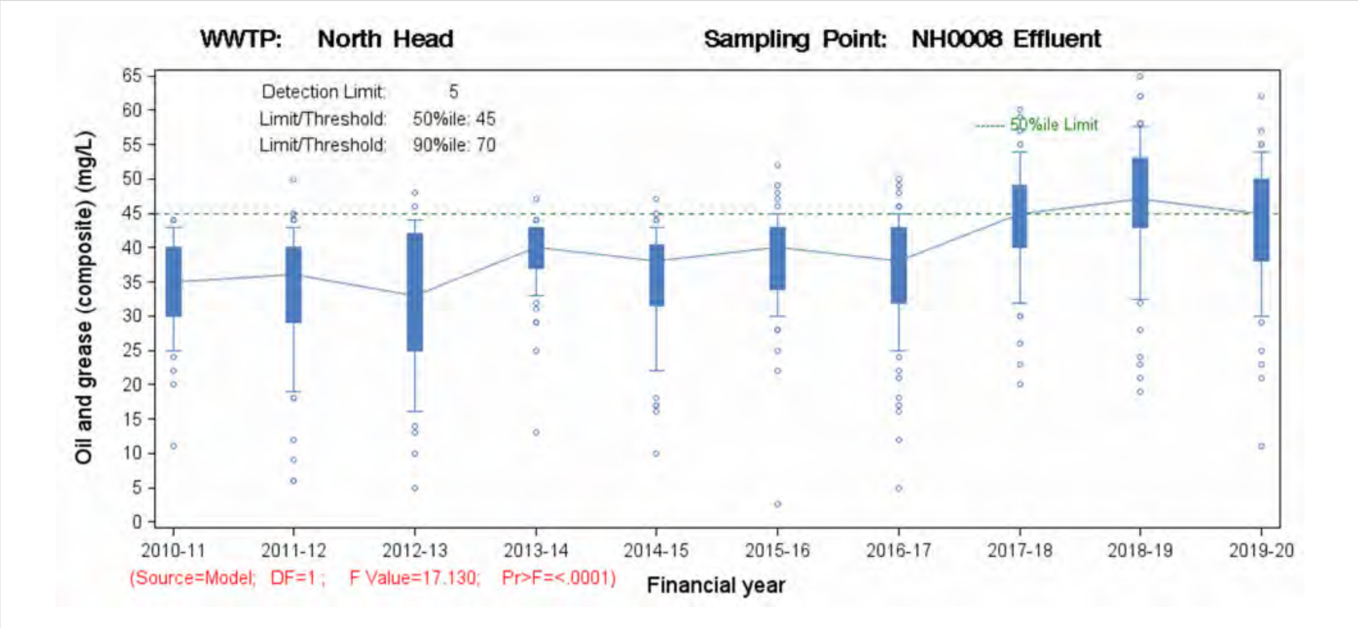
- increased oil and grease concentrations in influent due to decreased water use during drought (first half of 2019-20) and population density increase resulting in less dilution of fats, oils and grease (FOG)
- an increase in emulsified oil and grease due to changing practices in the catchment, including increased use of vegetable oils, detergents and hot water washes
- oil and grease load possibly related with the densification of housing and restaurants.

Sydney Water continues to conduct an educational campaign program to improve awareness and drive behavioural change in the way the community disposes FOG.


WWTP: North Head
Rainfall
Inflow
Discharge
Influent/Discharge volume (ML)
Rainfall (mm)
Financial year
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20


WWTP: North Head
------ Load Limit (kg)= 5569900
Oil and grease (kg)
Total LBL flow (ML)
Financial year
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20


WWTP: North Head
Sampling Point: NH0008 Effluent
Detection Limit: 5
Limit/Threshold: 50%ile: 45
Limit/Threshold: 90%ile: 70
------ 90%ile Limit
------ 50%ile Limit
Oil and grease (composite) (mg/L)
Financial year
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=17.130; Pr>F=<.0001)


WWTP: North Head
Sampling Point: NH0008 Effluent
Detection Limit: 5
Limit/Threshold: 50%ile: 45
Limit/Threshold: 90%ile: 70
50%ile Limit
Oil and grease (composite) (mg/L)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=17.130; Pr>F=<.0001)
Financial year

4.1.3 Bondi WWTP

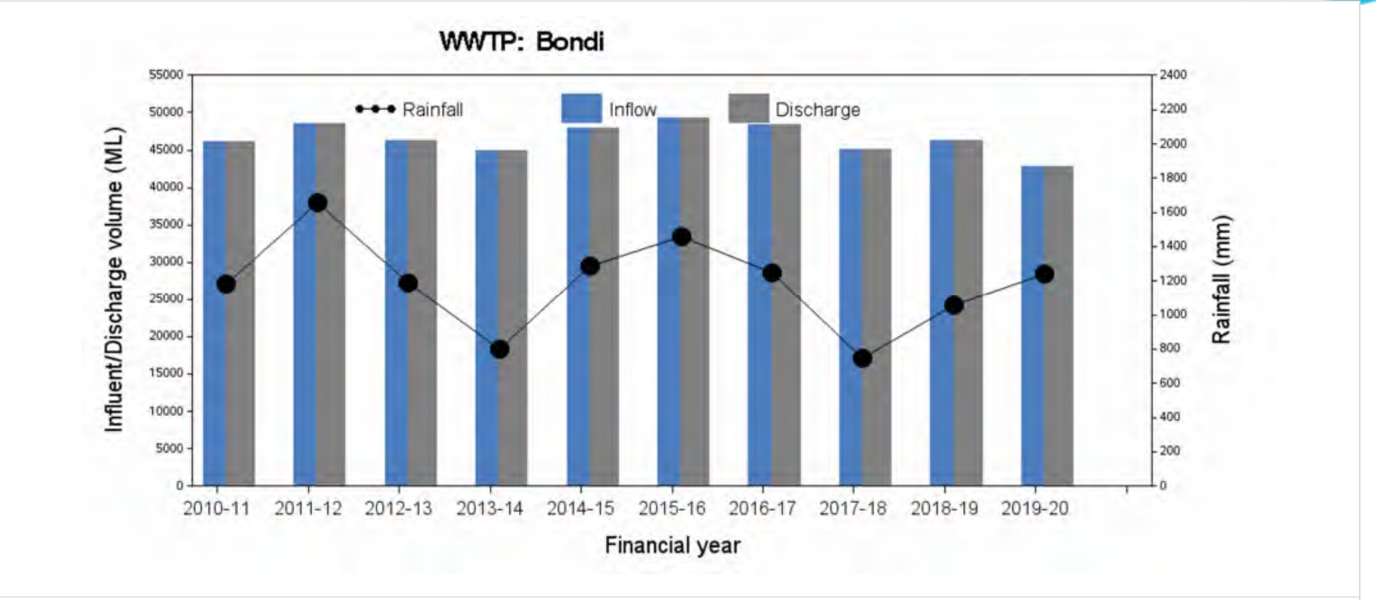
The 50th and 90th percentile concentration limits of oil and grease exceeded the EPL limit in the discharge from the Bondi WWTP during the 2019-20 period. Concentrations of all other analytes and load limits in the final discharge were within the EPL limits. Statistical analysis identified significant increasing trends in oil and grease, toxicity and nonyl phenol ethoxylate concentrations in Bondi WWTP discharges in 2019-20 in comparison to earlier nine years. Significant decreasing trends were observed in total suspended solids and aluminium concentrations. The load plots for oil and grease and total suspended solids are also shown below, illustrating a drop in load levels in 2019-20 compared to earlier years.

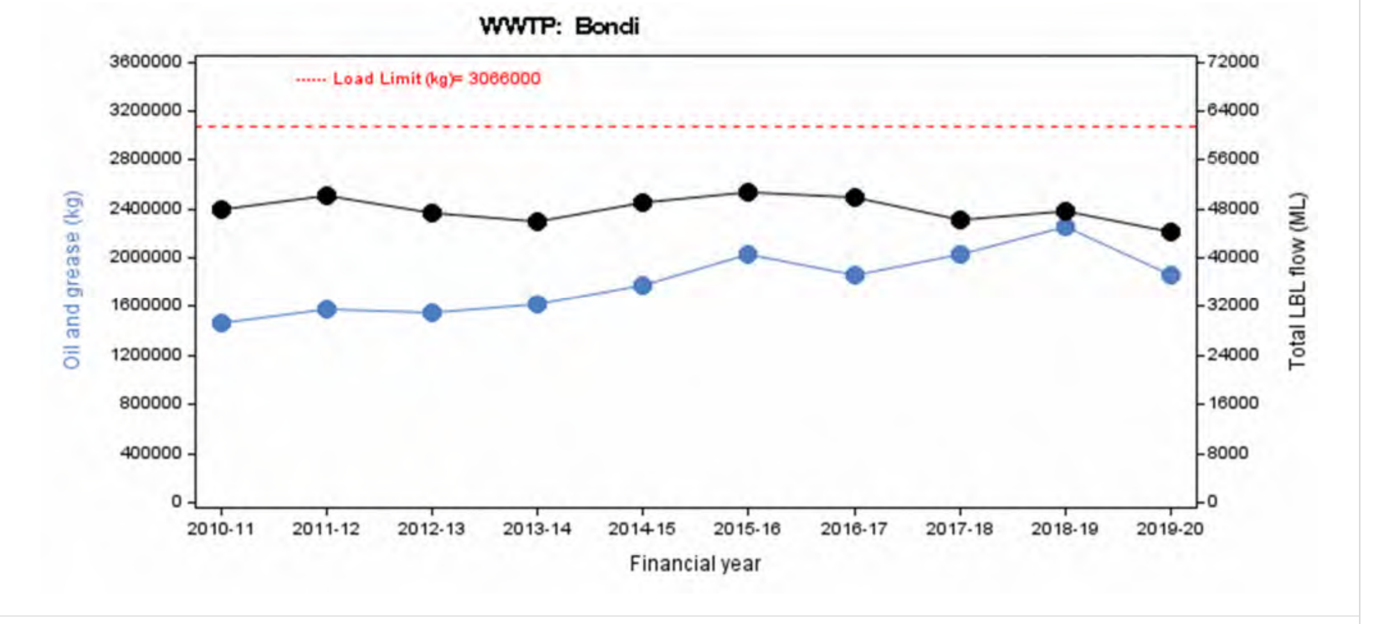
The increase in oil and grease concentration in Bondi WWTP discharges has led to the non-compliances of the 50th and 90th percentile concentration limits. Possible explanations may be related to:

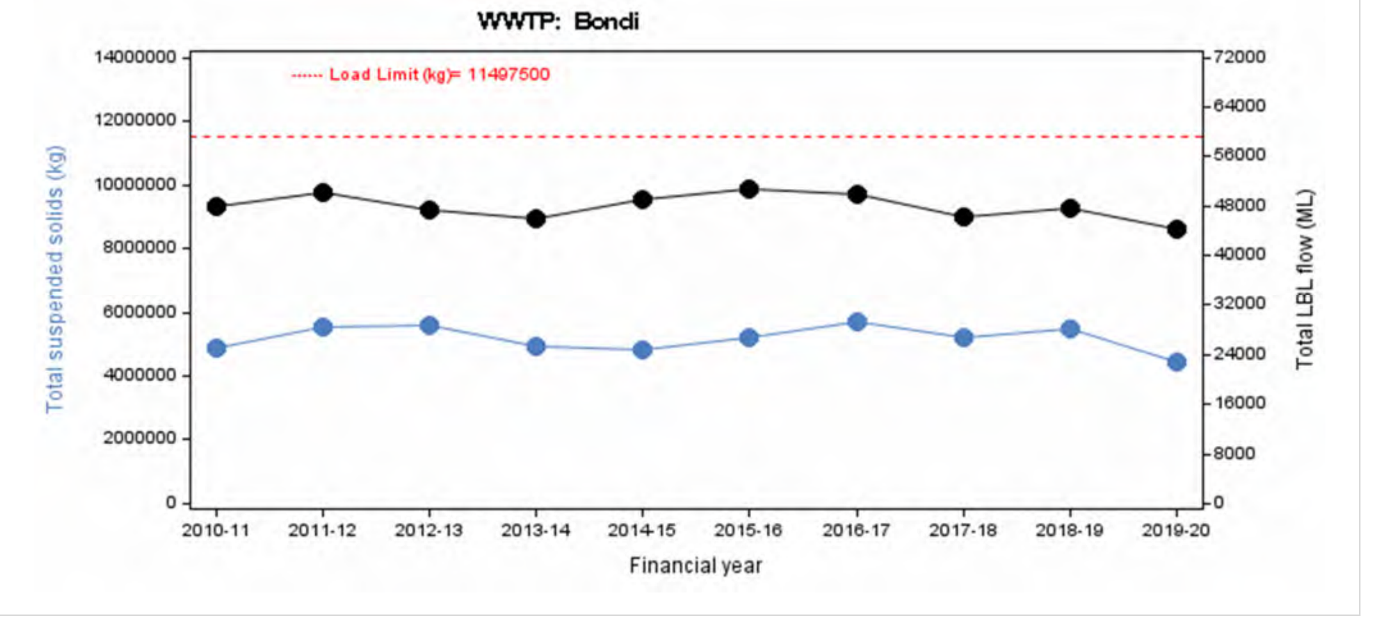
- an increase in emulsified oil and grease due to changing practices in the catchment, including increased use of vegetable oils, detergents and hot water washes
- oil and grease loads possibly related with the densification of housing and restaurants.

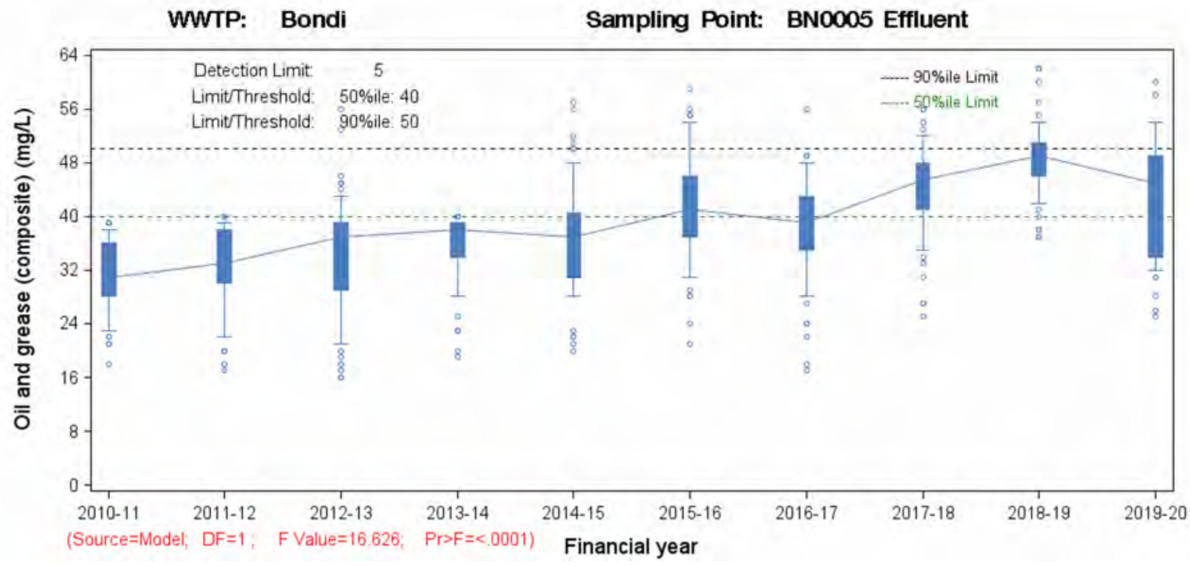
Actions being undertaken to reduce oil and grease at Bondi WWTP while maintaining only primary level treatment include the ongoing upgrades to the scum skimmers in the primary sedimentation tanks (improve overall reliability), as well as reducing digester supernatant by maximising and optimisation of the recuperative thickening process. Sydney Water also continues to conduct an educational campaign program to improve awareness and drive behavioural change in the way the community disposes FOG.

Changes to the Sydney City catchment demographic in response to the COVID-19 pandemic makes it hard to measure the process operation changes that were implemented at the start of 2020, which align with some improvement in licence performance at Bondi WWTP during the 2nd half of the 2019-20 financial year. The high variance in 25th – 75th percentile range in 2019-20 for oil and grease and nonyl phenol ethoxylate is possibly attributed to COVID-19 and the changing patterns of detergent use with regards to restaurant operation, office building closures, in-home dining, and increased commercial cleaning within the catchment. Lower inflows were recorded during the 2019-20 financial year compared with previous years, again, possibly in response to the COVID-19 pandemic with Sydney City catchment demographic changes.

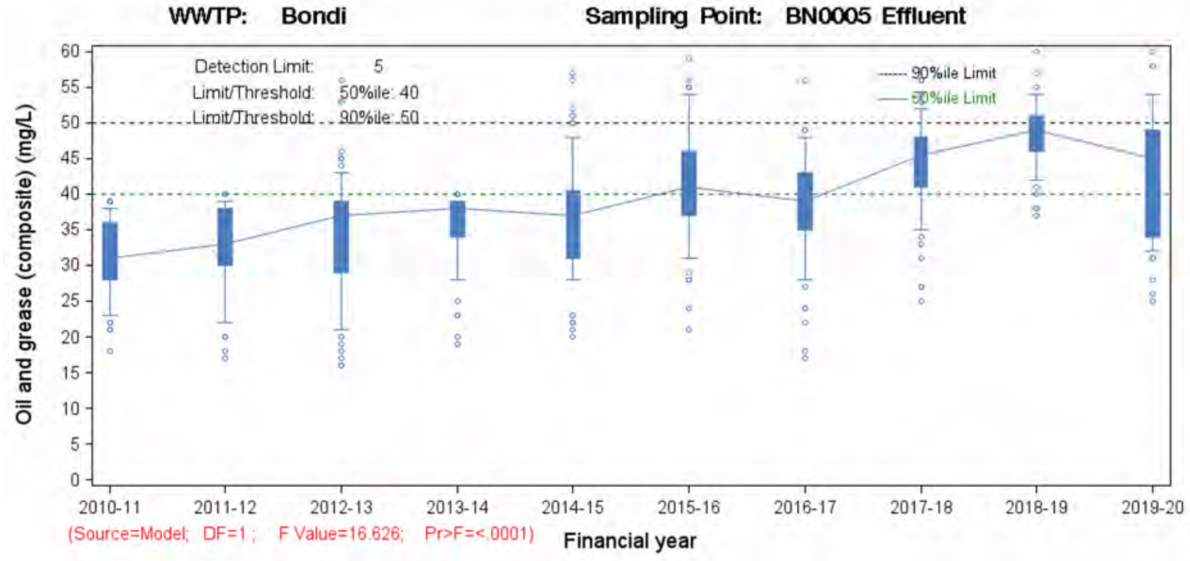

WWTP: Bondi
Rainfall
Inflow
Discharge
Influent/Discharge volume (ML)
Rainfall (mm)
Financial year
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20


WWTP: Bondi
Load Limit (kg)= 3066000
Oil and grease (kg)
Total LBL flow (ML)
Financial year
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20

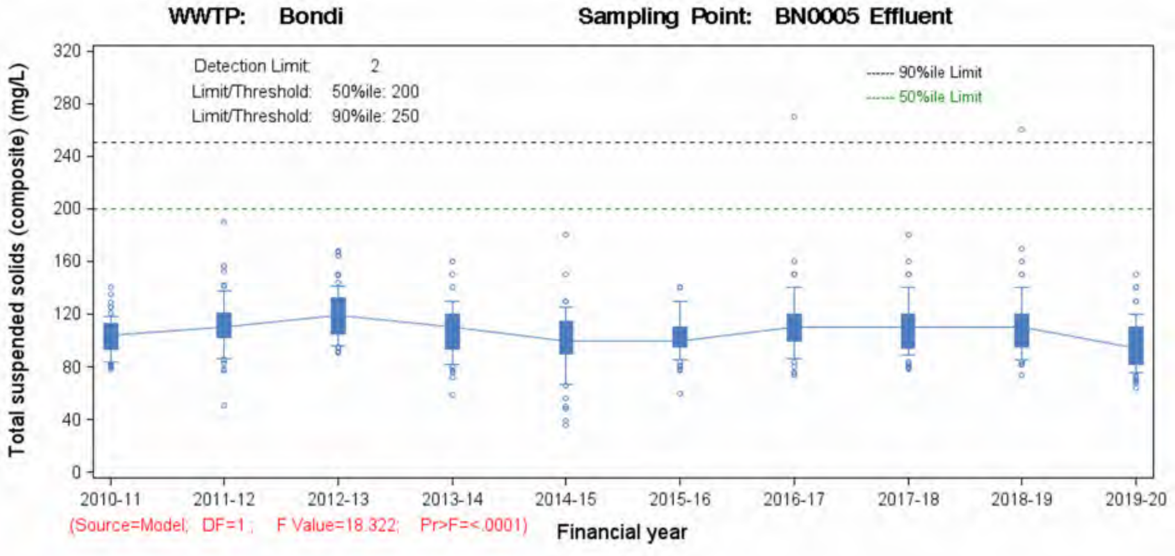

WWTP: Bondi
Load Limit (kg)= 11497500
Total suspended solids (kg)
Total LBL flow (ML)
Financial year
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20



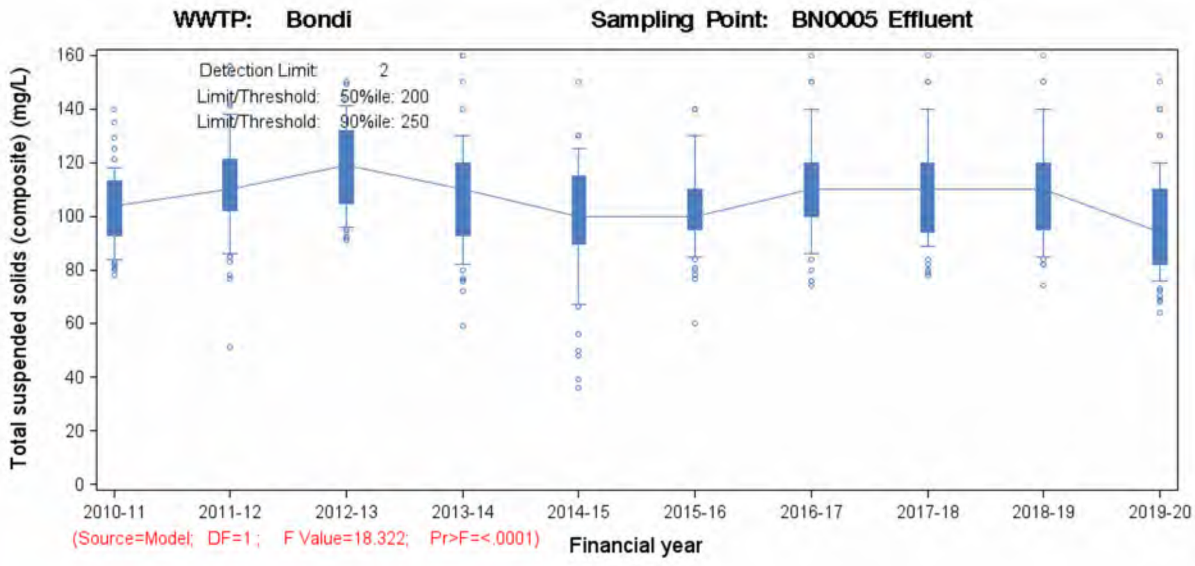
WWTP: Bondi
Sampling Point: BN0005 Effluent
Detection Limit: 5
Limit/Threshold: 50%ile: 40
Limit/Threshold: 90%ile: 50
90%ile Limit
50%ile Limit
Oil and grease (composite) (mg/L)
Financial year
(Source=Model; DF=1 ; F Value=16.626; Pr>F=<.0001)

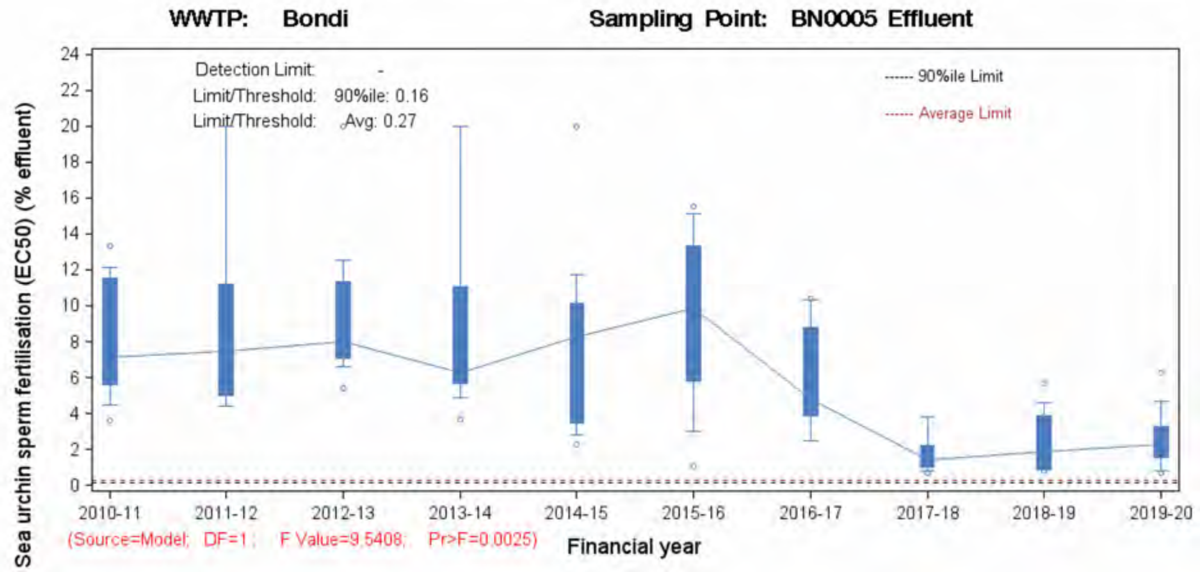


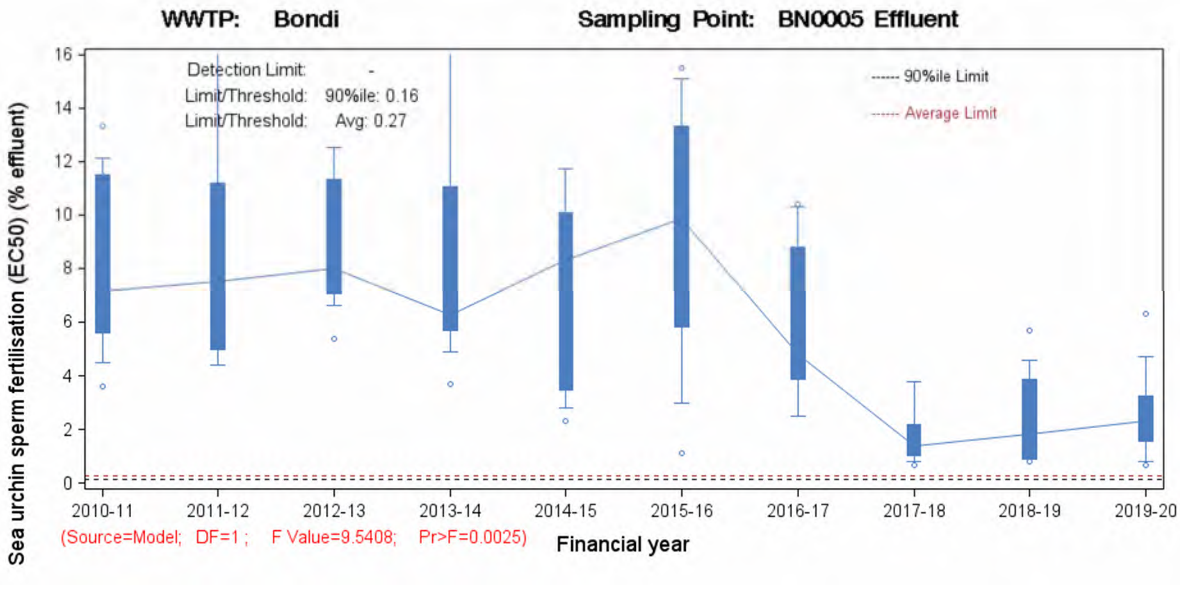
WWTP: Bondi
Sampling Point: BN0005 Effluent
Detection Limit: 5
Limit/Threshold: 50%ile: 40
Limit/Threshold: 90%ile: 50
90%ile Limit
50%ile Limit
Oil and grease (composite) (mg/L)
Financial year
(Source=Model; DF=1 ; F Value=16.626; Pr>F=<.0001)

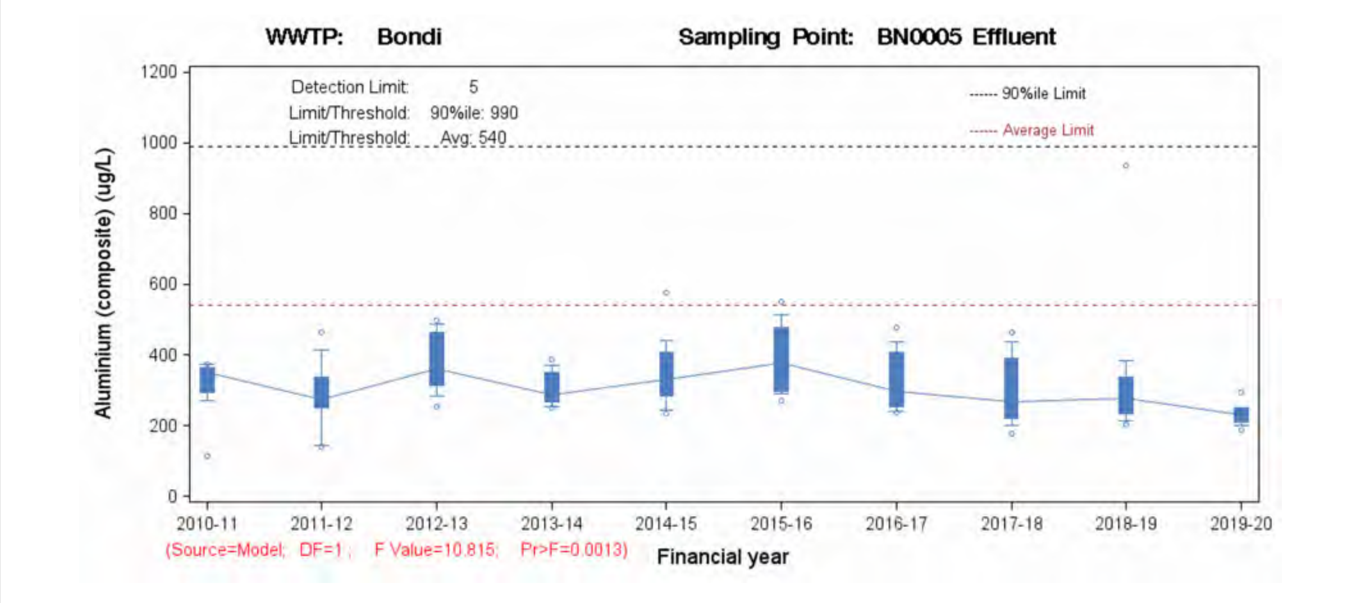


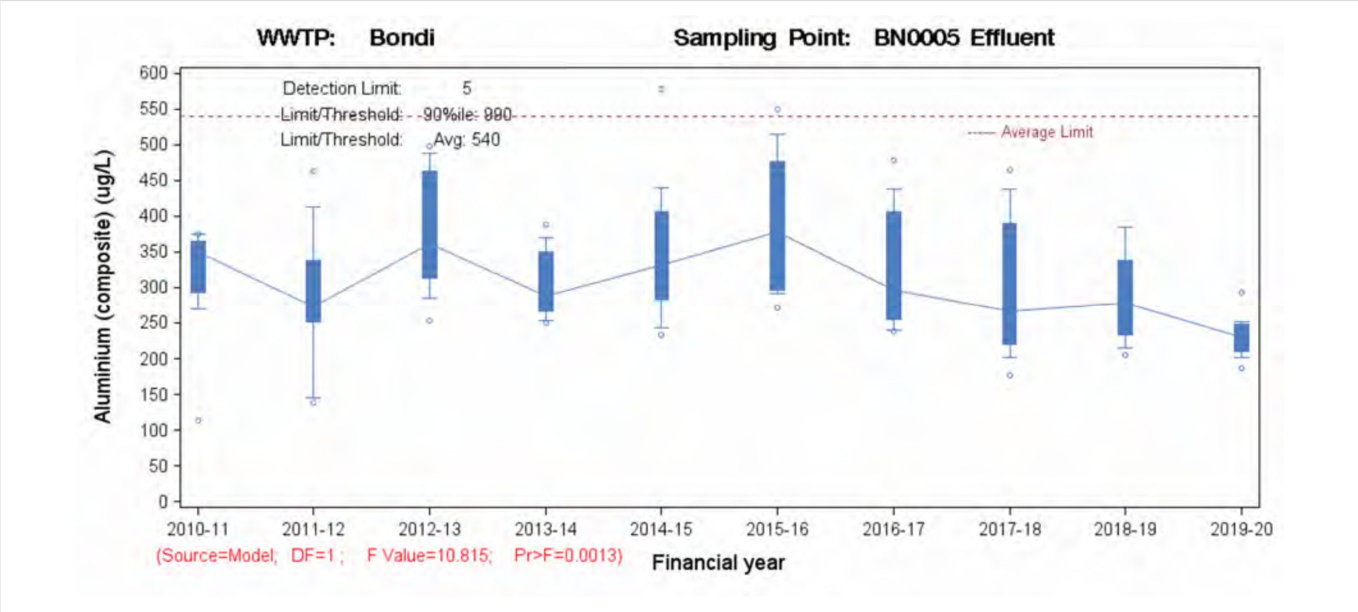
WWTP: Bondi
Sampling Point: BN0005 Effluent
Detection Limit: 2
Limit/Threshold: 50%ile: 200
Limit/Threshold: 90%ile: 250
90%ile Limit
50%ile Limit
Total suspended solids (composite) (mg/L)
Financial year
(Source=Model; DF=1 ; F Value=18.322; Pr>F=<.0001)

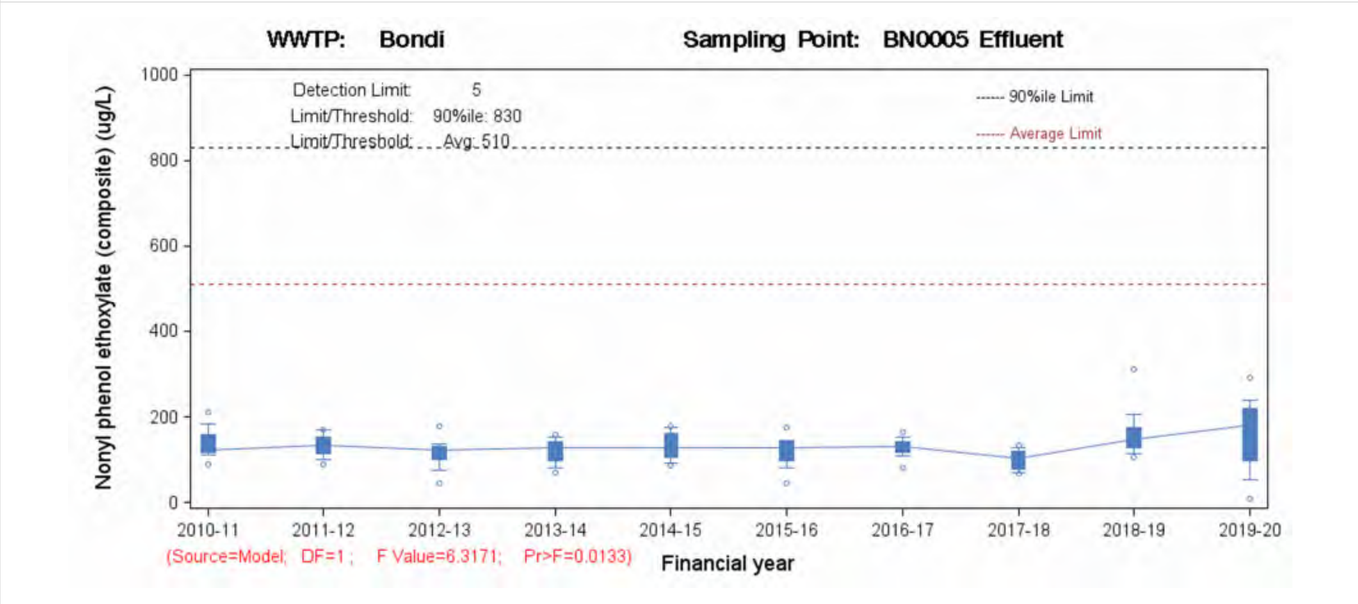

WWTP: Bondi
Sampling Point: BN0005 Effluent
Total suspended solids (composite) (mg/L)
Detection Limit: 2
Limit/Threshold: 50%ile: 200
Limit/Threshold: 90%ile: 250
(Source=Model; DF=1 ; F Value=18.322; Pr>F=<.0001)
Financial year

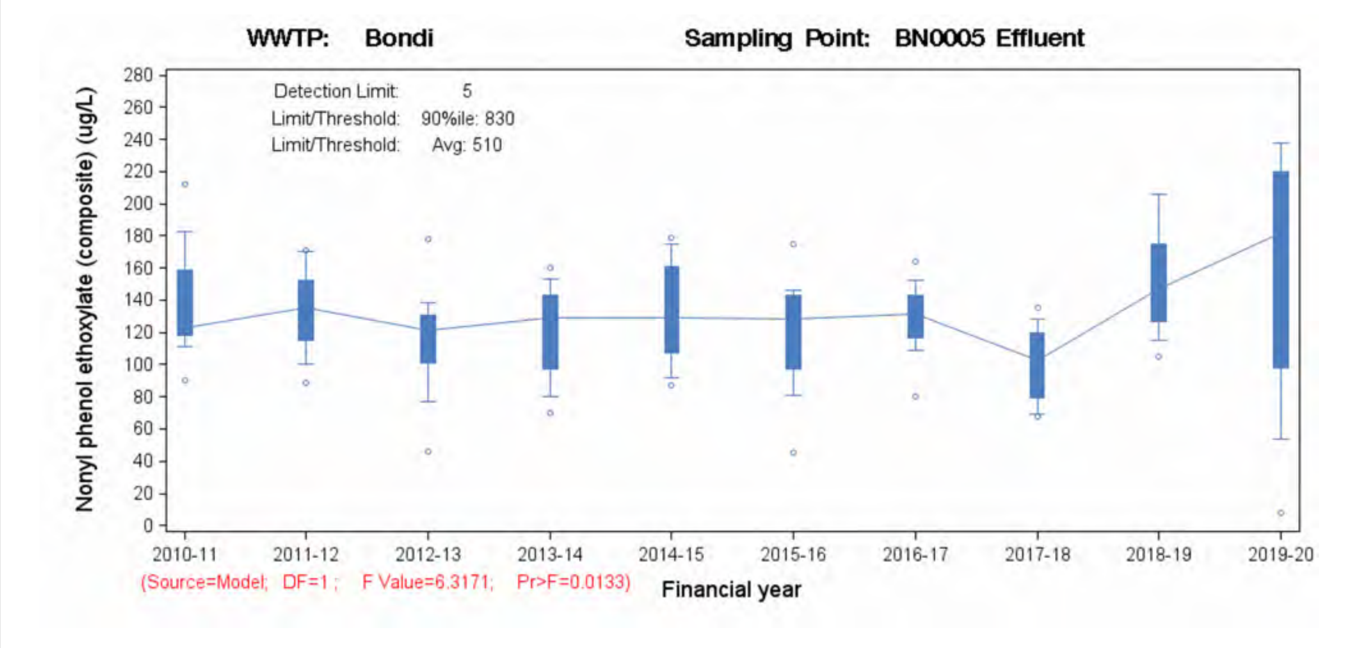

WWTP: Bondi
Sampling Point: BN0005 Effluent
Sea urchin sperm fertilisation (EC50) (% effluent)
Detection Limit: -
Limit/Threshold: 90%ile: 0.16
Limit/Threshold: Avg: 0.27
------ 90%ile Limit
------ Average Limit
(Source=Model; DF=1 ; F Value=9.5408; Pr>F=0.0025)
Financial year


WWTP: Bondi
Sampling Point: BN0005 Effluent
Sea urchin sperm fertilisation (EC50) (% effluent)
Detection Limit: -
Limit/Threshold: 90%ile: 0.16
Limit/Threshold: Avg: 0.27
------ 90%ile Limit
------ Average Limit
(Source=Model; DF=1 ; F Value=9.5408; Pr>F=0.0025)
Financial year


WWTP: Bondi
Sampling Point: BN0005 Effluent
Detection Limit: 5
Limit/Threshold: 90%ile: 990
Limit/Threshold: Avg: 540
------ 90%ile Limit
------ Average Limit
Aluminium (composite) (ug/L)
1200
1000
800
600
400
200
0
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=10.815; Pr>F=0.0013)
Financial year


WWTP: Bondi
Sampling Point: BN0005 Effluent
Detection Limit: 5
Limit/Threshold: 90%ile: 990
Limit/Threshold: Avg: 540
------ Average Limit
Aluminium (composite) (ug/L)
600
550
500
450
400
350
300
250
200
150
100
50
0
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=10.815; Pr>F=0.0013)
Financial year


WWTP: Bondi
Sampling Point: BN0005 Effluent
Detection Limit: 5
Limit/Threshold: 90%ile: 830
Limit/Threshold: Avg: 510
------ 90%ile Limit
------ Average Limit
Nonyl phenol ethoxylate (composite) (ug/L)
1000
800
600
400
200
0
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=6.3171; Pr>F=0.0133)
Financial year

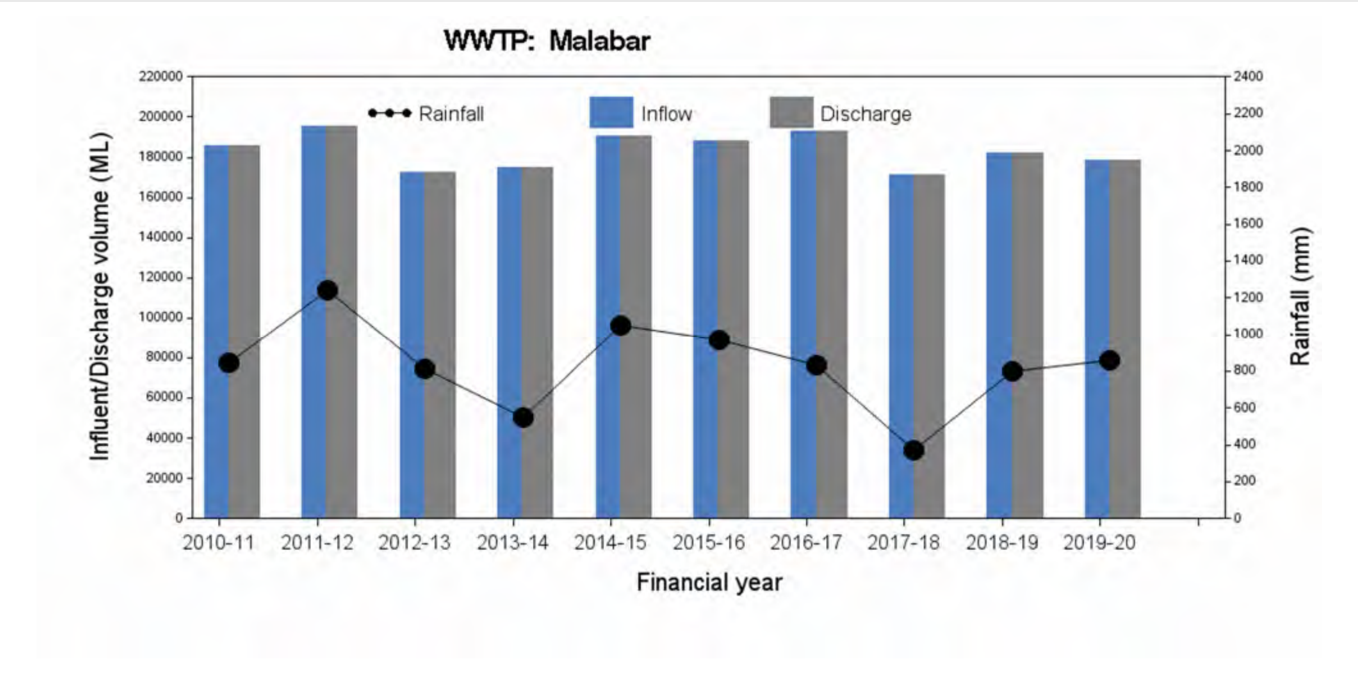

WWTP: Bondi
Sampling Point: BN0005 Effluent
Detection Limit: 5
Limit/Threshold: 90%ile: 830
Limit/Threshold: Avg: 510
Nonyl phenol ethoxylate (composite) (ug/L)
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=6.3171; Pr>F=0.0133)
Financial year

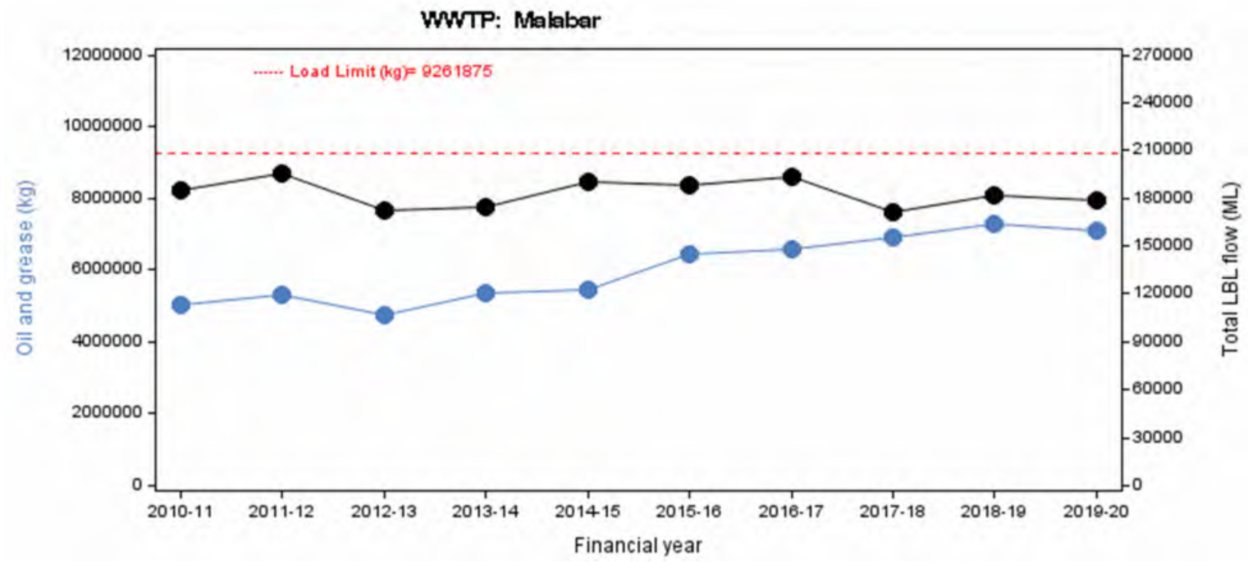
4.1.4 Malabar WWTP

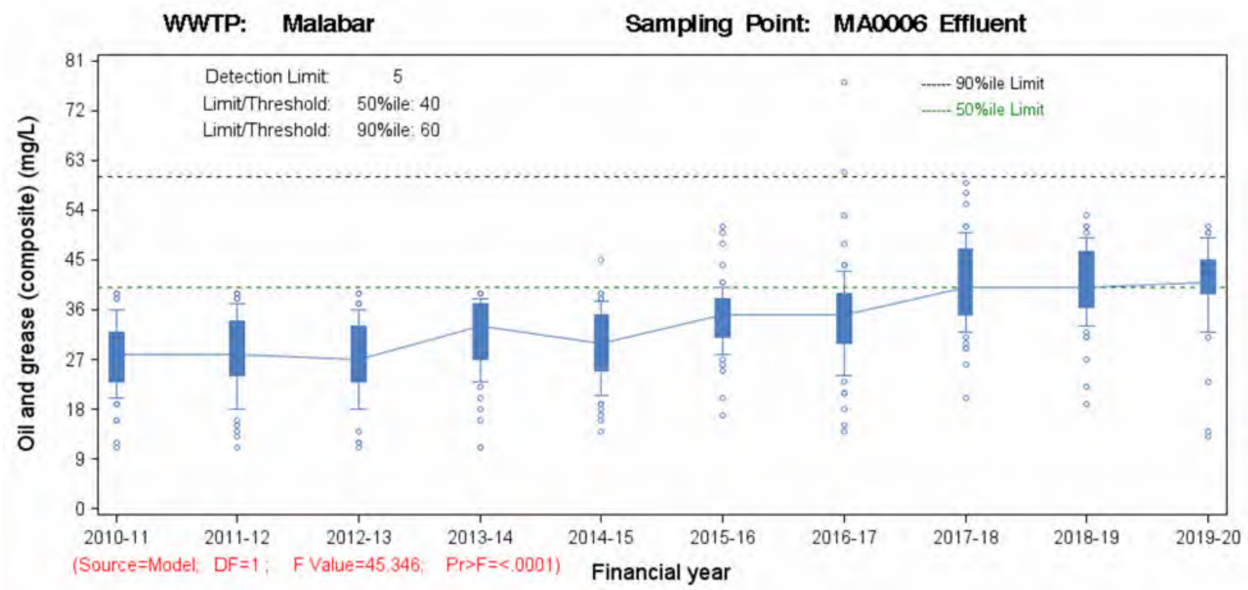
The 50th percentile concentration limit of oil and grease exceeded the EPL limit in the discharge from the Malabar WWTP during the 2019-20 period. Concentrations of all other analytes and load limits in the final discharge were within the EPL limits during this period. Statistical analysis identified significantly increasing trends in oil and grease concentration. The load plots for oil and grease are also shown below, illustrating a drop in load levels during 2019-20 compared to earlier years.

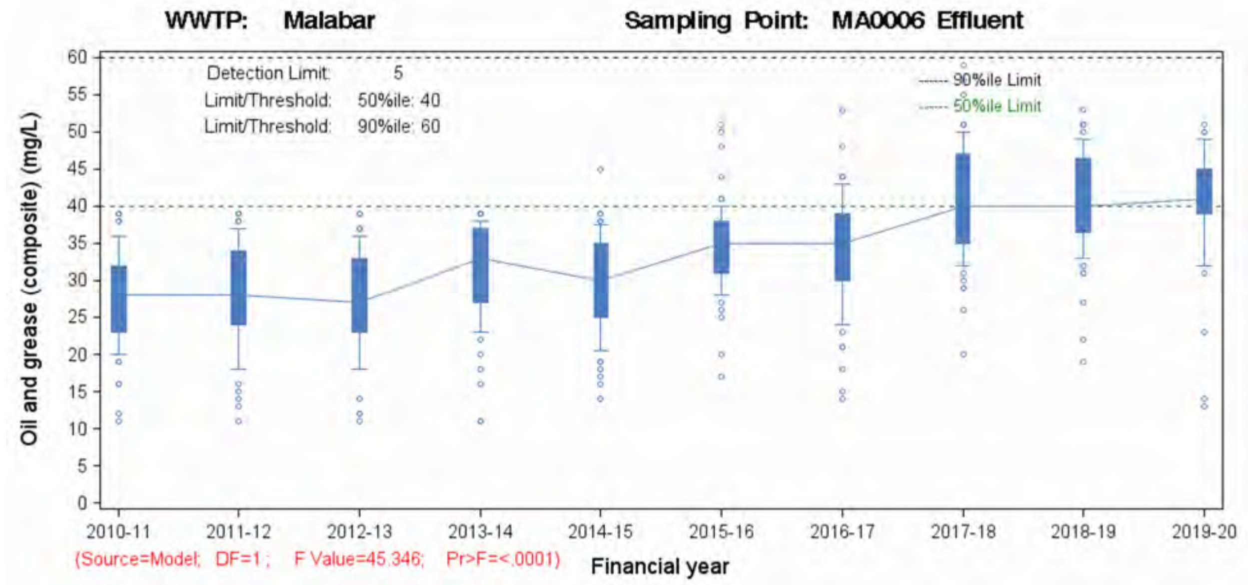
The high variance between the 25th percentile and the low exception values in 2019-20 for oil and grease is possibly a sign of the COVID-19 impact on the catchment demographic, with changes to patterns of detergent use, restaurant and business operation, in-home dining, and increased commercial cleaning within the catchment. Lower inflows to Malabar WWTP were also recorded during the 2019-20 financial year compared with previous years, again a possible reflection of the catchment's response to the COVID-19 pandemic.

Consistent with North Head and Bondi, Sydney Water also targeted the Malabar WWTP catchment to educate the public and their awareness on proper ways to dispose FOG to reduce incoming loads and to prevent blockage in the sewer networks. All available primary sedimentation tanks were online at Malabar WWTP during the 2019-20 reporting period with the plant operating under normal conditions.



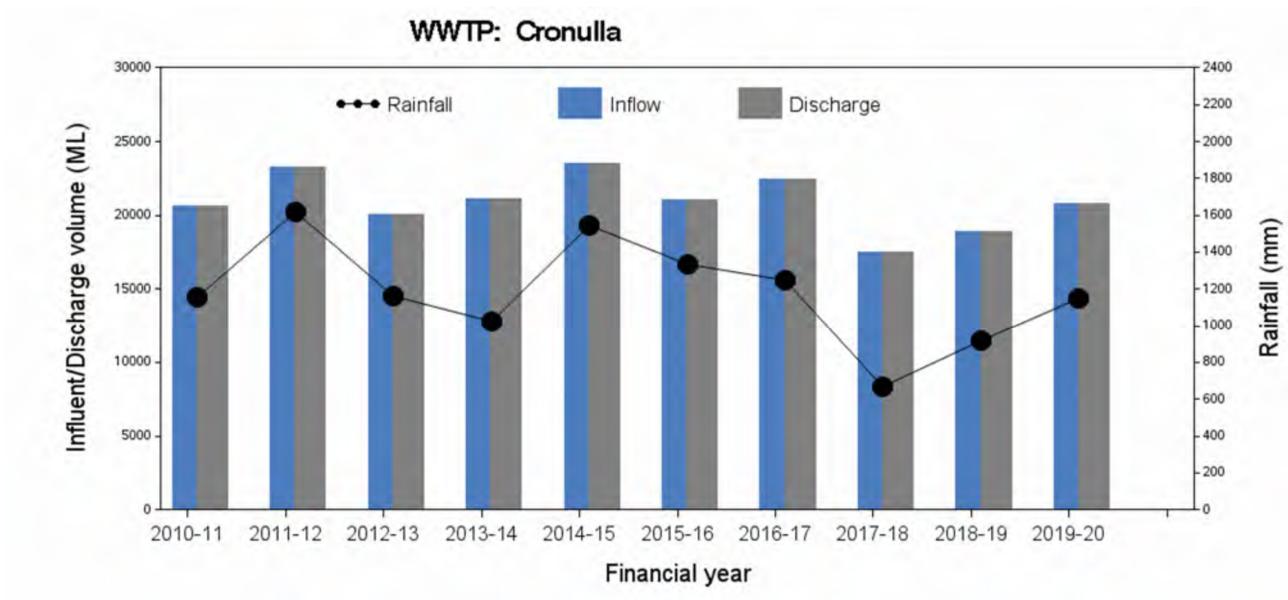

WWTP: Malabar
Load Limit (kg)= 9261875
Oil and grease (kg)
Total LBL flow (ML)
Financial year
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20

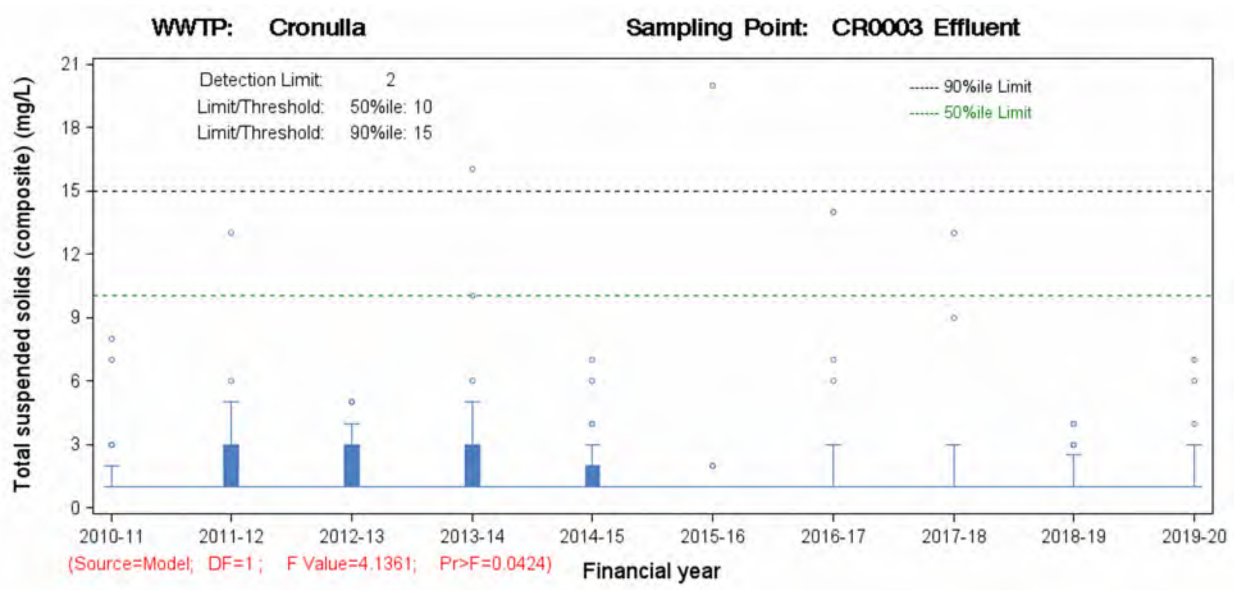

WWTP: Malabar
Sampling Point: MA0006 Effluent
Detection Limit: 5
Limit/Threshold: 50%ile: 40
Limit/Threshold: 90%ile: 60
90%ile Limit
50%ile Limit
Oil and grease (composite) (mg/L)
(Source=Model; DF=1 ; F Value=45.346; Pr>F=<.0001)
Financial year

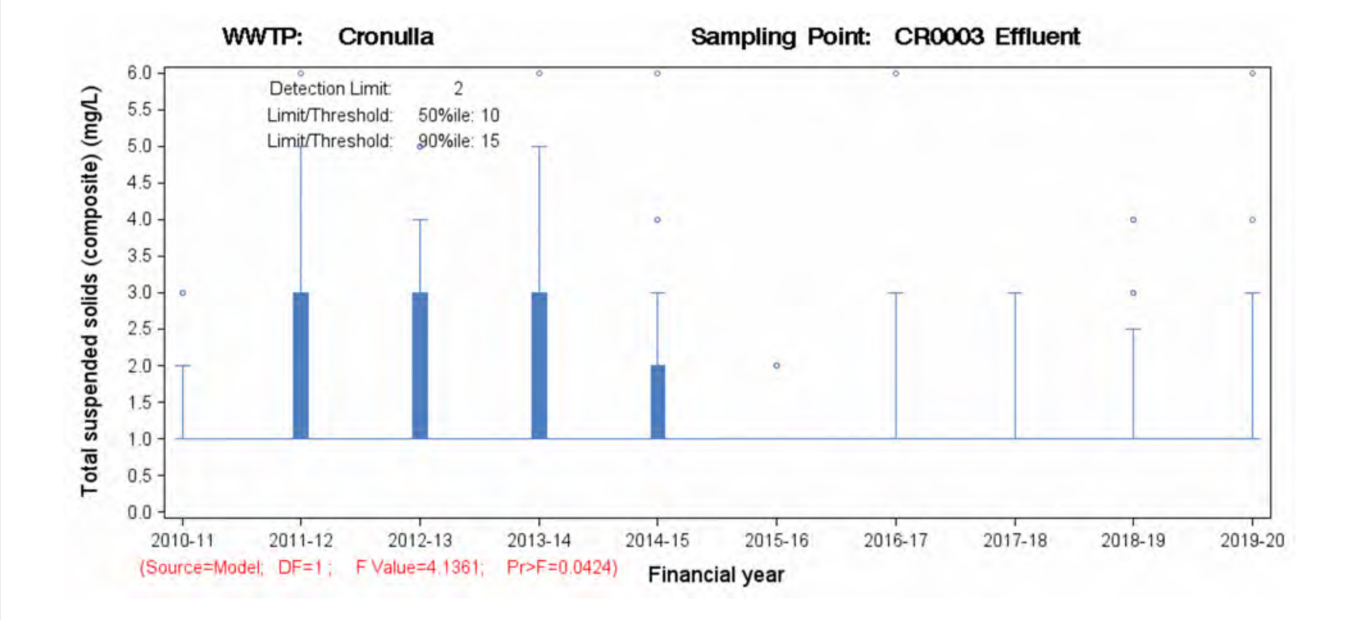

WWTP: Malabar
Sampling Point: MA0006 Effluent
Detection Limit: 5
Limit/Threshold: 50%ile: 40
Limit/Threshold: 90%ile: 60
90%ile Limit
50%ile Limit
Oil and grease (composite) (mg/L)
(Source=Model; DF=1 ; F Value=45.346; Pr>F=<.0001)
Financial year

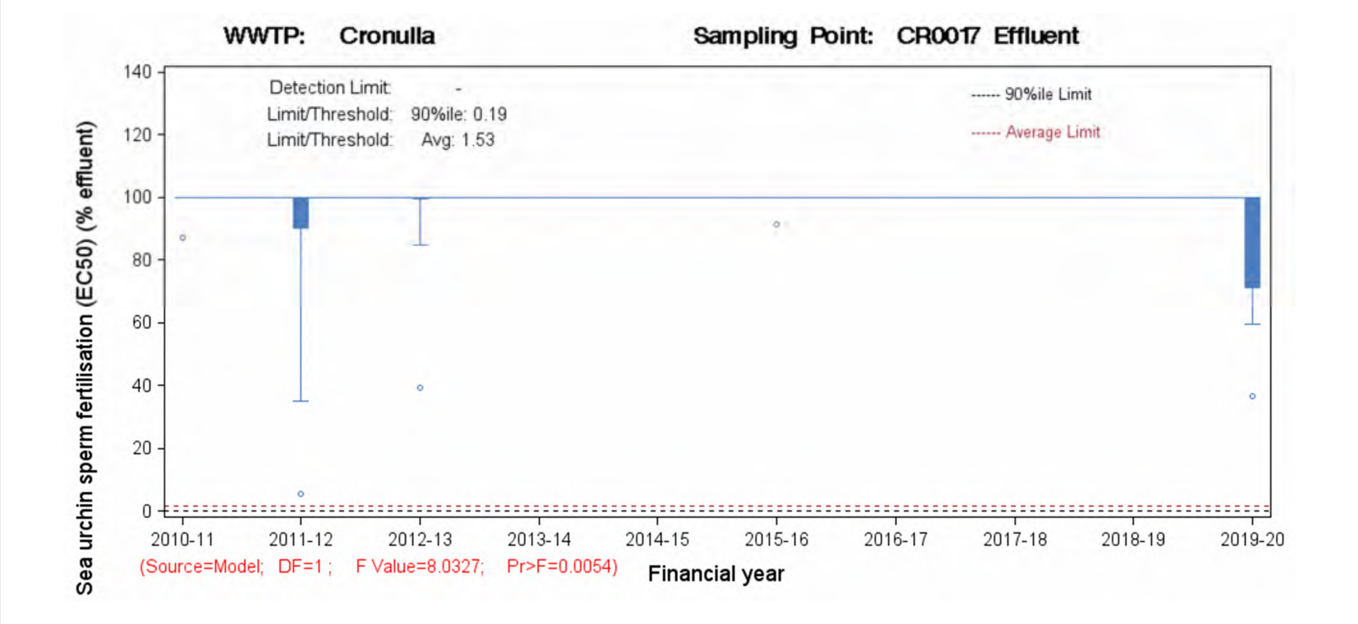
4.1.5 Cronulla WWTP

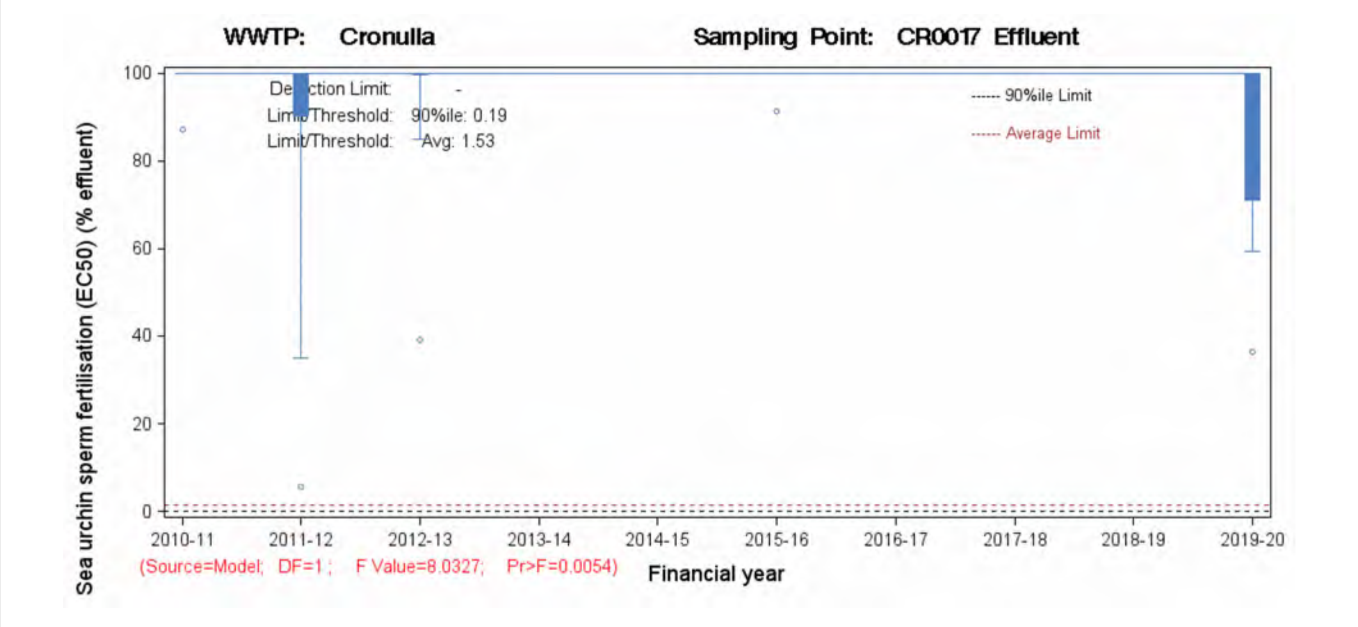
All concentration and load limits in the discharge from Cronulla WWTP were within the EPL limits during the 2019-20 period. Statistical analysis identified a significantly increasing trend in toxicity and zinc concentrations. The increasing trend in toxicity has been linked to major wet weather events experienced at the plant during 2019-20. Work is being carried out to upgrade the filters to improve performance during wet weather events. The increasing concentration trend in zinc is possibly related to trade waste customers. Cronulla WWTP saw an increase in inflows and subsequent loads during the second half of 2020, possibly due to the COVID-19 pandemic with more people working from home. A decreasing trend in total suspended solids was also observed in 2019-20 in comparison to the earlier nine years.

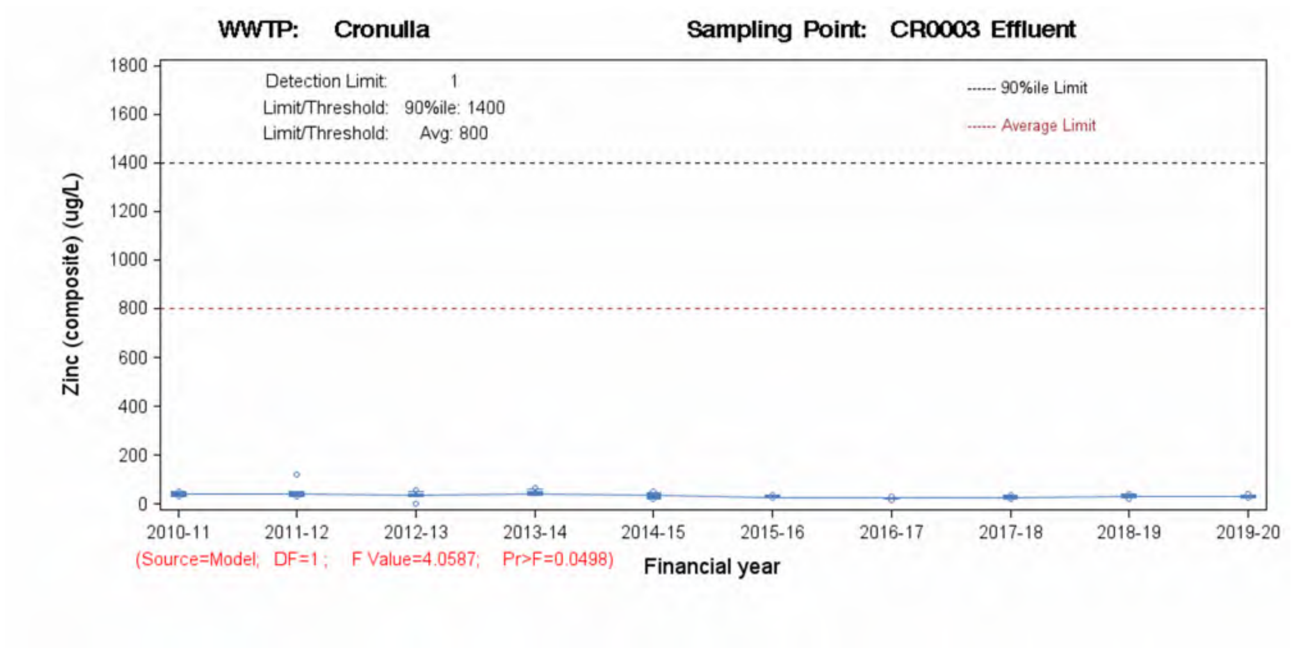




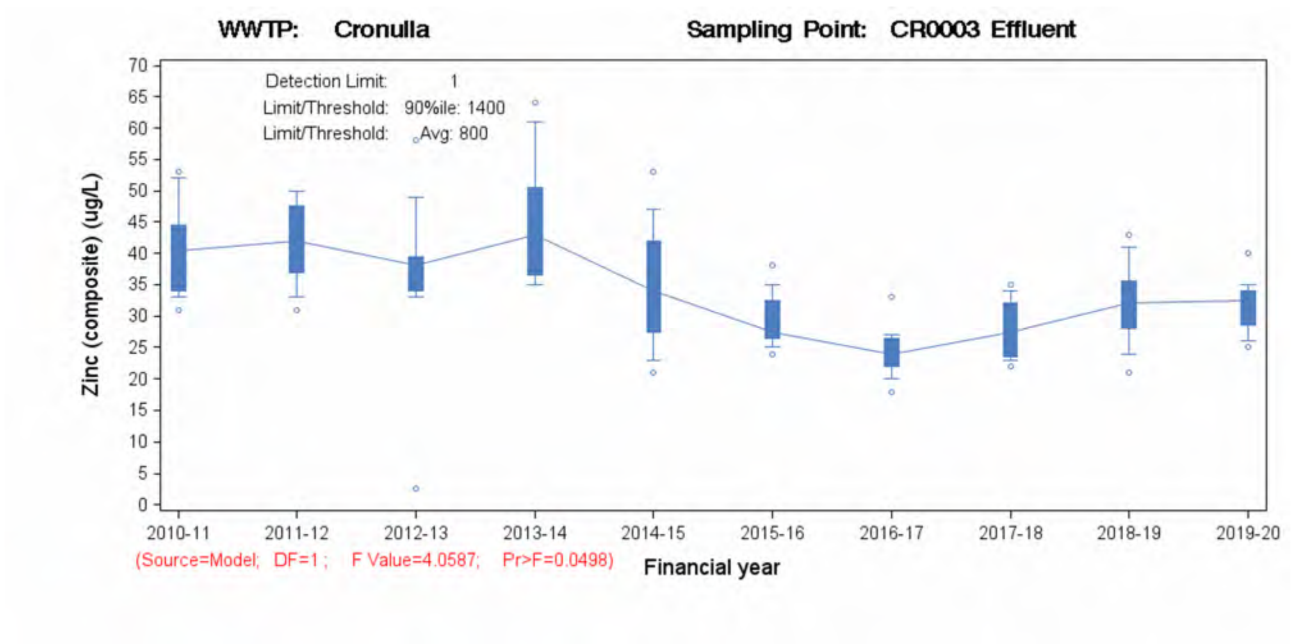

WWTP: Cronulla
Sampling Point: CR0003 Effluent
Detection Limit: 2
Limit/Threshold: 50%ile: 10
Limit/Threshold: 90%ile: 15
Total suspended solids (composite) (mg/L)
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=4.1361; Pr>F=0.0424)
Financial year


WWTP: Cronulla
Sampling Point: CR0017 Effluent
Detection Limit: -
Limit/Threshold: 90%ile: 0.19
Limit/Threshold: Avg: 1.53
------ 90%ile Limit
------ Average Limit
Sea urchin sperm fertilisation (EC50) (% effluent)
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=8.0327; Pr>F=0.0054)
Financial year


WWTP: Cronulla
Sampling Point: CR0017 Effluent
Detection Limit: -
Limit/Threshold: 90%ile: 0.19
Limit/Threshold: Avg: 1.53
------ 90%ile Limit
------ Average Limit
Sea urchin sperm fertilisation (EC50) (% effluent)
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=8.0327; Pr>F=0.0054)
Financial year



Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.

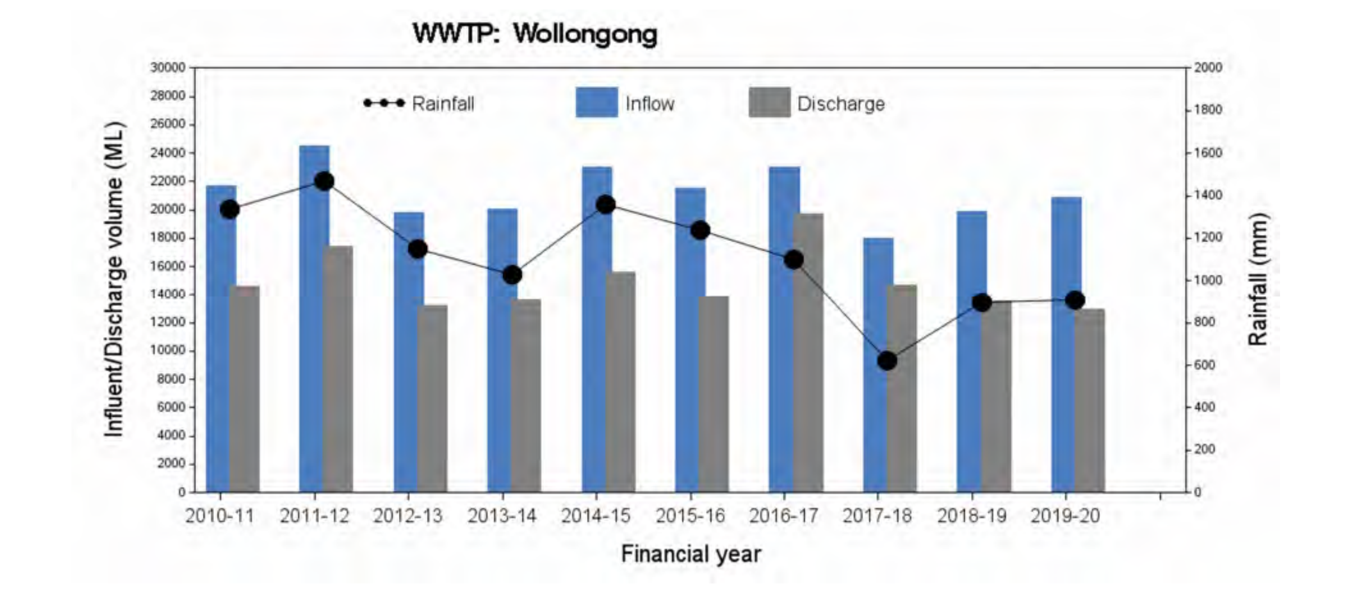


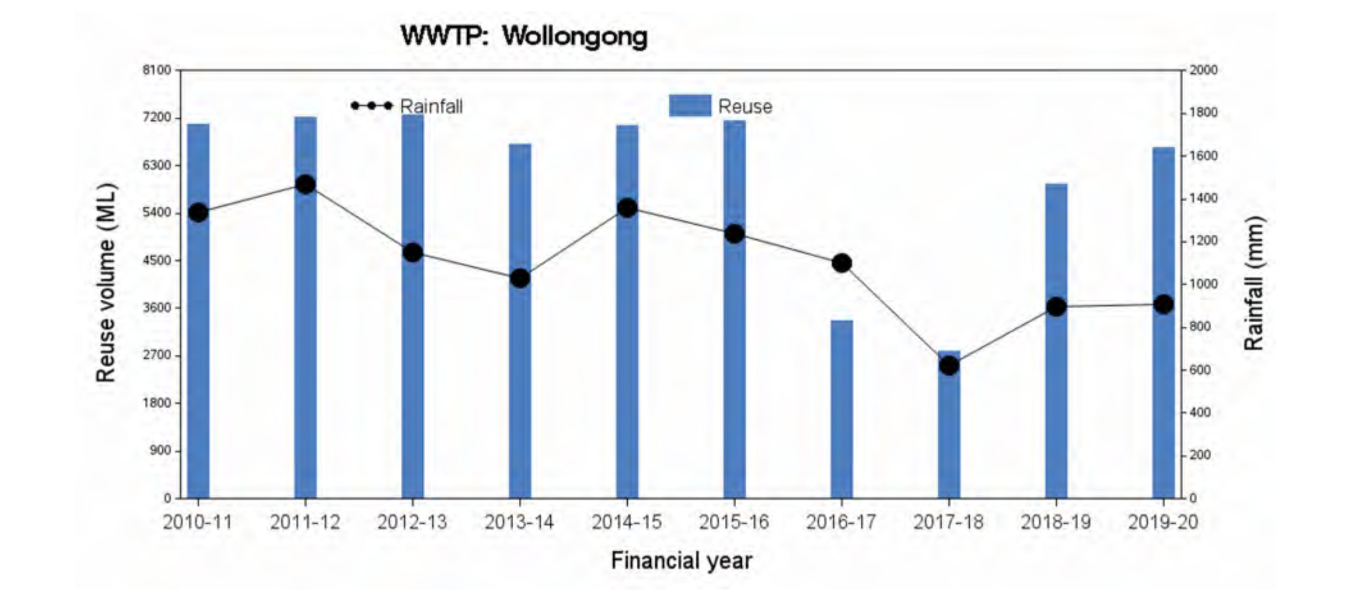
Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.

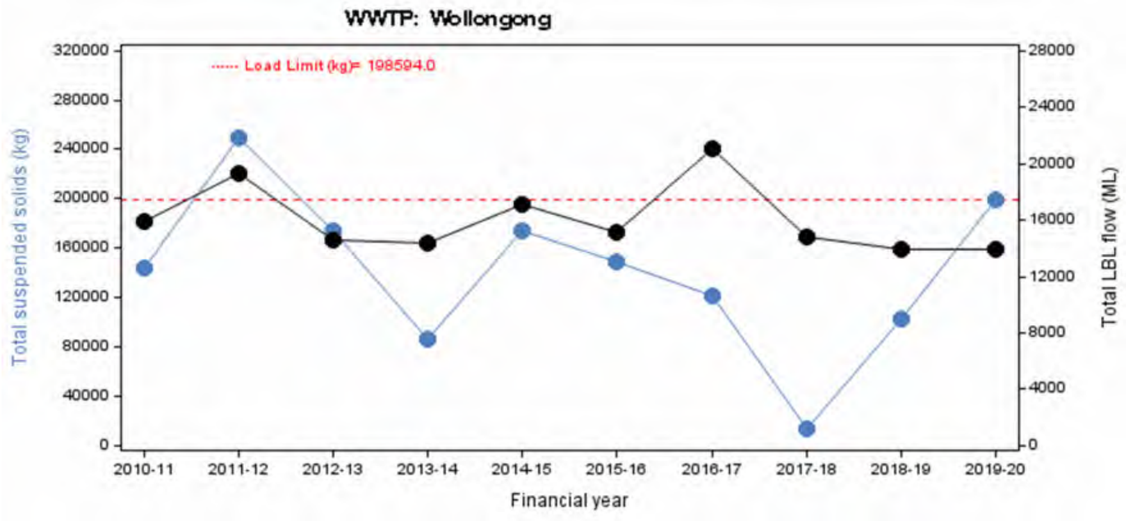
4.1.6 Wollongong WWTP

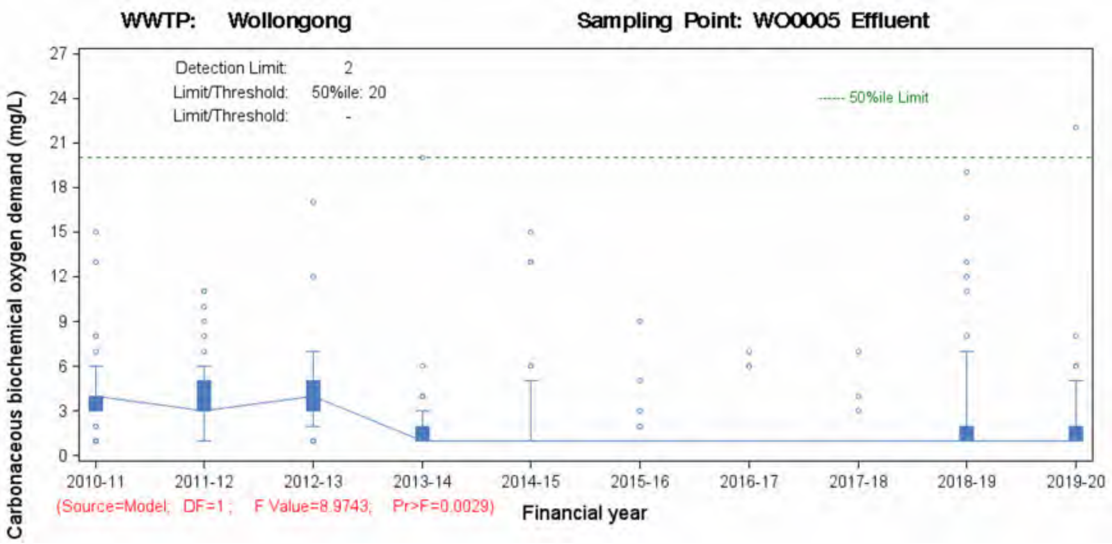
The load limit for total suspended solids was exceeded in the discharge from Wollongong WWTP during the 2019-20 period. All concentration limits in the discharge from Wollongong WWTP were within the EPL limits during this period. Statistical analysis identified significant increasing trends in carbonaceous biochemical oxygen demand and total suspended solids concentrations in comparison to earlier years.

One factor for the increasing trends may be due to the drought conditions and lower influent flows experienced in the previous couple of years, as well as major rainfall events coinciding with compliance monitoring from the beginning of 2020. Secondly, the tertiary filters began media replacement in 2019. Some filters were found to have some media (sand) loss into the underlying plenum. This has the potential to contribute in some part to an increase in carbonaceous biochemical oxygen demand and total suspended solids concentrations in effluent. Wollongong WWTP saw an increase in inflows and subsequent loads during the second half of 2020, possibly due to the COVID-19 pandemic with more people working from home.

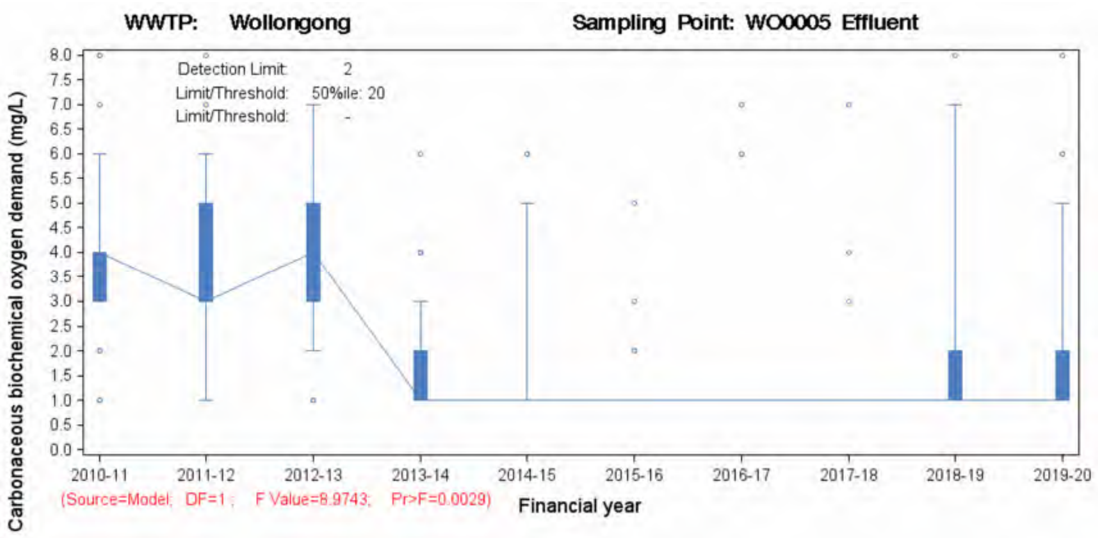




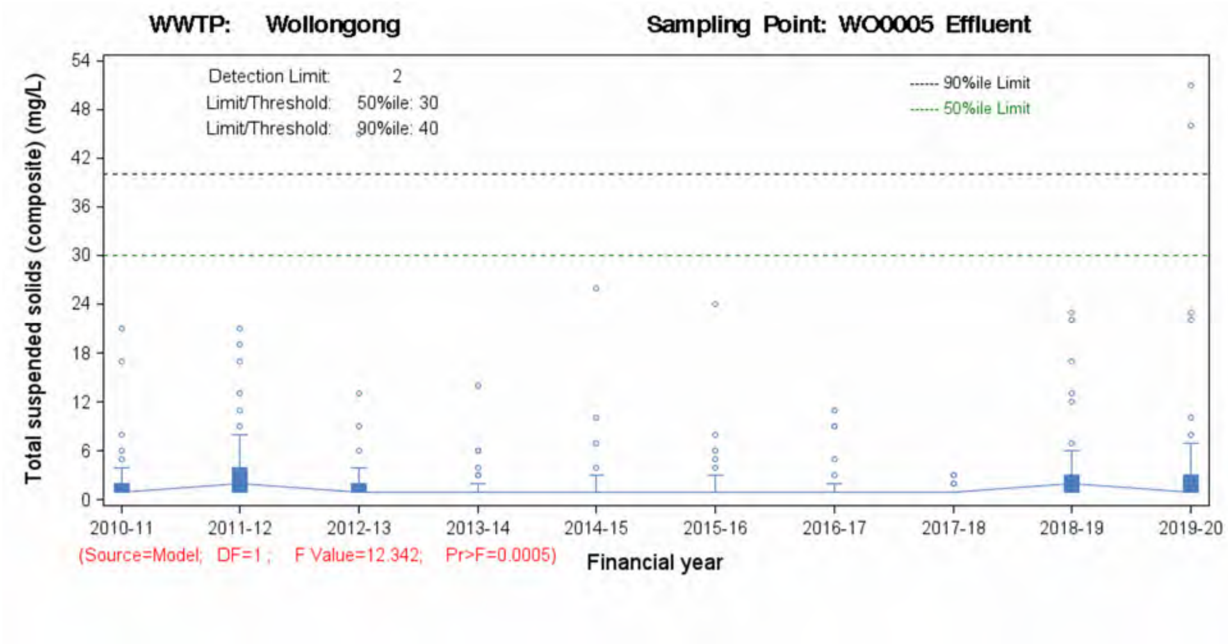


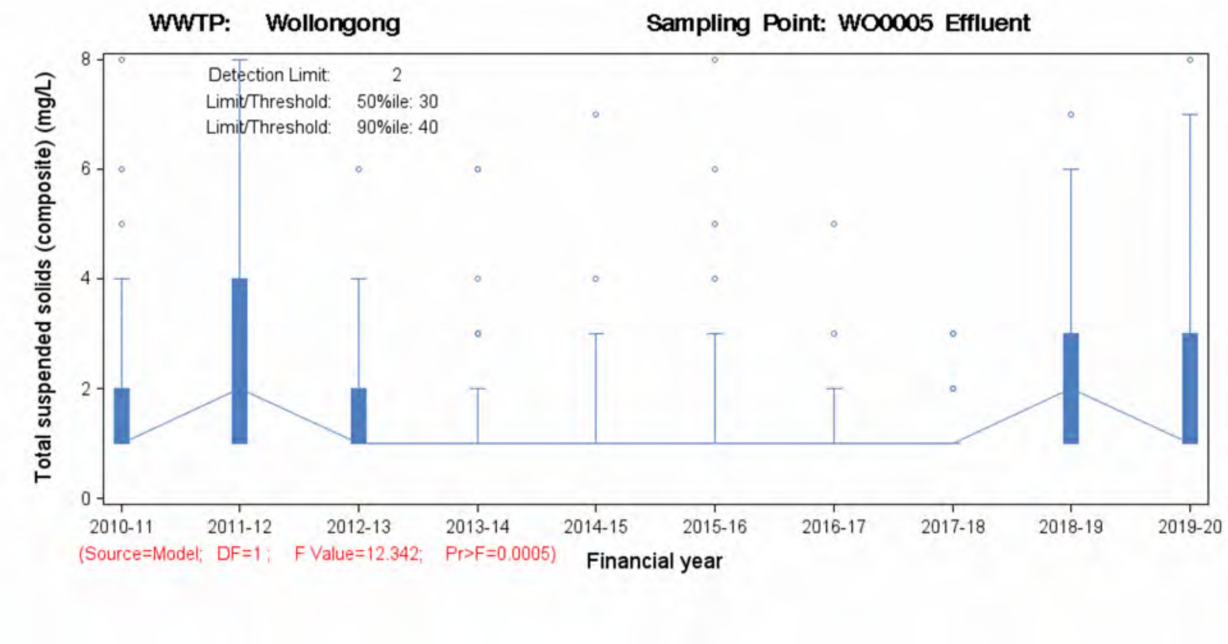


Note: Statistical test was based on 2019-20 data with previous five years data (2014-2019) due to detection limit change in 2014-15.



Note: Statistical test was based on 2019-20 data with previous five years data (2014-2019) due to detection limit change in 2014-15.

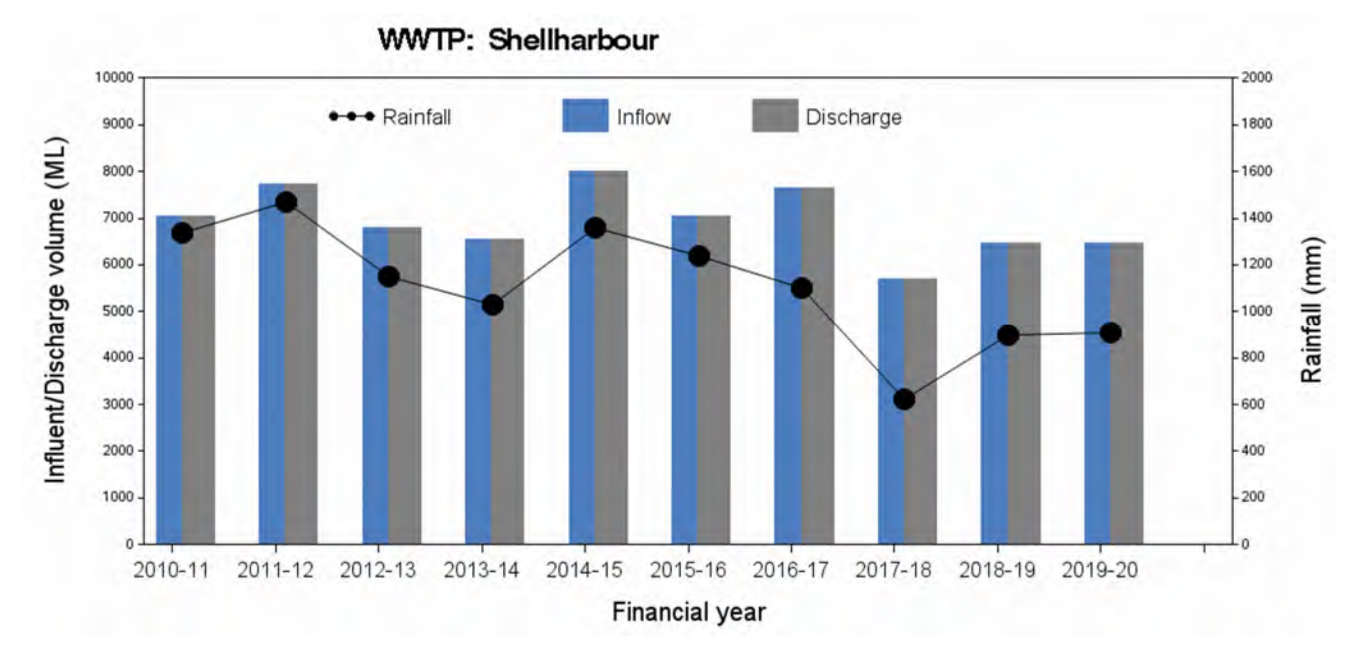

WWTP: Wollongong
Sampling Point: WO0005 Effluent
Detection Limit: 2
Limit/Threshold: 50%ile: 30
Limit/Threshold: 90%ile: 40
------ 90%ile Limit
------ 50%ile Limit
Total suspended solids (composite) (mg/L)
0
6
12
18
24
30
36
42
48
54
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=12.342; Pr>F=0.0005)
Financial year

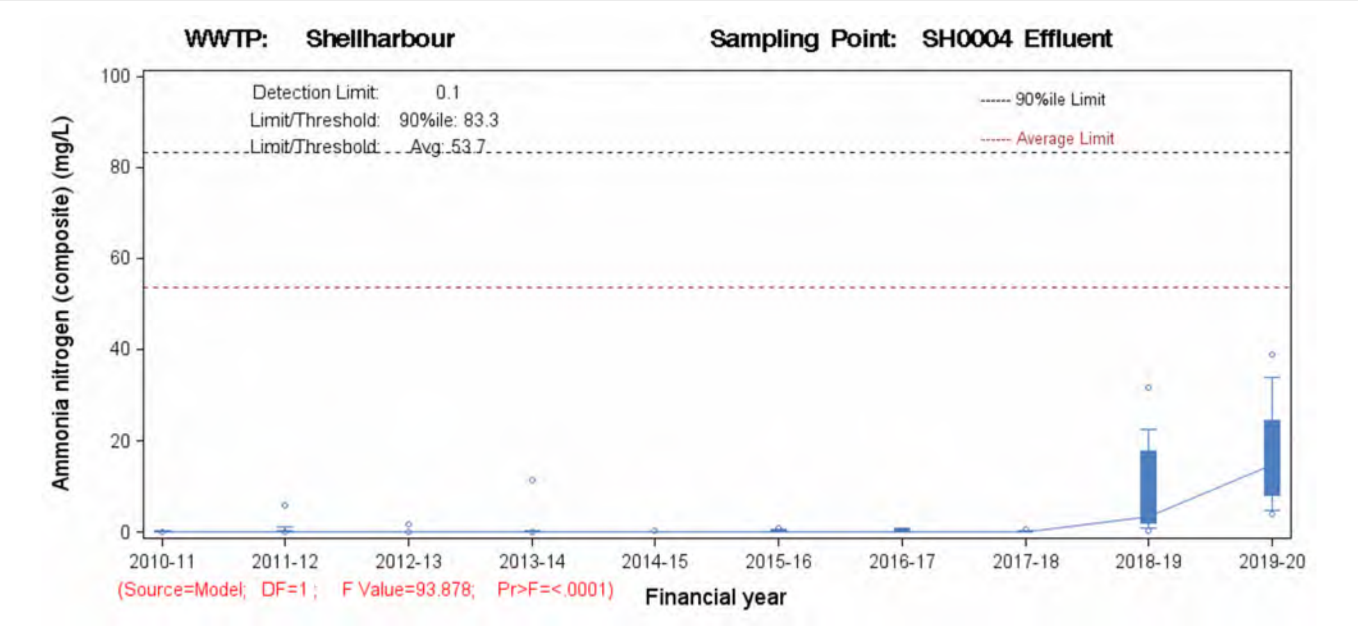

WWTP: Wollongong
Sampling Point: WO0005 Effluent
Detection Limit: 2
Limit/Threshold: 50%ile: 30
Limit/Threshold: 90%ile: 40
Total suspended solids (composite) (mg/L)
0
2
4
6
8
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=12.342; Pr>F=0.0005)
Financial year

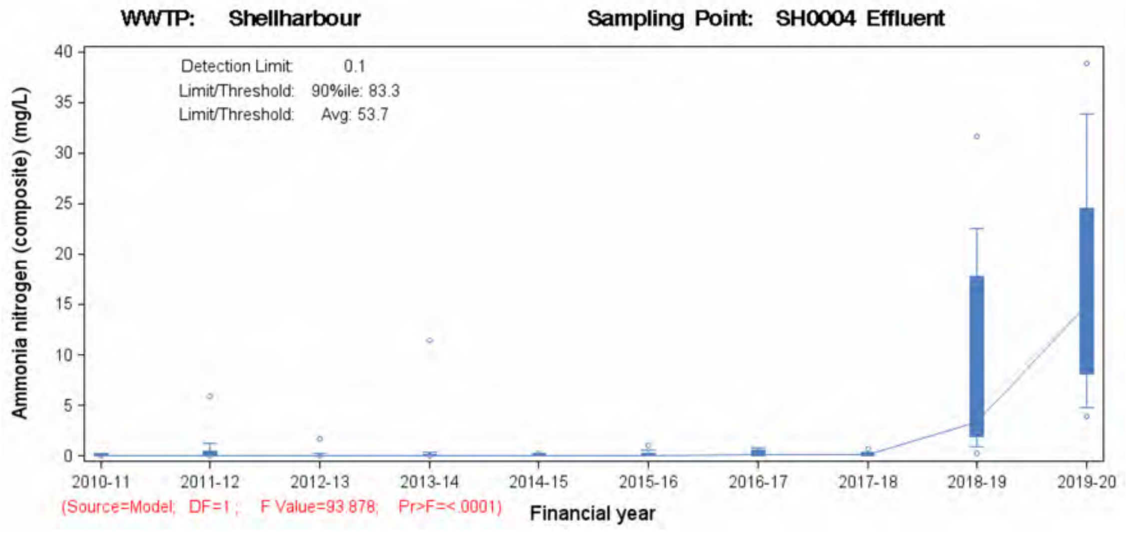
4.1.7 Shellharbour WWTP

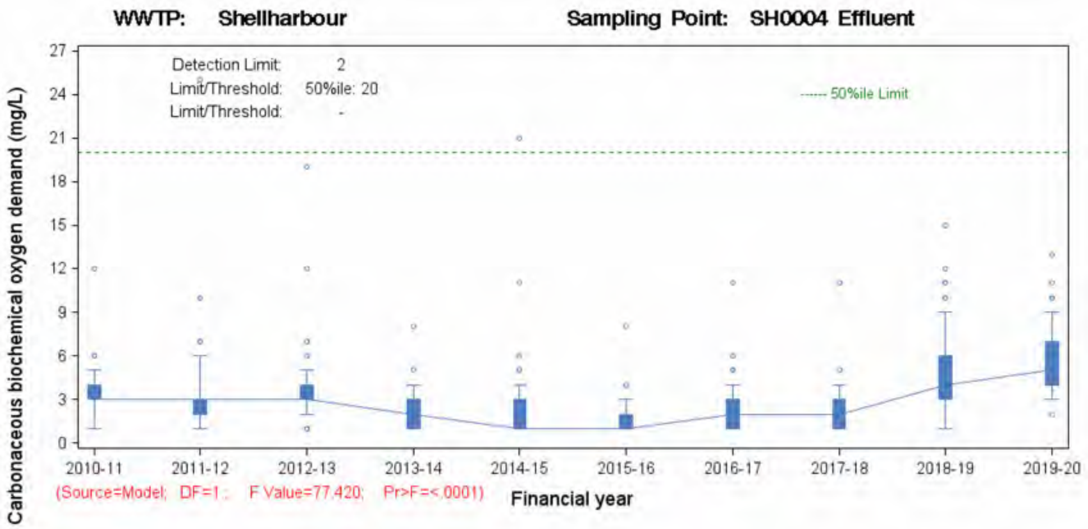
All concentration and load limits in the discharge from Shellharbour WWTP were within the EPL limits during the 2019-20 period. Statistical analysis identified a significant increasing trend in ammonia nitrogen, carbonaceous biochemical oxygen demand and total suspended solids concentrations.

Population growth with new developments like Shellcove in the catchment area would contribute to the upward trend in these analytes. Another factor for the increasing trends is the recent drought conditions and lower flows received in the previous couple of years, as well as major rain fall events coinciding with compliance monitoring dates from the beginning of 2020. The high variance in 25th – 75th percentile range in 2019-20 particularly for ammonia nitrogen illustrates this. Shellharbour WWTP saw an increase in inflows and subsequent loads during the second half of 2020, possibly due to the COVID-19 pandemic with more people working from home.

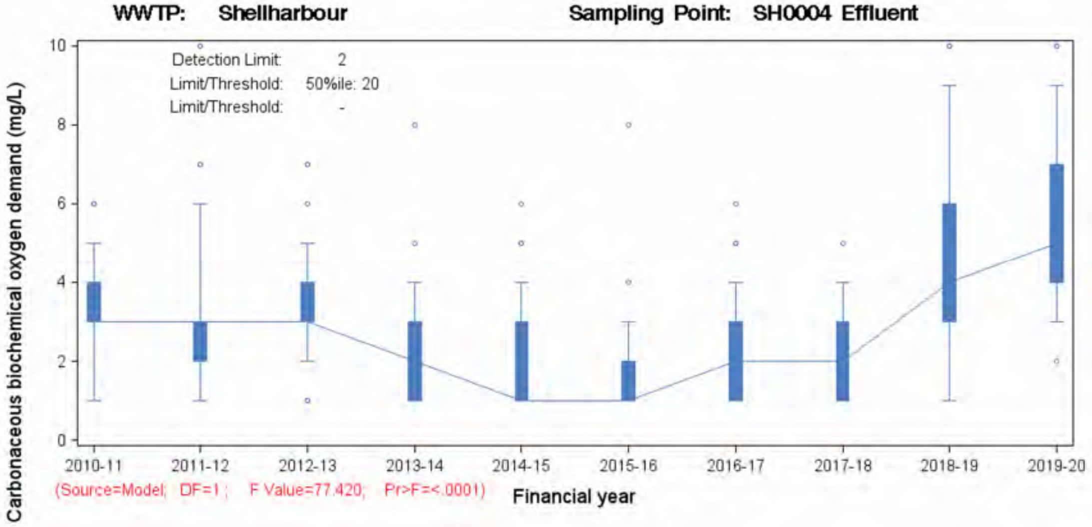




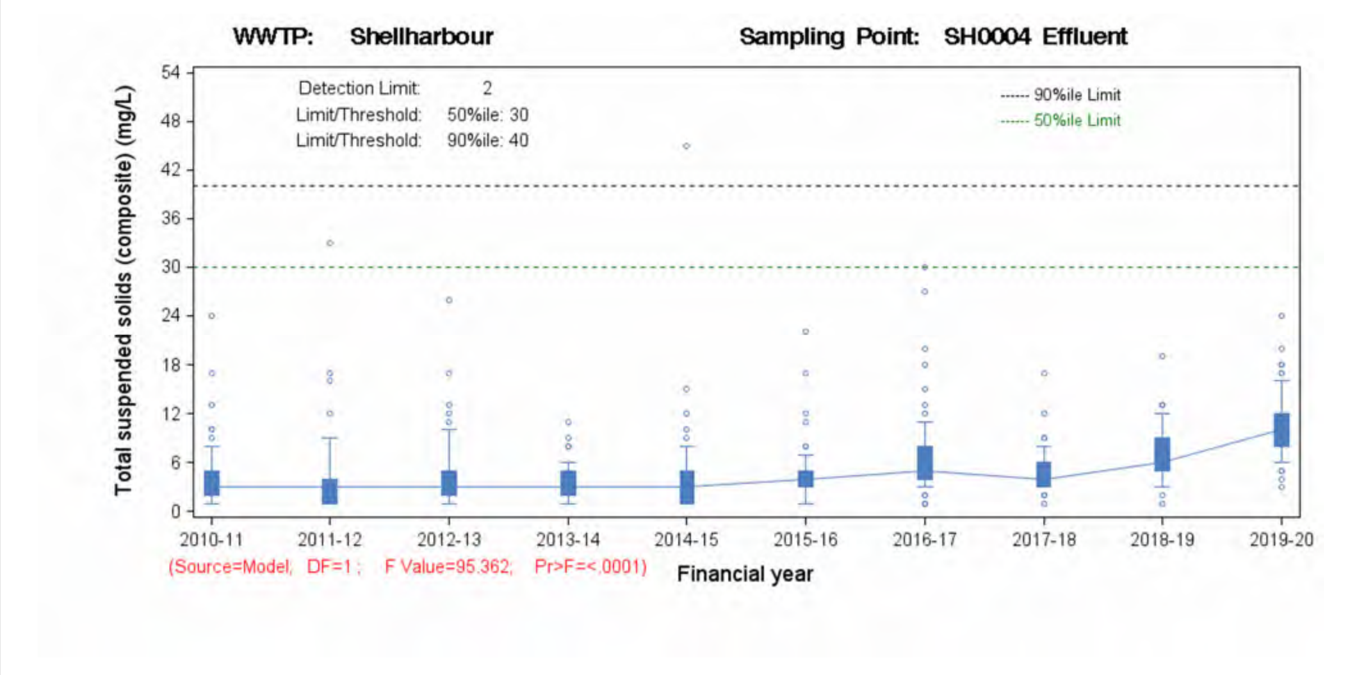




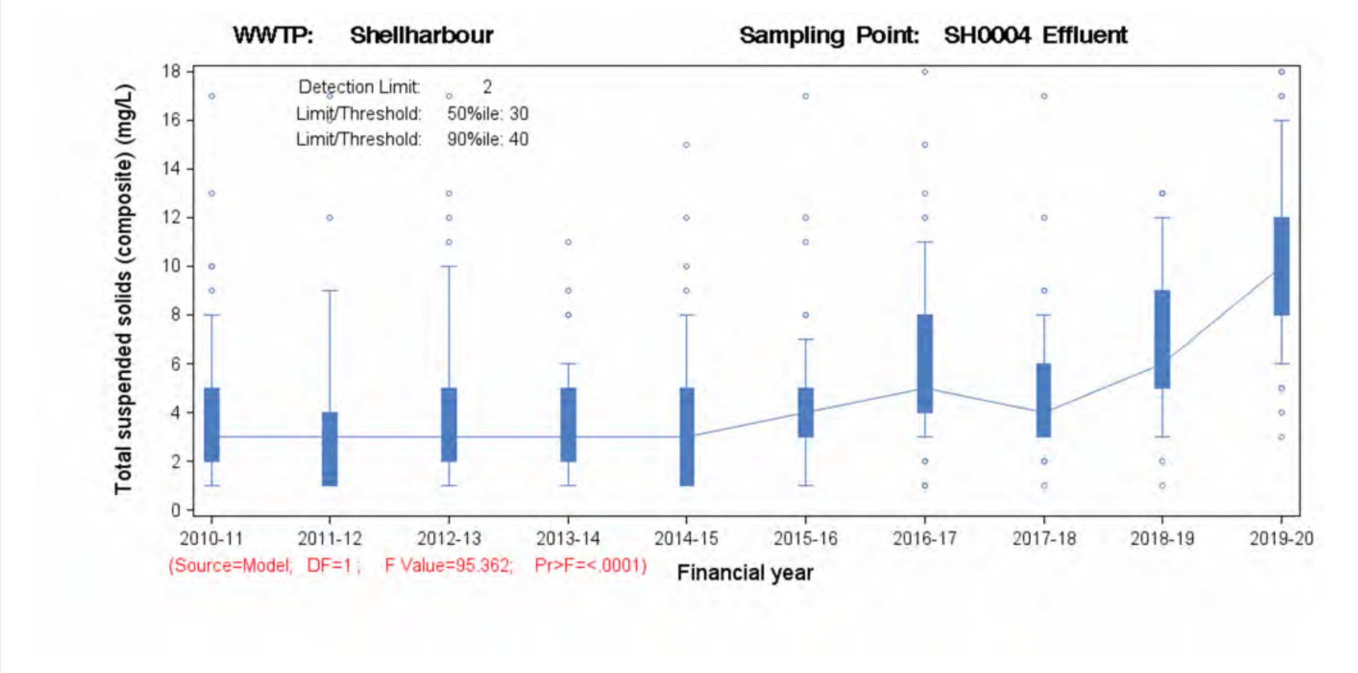
Note: Statistical test was based on 2019-20 data with previous five years data (2014-2019) due to detection limit change in 2014-15.



Note: Statistical test was based on 2019-20 data with previous five years data (2014-2019) due to detection limit change in 2014-15.



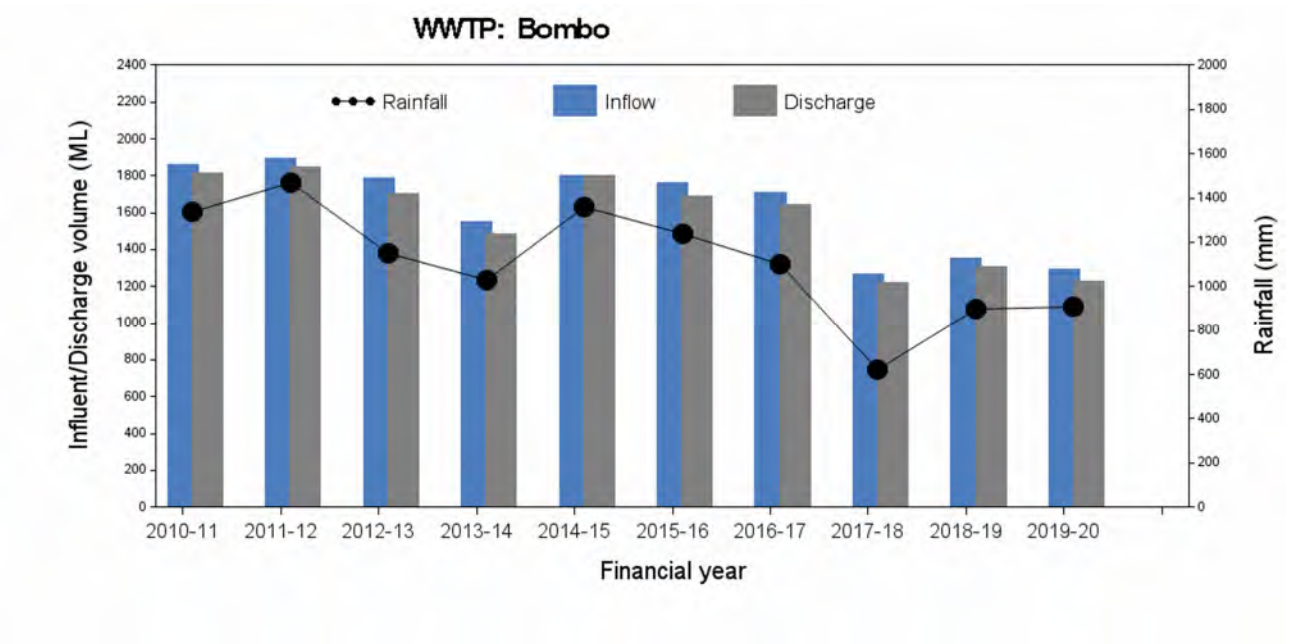
WWTP: Shellharbour
Sampling Point: SH0004 Effluent
Detection Limit: 2
Limit/Threshold: 50%ile: 30
Limit/Threshold: 90%ile: 40
------ 90%ile Limit
------ 50%ile Limit
Total suspended solids (composite) (mg/L)
0
6
12
18
24
30
36
42
48
54
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=95.362; Pr>F=<.0001)
Financial year

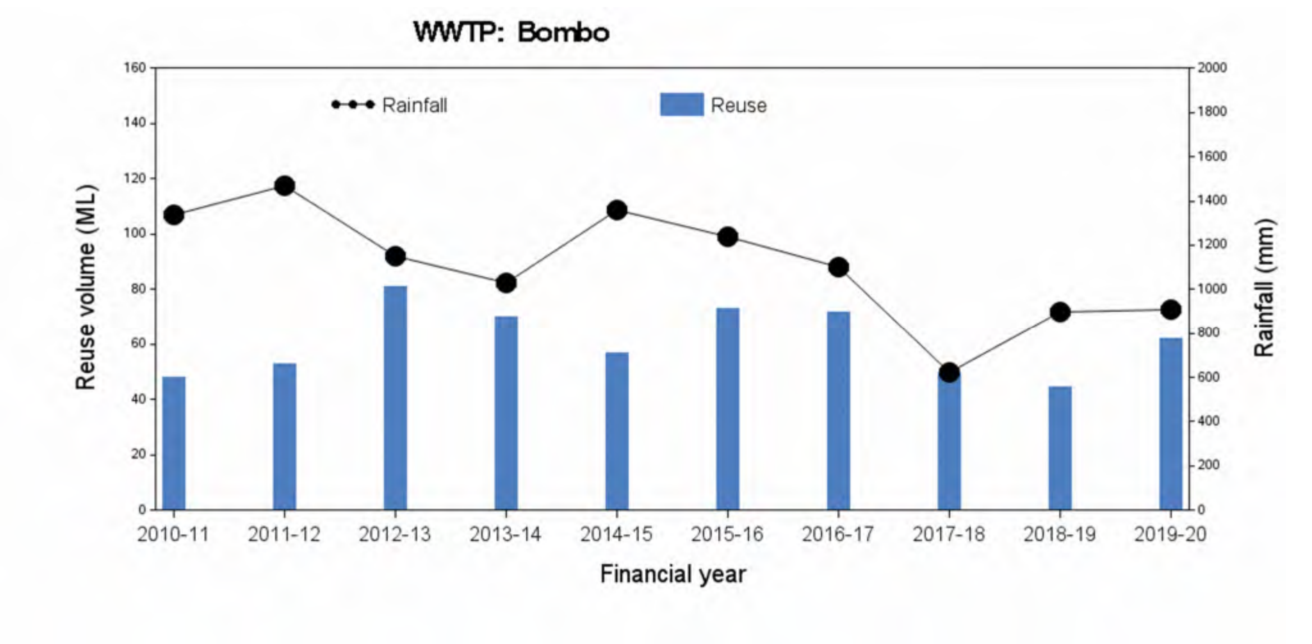


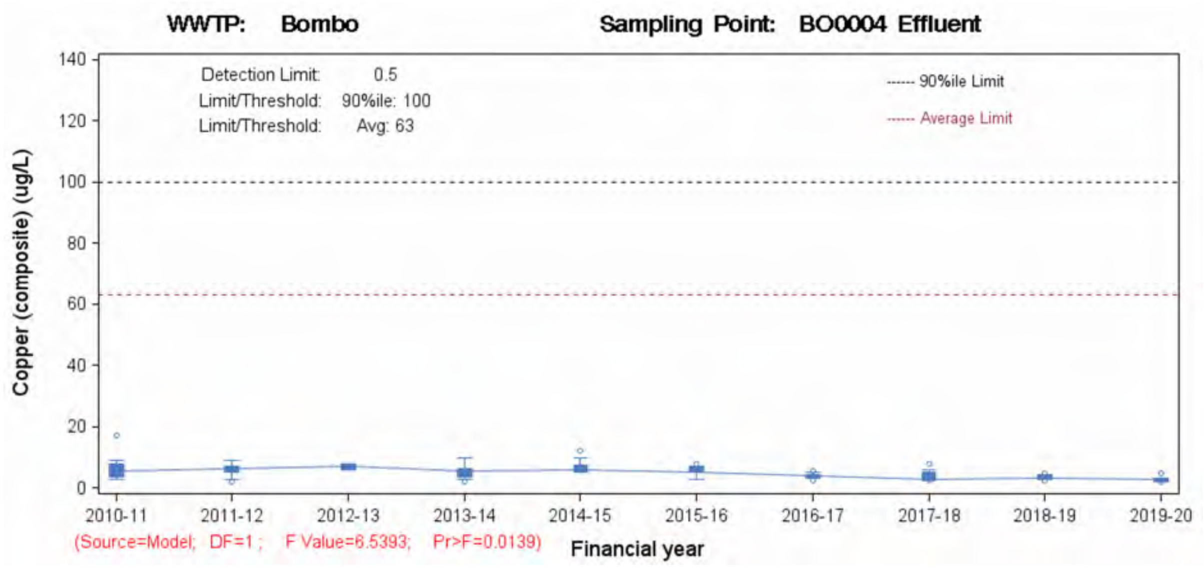
WWTP: Shellharbour
Sampling Point: SH0004 Effluent
Detection Limit: 2
Limit/Threshold: 50%ile: 30
Limit/Threshold: 90%ile: 40
Total suspended solids (composite) (mg/L)
0
2
4
6
8
10
12
14
16
18
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=95.362; Pr>F=<.0001)
Financial year

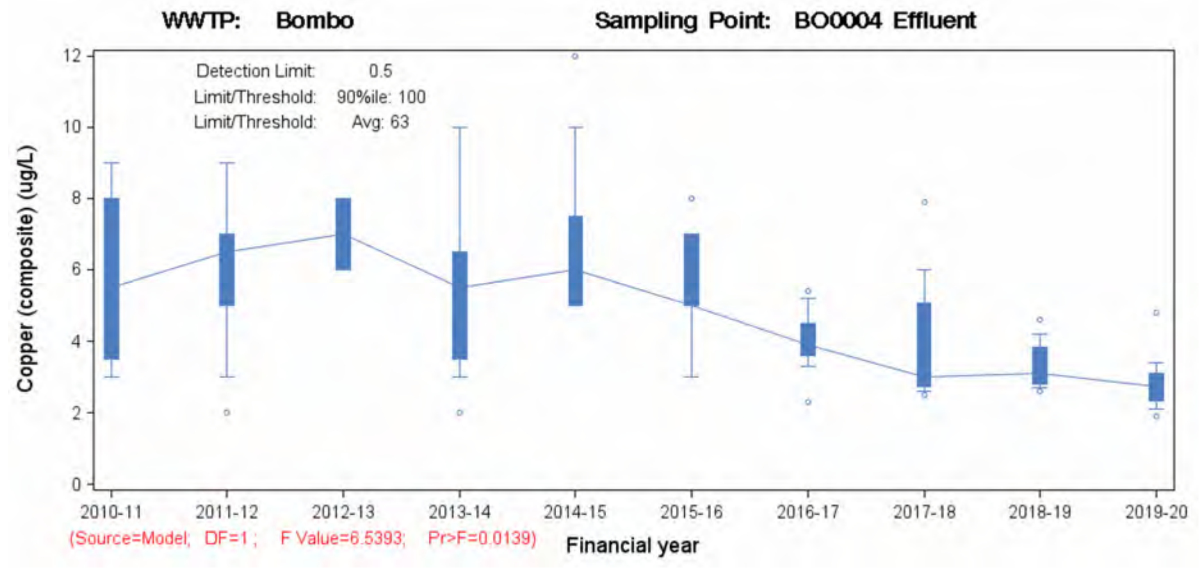
4.1.8 Bombo WWTP

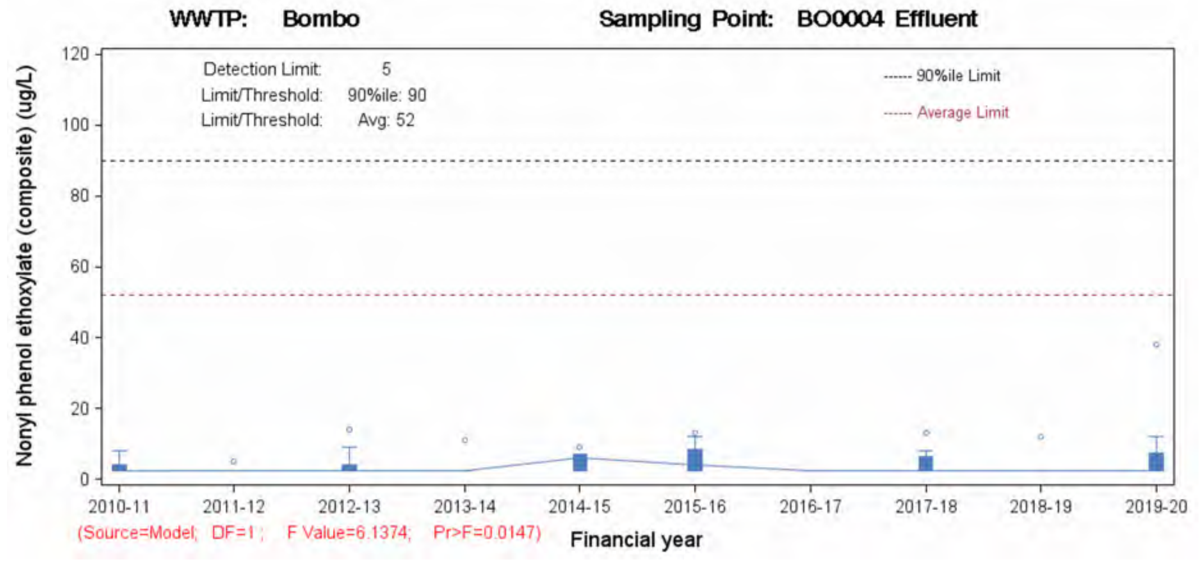
All concentration and load limits in the discharge from Bombo WWTP were within the EPL limits during the 2019-20 period. Statistical analysis identified a significantly increasing trend in nonyl phenol ethoxylates and a significantly decreasing trend in copper concentrations in the discharge from Bombo WWTP during the 2019-20 period compared with previous years. Because nonyl phenol ethoxylates tend to represent detergent like substances, the trend may represent the catchments response to the COVID-19 pandemic in 2020, with more people working from home and increased use of cleaning products.

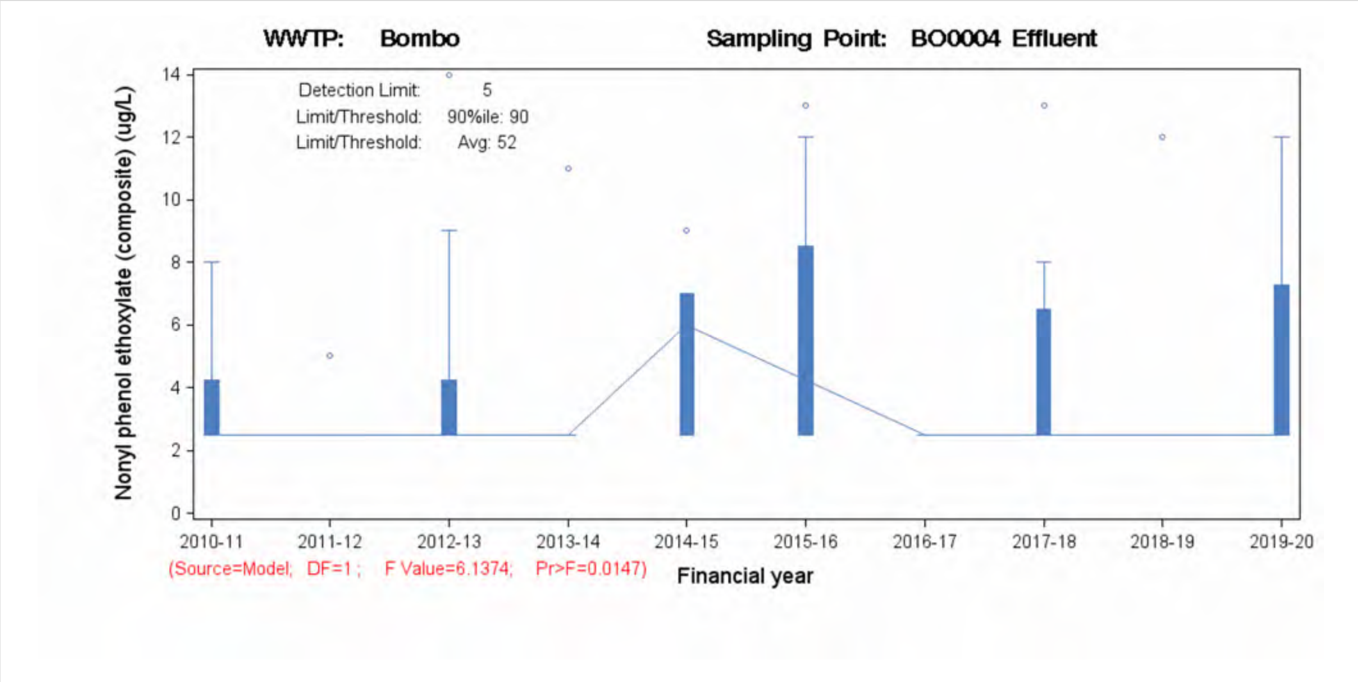





WWTP: Bombo
Sampling Point: BO0004 Effluent
Detection Limit: 0.5
Limit/Threshold: 90%ile: 100
Limit/Threshold: Avg: 63
------ 90%ile Limit
------ Average Limit
Copper (composite) (ug/L)
0
20
40
60
80
100
120
140
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=6.5393; Pr>F=0.0139)
Financial year


WWTP: Bombo
Sampling Point: BO0004 Effluent
Detection Limit: 0.5
Limit/Threshold: 90%ile: 100
Limit/Threshold: Avg: 63
Copper (composite) (ug/L)
0
2
4
6
8
10
12
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=6.5393; Pr>F=0.0139)
Financial year


WWTP: Bombo
Sampling Point: BO0004 Effluent
Detection Limit: 5
Limit/Threshold: 90%ile: 90
Limit/Threshold: Avg: 52
------ 90%ile Limit
------ Average Limit
Nonyl phenol ethoxylate (composite) (ug/L)
0
20
40
60
80
100
120
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=6.1374; Pr>F=0.0147)
Financial year

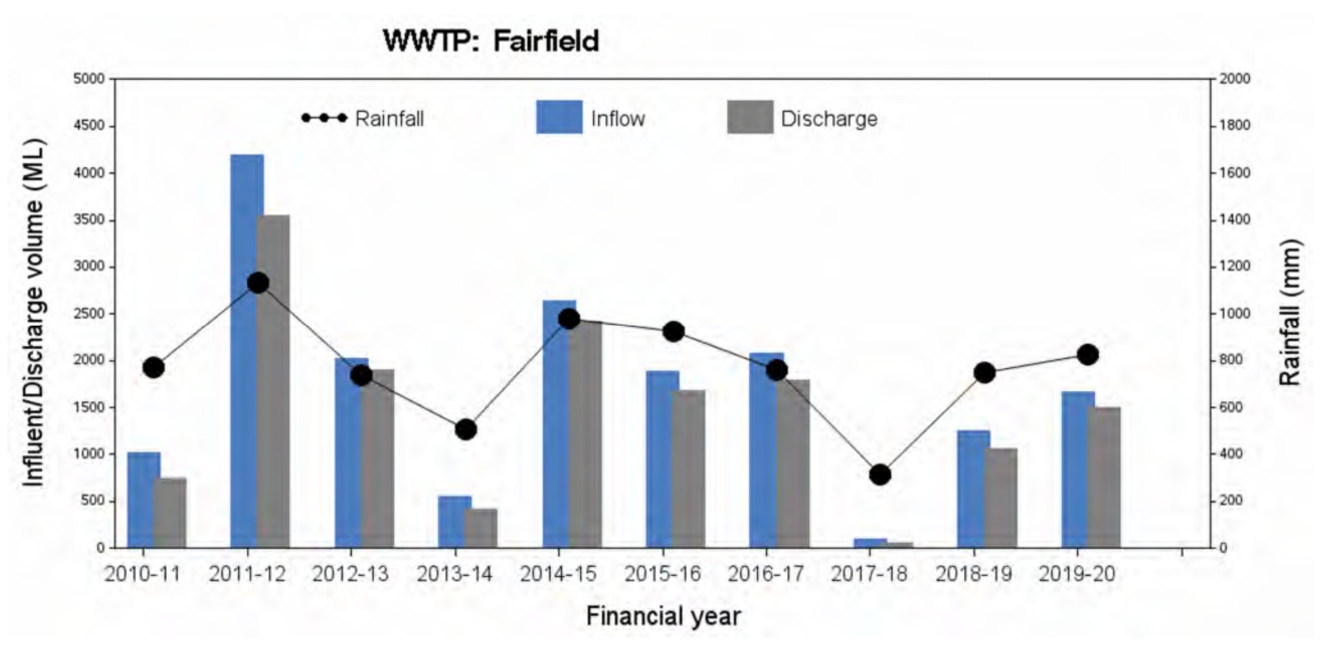


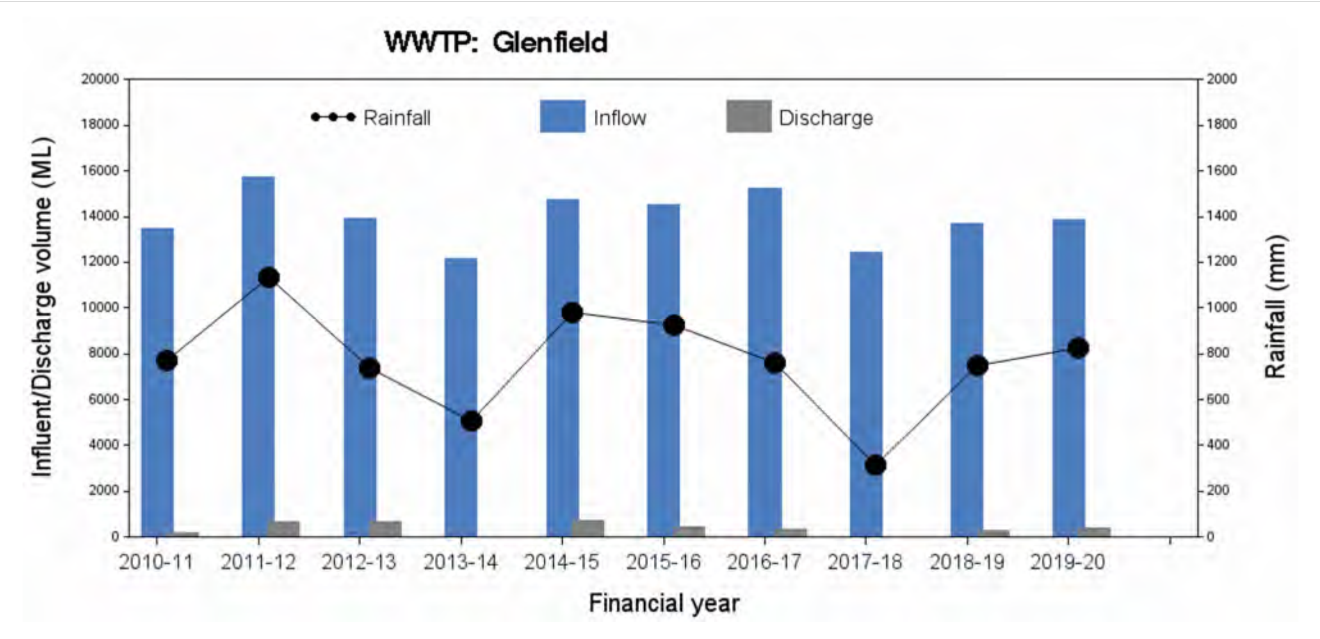
WWTP: Bombo
Sampling Point: BO0004 Effluent
Detection Limit: 5
Limit/Threshold: 90%ile: 90
Limit/Threshold: Avg: 52
Nonyl phenol ethoxylate (composite) (ug/L)
0
2
4
6
8
10
12
14
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=6.1374; Pr>F=0.0147)
Financial year

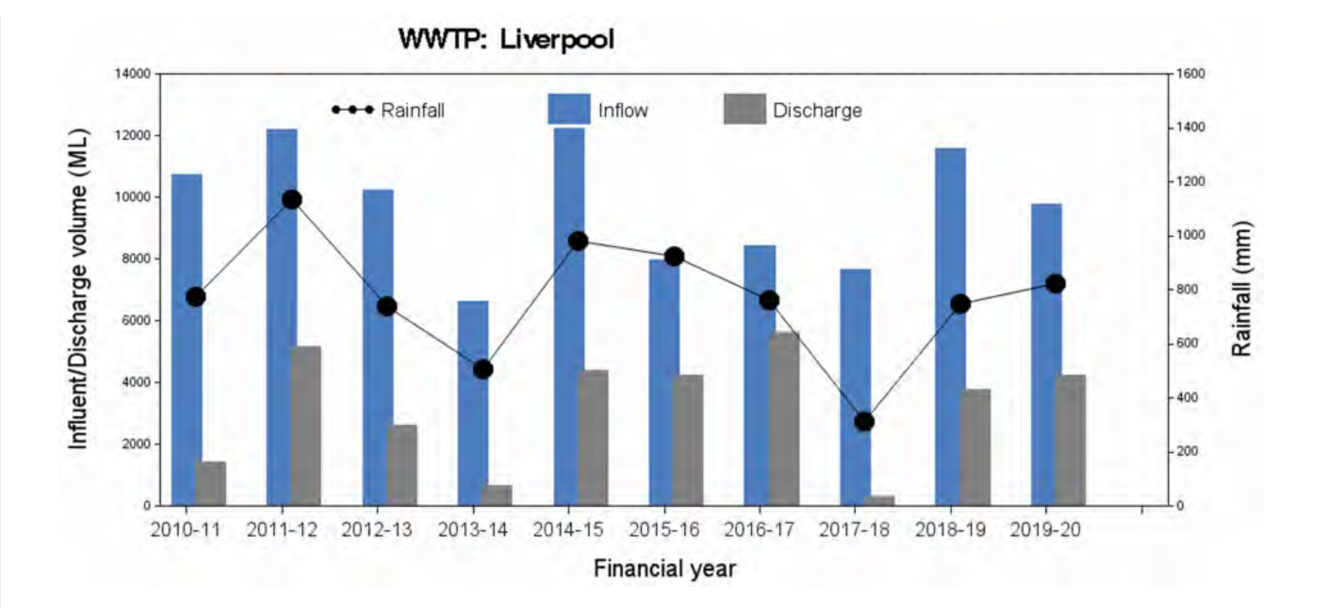
4.1.9 Malabar storm WWTPs

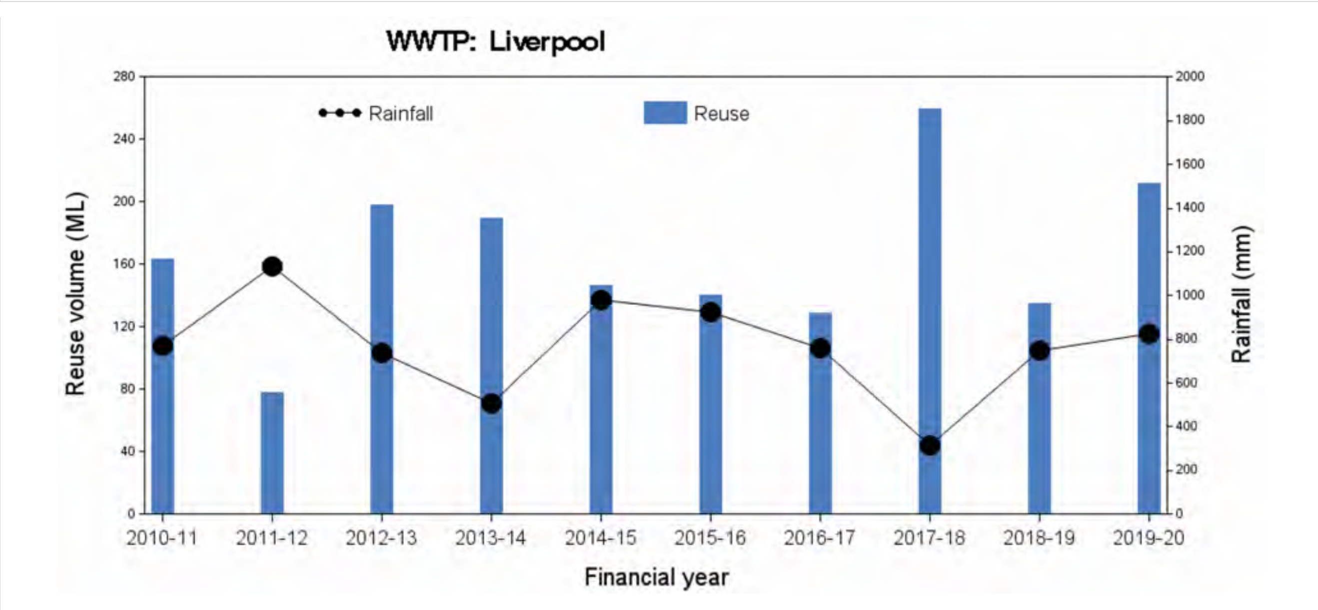
Statistical analysis identified a significantly increasing trend in total suspended solids concentration at Fairfield WWTP. Carbonaceous biochemical oxygen demand and total suspended solids concentrations increased significantly at Liverpool WWTP (LP0015) in 2019-20.

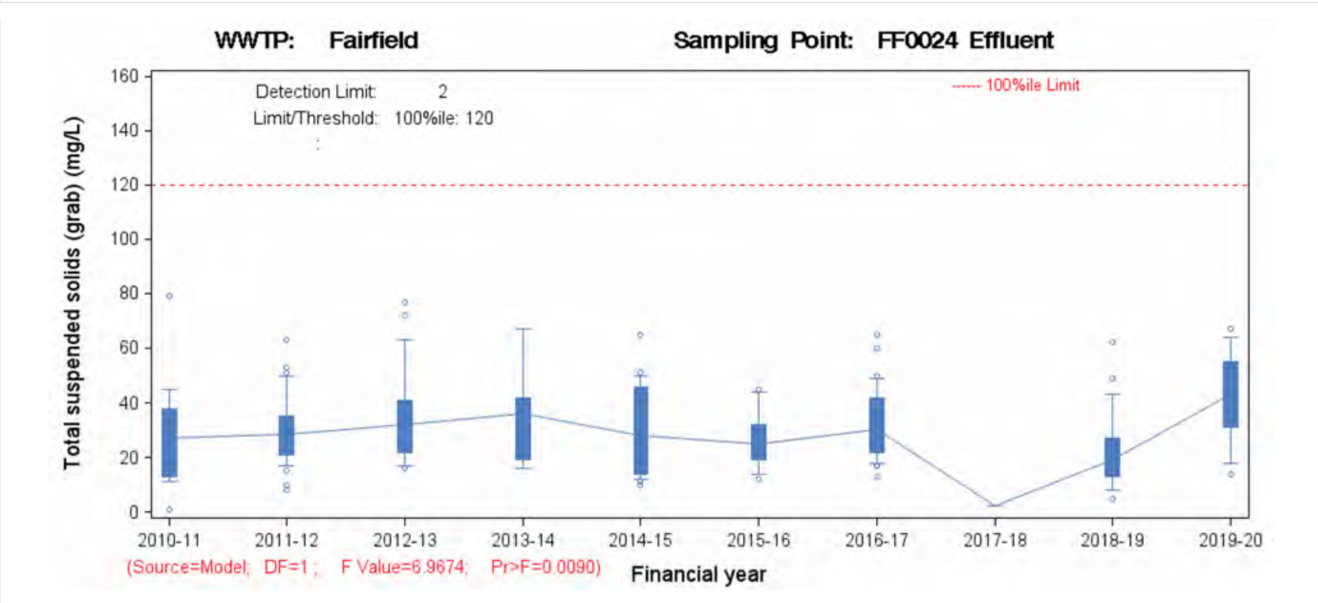
All concentration limits in the discharges from Fairfield, Glenfield and Liverpool WWTPs were within the Malabar EPL limits during the 2019-20 period. Under EPL 372 conditions, as set by the NSW EPA, the 100 percentile limits can be exceeded during wet weather. Wet weather on 5 July 2019, 20 September 2019 and between 9-13 February 2020 and 4-8 March 2020 resulted in the plant operating under EPL wet weather requirements. These wet weather events had a significant impact on the increasing trends noted above, particularly coming out of drought conditions during the second half of the 2019-20 monitoring period.

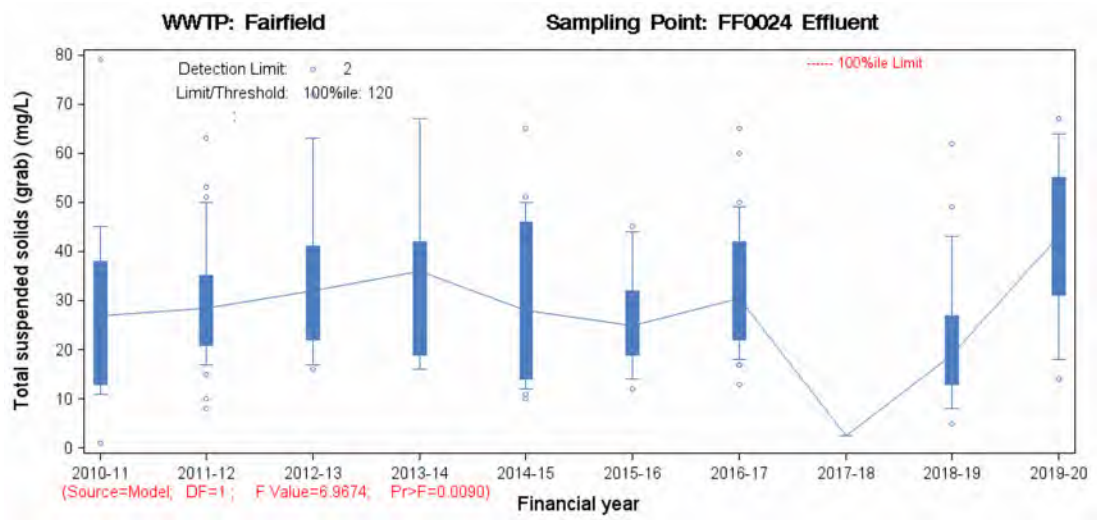


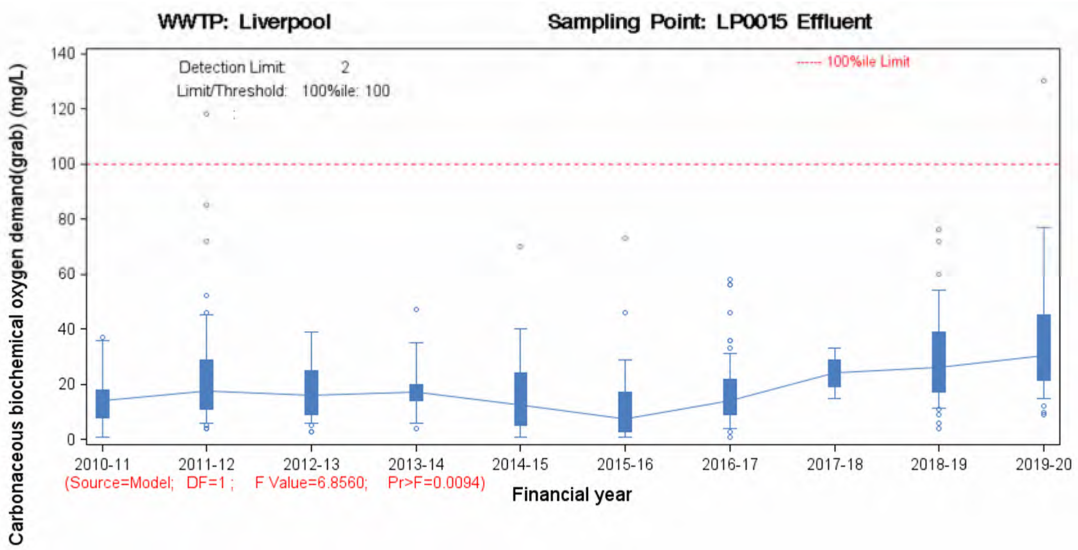



WWTP: Liverpool
Rainfall
Inflow
Discharge
Influent/Discharge volume (ML)
Rainfall (mm)
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
Financial year

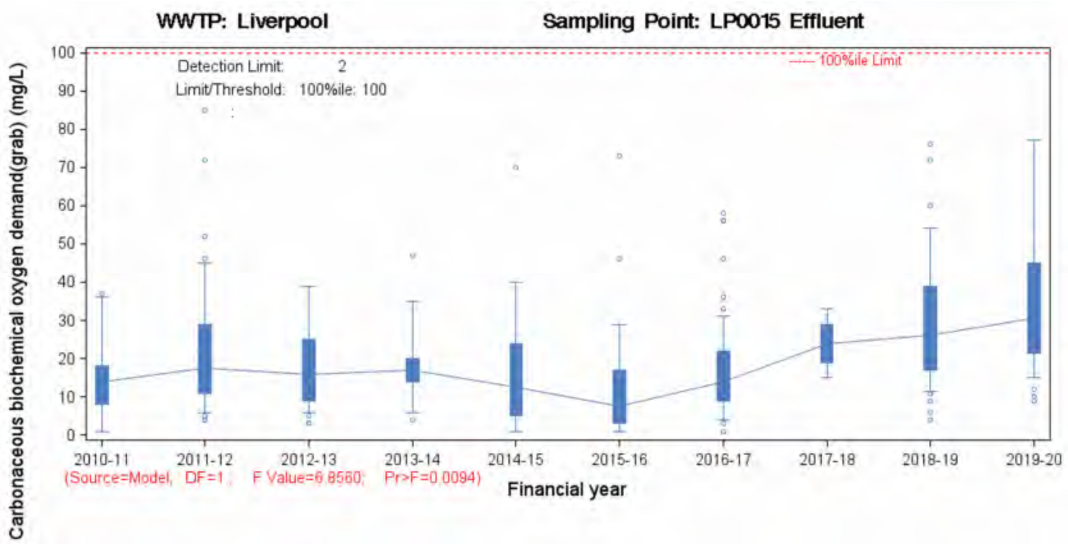

WWTP: Liverpool
Rainfall
Reuse
Reuse volume (ML)
Rainfall (mm)
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
Financial year


WWTP: Fairfield
Sampling Point: FF0024 Effluent
Detection Limit: 2
Limit/Threshold: 100%ile: 120
------ 100%ile Limit
Total suspended solids (grab) (mg/L)
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=6.9674; Pr>F=0.0090)
Financial year

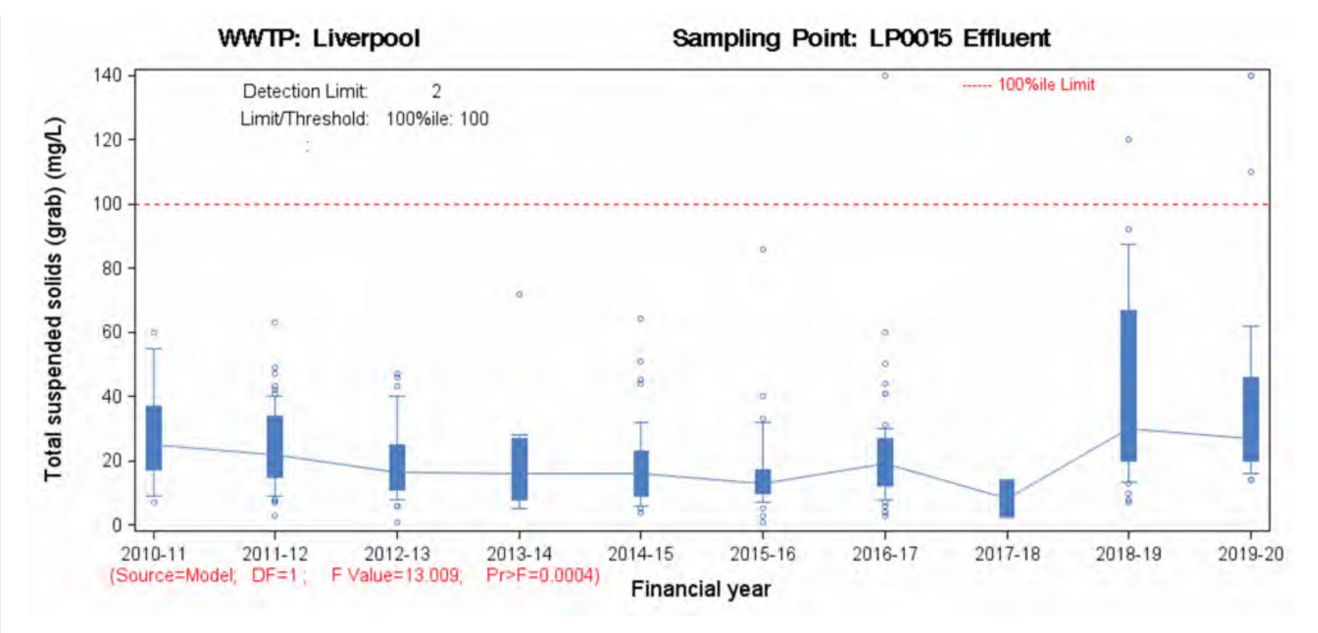


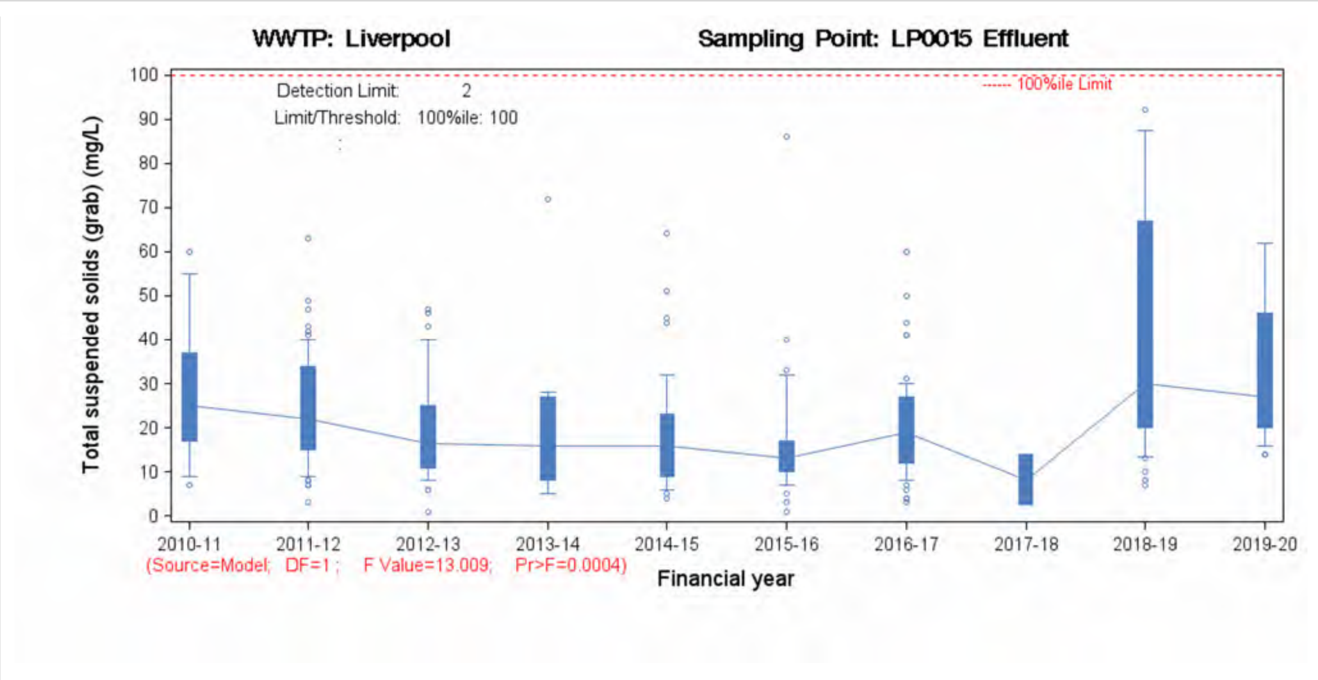


Note: Statistical test was based on 2019-20 data with previous five years data (2014-2019) due to detection limit change in 2014-15.



Note: Statistical test was based on 2019-20 data with previous five years data (2014-2019) due to detection limit change in 2014-15.


WWTP: Liverpool
Sampling Point: LP0015 Effluent
Detection Limit: 2
Limit/Threshold: 100%ile: 100
------ 100%ile Limit
Total suspended solids (grab) (mg/L)
140
120
100
80
60
40
20
0
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=13.009; Pr>F=0.0004)
Financial year


WWTP: Liverpool
Sampling Point: LP0015 Effluent
Detection Limit: 2
Limit/Threshold: 100%ile: 100
------ 100%ile Limit
Total suspended solids (grab) (mg/L)
100
90
80
70
60
50
40
30
20
10
0
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=13.009; Pr>F=0.0004)
Financial year

4.2 Wastewater discharges from Inland WWTPs

The treated wastewater discharged from inland WWTPs in 2019-20 and the population serviced by these WWTPs are shown in Table 4-2.

This section contains a summary of exceptions for each of the inland discharging WWTPs. All inland trend plots on discharge volume and catchment specific rainfall are presented first and then reuse volume where applicable. This is followed by a load limit plot where there was an exceedance during 2019-20.

Trend plots on concentrations of analytes in discharges were only presented where it exceeded the respective EPL limit for a particular WWTP or there was a significant increase/decrease in concentrations in 2019-20 in comparison to earlier years. All trend plots on concentrations of analytes and load data for inland WWTPs can be found in Volume 2: Appendix D.

Each analyte presented in this section or in Volume 2 has up to two plots. One plot shows data in relation to EPL percentile limit values. The second plot has a reduced analyte scale to provide a zoomed in view, if required.

An electronic appendix file (EA_8) is also provided on summary of results for all inland WWTPs by year.

Table 4-2 Inland WWTPs operated by Sydney Water

WWTPs	Treatment level	Discharge 2019-20 (ML/year)	Projected population 2019-20#	Discharge location
Picton	Tertiary and disinfection	506	16,450	Reused for onsite agricultural irrigation; wet-weather overflows to Stonequarry Creek
West Camden	Tertiary and disinfection	6,740	99,850	Matahil Creek to the Hawkesbury-Nepean River
Wallacia	Tertiary and disinfection	311	4,820	Warragamba River to the Hawkesbury-Nepean River
Penrith	Tertiary and disinfection	4,587	112,010	Boundary Creek to the Hawkesbury-Nepean River
Winmalee	Tertiary and disinfection	6,963	59,810	Unnamed creek to the Hawkesbury-Nepean River
North Richmond	Tertiary and disinfection	380	5,890	Redbank Creek to the Hawkesbury River
Richmond	Tertiary and disinfection	575	15,200	Reused for irrigation at the University of Western Sydney Richmond campus and Richmond Golf Club; excess overflows to Rickabys Creek
St Marys	Tertiary and disinfection	9,294	170,230	Unnamed creek to South Creek
Quakers Hill	Tertiary and disinfection	11,203	166,370	Breakfast Creek to Eastern Creek
Riverstone	Tertiary and disinfection	2,825	47,350	Eastern Creek to South Creek
Castle Hill	Tertiary and disinfection	2,342	28,710	Cattai Creek
Rouse Hill	Tertiary and disinfection	6,452	114,390	Second Ponds Creek to Cattai Creek; also reused for local recycling scheme
Hornsby Heights	Tertiary and disinfection	2,697	32,340	Calna Creek to Berowra Creek
West Hornsby	Tertiary and disinfection	5,870	58,390	Waitara Creek to Berowra Creek
Brooklyn	Tertiary and disinfection	94	1,460	Hawkesbury River at 14 m depth on the second pylon of the old road bridge adjacent to Kangaroo Point

Projected populations are based on forecasts by the Australian Bureau of Statistics and the Department of Planning, Industry and Environment.

4.2.1 Picton WWTP

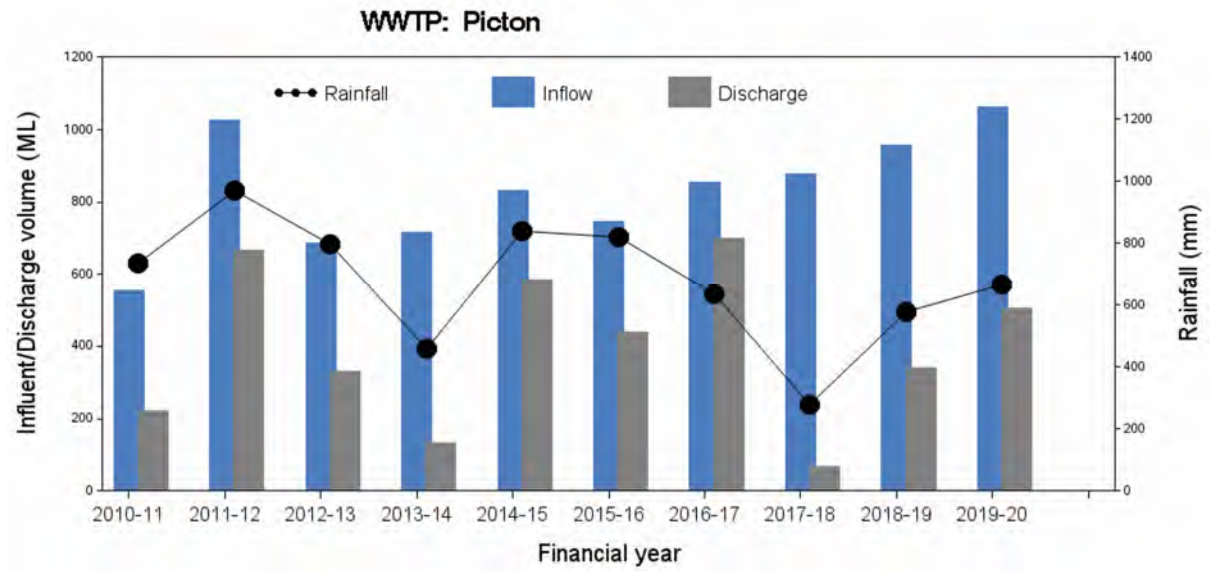
The load limits for total suspended solids and total nitrogen were exceeded in the precautionary discharge from Picton WWTP (PI0001) during the 2019-20 period. The 80th percentile concentration limit for faecal coliforms was also exceeded in the precautionary discharge from Picton WWTP (PI0001) during the 2019-20 period. All other concentration and load limits in the precautionary discharge and irrigation storage dams were within EPL limits during this period. Statistical analysis identified a significant increasing trend in ammonia nitrogen and total nitrogen and a significant decreasing trend in carbonaceous biochemical oxygen demand in the precautionary discharges from Picton WWTP (PI0001). The increasing trends in ammonia nitrogen and total nitrogen are related to the additional flow and loads from the Bargo and Buxton townships, together with loads from trade waste customers and commissioning of the Stage 2 amplification works. A significantly increasing trend in total nitrogen and pH was also observed in the eastern irrigation storage dam (PI0011). Seasonal algal blooms in the storage dam have resulted in a pH increase within the storage dam.

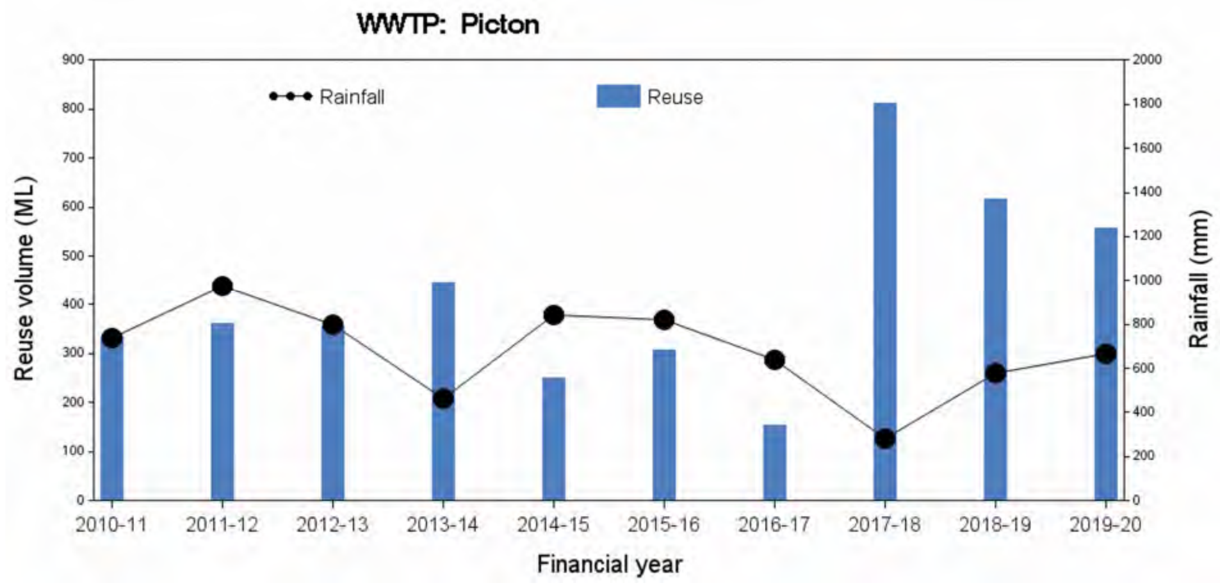
The current load on Picton WWTP exceeds its design capacity due to the addition of flow and loads from the Bargo and Buxton townships, together with loads from trade waste customers. In 2019-20, non-compliant discharges were triggered on four occasions (September 2019, October 2019, April-May 2020 and June 2020) ie Picton WWTP was operating under an Emergency Operations Protocol (EOP) as the Picton storage dams reached capacity.

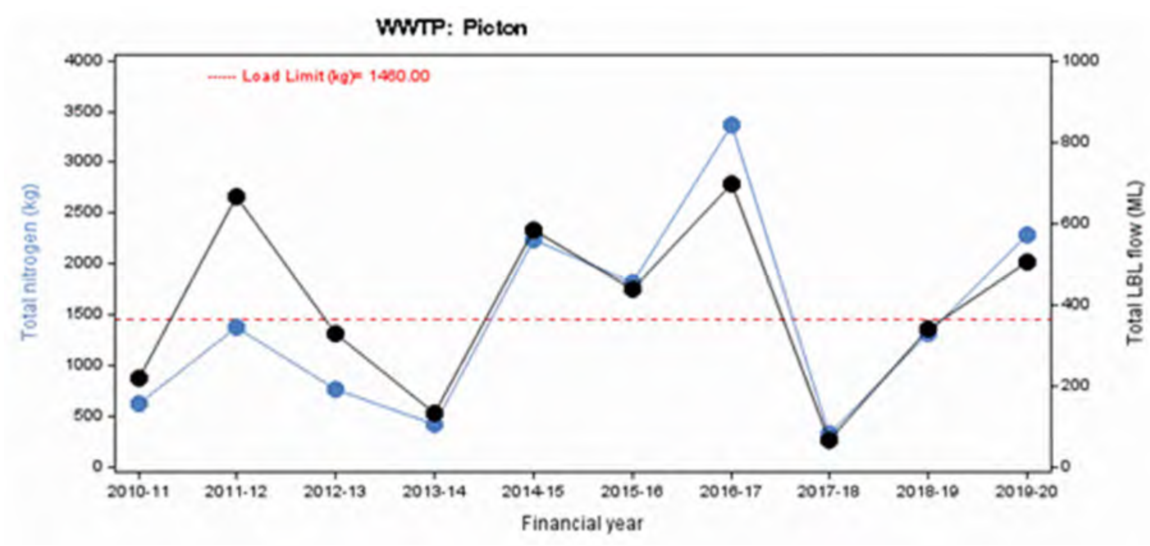
The EPA raised a Pollution Study for Picton WWTP in 2016. The objective of this Pollution Study is for Sydney Water to undertake a short-term water quality sampling program to characterise Picton WWTP effluent discharged to Stonequarry Creek and to obtain in-stream water quality sampling data. Monitoring and reporting are in progress to meet the Pollution Study requirements. Outcomes from that study are being used to review the Picton effluent management strategy (EMS) with the EPA.

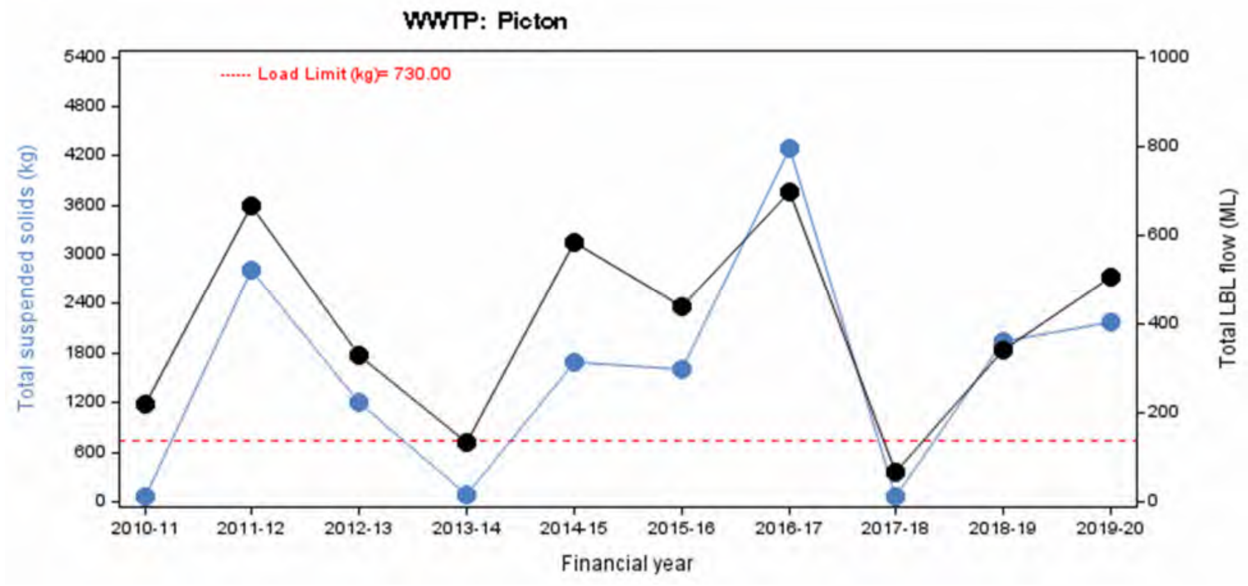
Ultimately, the Picton EMS will need to accommodate much higher inflows (more than double the current volume) to Picton WWTP. Sydney Water is currently evaluating the EMS management options, including:

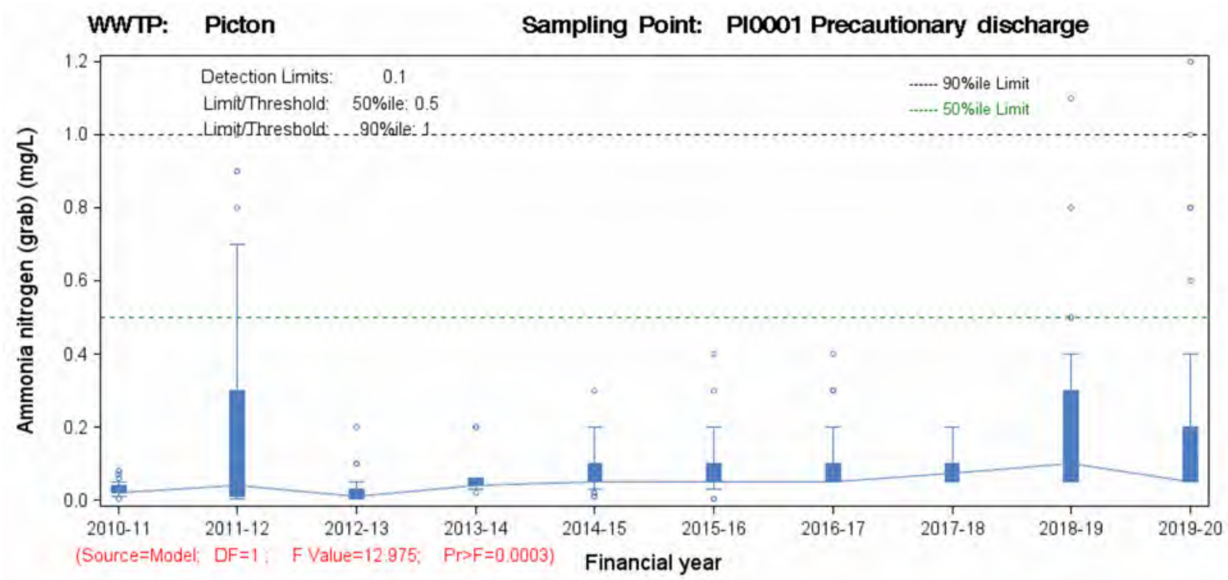
- improving the current nitrogen treatment performance
- assessing potential new wastewater discharge locations in the Nepean River
- wetland treatment, and
- modelling the water quality at Stonequarry and Nepean River locations for various discharge scenarios

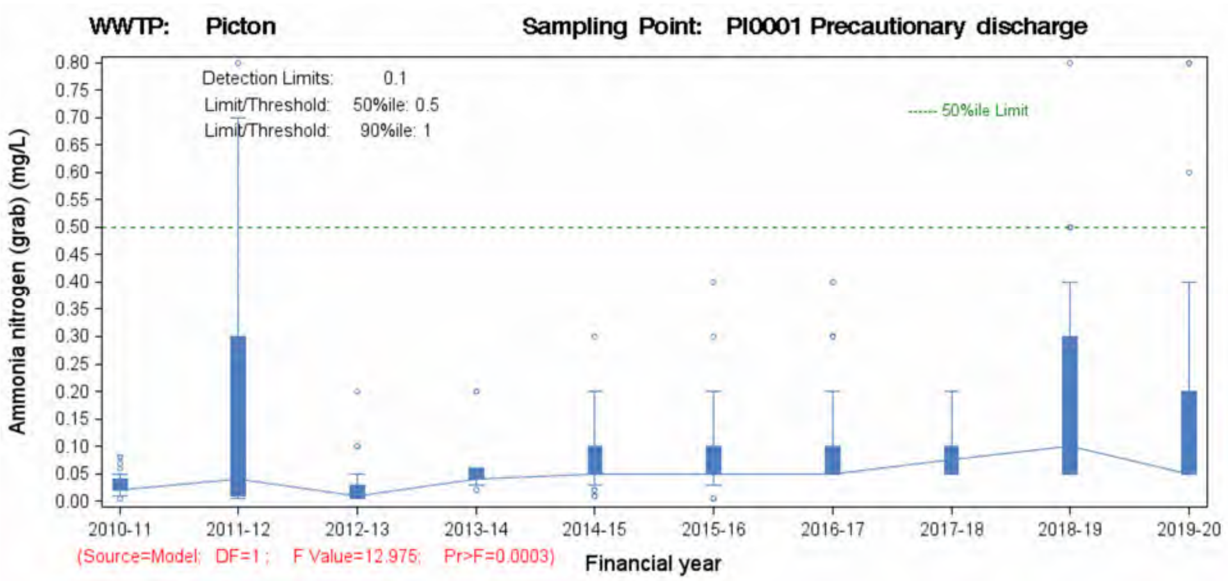

WWTP: Picton
Rainfall
Inflow
Discharge
Influent/Discharge volume (ML)
Rainfall (mm)
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
Financial year

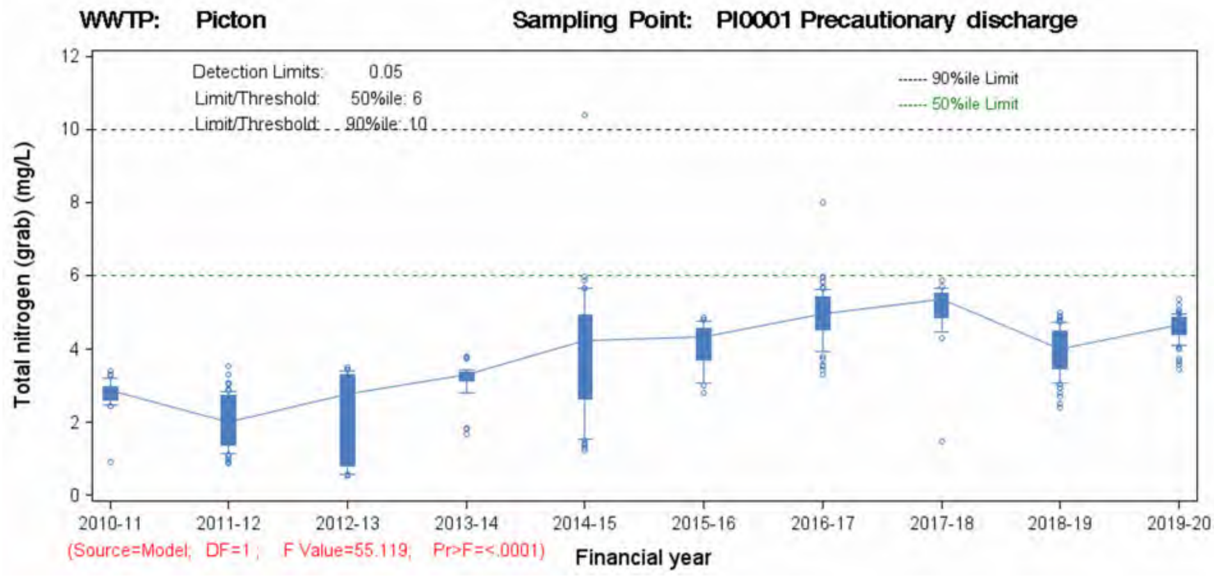

WWTP: Picton
Rainfall
Reuse
Reuse volume (ML)
Rainfall (mm)
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
Financial year

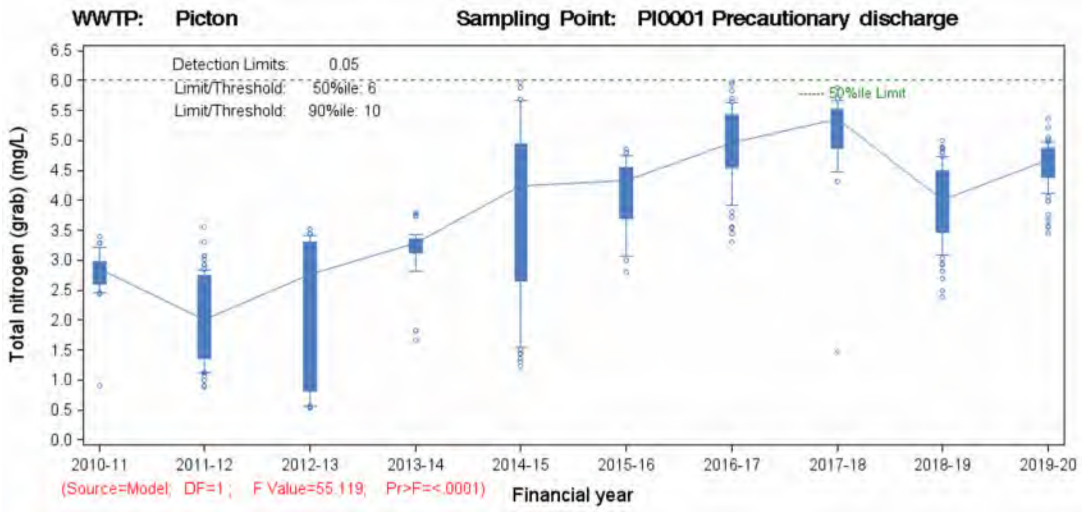

WWTP: Picton
Load Limit (kg)= 1460.00
Total nitrogen (kg)
Total LBL flow (ML)
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
Financial year

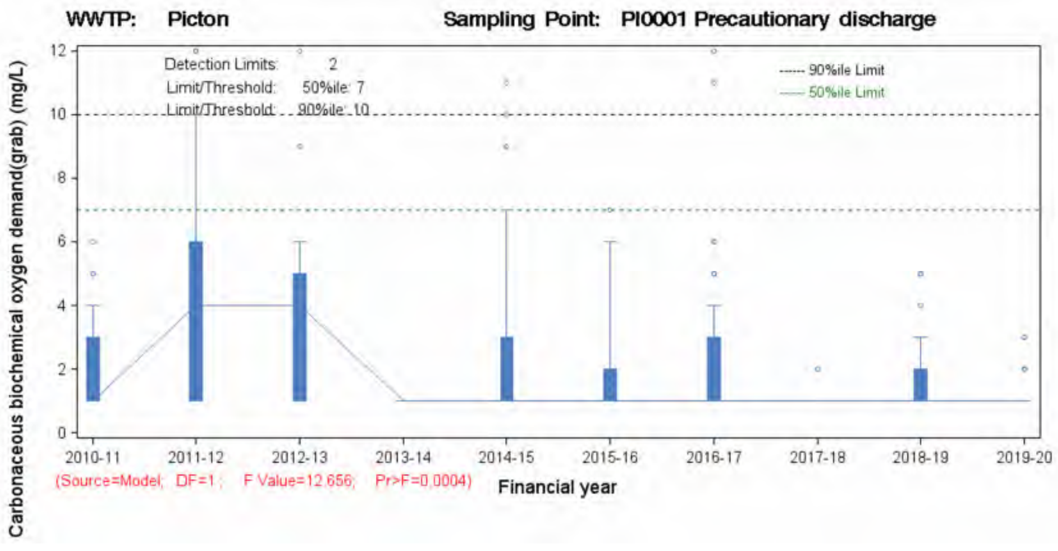

WWTP: Picton
Load Limit (kg)= 730.00
Total suspended solids (kg)
Total LBL flow (ML)
Financial year
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20


WWTP: Picton
Sampling Point: PI0001 Precautionary discharge
Detection Limits: 0.1
Limit/Threshold: 50%ile: 0.5
Limit/Threshold: 90%ile: 1
90%ile Limit
50%ile Limit
Ammonia nitrogen (grab) (mg/L)
(Source=Model; DF=1 ; F Value=12.975; Pr>F=0.0003)
Financial year

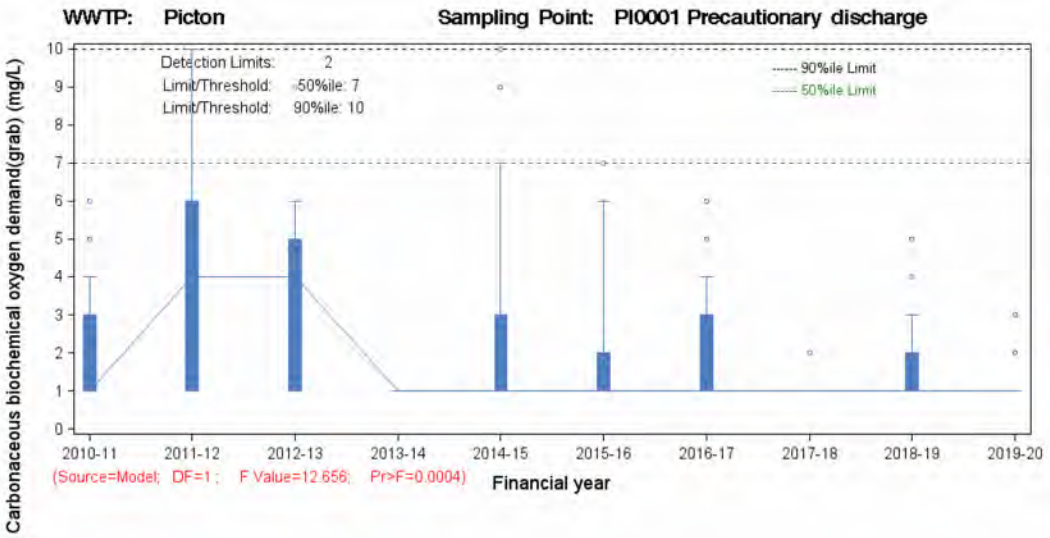

WWTP: Picton
Sampling Point: PI0001 Precautionary discharge
Detection Limits: 0.1
Limit/Threshold: 50%ile: 0.5
Limit/Threshold: 90%ile: 1
50%ile Limit
Ammonia nitrogen (grab) (mg/L)
(Source=Model; DF=1 ; F Value=12.975; Pr>F=0.0003)
Financial year



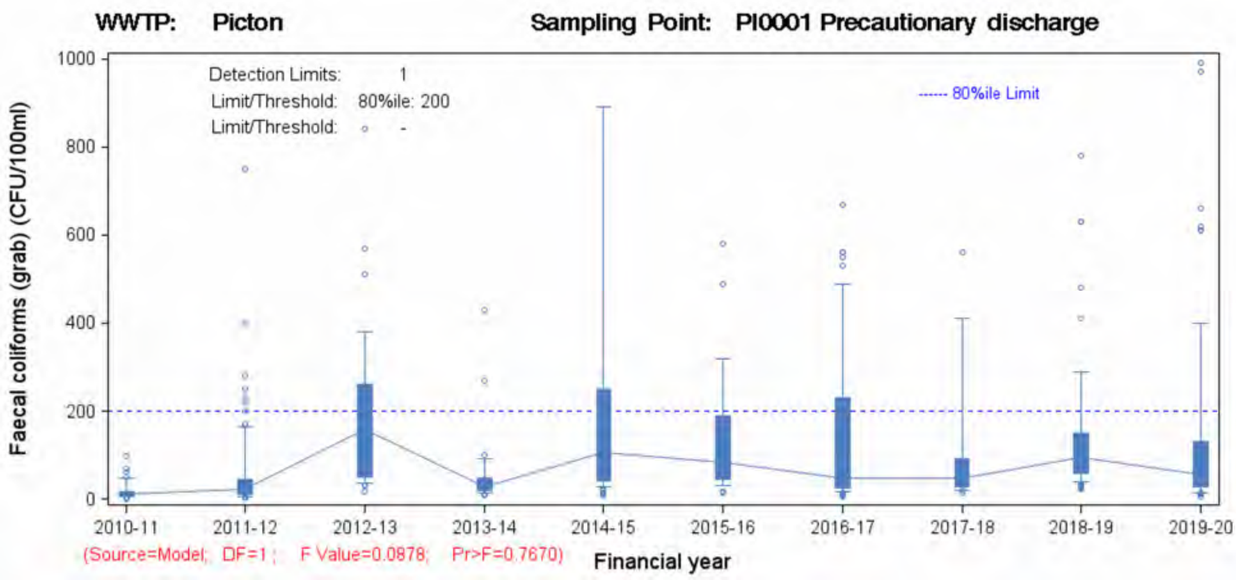


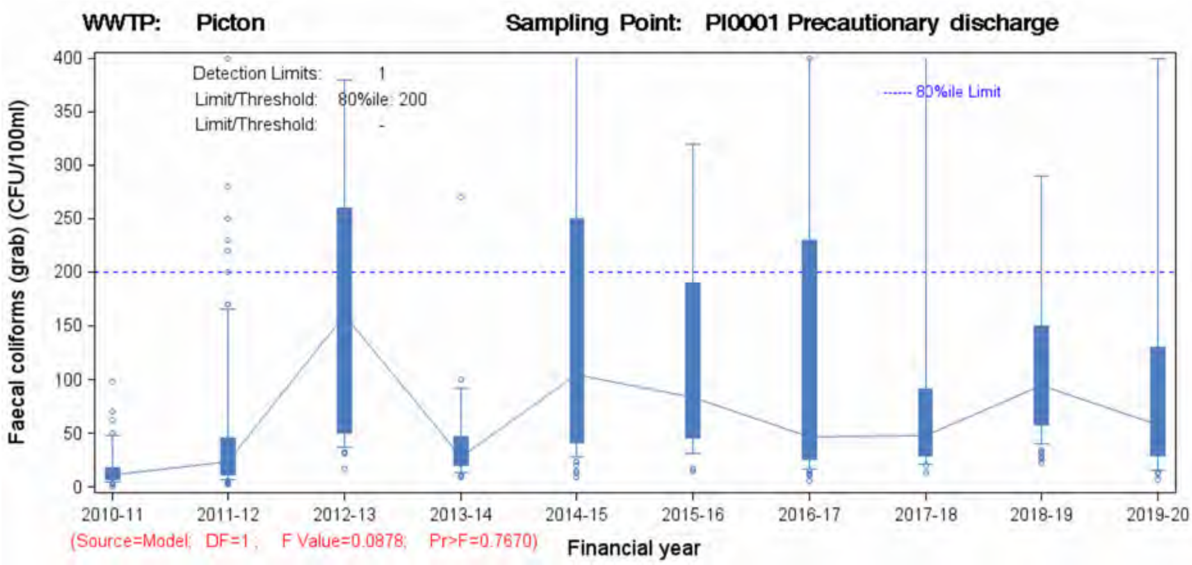


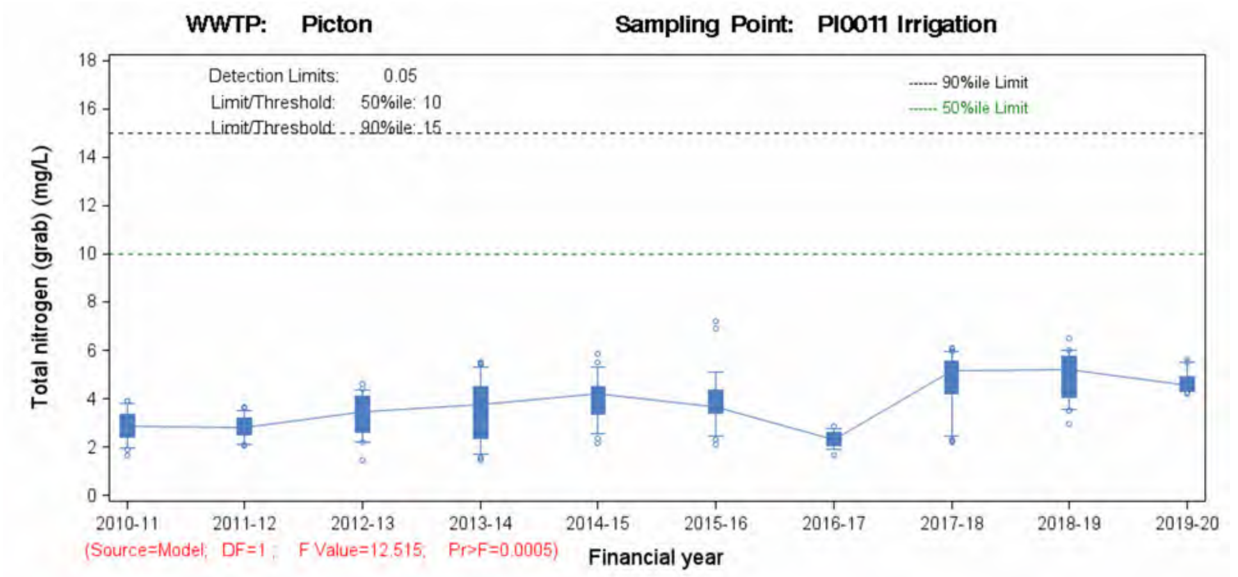
Note: Statistical test was based on 2019-20 data with previous five years data (2014-2019) due to detection limit change in 2014-15.

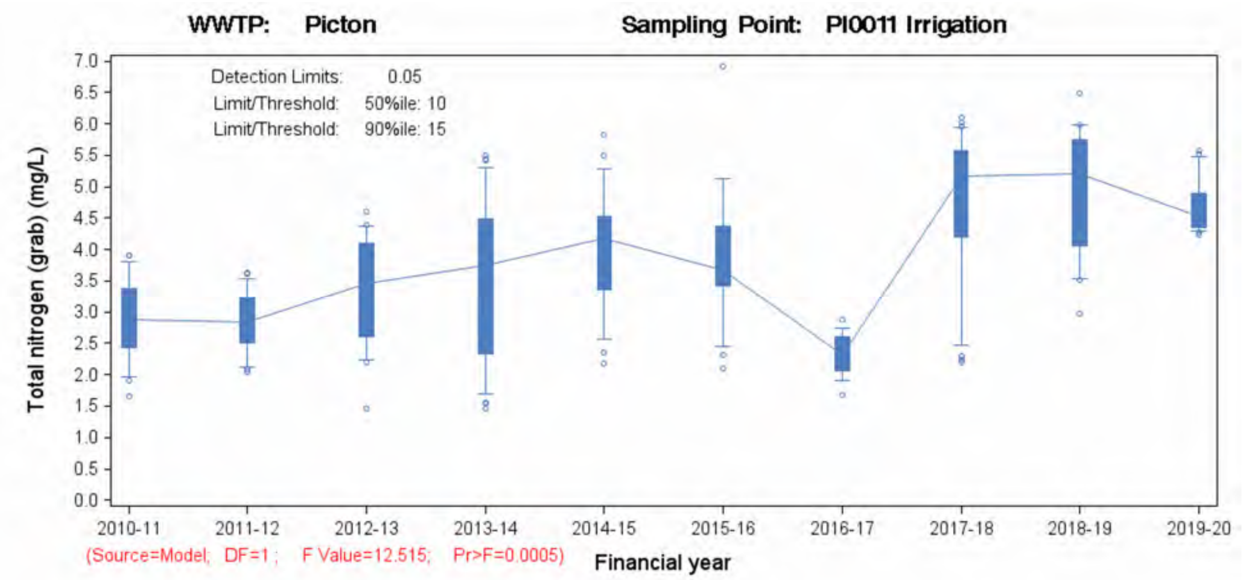


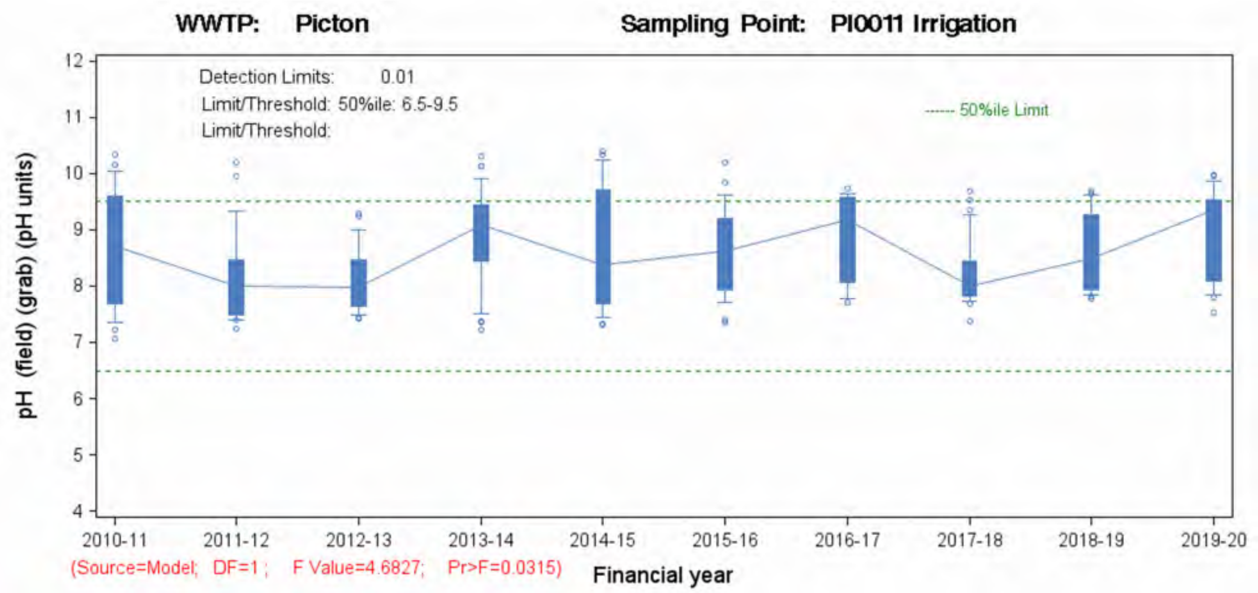
Note: Statistical test was based on 2019-20 data with previous five years data (2014-2019) due to detection limit change in 2014-15.





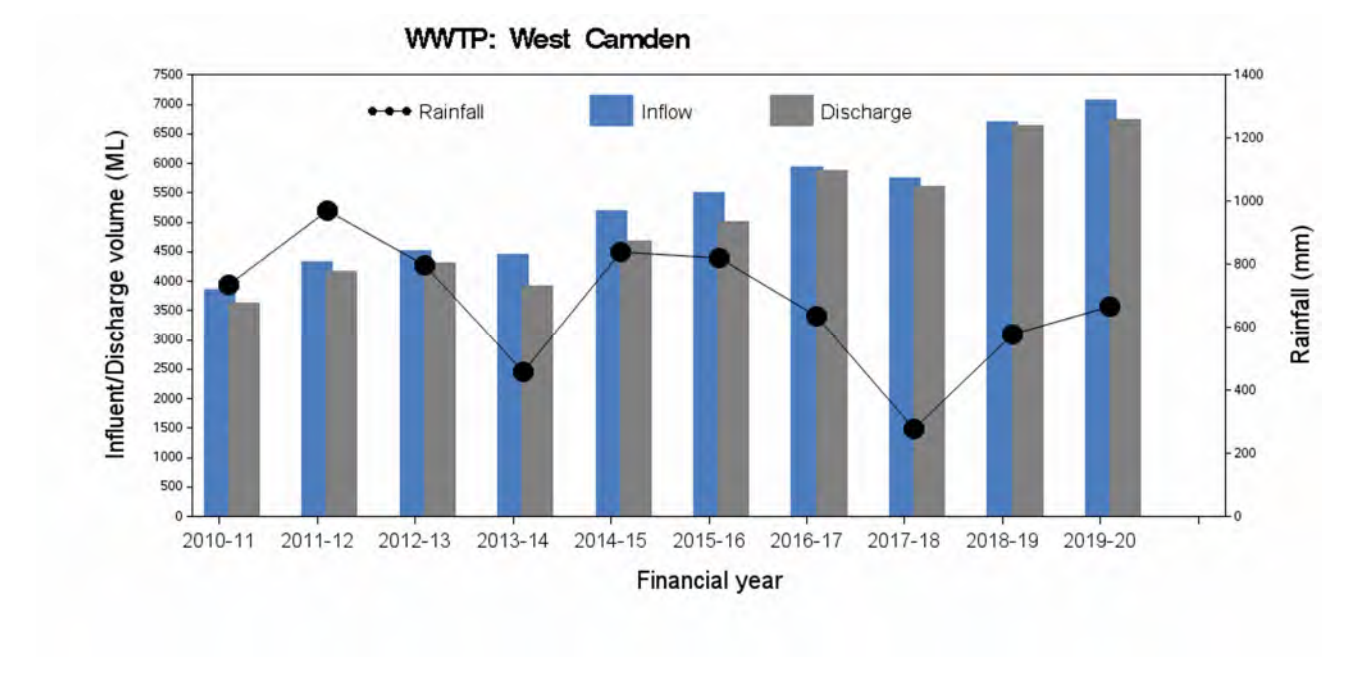

WWTP: Picton
Sampling Point: PI0011 Irrigation
Detection Limits: 0.05
Limit/Threshold: 50%ile: 10
Limit/Threshold: 90%ile: 15
------ 90%ile Limit
------ 50%ile Limit
Total nitrogen (grab) (mg/L)
0
2
4
6
8
10
12
14
16
18
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=12.515; Pr>F=0.0005)
Financial year

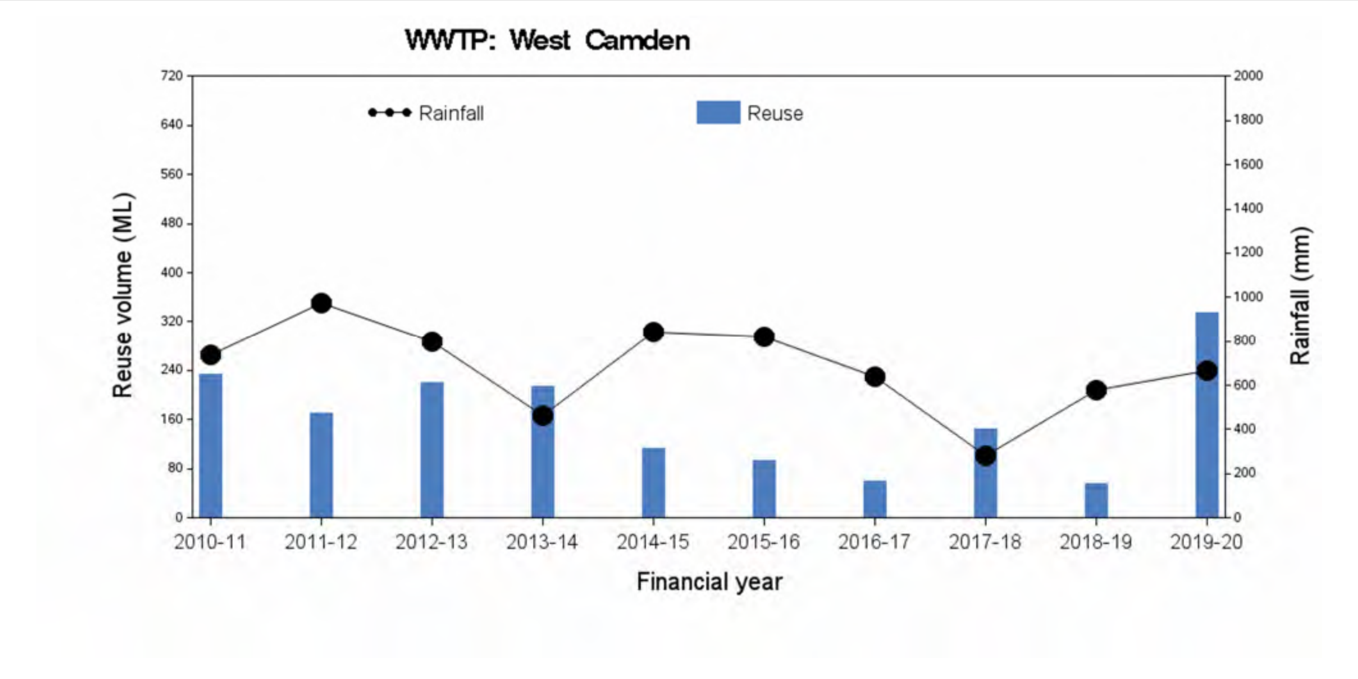

WWTP: Picton
Sampling Point: PI0011 Irrigation
Detection Limits: 0.05
Limit/Threshold: 50%ile: 10
Limit/Threshold: 90%ile: 15
Total nitrogen (grab) (mg/L)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=12.515; Pr>F=0.0005)
Financial year

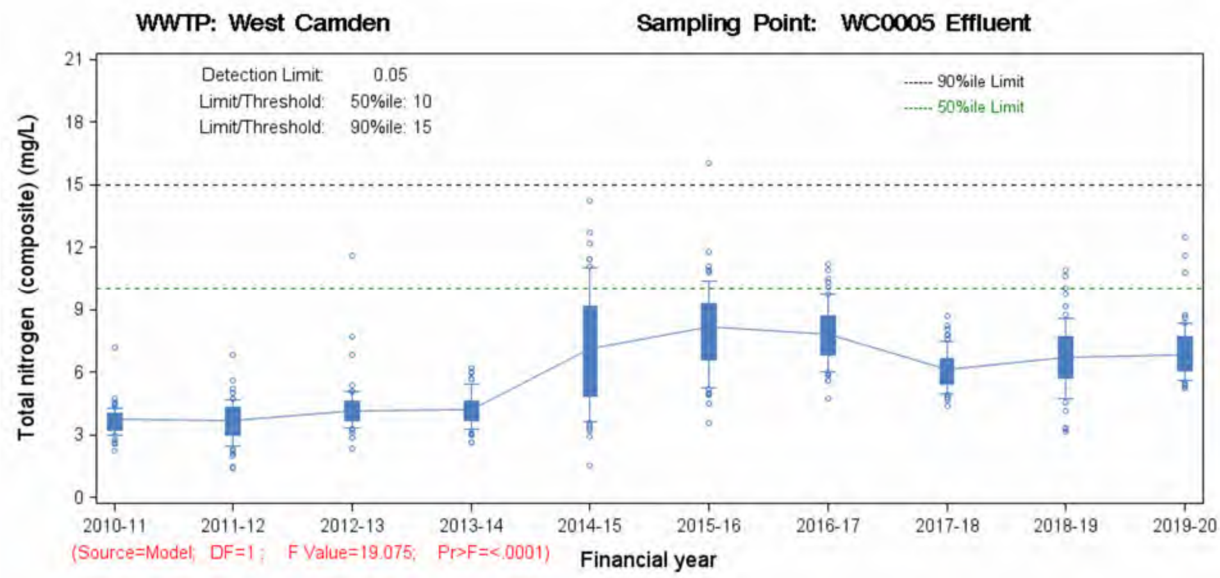

WWTP: Picton
Sampling Point: PI0011 Irrigation
Detection Limits: 0.01
Limit/Threshold: 50%ile: 6.5-9.5
Limit/Threshold:
------ 50%ile Limit
pH (field) (grab) (pH units)
4
5
6
7
8
9
10
11
12
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=4.6827; Pr>F=0.0315)
Financial year

4.2.2 West Camden WWTP

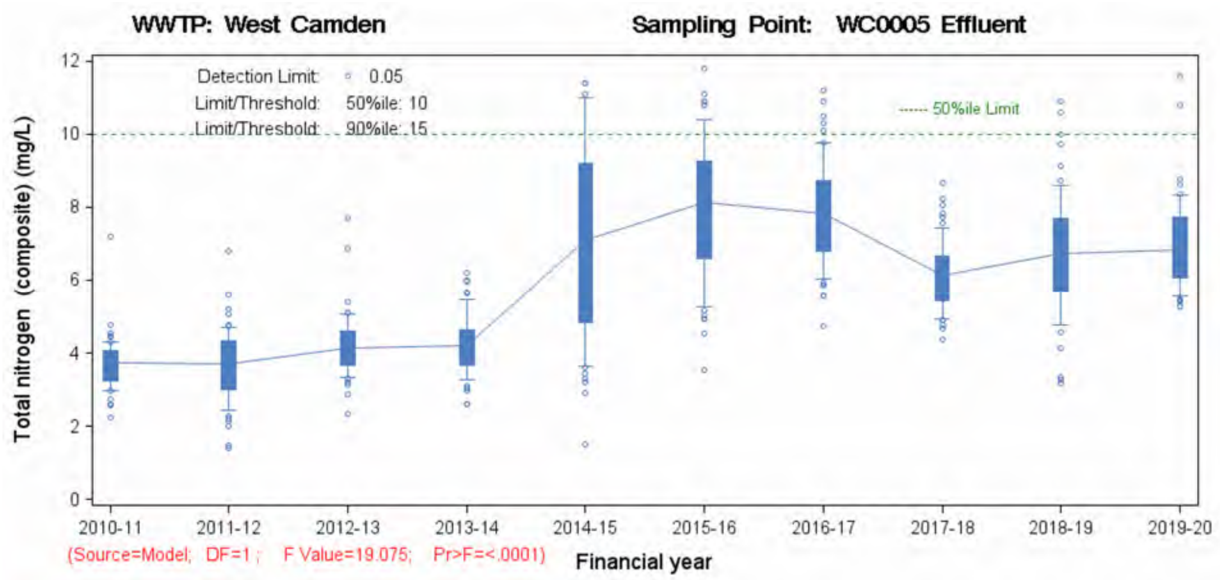
All concentration and load limits in the discharge from West Camden WWTP were within the EPL limit during the 2019-20 period. Statistical analysis identified significantly increasing trends in total nitrogen and copper concentrations, and significant decreasing trends in total phosphorus and cobalt during 2019-20 in comparison to earlier years. The increasing trends in total nitrogen and copper concentration levels can possibly be attributed to the addition of flow and loads from the increasing growth within the catchment area (population growth from 87,420 in 2017-18 to 99,850 in 2019-20), together with trade waste customer loads. Generally, the pollutant loads were steady and followed a pattern similar to the rainfall and flow to the plant and were well below the load limits.



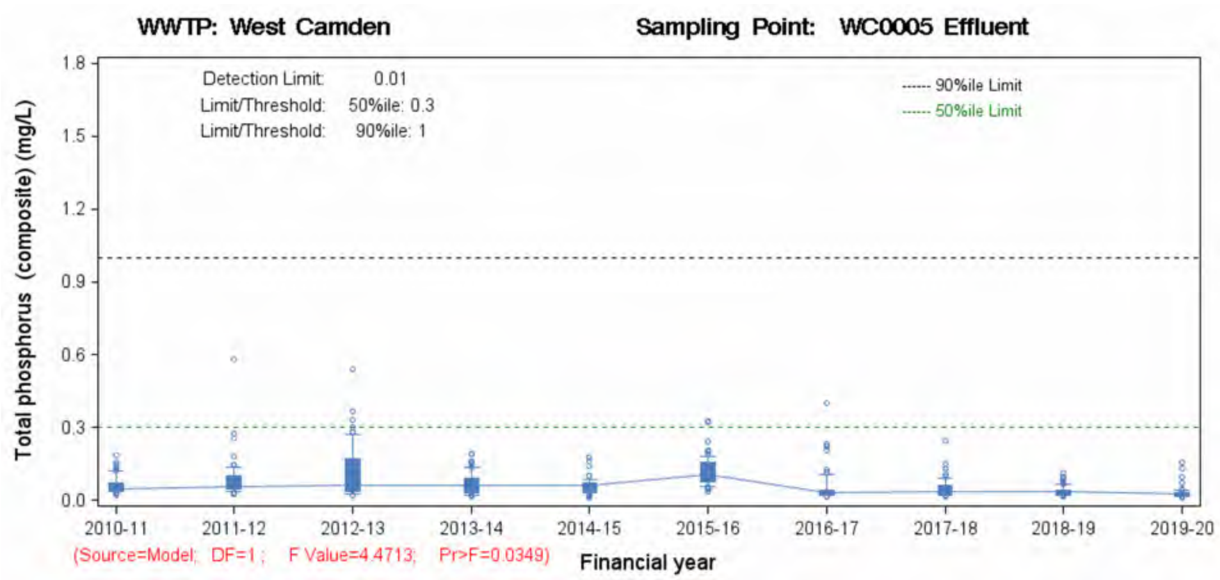




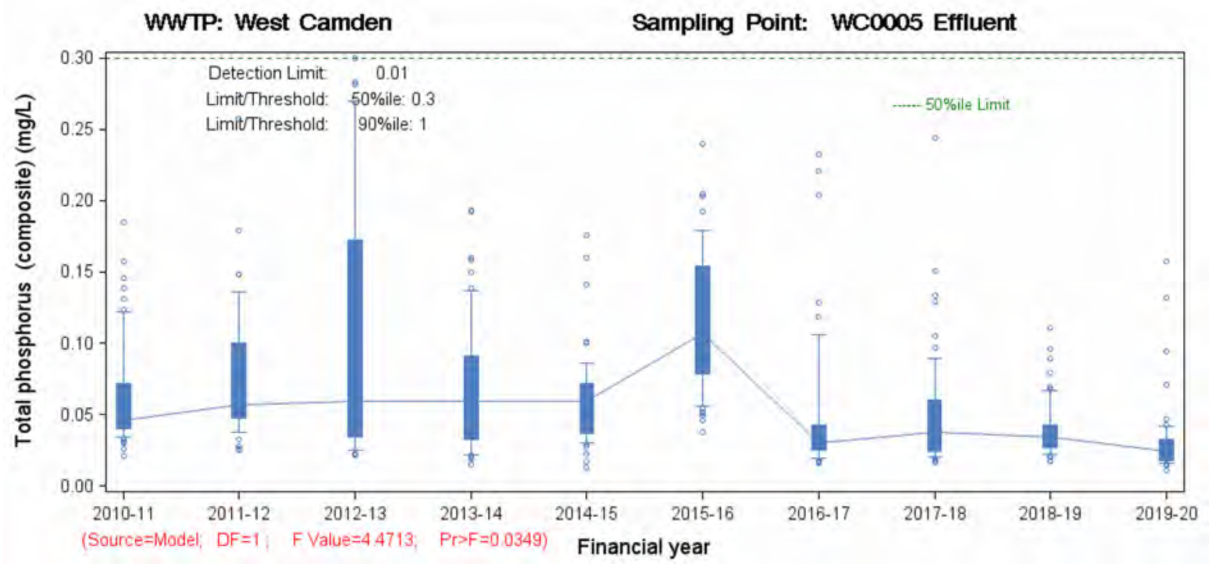
WWTP: West Camden
Sampling Point: WC0005 Effluent
Detection Limit 0.05
Limit/Threshold: 50%ile: 10
Limit/Threshold: 90%ile: 15
------ 90%ile Limit
------ 50%ile Limit
Total nitrogen (composite) (mg/L)
Financial year
(Source=Model; DF=1 ; F Value=19.075; Pr>F=<.0001)

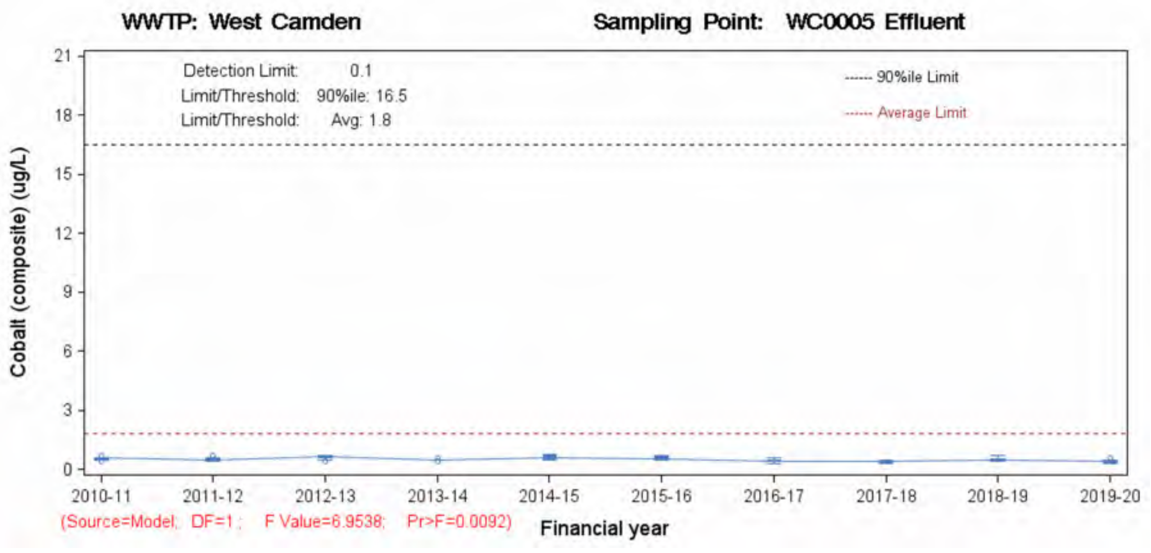


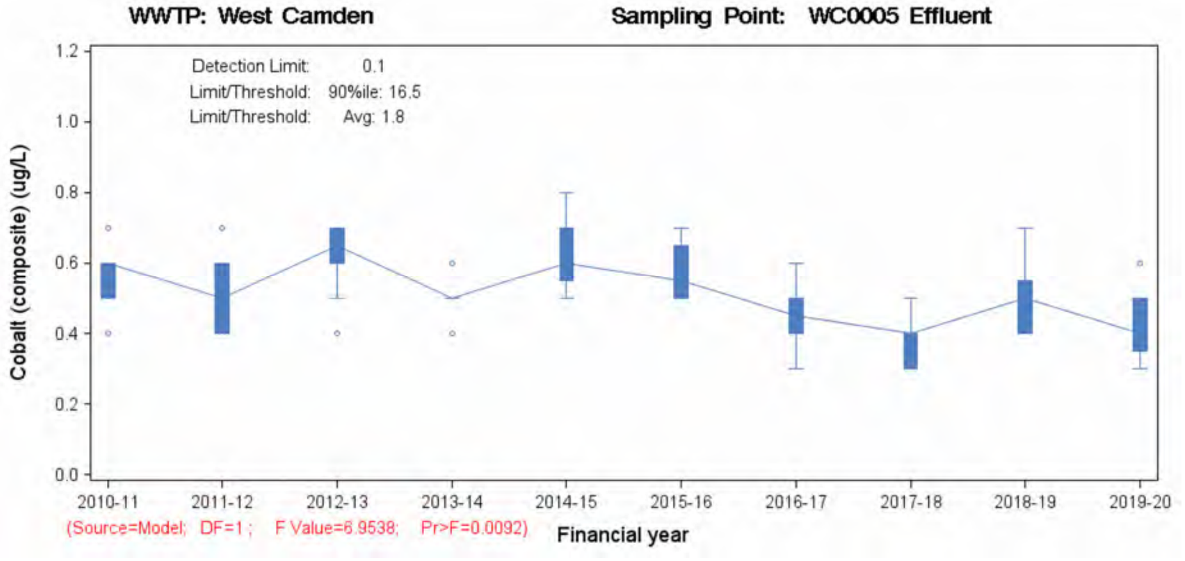
WWTP: West Camden
Sampling Point: WC0005 Effluent
Detection Limit 0.05
Limit/Threshold: 50%ile: 10
Limit/Threshold: 90%ile: 15
------ 50%ile Limit
Total nitrogen (composite) (mg/L)
Financial year
(Source=Model; DF=1 ; F Value=19.075; Pr>F=<.0001)

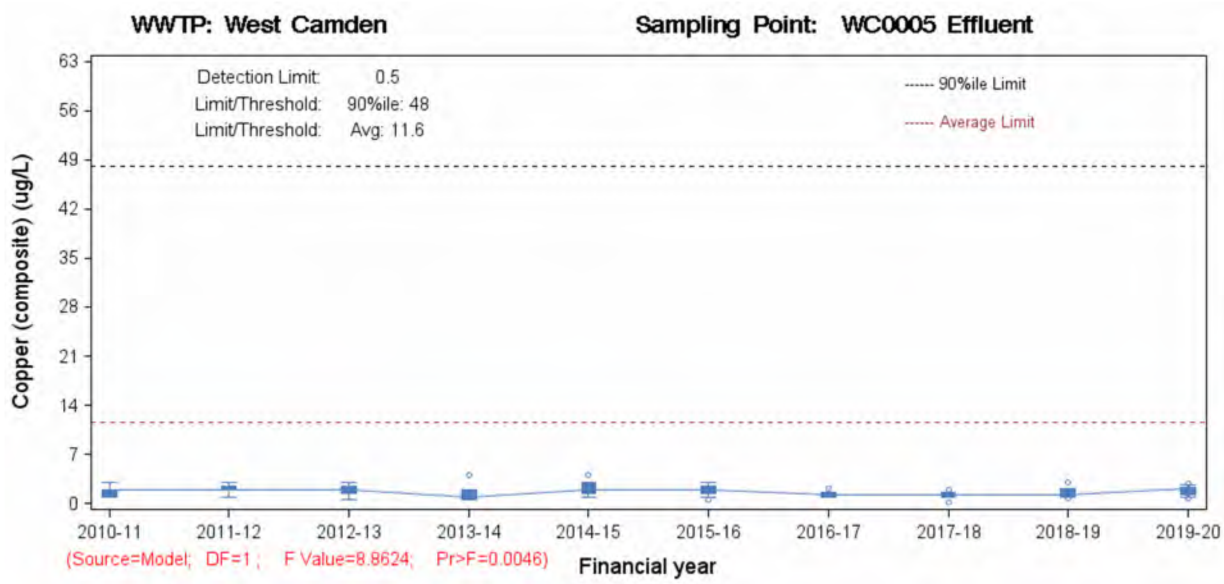


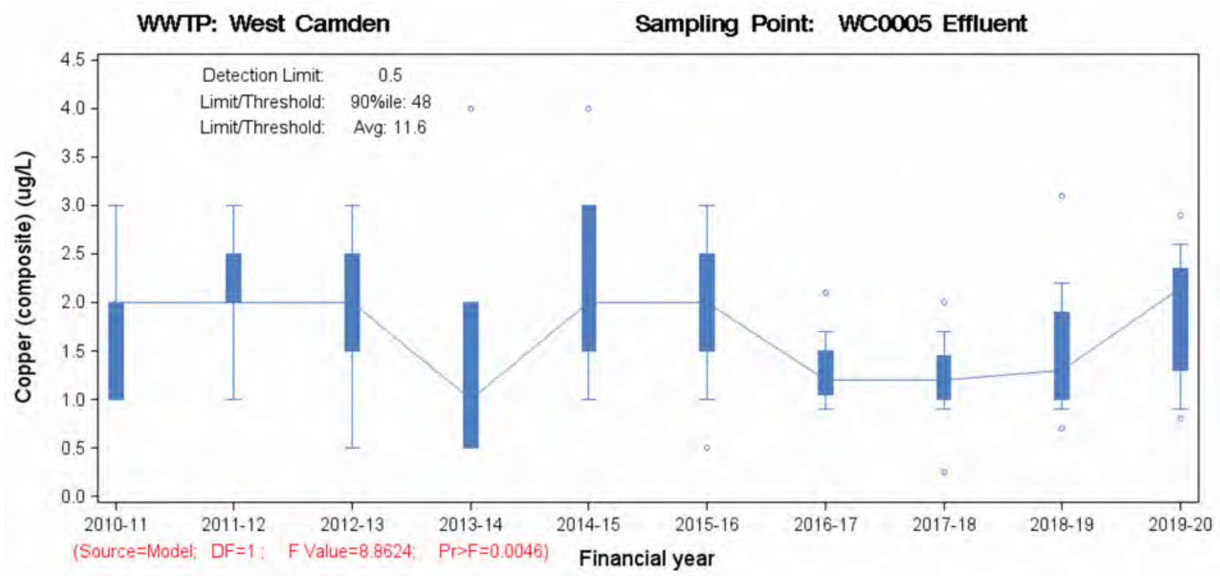
WWTP: West Camden
Sampling Point: WC0005 Effluent
Detection Limit 0.01
Limit/Threshold: 50%ile: 0.3
Limit/Threshold: 90%ile: 1
------ 90%ile Limit
------ 50%ile Limit
Total phosphorus (composite) (mg/L)
Financial year
(Source=Model; DF=1 ; F Value=4.4713; Pr>F=0.0349)


WWTP: West Camden
Sampling Point: WC0005 Effluent
Detection Limit: 0.01
Limit/Threshold: 50%ile: 0.3
Limit/Threshold: 90%ile: 1
------ 50%ile Limit
Total phosphorus (composite) (mg/L)
0.30
0.25
0.20
0.15
0.10
0.05
0.00
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=4.4713; Pr>F=0.0349)
Financial year


WWTP: West Camden
Sampling Point: WC0005 Effluent
Detection Limit: 0.1
Limit/Threshold: 90%ile: 16.5
Limit/Threshold: Avg: 1.8
------ 90%ile Limit
------ Average Limit
Cobalt (composite) (ug/L)
21
18
15
12
9
6
3
0
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=6.9538; Pr>F=0.0092)
Financial year

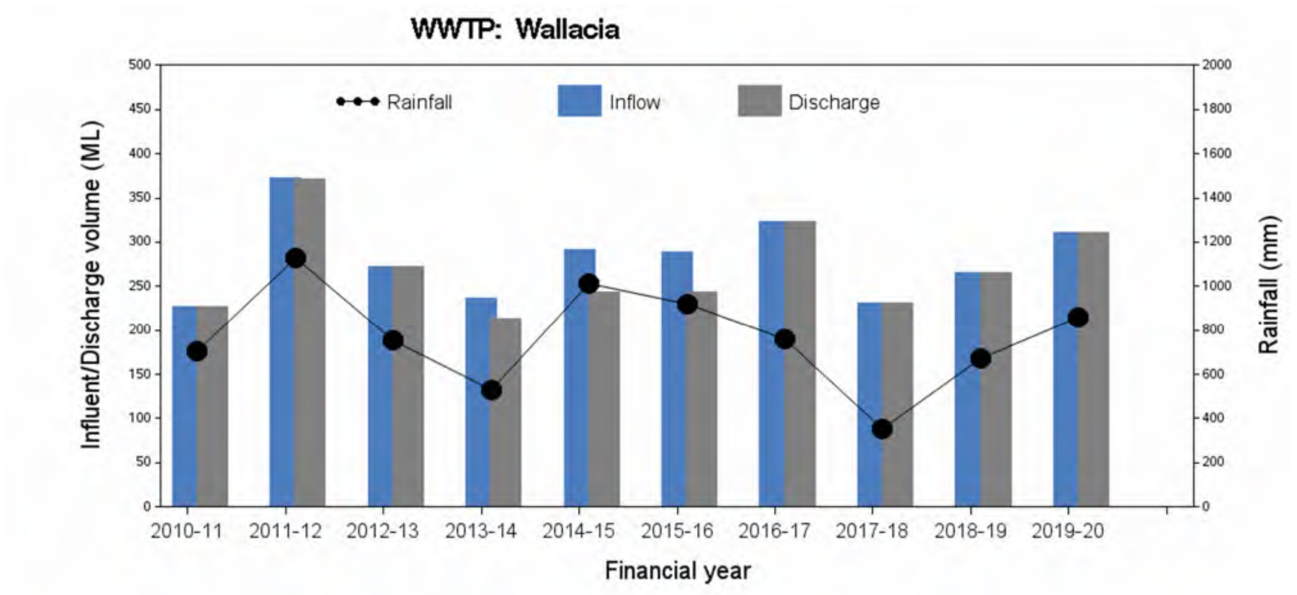

WWTP: West Camden
Sampling Point: WC0005 Effluent
Detection Limit: 0.1
Limit/Threshold: 90%ile: 16.5
Limit/Threshold: Avg: 1.8
Cobalt (composite) (ug/L)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=6.9538; Pr>F=0.0092)
Financial year

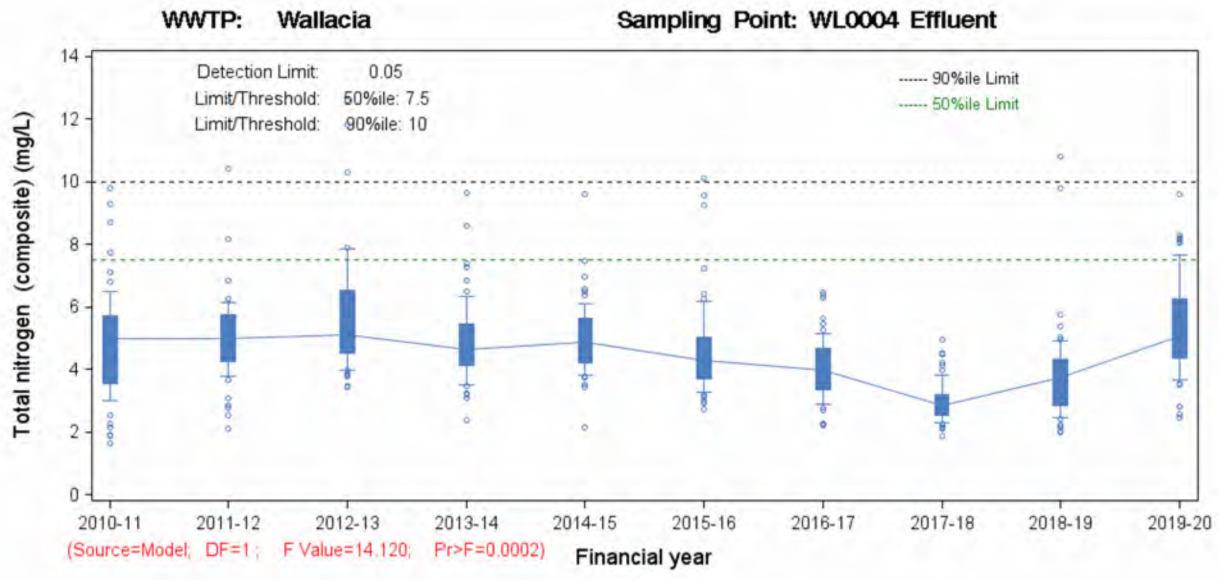

WWTP: West Camden
Sampling Point: WC0005 Effluent
Detection Limit: 0.5
Limit/Threshold: 90%ile: 48
Limit/Threshold: Avg: 11.6
90%ile Limit
Average Limit
Copper (composite) (ug/L)
0
7
14
21
28
35
42
49
56
63
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=8.8624; Pr>F=0.0046)
Financial year

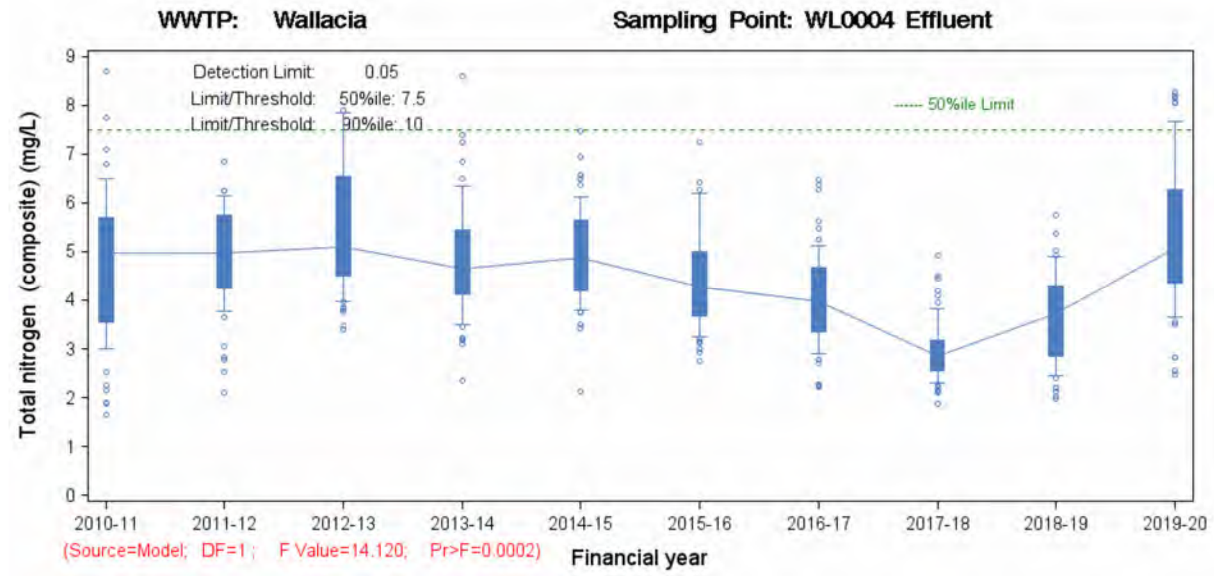

WWTP: West Camden
Sampling Point: WC0005 Effluent
Detection Limit: 0.5
Limit/Threshold: 90%ile: 48
Limit/Threshold: Avg: 11.6
Copper (composite) (ug/L)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=8.8624; Pr>F=0.0046)
Financial year

4.2.3 Wallacia WWTP

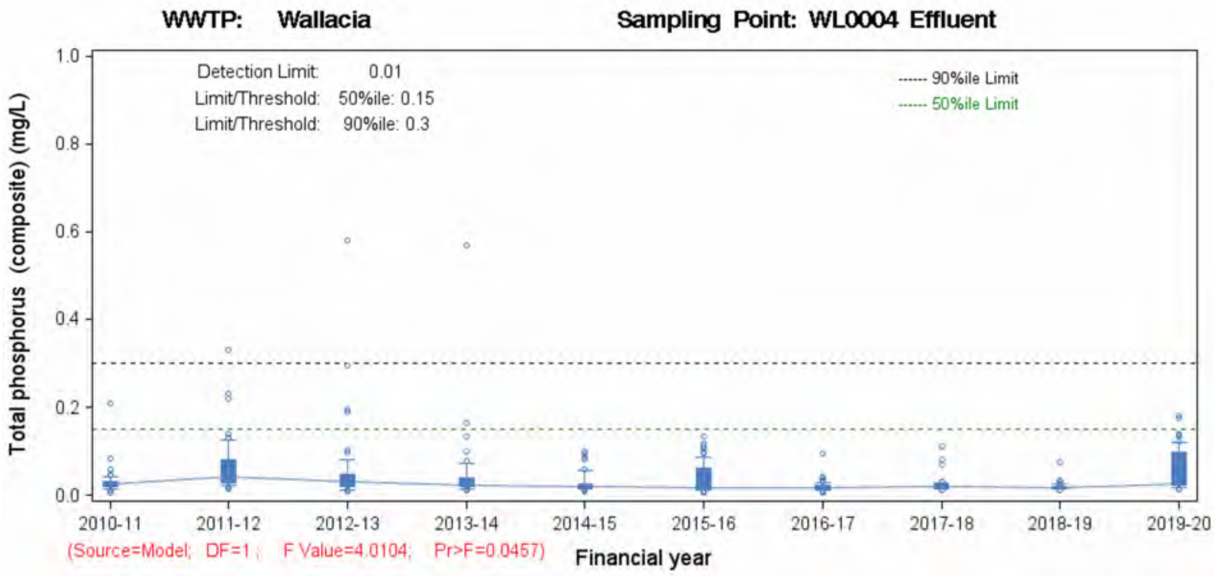
All concentration and load limits in the discharge from Wallacia WWTP were within the EPL limit during the 2019-20 period. Statistical analysis identified significantly increasing trends in total nitrogen and total phosphorus in discharges during 2019-20 in comparison to earlier years. This increasing trend may be attributed to the additional flow and loads being received within the catchment area. Following a review of this increasing trend, Wallacia WWTP has commenced further optimisation of its biological processes. Generally, the pollutant loads followed a pattern similar to the rainfall and flow to the plant, and were well below the load limits. Wallacia WWTP saw an increase in inflows and subsequent loads during the second half of 2020, possibly due to the COVID-19 pandemic with more people working from home.



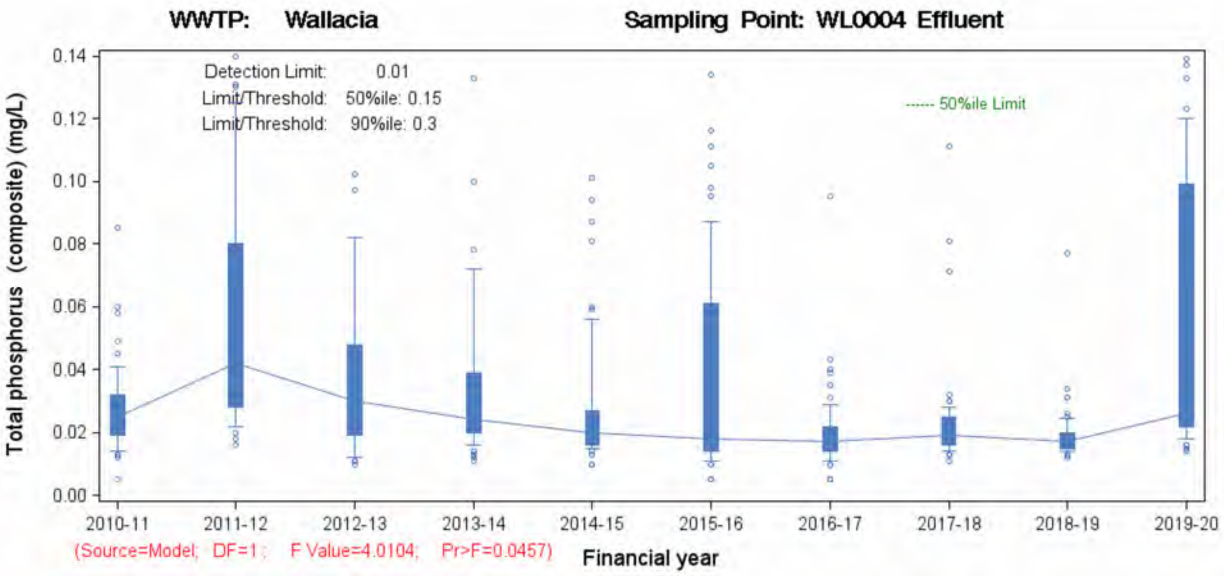




WWTP: Wallacia
Sampling Point: WL0004 Effluent
Detection Limit: 0.05
Limit/Threshold: 50%ile: 7.5
Limit/Threshold: 90%ile: 10
------ 50%ile Limit
Total nitrogen (composite) (mg/L)
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=14.120; Pr>F=0.0002)
Financial year



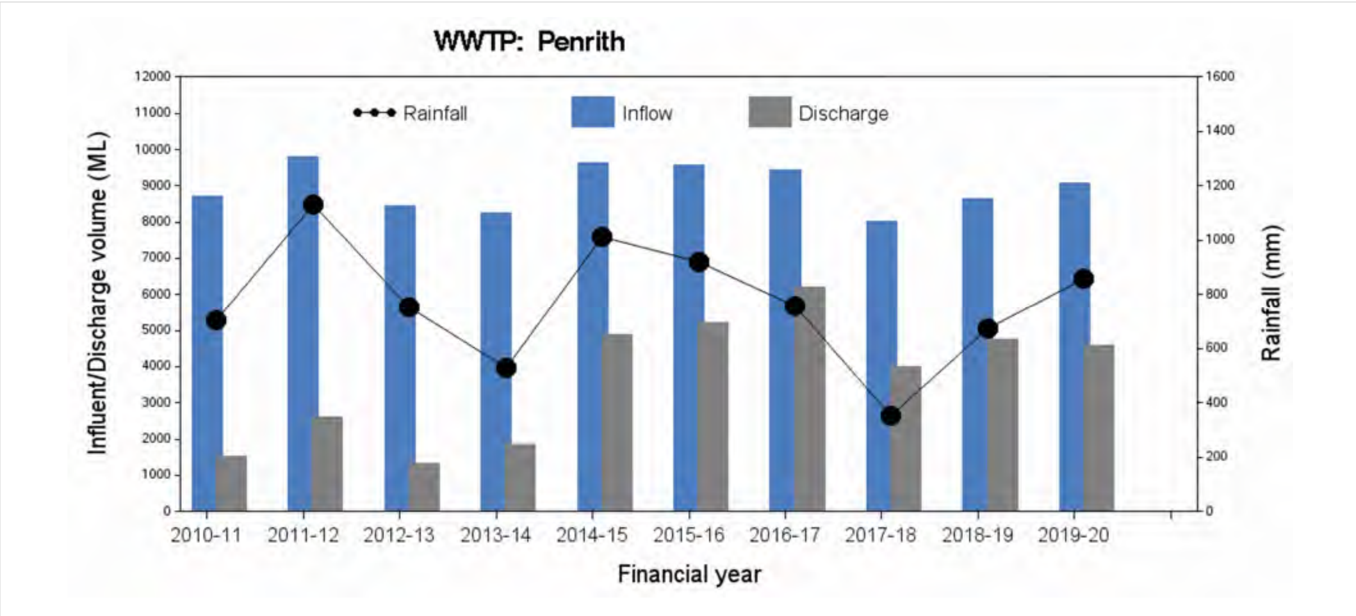
WWTP: Wallacia
Sampling Point: WL0004 Effluent
Detection Limit: 0.01
Limit/Threshold: 50%ile: 0.15
Limit/Threshold: 90%ile: 0.3
------ 90%ile Limit
------ 50%ile Limit
Total phosphorus (composite) (mg/L)
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=4.0104; Pr>F=0.0457)
Financial year

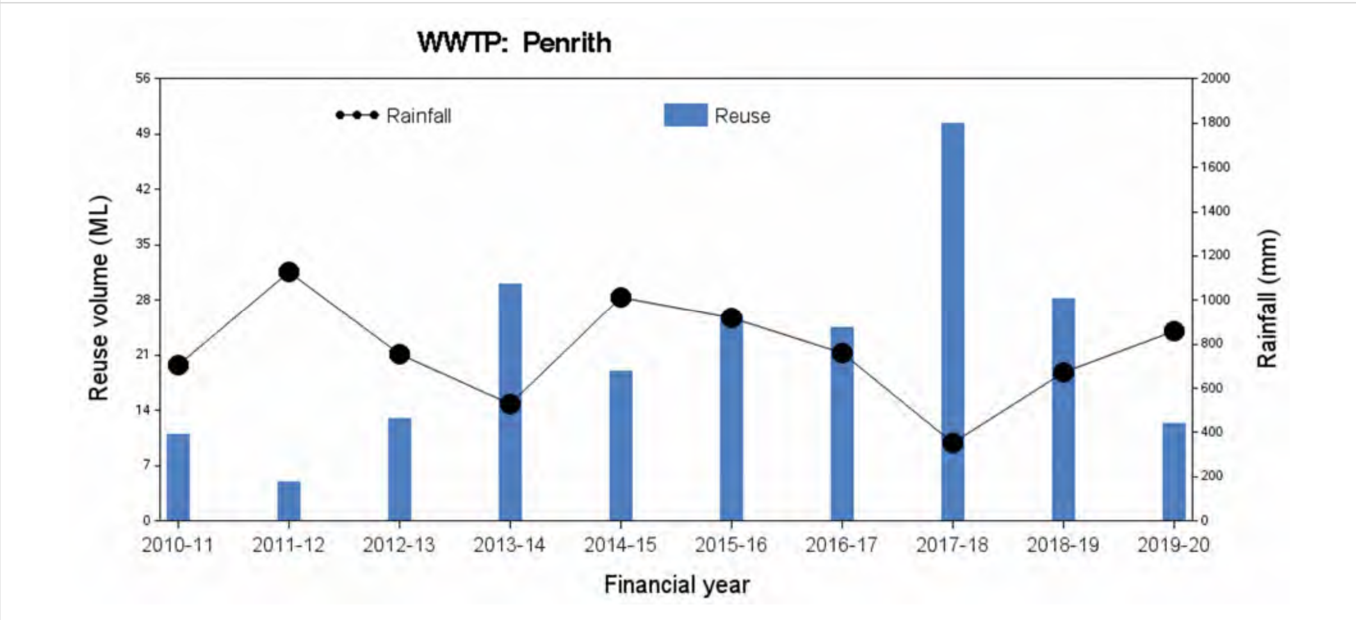


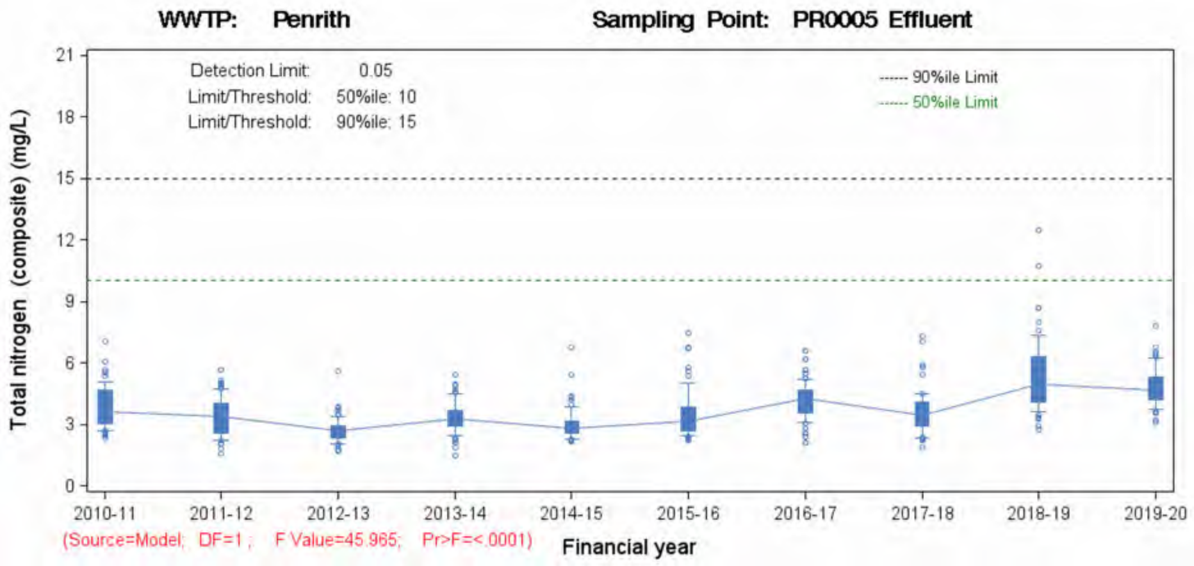
WWTP: Wallacia
Sampling Point: WL0004 Effluent
Detection Limit: 0.01
Limit/Threshold: 50%ile: 0.15
Limit/Threshold: 90%ile: 0.3
------ 50%ile Limit
Total phosphorus (composite) (mg/L)
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=4.0104; Pr>F=0.0457)
Financial year

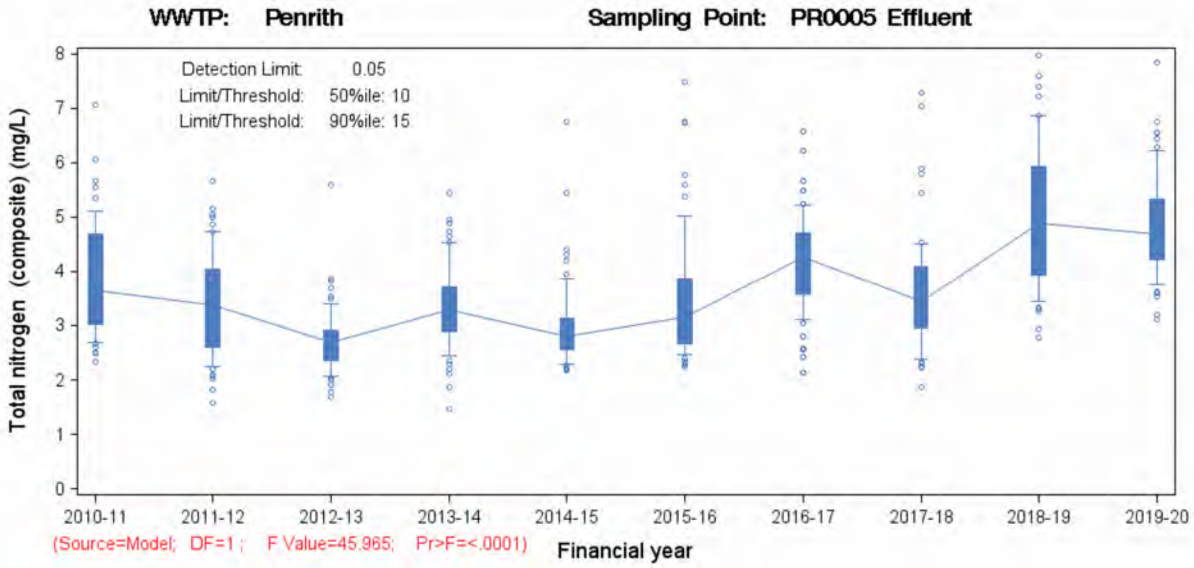
4.2.4 Penrith WWTP

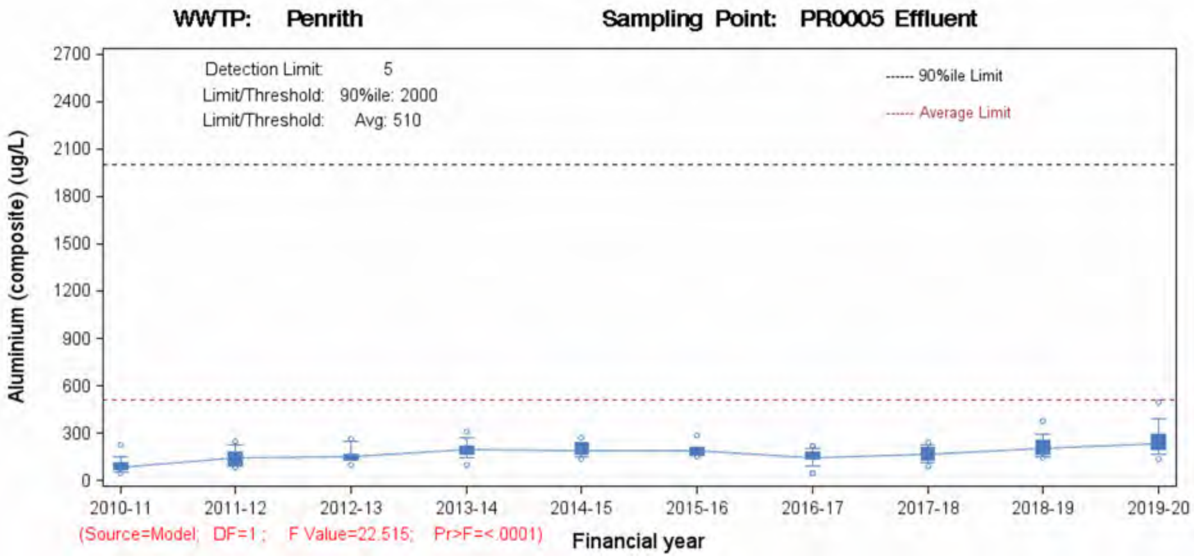
All concentration and load limits in the discharge from Penrith WWTP were within the EPL limits during the 2019-20 period. Statistical analysis identified significantly increasing trends in total nitrogen, aluminium and nickel concentrations. The overall increasing trend for total nitrogen is associated to the elevated concentration levels recorded during the 2018-19 financial year when only one IDAL was operational. The concentration is well below the licence concentration limit and slightly lower than from 2018-19. The aluminium increasing trend is possibly due to filter performance and the type of filter used (sand filter only). The increasing trend in nickel is thought to be related to trade waste customer loads from within the catchment. Significant decreasing trends were observed in copper and zinc concentrations during the 2019-20 period compared to earlier years. Generally, the pollutant loads were steady and followed a pattern similar to the rainfall and flow to the plant and were well below the load limits. Penrith WWTP saw an increase in inflows and subsequent loads during the second half of 2020, possibly due to the COVID-19 pandemic with more people working from home.

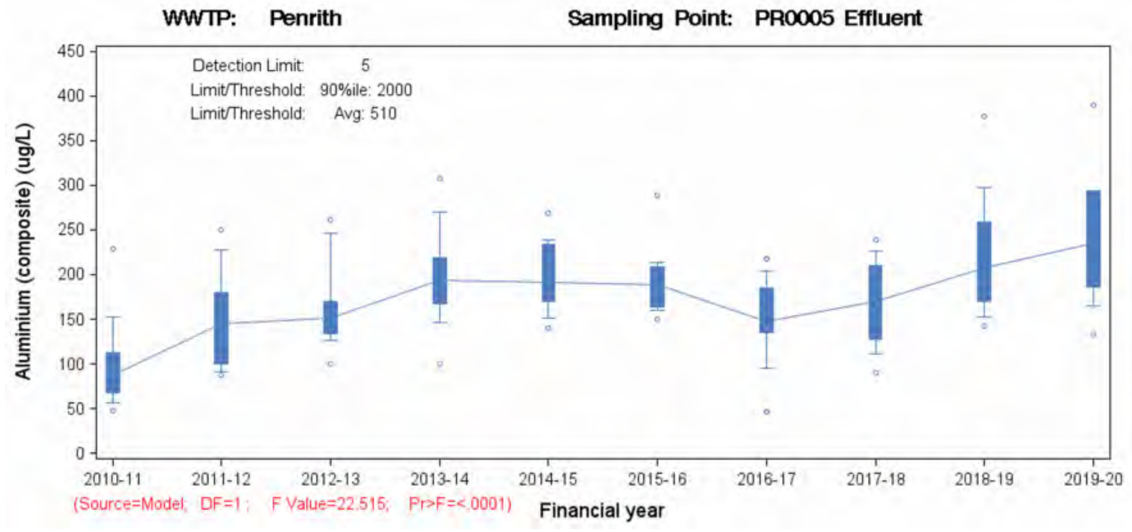


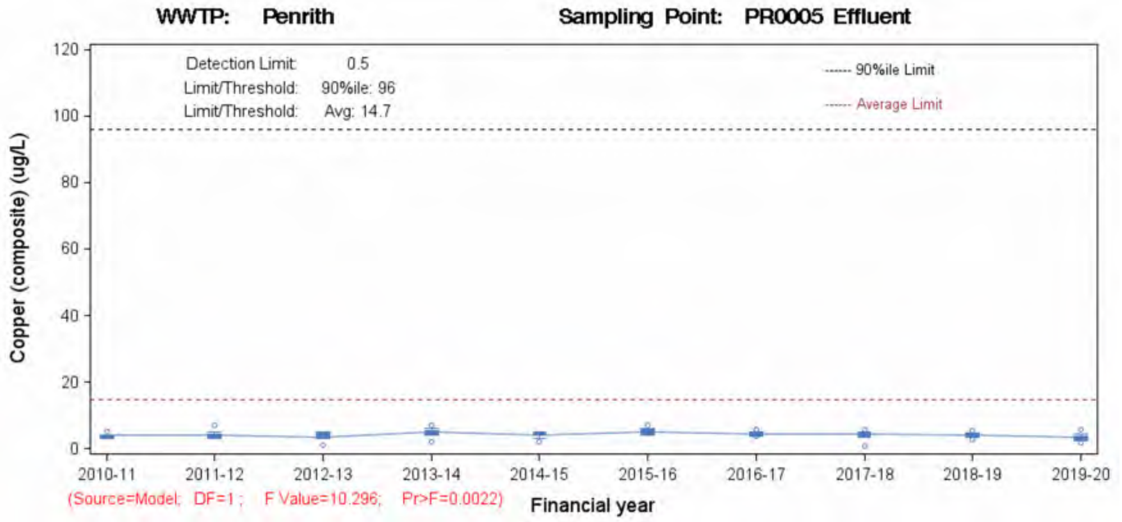



WWTP: Penrith
Sampling Point: PR0005 Effluent
Detection Limit: 0.05
Limit/Threshold: 50%ile: 10
Limit/Threshold: 90%ile: 15
90%ile Limit
50%ile Limit
Total nitrogen (composite) (mg/L)
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=45.965; Pr>F=<.0001)
Financial year

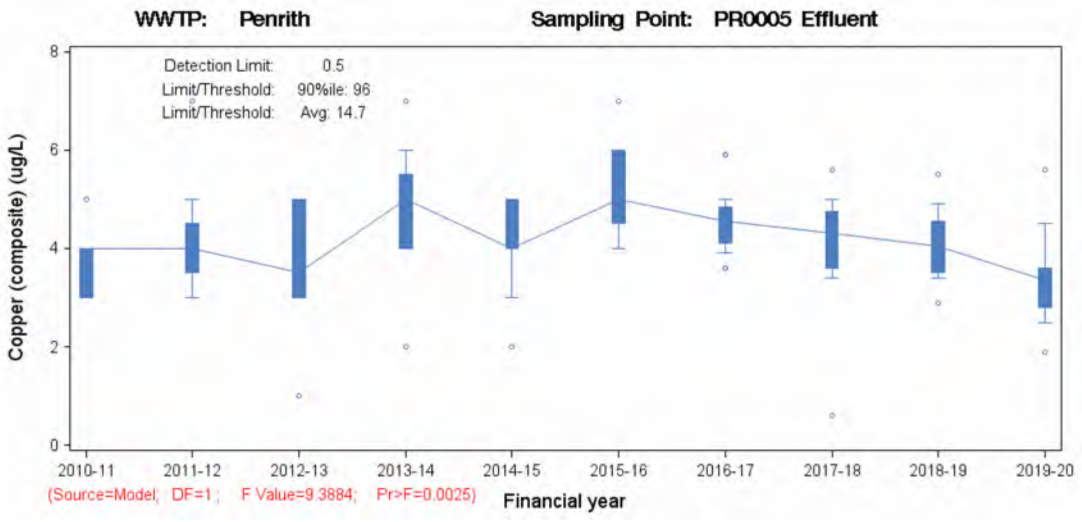

WWTP: Penrith
Sampling Point: PR0005 Effluent
Detection Limit: 0.05
Limit/Threshold: 50%ile: 10
Limit/Threshold: 90%ile: 15
Total nitrogen (composite) (mg/L)
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=45.965; Pr>F=<.0001)
Financial year


WWTP: Penrith
Sampling Point: PR0005 Effluent
Detection Limit: 5
Limit/Threshold: 90%ile: 2000
Limit/Threshold: Avg: 510
90%ile Limit
Average Limit
Aluminium (composite) (ug/L)
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=22.515; Pr>F=<.0001)
Financial year

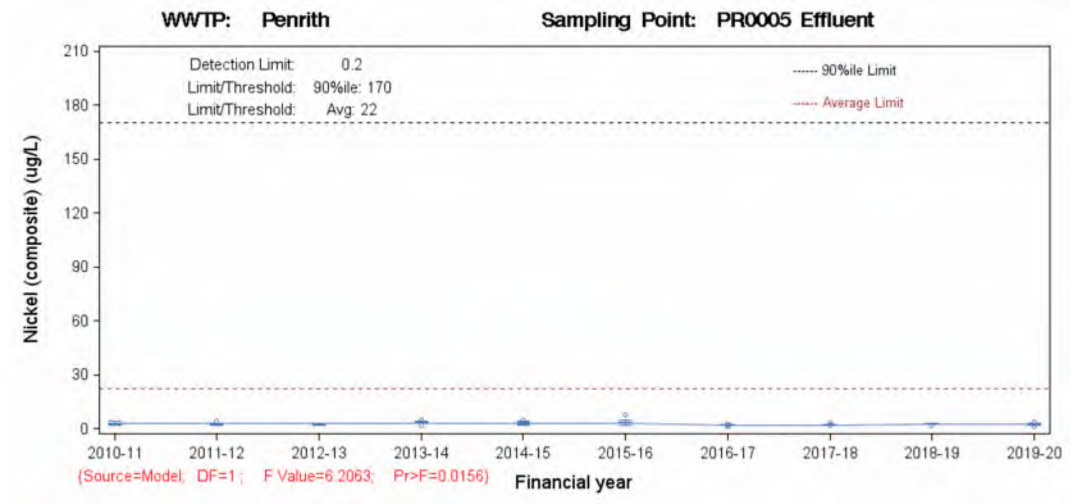




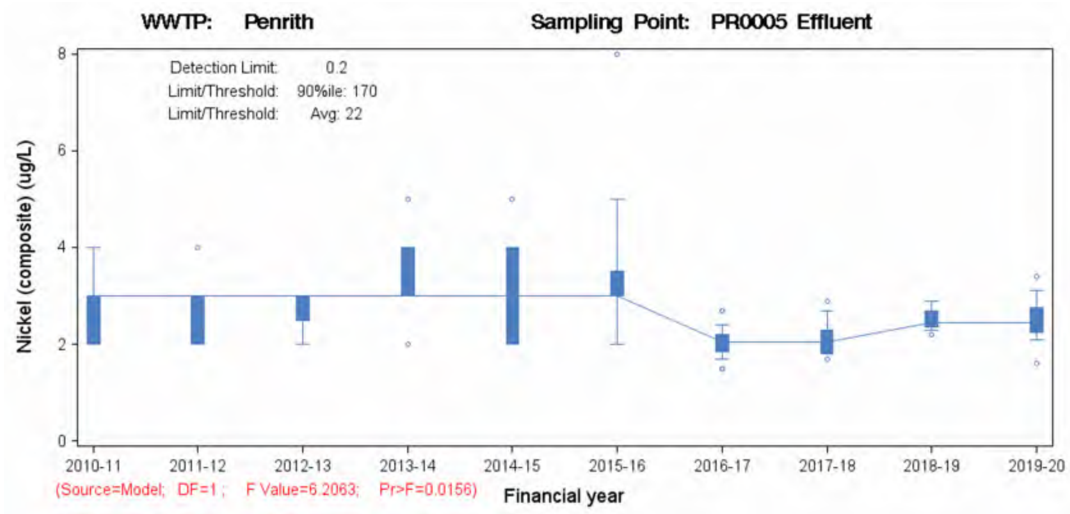
Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.



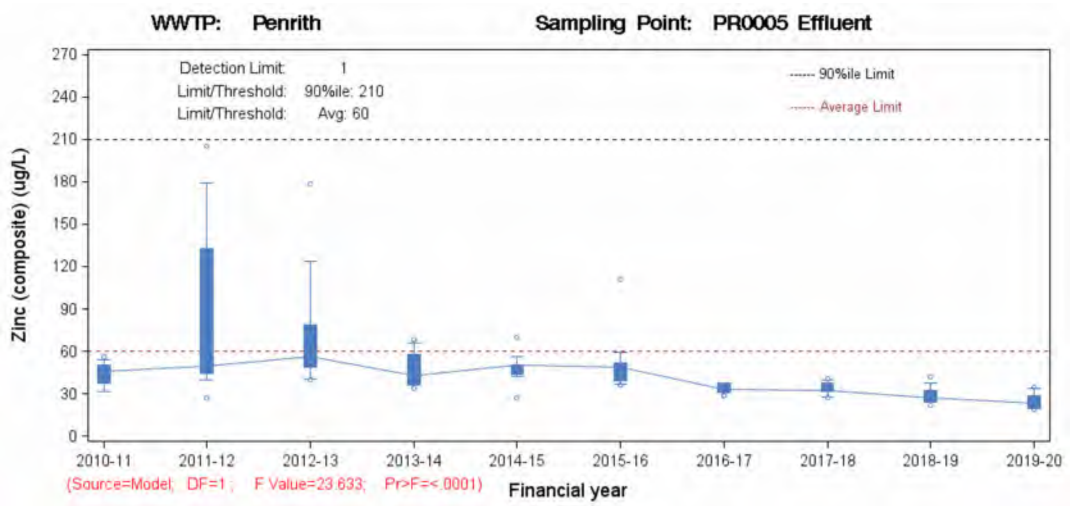
Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.



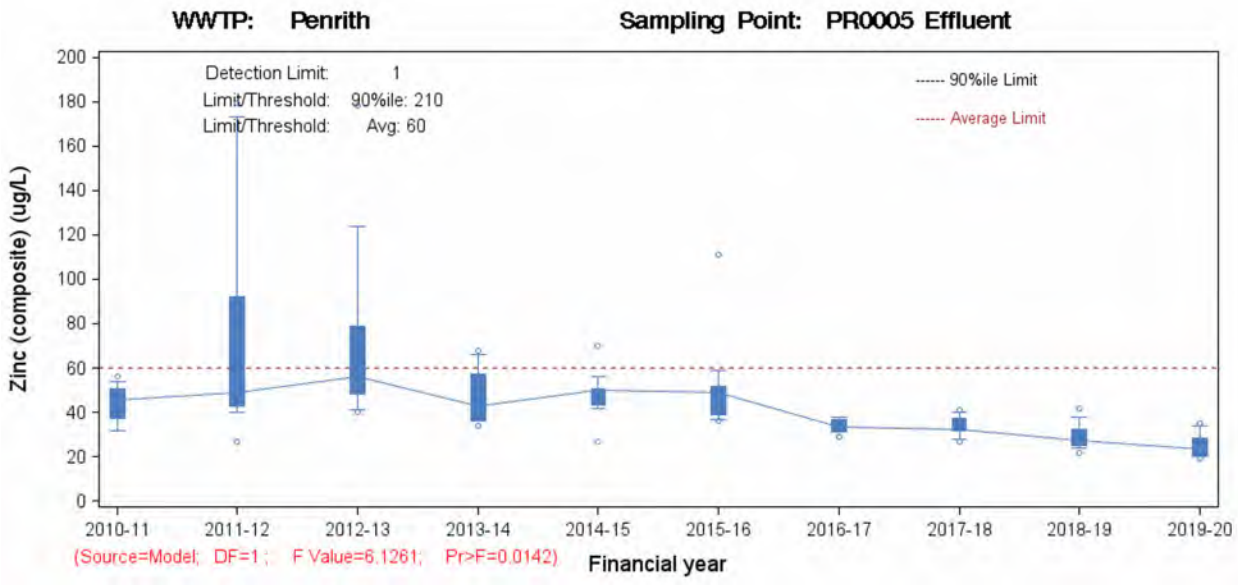
Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.



Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.



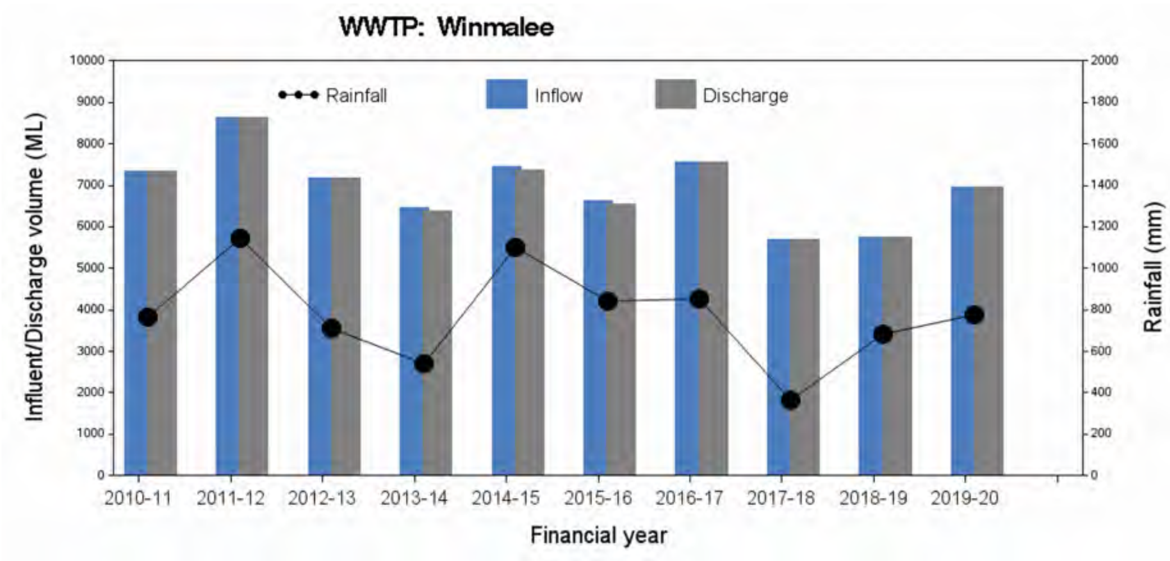
Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.

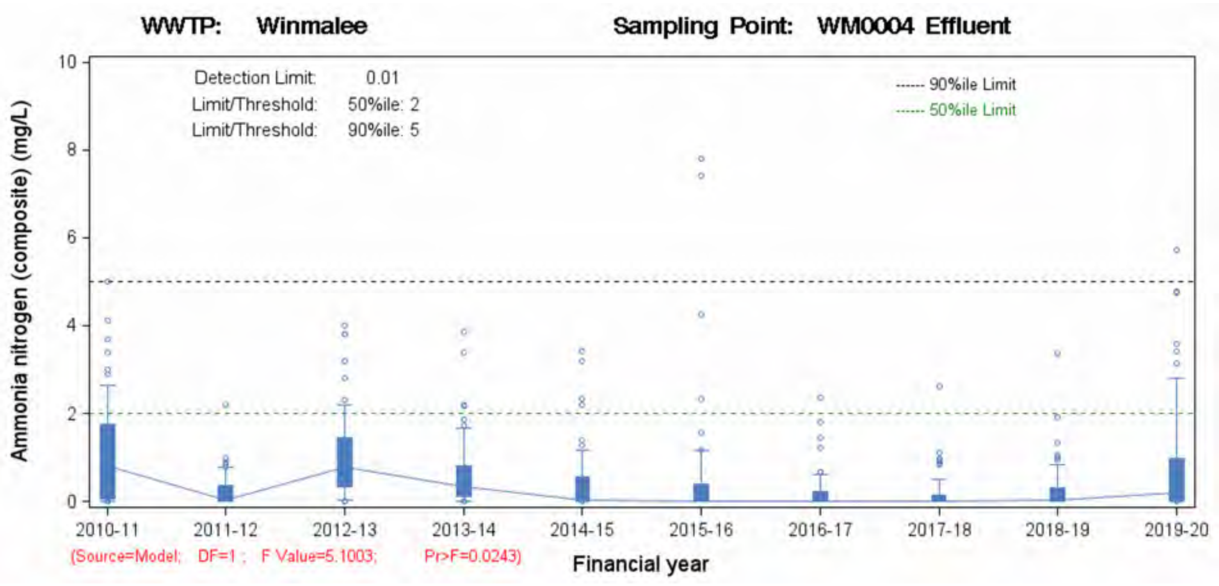


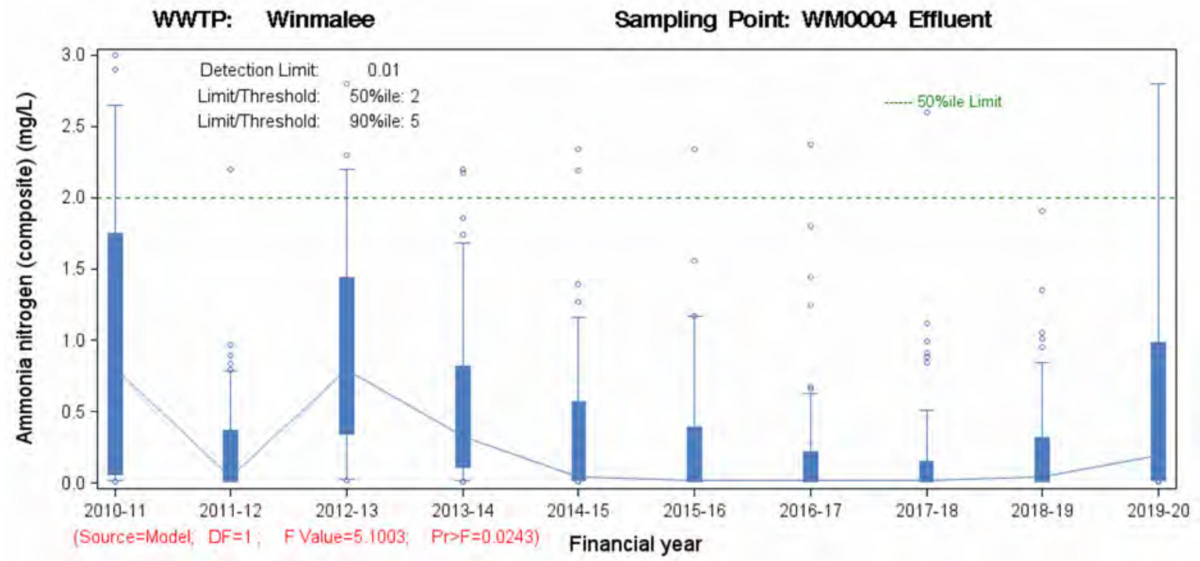
Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.

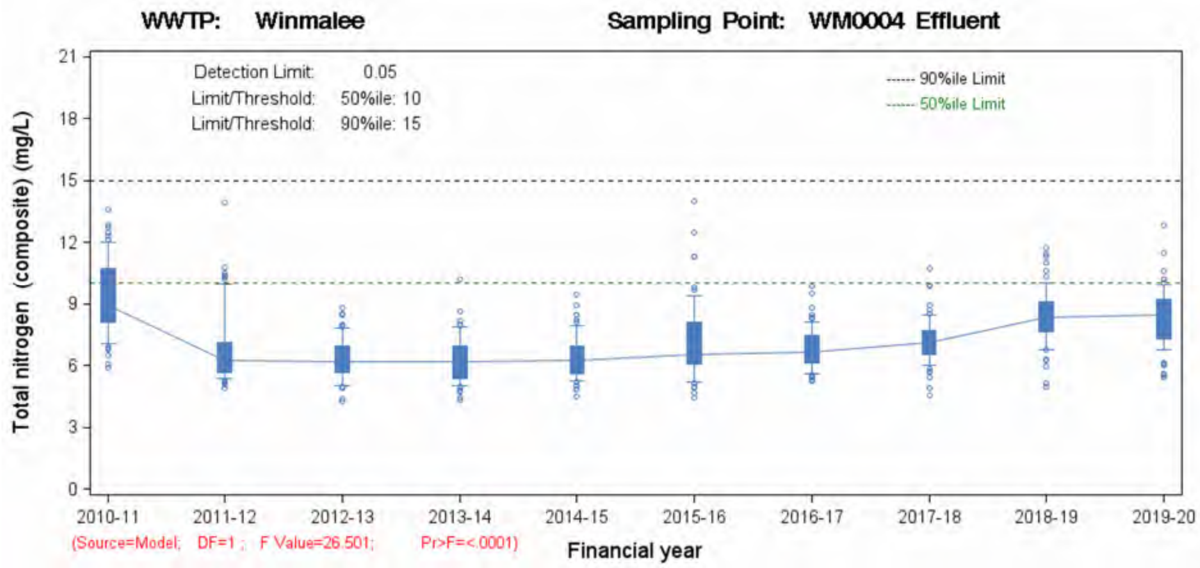
4.2.5 Winmalee WWTP

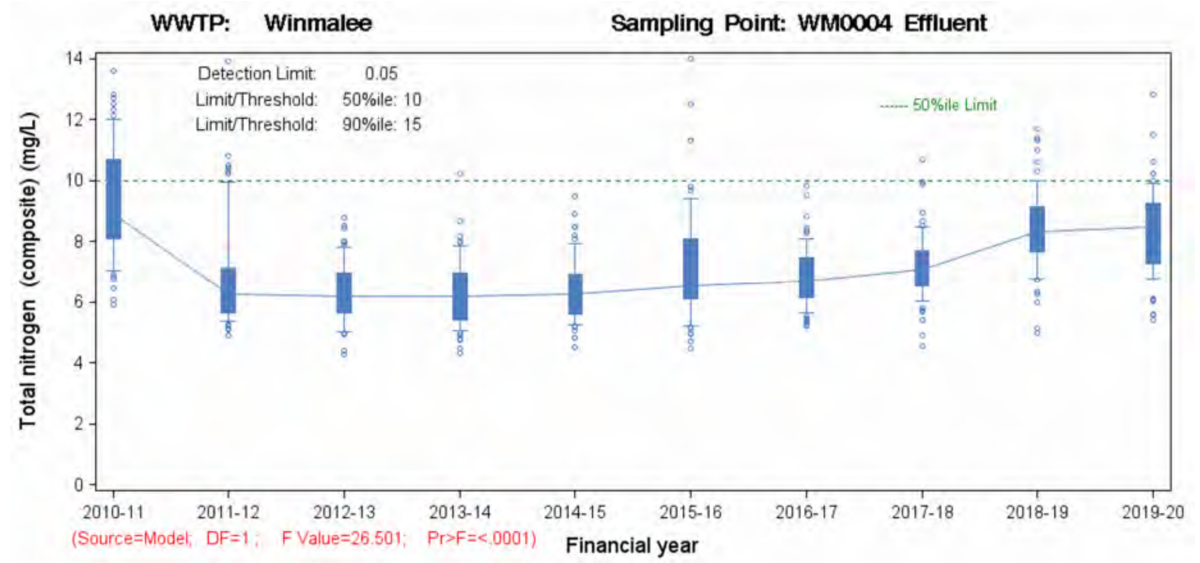
All concentration and load limits in the discharge from Winmalee WWTP were within the EPL limits during the 2019-20 period. Statistical analysis identified significantly increasing trends in ammonia nitrogen, total nitrogen, copper and zinc concentrations. A significantly decreasing trend in total phosphorus concentration was observed during the 2019-20 when compared to previous years. There was an increase in flows and subsequent loads during the second half of 2020 possibly in response to COVID-19 and more people working from home. Furthermore, the significant rain event in early February 2020 had a considerable impact on flows and loads recorded by the plant. These events had an influence on the increasing trends of ammonia nitrogen and total nitrogen at Winmalee WWTP. The increasing copper and zinc trends are thought to be related to trade waste customer loads within the catchment area.

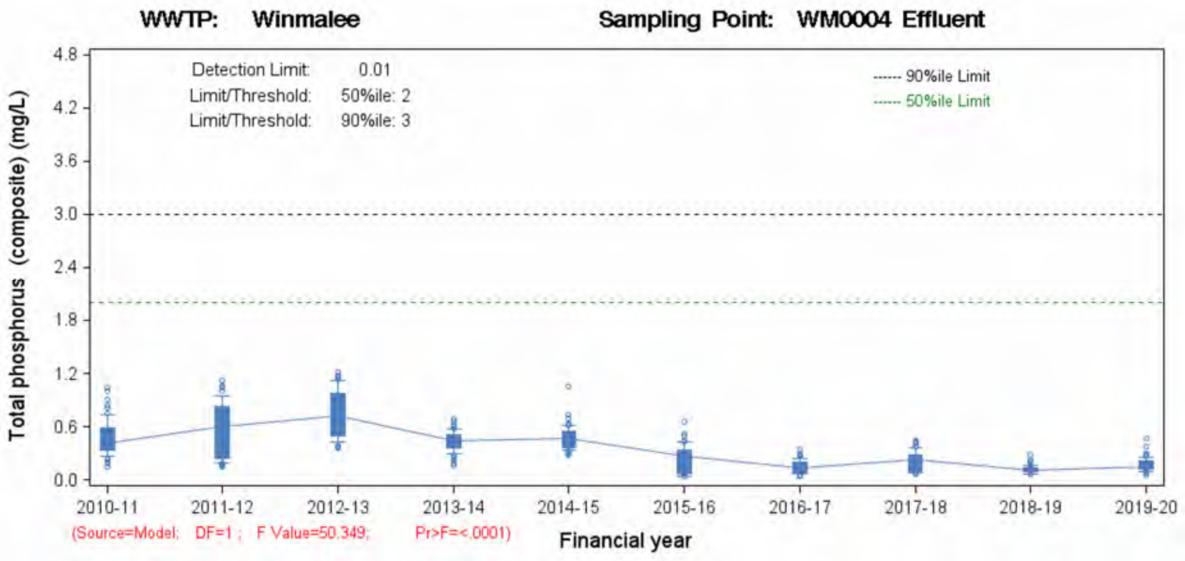


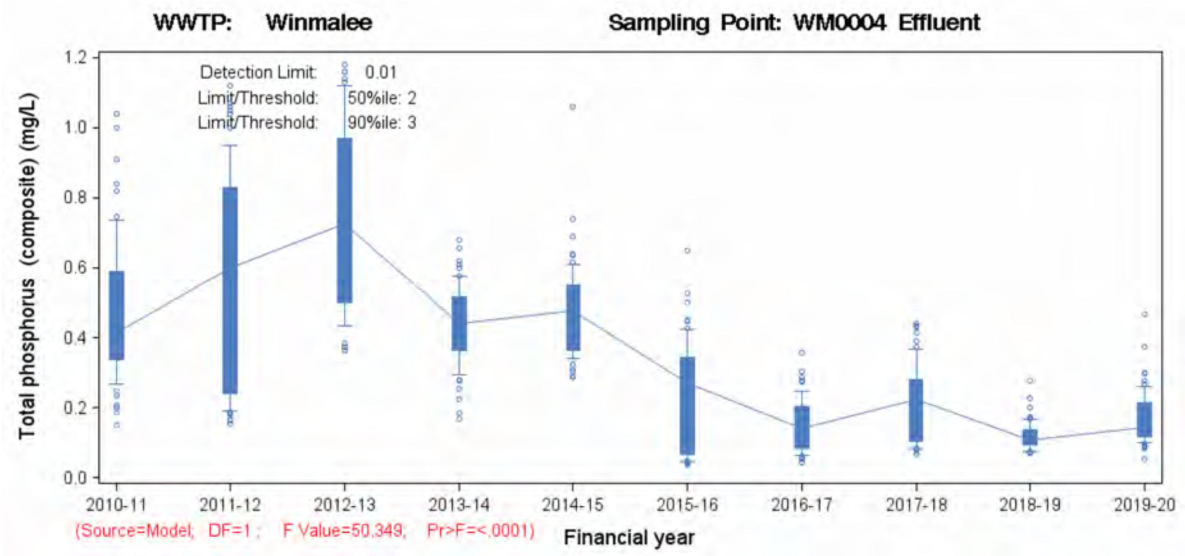


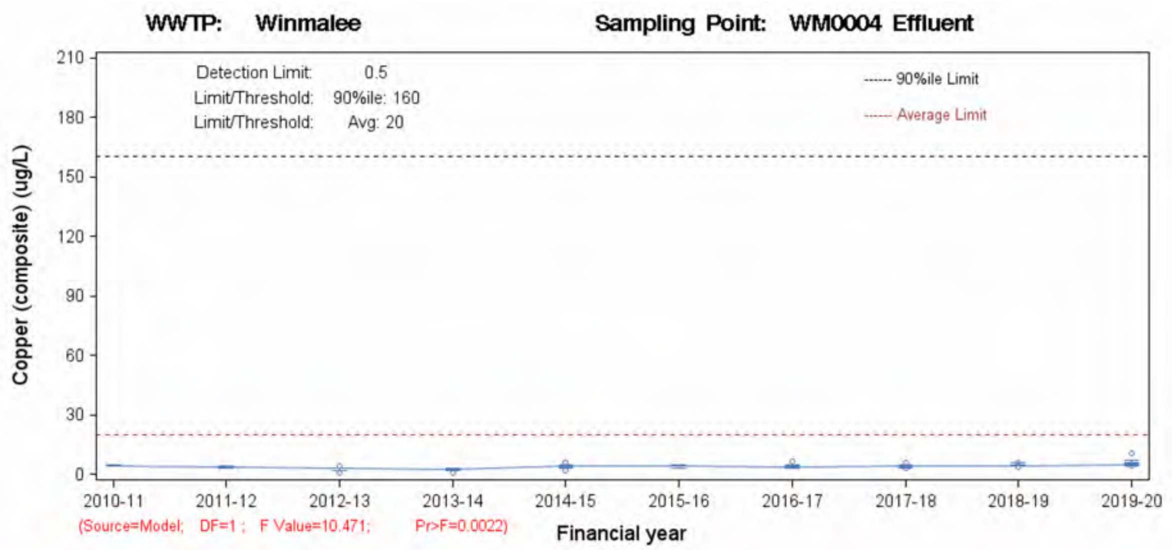

WWTP: Winmalee
Sampling Point: WM0004 Effluent
Detection Limit: 0.01
Limit/Threshold: 50%ile: 2
Limit/Threshold: 90%ile: 5
------ 50%ile Limit
Ammonia nitrogen (composite) (mg/L)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=5.1003; Pr>F=0.0243)
Financial year


WWTP: Winmalee
Sampling Point: WM0004 Effluent
Detection Limit: 0.05
Limit/Threshold: 50%ile: 10
Limit/Threshold: 90%ile: 15
------ 90%ile Limit
------ 50%ile Limit
Total nitrogen (composite) (mg/L)
21
18
15
12
9
6
3
0
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=26.501; Pr>F=<.0001)
Financial year

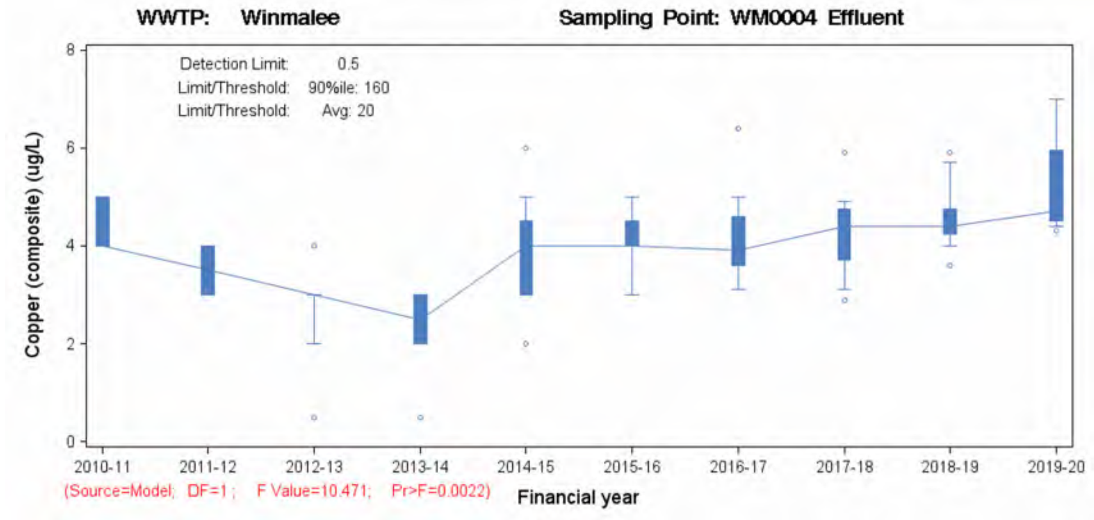

WWTP: Winmalee
Sampling Point: WM0004 Effluent
Detection Limit: 0.05
Limit/Threshold: 50%ile: 10
Limit/Threshold: 90%ile: 15
------ 50%ile Limit
Total nitrogen (composite) (mg/L)
14
12
10
8
6
4
2
0
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=26.501; Pr>F=<.0001)
Financial year



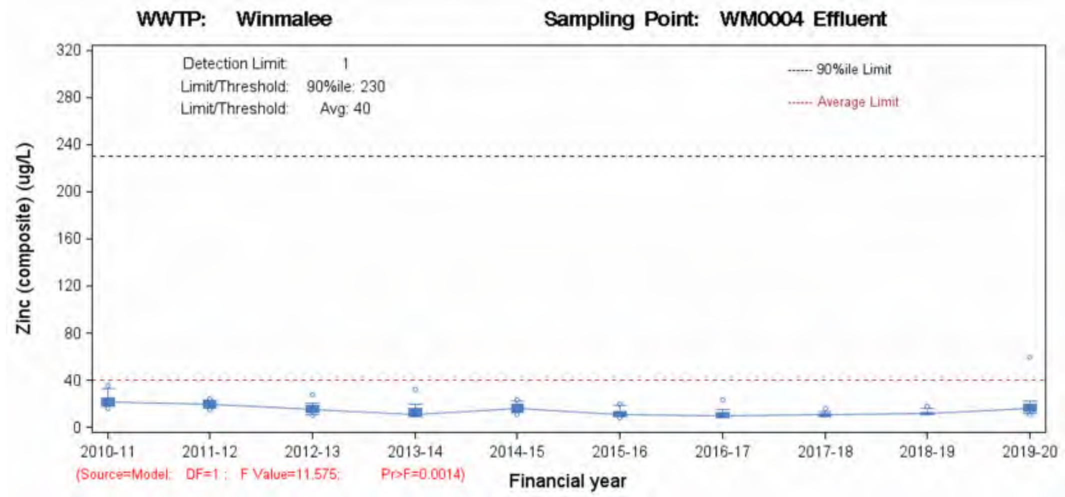




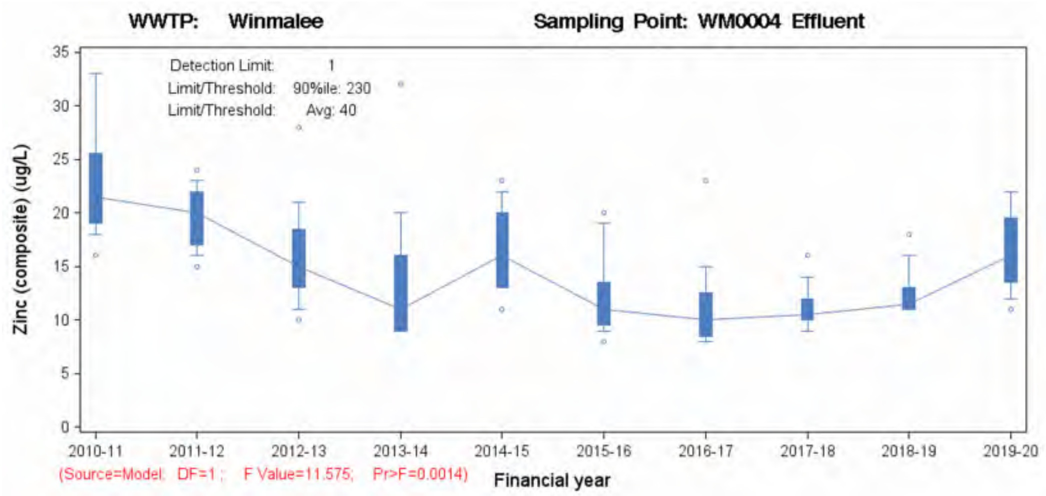
Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.



Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.



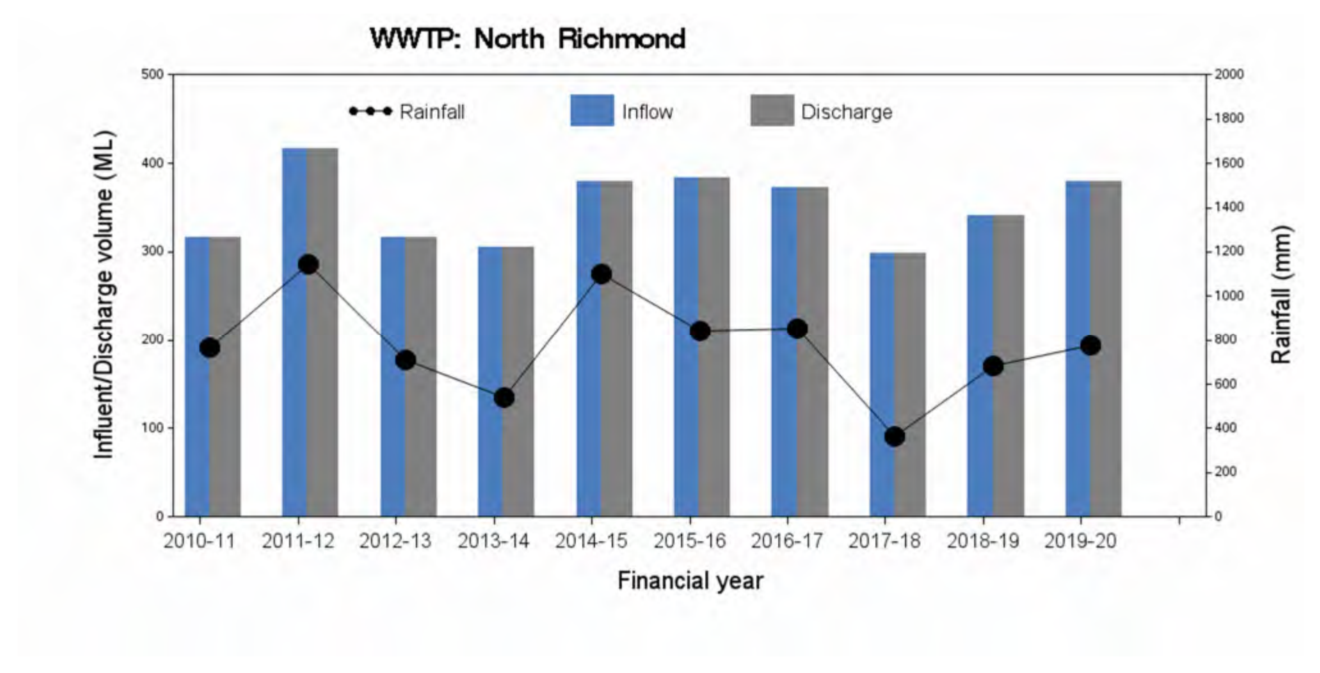
Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.

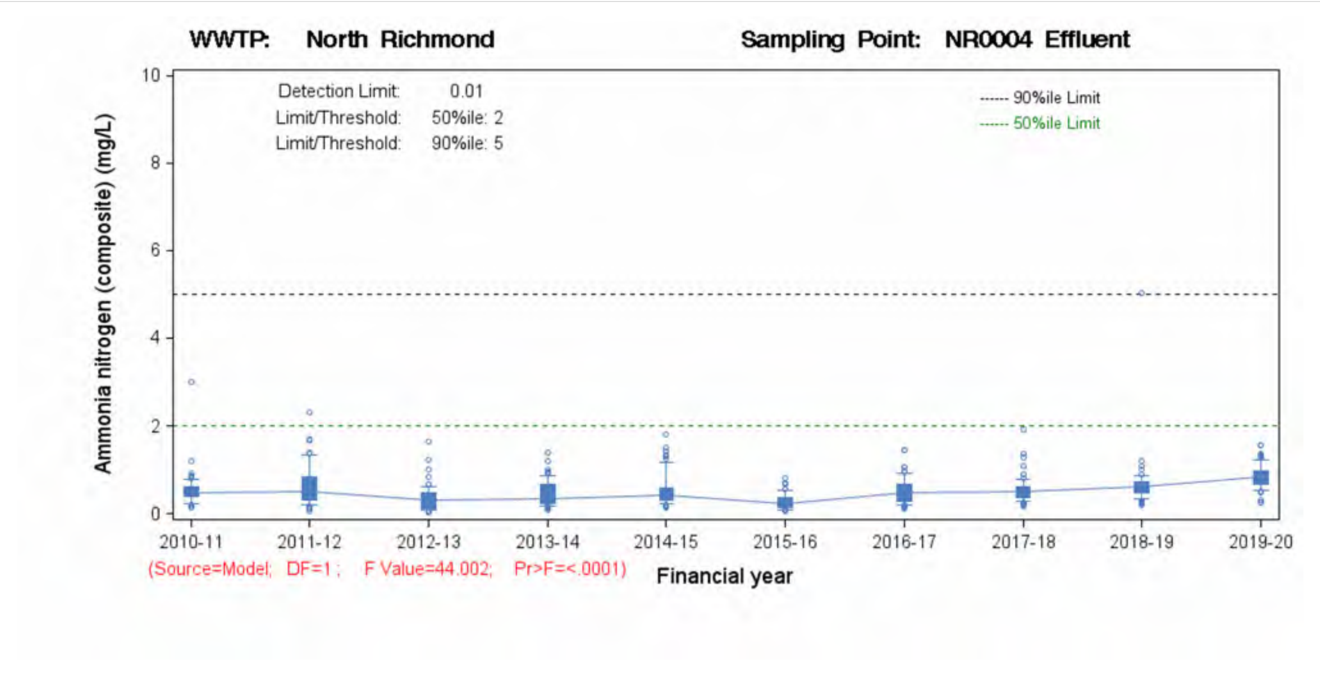


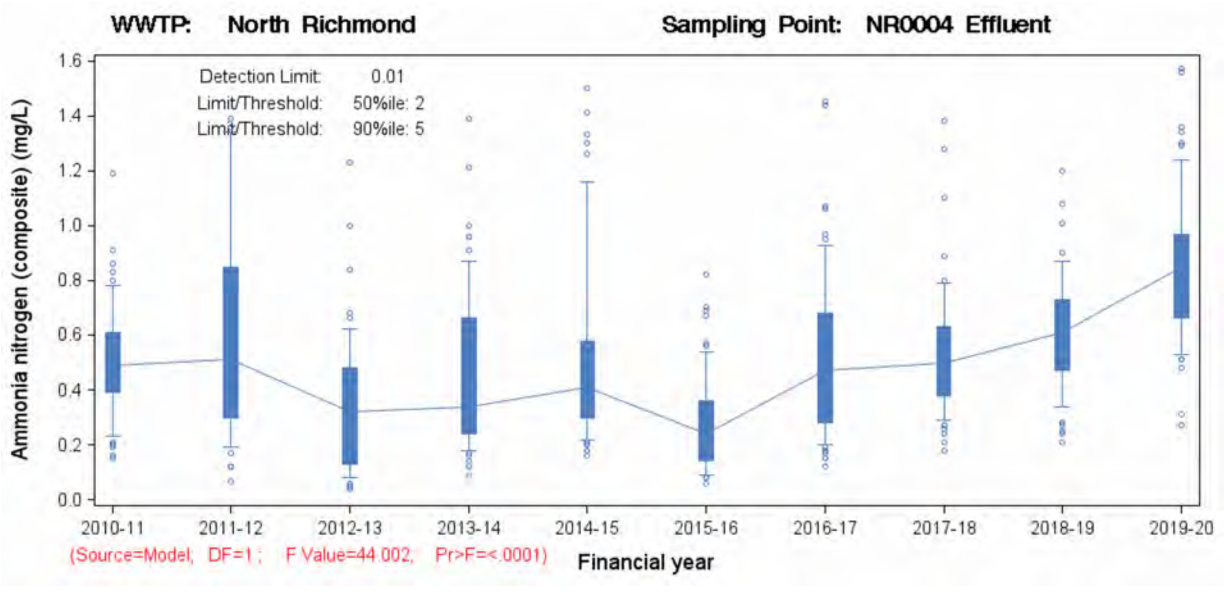
Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.

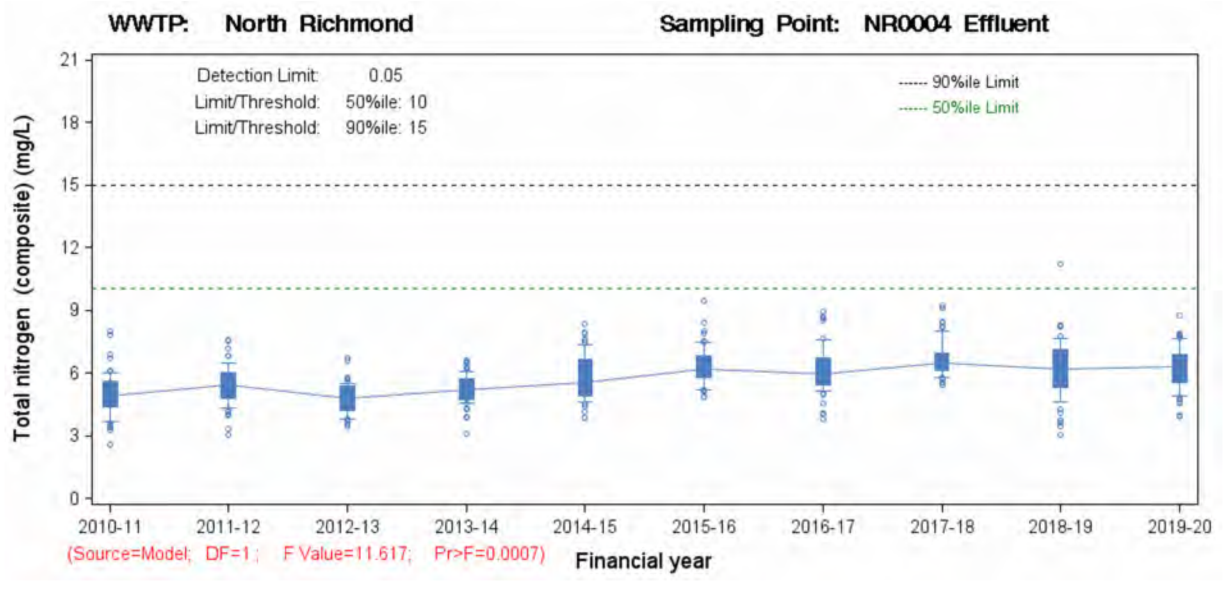
4.2.6 North Richmond WWTP

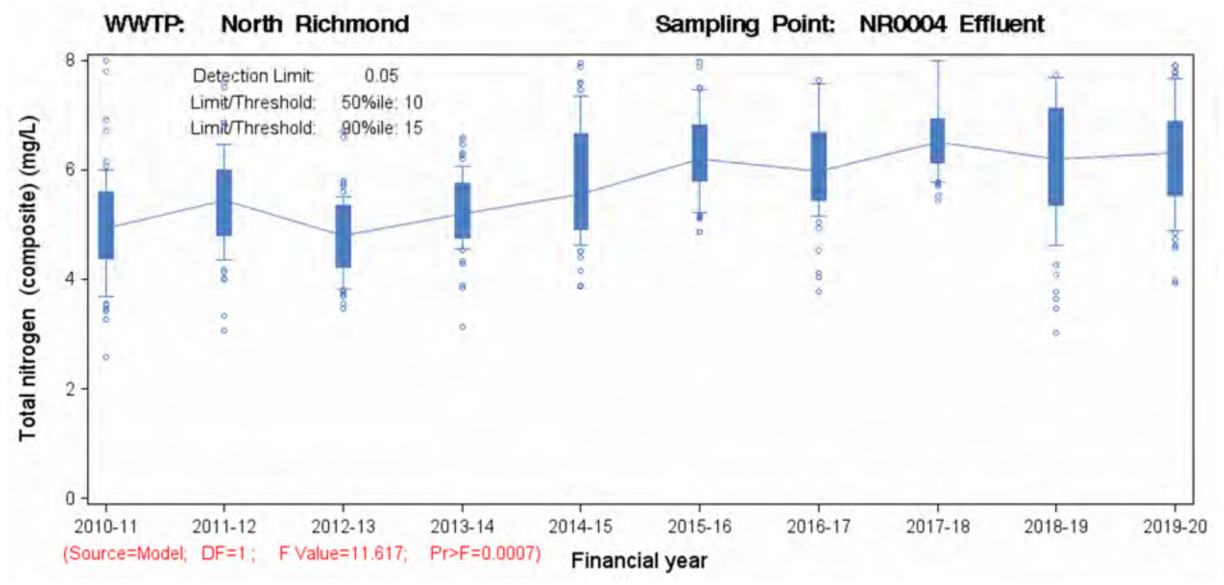
All concentration and load limits in the discharge from North Richmond WWTP were within the EPL limits during the 2019-20 period. Statistical analysis identified significantly increasing trends in ammonia nitrogen, total nitrogen and total phosphorus in discharges from North Richmond WWTP. Generally, the pollutant loads were steady and followed a pattern similar to the rainfall and flow to the plant and were well below the load limits. Significantly decreasing trends in total suspended solids, aluminium and zinc concentrations were observed 2019-20 data compared with previous years' data.

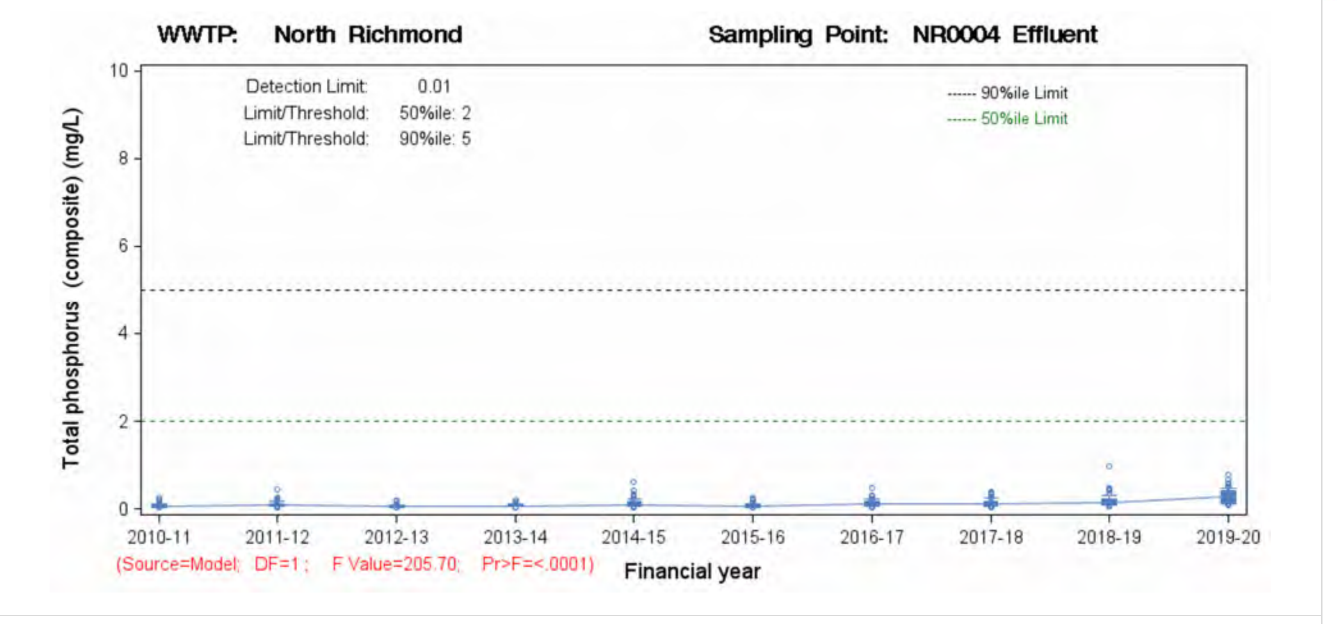


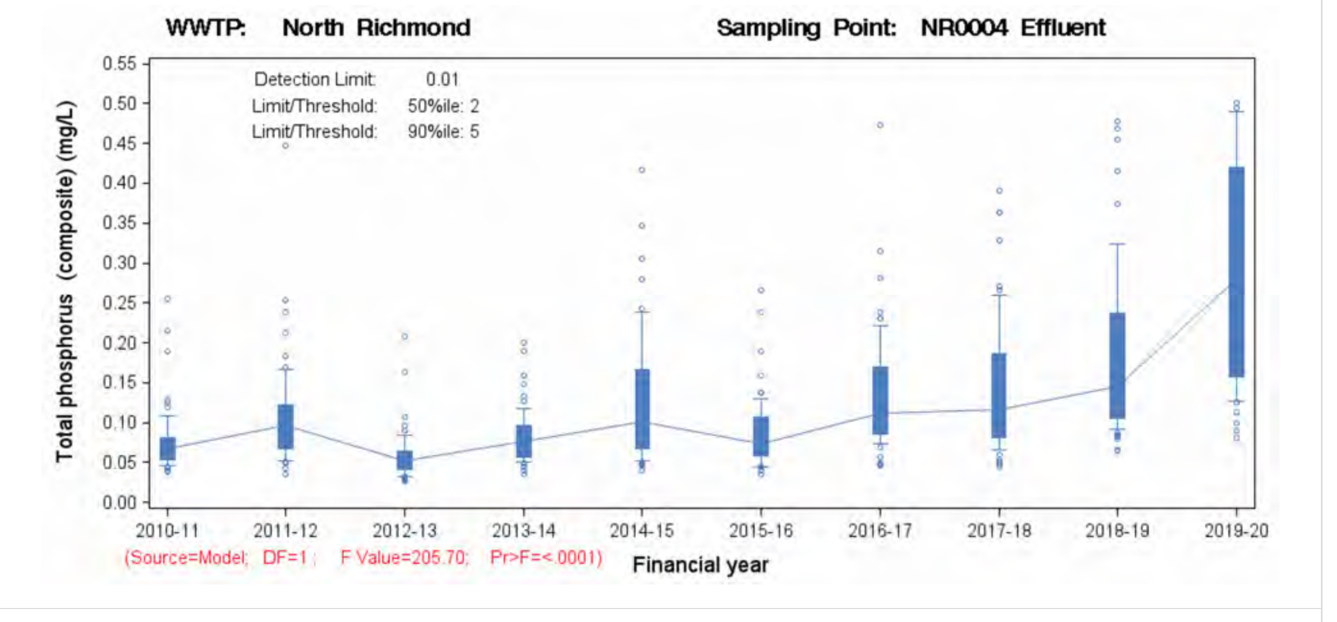


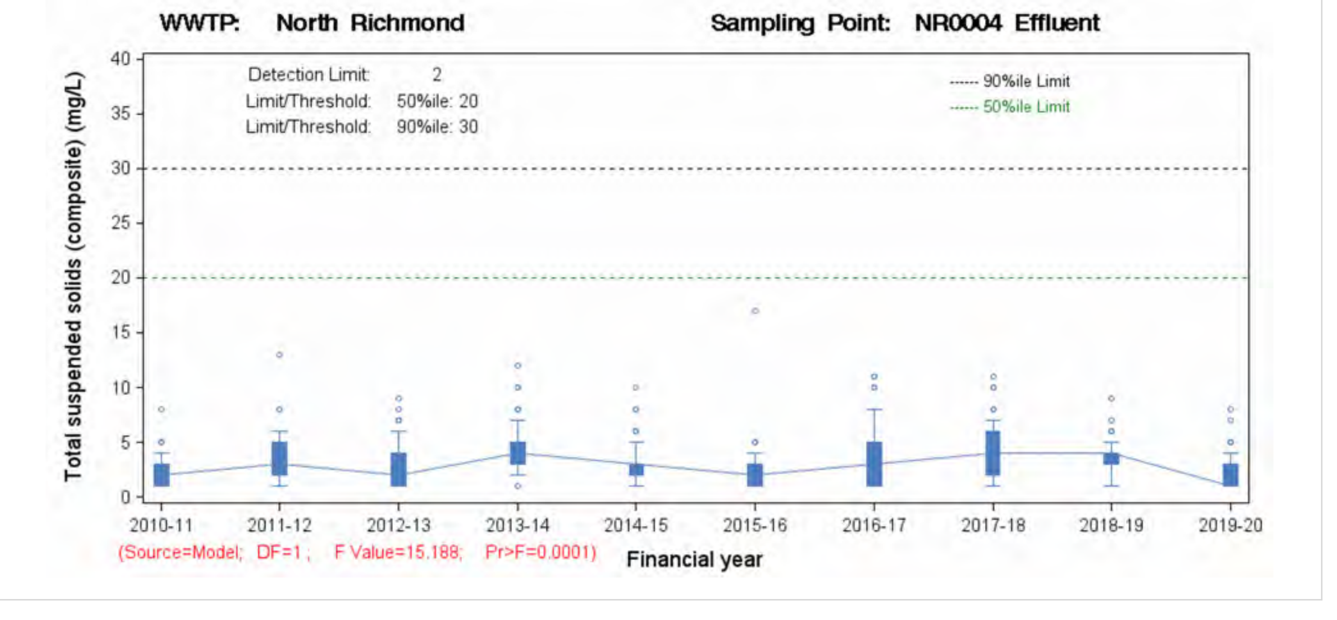

WWTP: North Richmond
Sampling Point: NR0004 Effluent
Detection Limit: 0.01
Limit/Threshold: 50%ile: 2
Limit/Threshold: 90%ile: 5
Ammonia nitrogen (composite) (mg/L)
Financial year
(Source=Model; DF=1 ; F Value=44.002; Pr>F=<.0001)

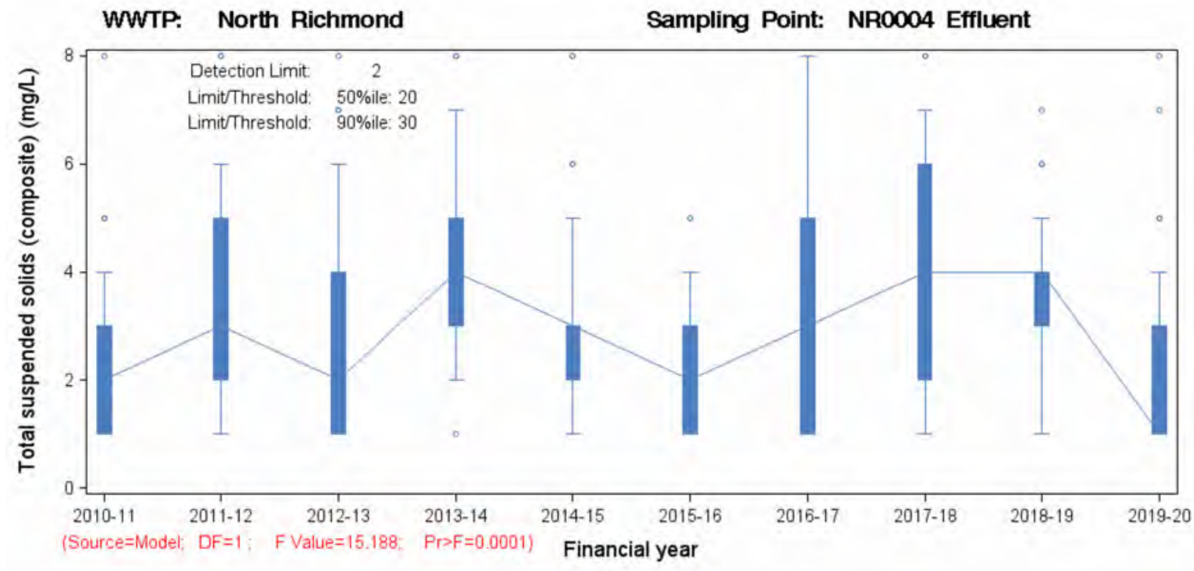

WWTP: North Richmond
Sampling Point: NR0004 Effluent
Detection Limit: 0.05
Limit/Threshold: 50%ile: 10
Limit/Threshold: 90%ile: 15
------ 90%ile Limit
------ 50%ile Limit
Total nitrogen (composite) (mg/L)
Financial year
(Source=Model; DF=1 ; F Value=11.617; Pr>F=0.0007)


WWTP: North Richmond
Sampling Point: NR0004 Effluent
Detection Limit: 0.05
Limit/Threshold: 50%ile: 10
Limit/Threshold: 90%ile: 15
Total nitrogen (composite) (mg/L)
Financial year
(Source=Model; DF=1 ; F Value=11.617; Pr>F=0.0007)

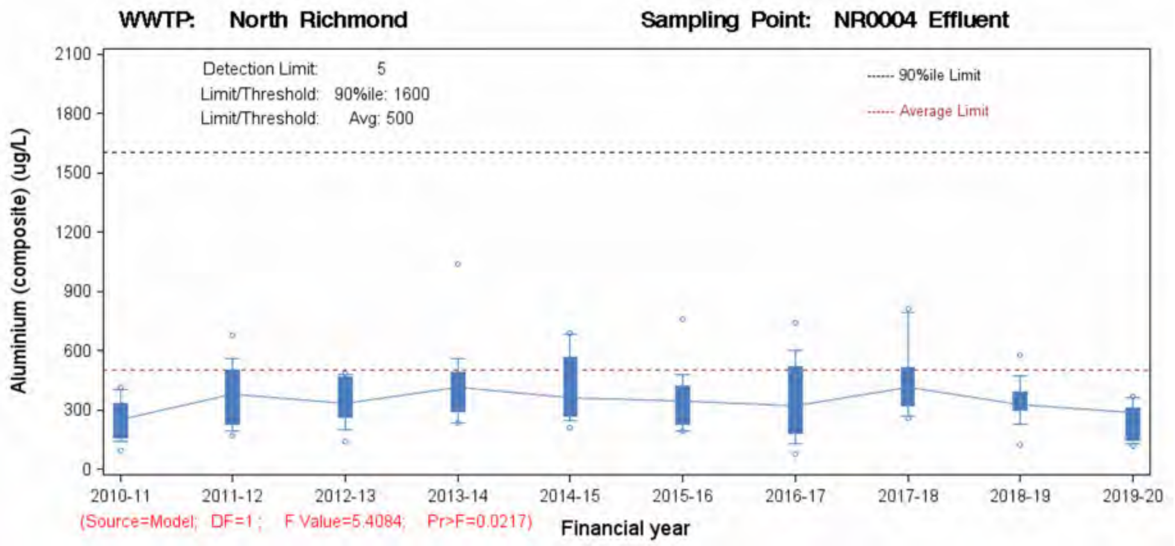

WWTP: North Richmond
Sampling Point: NR0004 Effluent
Detection Limit: 0.01
Limit/Threshold: 50%ile: 2
Limit/Threshold: 90%ile: 5
------ 90%ile Limit
------ 50%ile Limit
Total phosphorus (composite) (mg/L)
10
8
6
4
2
0
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=205.70; Pr>F=<.0001)
Financial year


WWTP: North Richmond
Sampling Point: NR0004 Effluent
Detection Limit: 0.01
Limit/Threshold: 50%ile: 2
Limit/Threshold: 90%ile: 5
Total phosphorus (composite) (mg/L)
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=205.70; Pr>F=<.0001)
Financial year

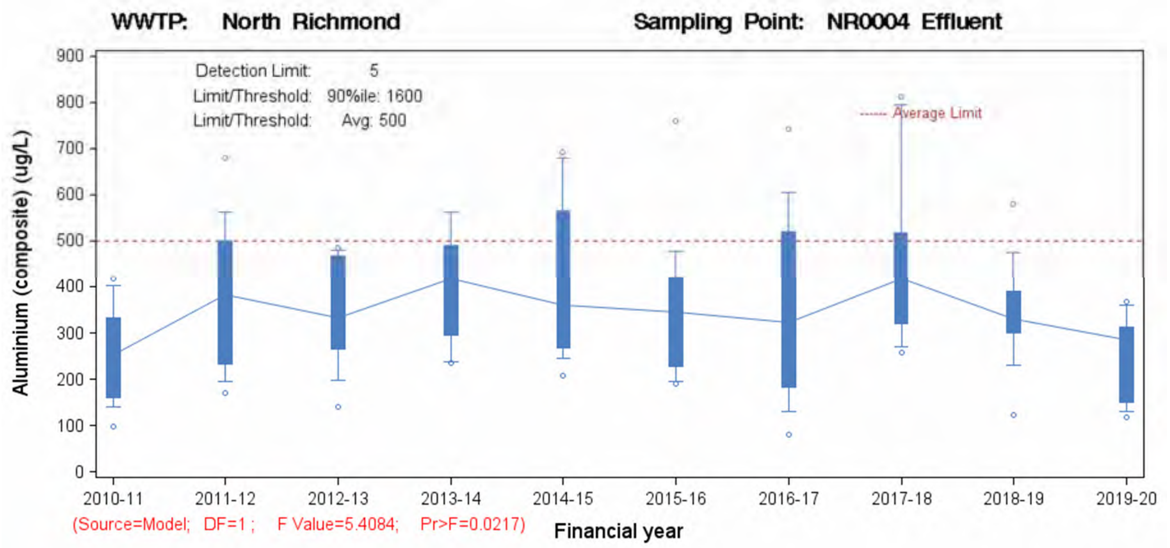

WWTP: North Richmond
Sampling Point: NR0004 Effluent
Detection Limit: 2
Limit/Threshold: 50%ile: 20
Limit/Threshold: 90%ile: 30
------ 90%ile Limit
------ 50%ile Limit
Total suspended solids (composite) (mg/L)
40
35
30
25
20
15
10
5
0
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=15.188; Pr>F=0.0001)
Financial year



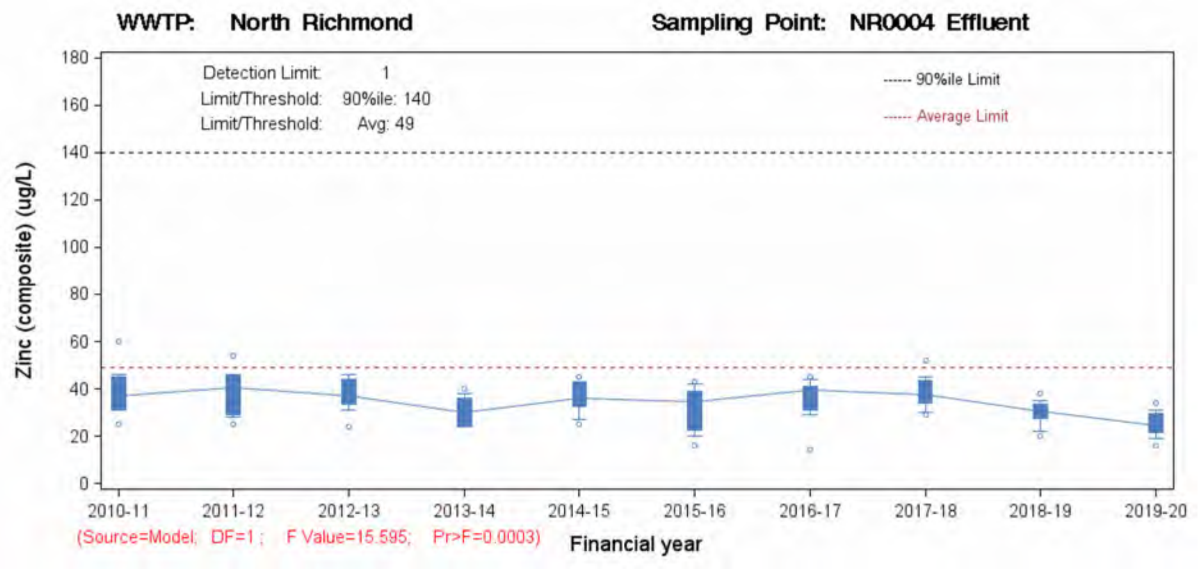
WWTP: North Richmond
Sampling Point: NR0004 Effluent
Detection Limit: 2
Limit/Threshold: 50%ile: 20
Limit/Threshold: 90%ile: 30
Total suspended solids (composite) (mg/L)
0
2
4
6
8
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=15.188; Pr>F=0.0001)
Financial year



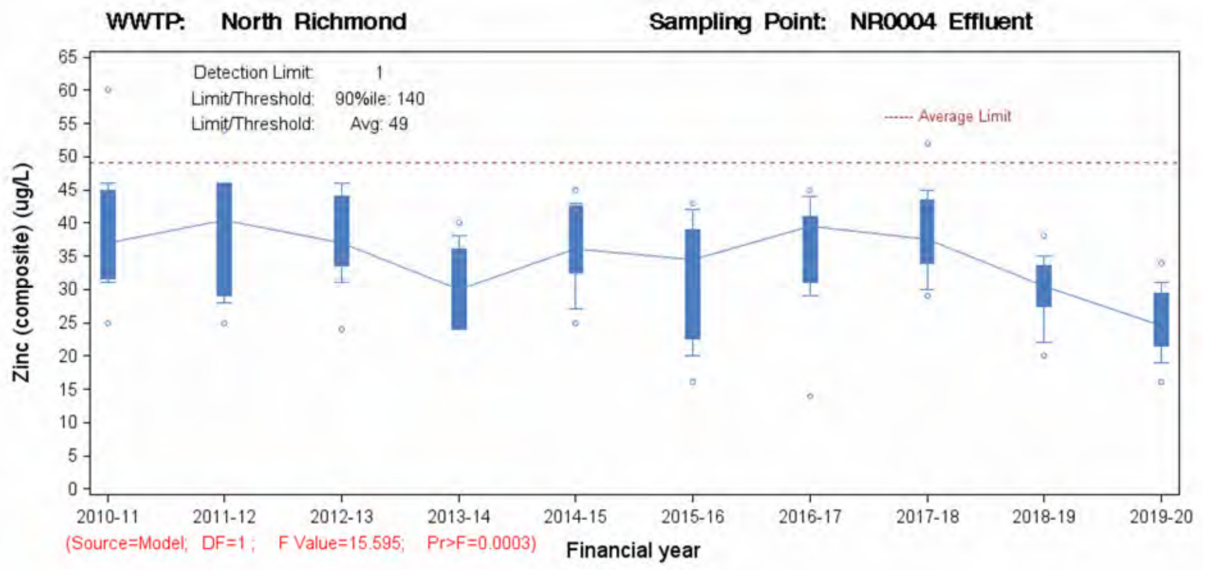
WWTP: North Richmond
Sampling Point: NR0004 Effluent
Detection Limit: 5
Limit/Threshold: 90%ile: 1600
Limit/Threshold: Avg: 500
------ 90%ile Limit
------ Average Limit
Aluminium (composite) (ug/L)
0
300
600
900
1200
1500
1800
2100
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=5.4084; Pr>F=0.0217)
Financial year



WWTP: North Richmond
Sampling Point: NR0004 Effluent
Detection Limit: 5
Limit/Threshold: 90%ile: 1600
Limit/Threshold: Avg: 500
------ Average Limit
Aluminium (composite) (ug/L)
0
100
200
300
400
500
600
700
800
900
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=5.4084; Pr>F=0.0217)
Financial year



Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.



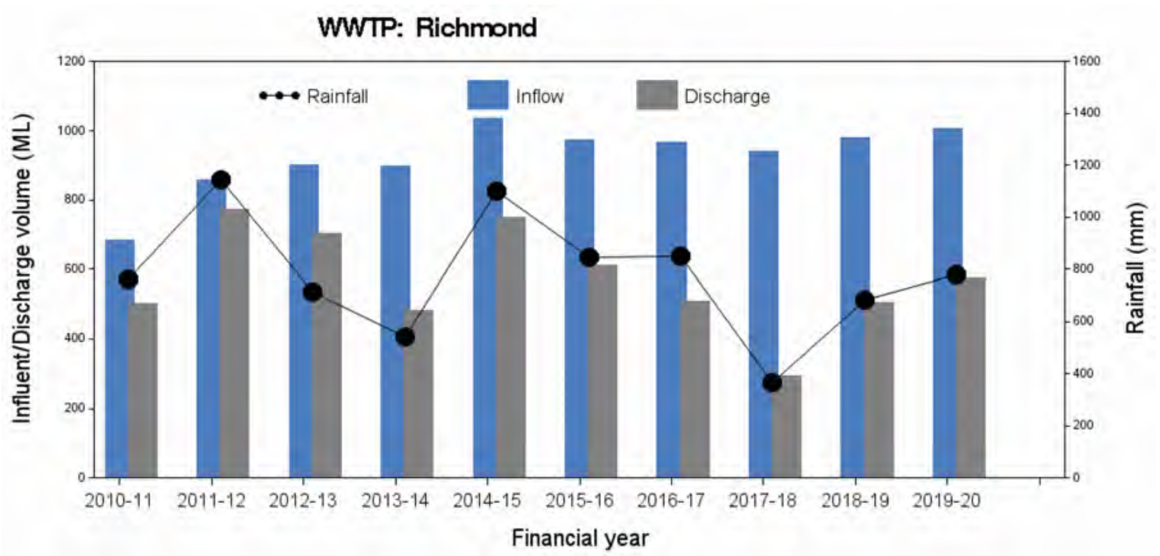
Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.

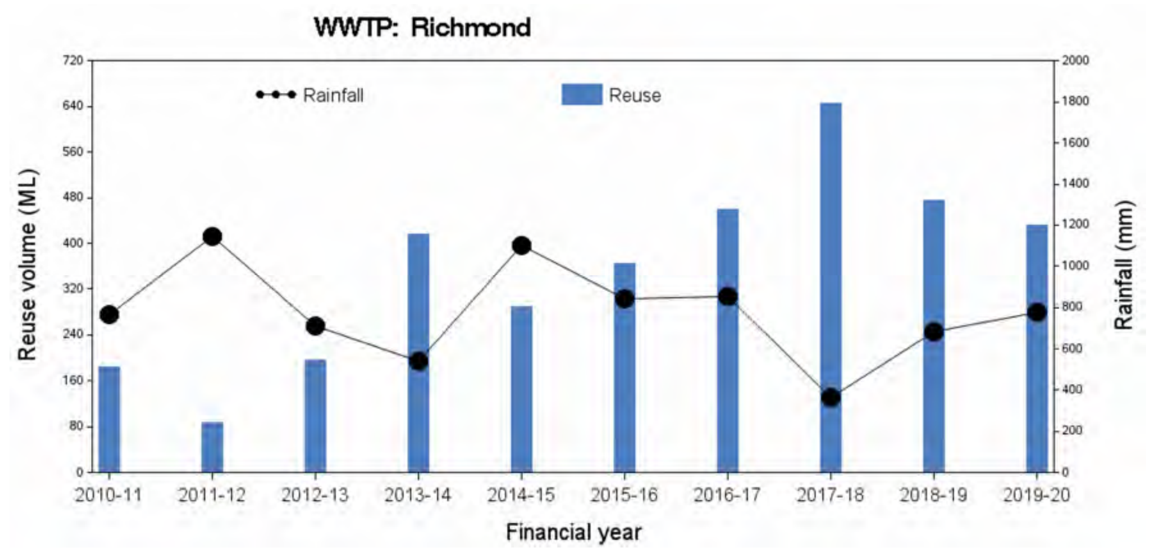
4.2.7 Richmond WWTP

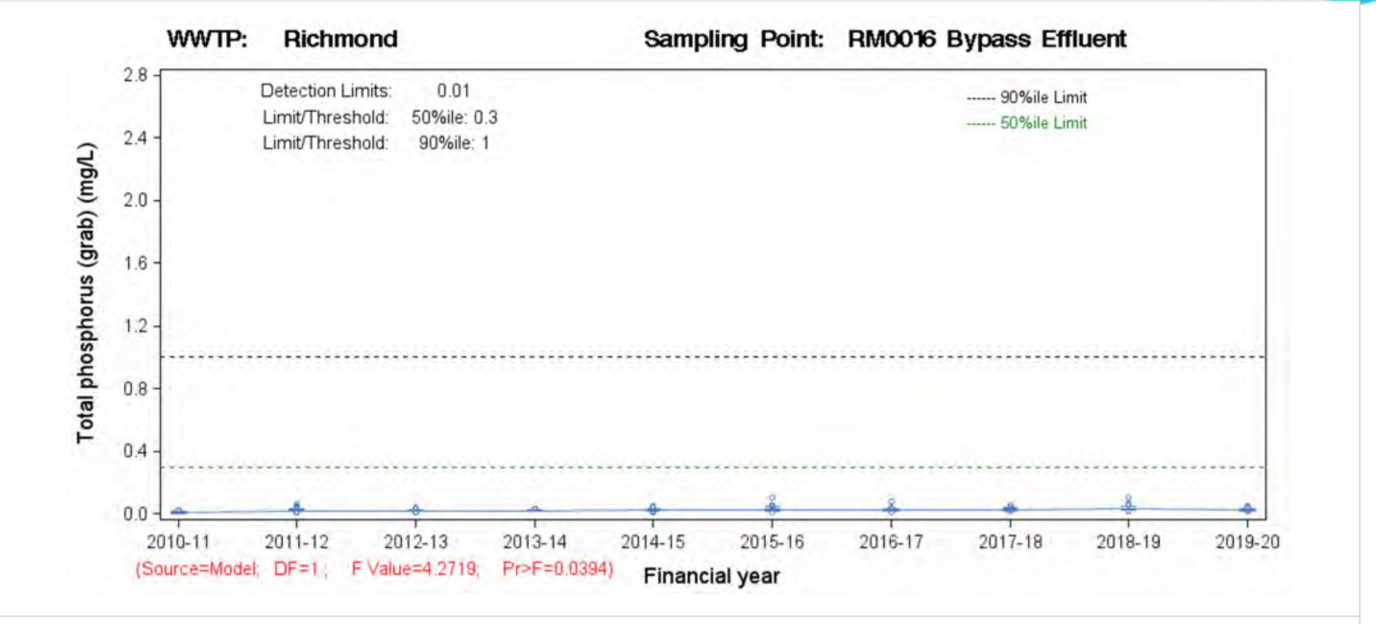
The 80th percentile concentration limit for faecal coliform at RM0016 (outlet of the dechlorination tank) was exceeded in the discharge from the Richmond WWTP during the 2019-20 period. All other concentration and load limits in the discharge from Richmond WWTP were within the EPL limits during this period. Statistical analysis identified a significantly increasing trend in faecal coliform and total phosphorus concentrations in the discharges from Richmond WWTP (RM0016) to Rickaby's Creek.

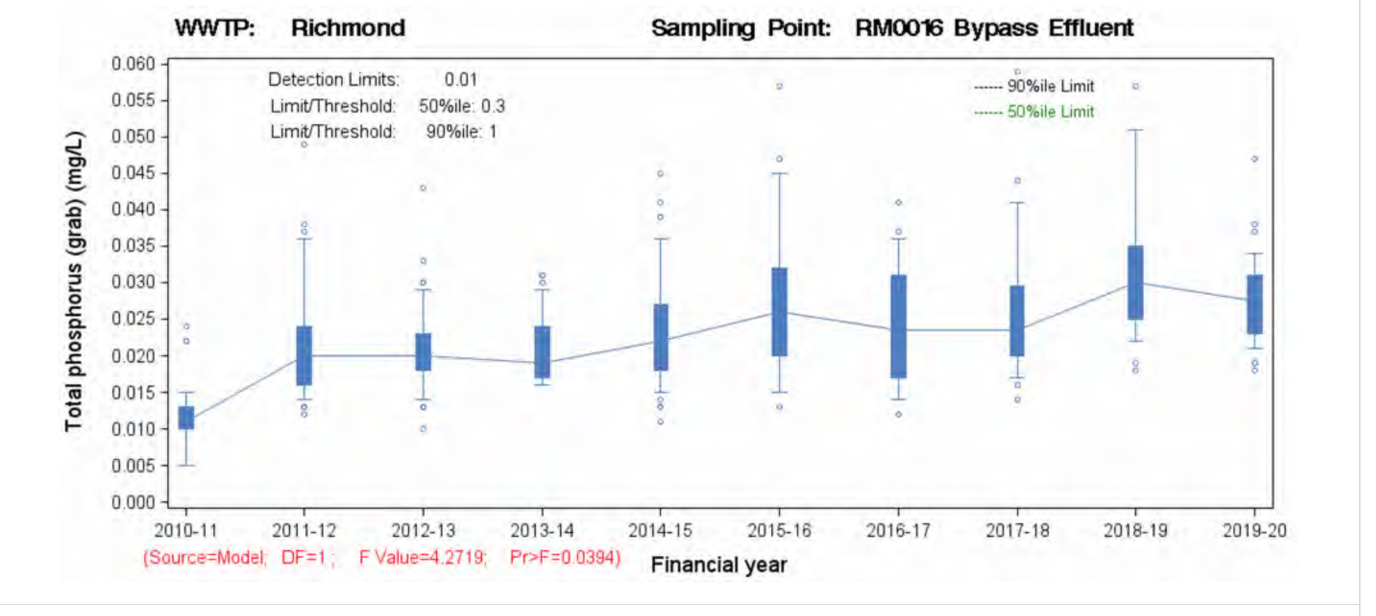
Statistical analysis identified a significantly increasing trend in total phosphorus and significantly decreasing trends in total suspended solid and total residual chlorine concentrations from the Richmond WWTP storage tank for offsite irrigation (RM0017).

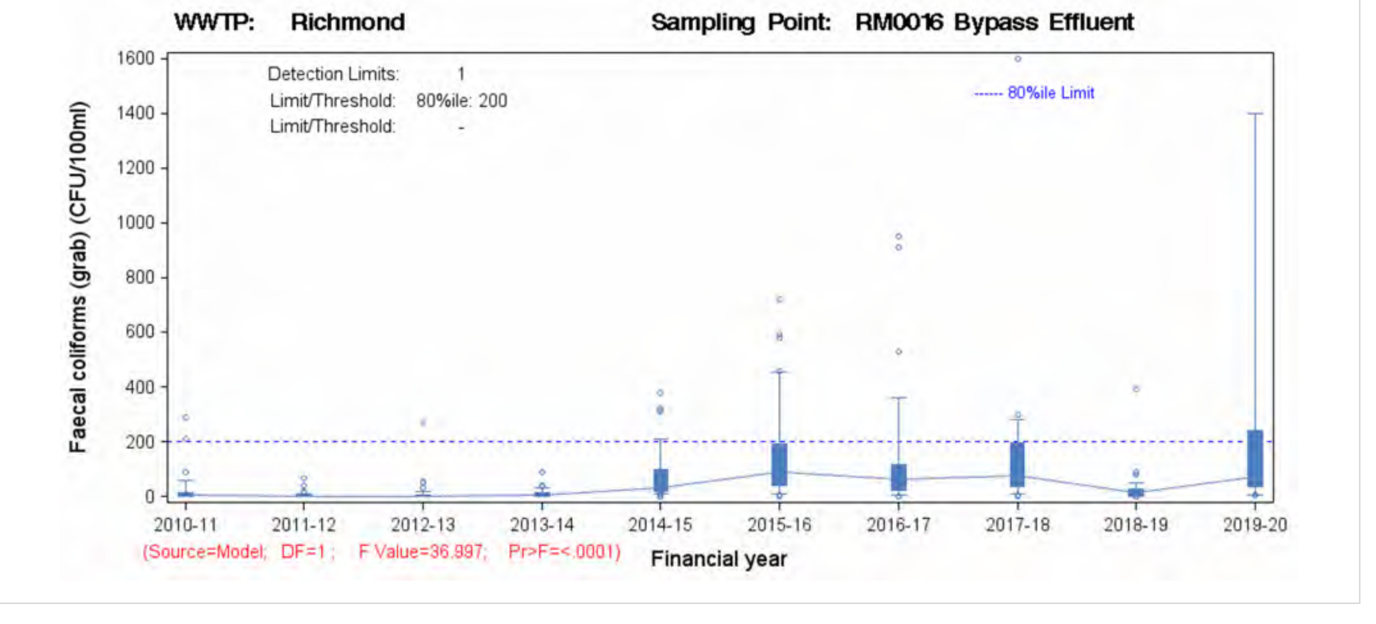
A decrease in recycled water demand over the past few years has resulted in stored effluent remaining in the holding tank for extended periods of time. Birds and ducks regularly roost above the tank which may contribute to the elevated faecal coliform counts recorded at the discharge point RM0016. Overall, the total phosphorus concentration levels are low and well within the licence limits.

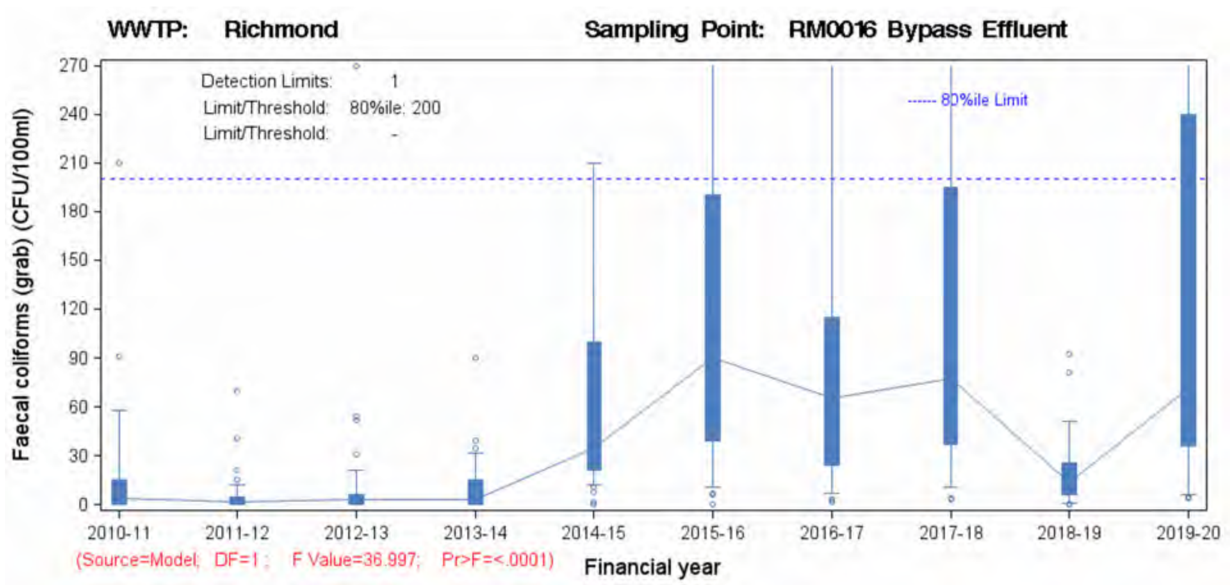


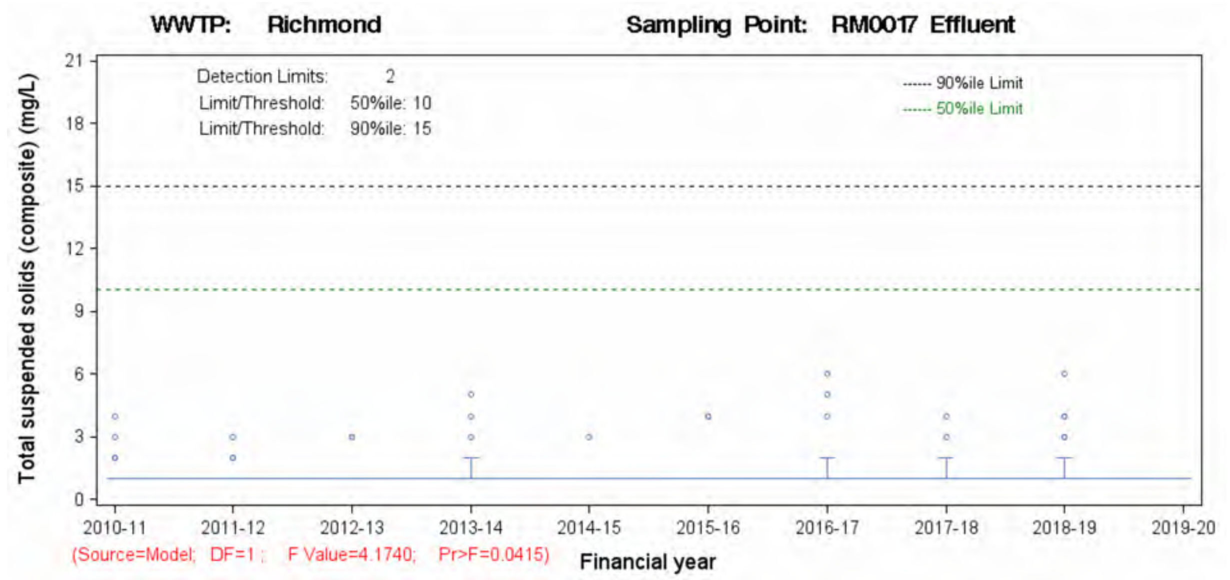


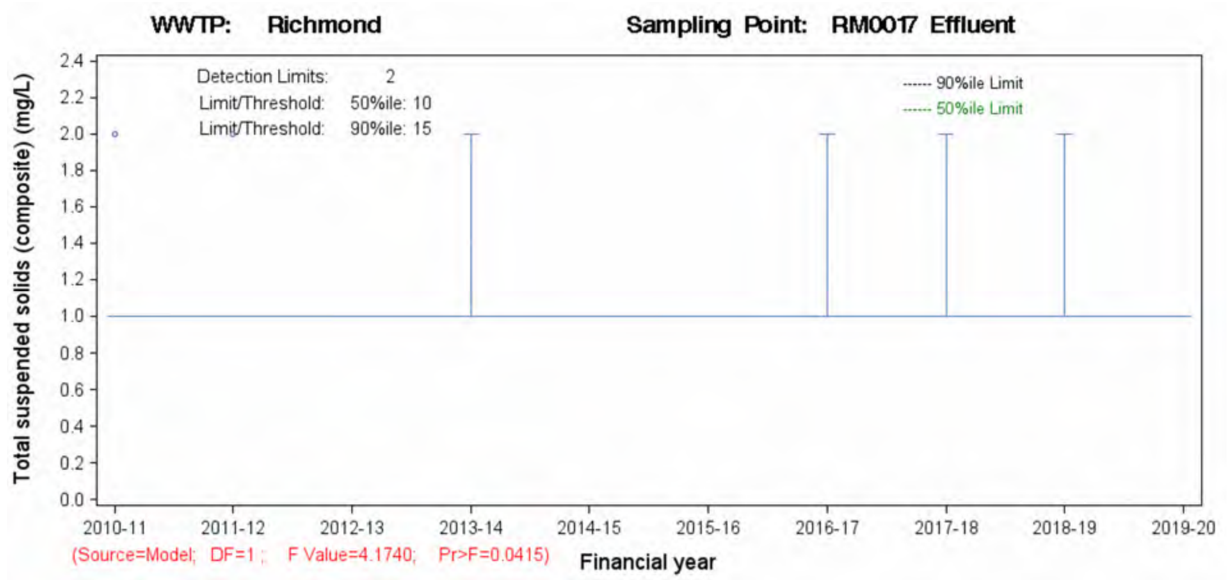

WWTP: Richmond
Sampling Point: RM0016 Bypass Effluent
Detection Limits: 0.01
Limit/Threshold: 50%ile: 0.3
Limit/Threshold: 90%ile: 1
------ 90%ile Limit
------ 50%ile Limit
Total phosphorus (grab) (mg/L)
Financial year
(Source=Model; DF=1 ; F Value=4.2719; Pr>F=0.0394)

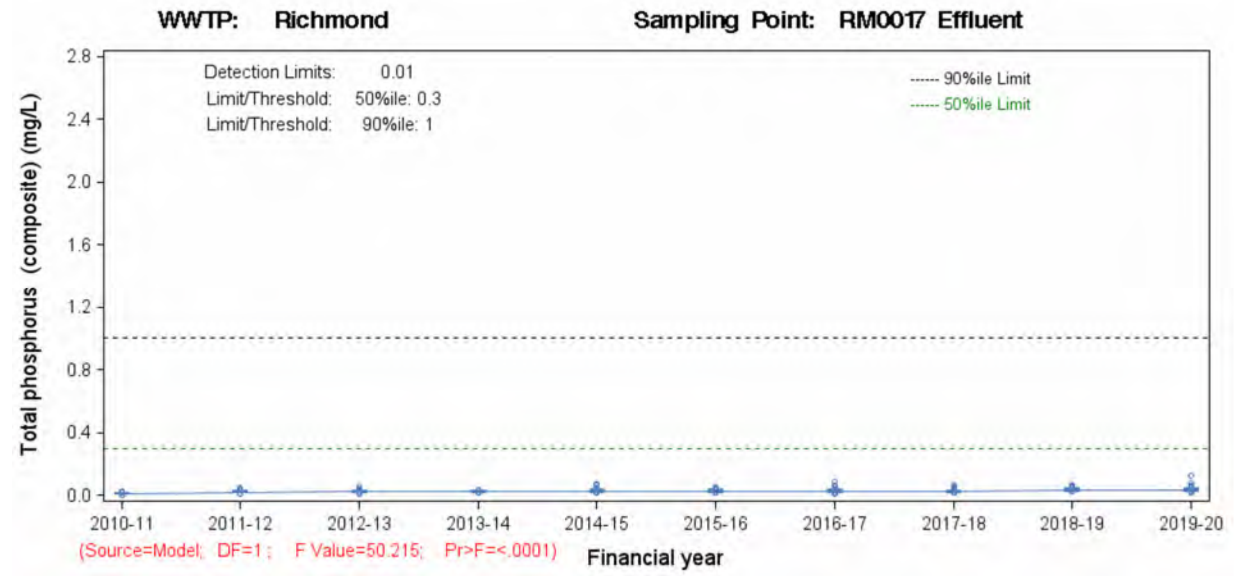

WWTP: Richmond
Sampling Point: RM0016 Bypass Effluent
Detection Limits: 0.01
Limit/Threshold: 50%ile: 0.3
Limit/Threshold: 90%ile: 1
------ 90%ile Limit
------ 50%ile Limit
Total phosphorus (grab) (mg/L)
Financial year
(Source=Model; DF=1 ; F Value=4.2719; Pr>F=0.0394)


WWTP: Richmond
Sampling Point: RM0016 Bypass Effluent
Detection Limits: 1
Limit/Threshold: 80%ile: 200
Limit/Threshold: -
------ 80%ile Limit
Faecal coliforms (grab) (CFU/100ml)
Financial year
(Source=Model; DF=1 ; F Value=36.897; Pr>F=<.0001)

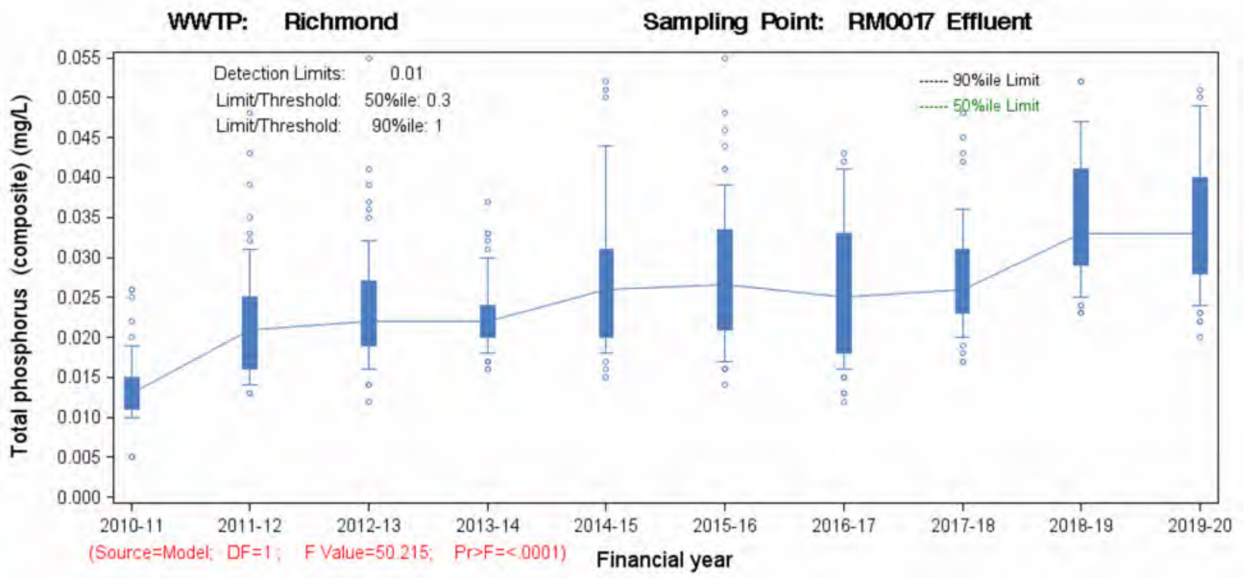

WWTP: Richmond
Sampling Point: RM0016 Bypass Effluent
Detection Limits: 1
Limit/Threshold: 80%ile: 200
Limit/Threshold: -
------ 80%ile Limit
Faecal coliforms (grab) (CFU/100ml)
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=36.997; Pr>F=<.0001)
Financial year


WWTP: Richmond
Sampling Point: RM0017 Effluent
Detection Limits: 2
Limit/Threshold: 50%ile: 10
Limit/Threshold: 90%ile: 15
------ 90%ile Limit
------ 50%ile Limit
Total suspended solids (composite) (mg/L)
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=4.1740; Pr>F=0.0415)
Financial year

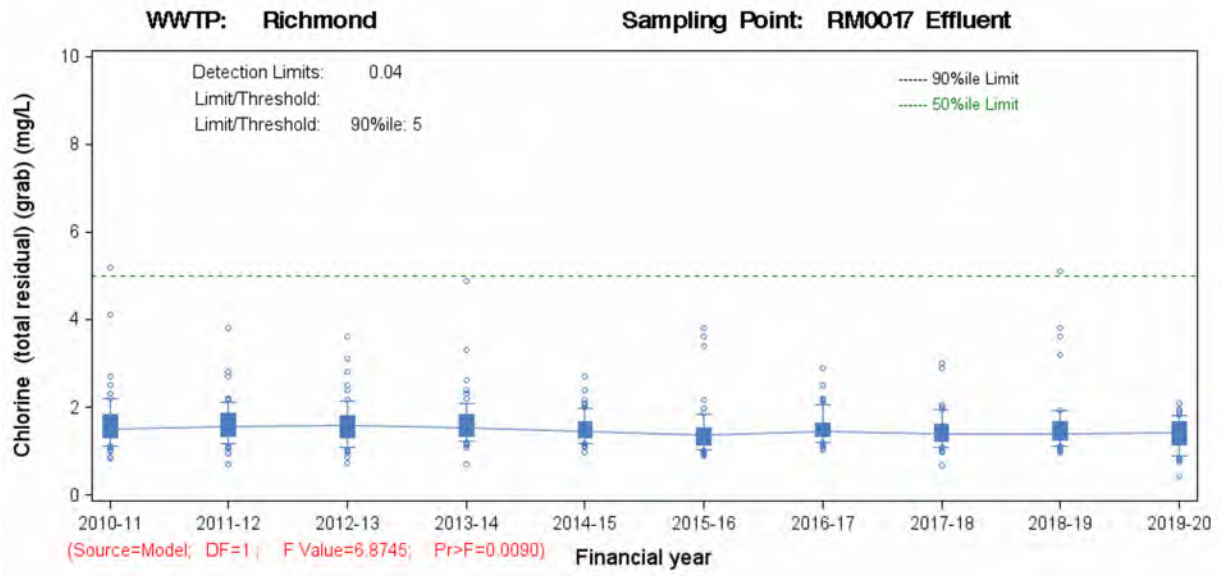

WWTP: Richmond
Sampling Point: RM0017 Effluent
Detection Limits: 2
Limit/Threshold: 50%ile: 10
Limit/Threshold: 90%ile: 15
------ 90%ile Limit
------ 50%ile Limit
Total suspended solids (composite) (mg/L)
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=4.1740; Pr>F=0.0415)
Financial year



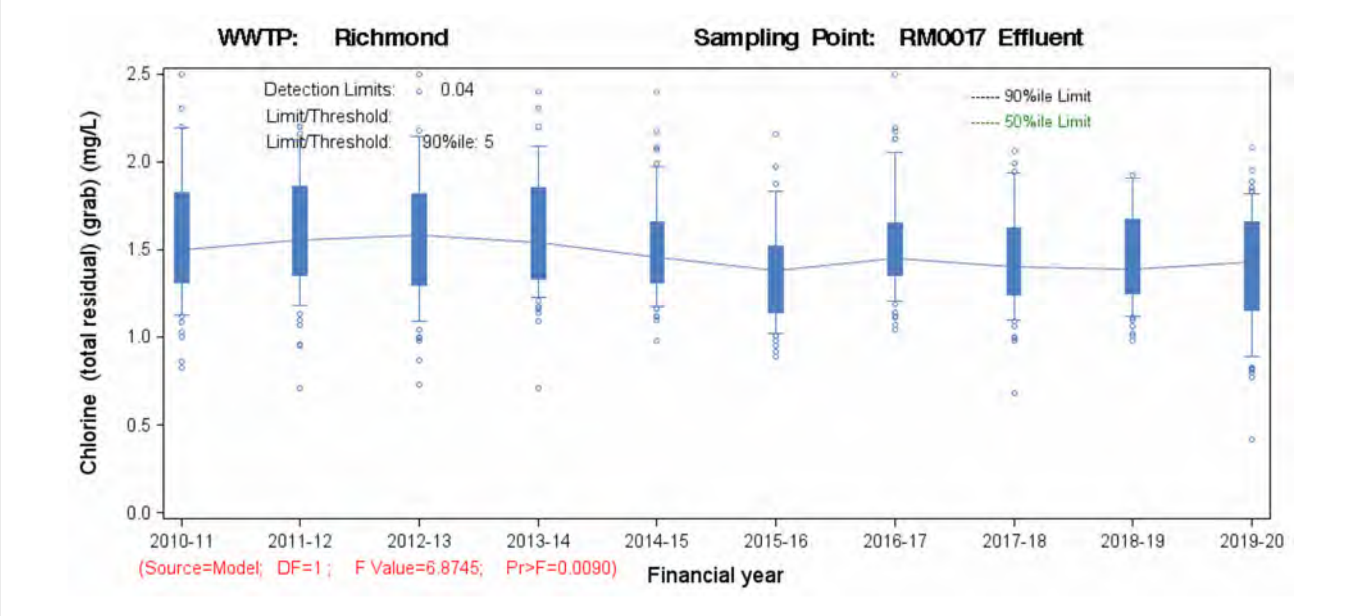
WWTP: Richmond
Sampling Point: RM0017 Effluent
Detection Limits: 0.01
Limit/Threshold: 50%ile: 0.3
Limit/Threshold: 90%ile: 1
------ 90%ile Limit
------ 50%ile Limit
Total phosphorus (composite) (mg/L)
Financial year
(Source=Model; DF=1 ; F Value=50.215; Pr>F=<.0001)



WWTP: Richmond
Sampling Point: RM0017 Effluent
Detection Limits: 0.01
Limit/Threshold: 50%ile: 0.3
Limit/Threshold: 90%ile: 1
------ 90%ile Limit
------ 50%ile Limit
Total phosphorus (composite) (mg/L)
Financial year
(Source=Model; DF=1 ; F Value=50.215; Pr>F=<.0001)



WWTP: Richmond
Sampling Point: RM0017 Effluent
Detection Limits: 0.04
Limit/Threshold:
Limit/Threshold: 90%ile: 5
------ 90%ile Limit
------ 50%ile Limit
Chlorine (total residual) (grab) (mg/L)
Financial year
(Source=Model; DF=1 ; F Value=6.8745; Pr>F=0.0090)

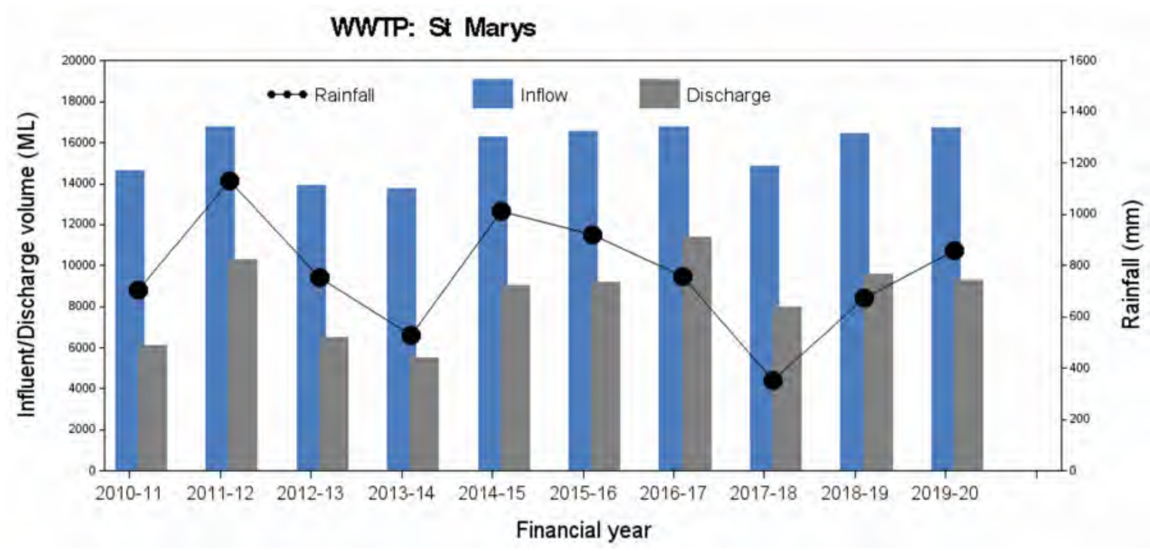

WWTP: Richmond
Sampling Point: RM0017 Effluent
Detection Limits: 0.04
Limit/Threshold:
Limit/Threshold: 90%ile: 5
------ 90%ile Limit
------ 50%ile Limit
Chlorine (total residual) (grab) (mg/L)
2.5
2.0
1.5
1.0
0.5
0.0
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=6.8745; Pr>F=0.0090)
Financial year

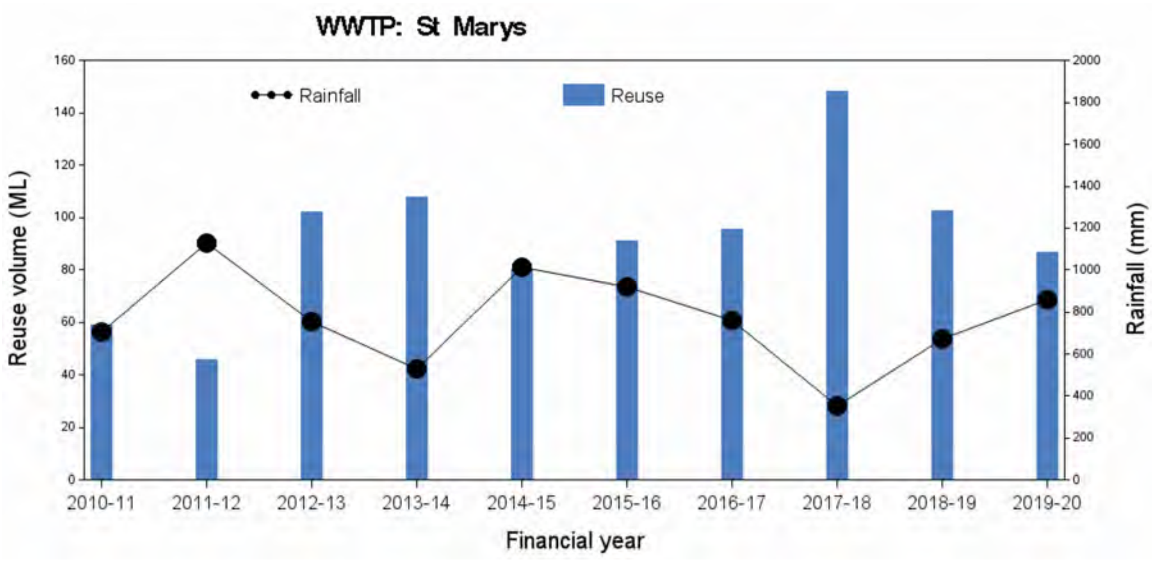
4.2.8 St Marys WWTP

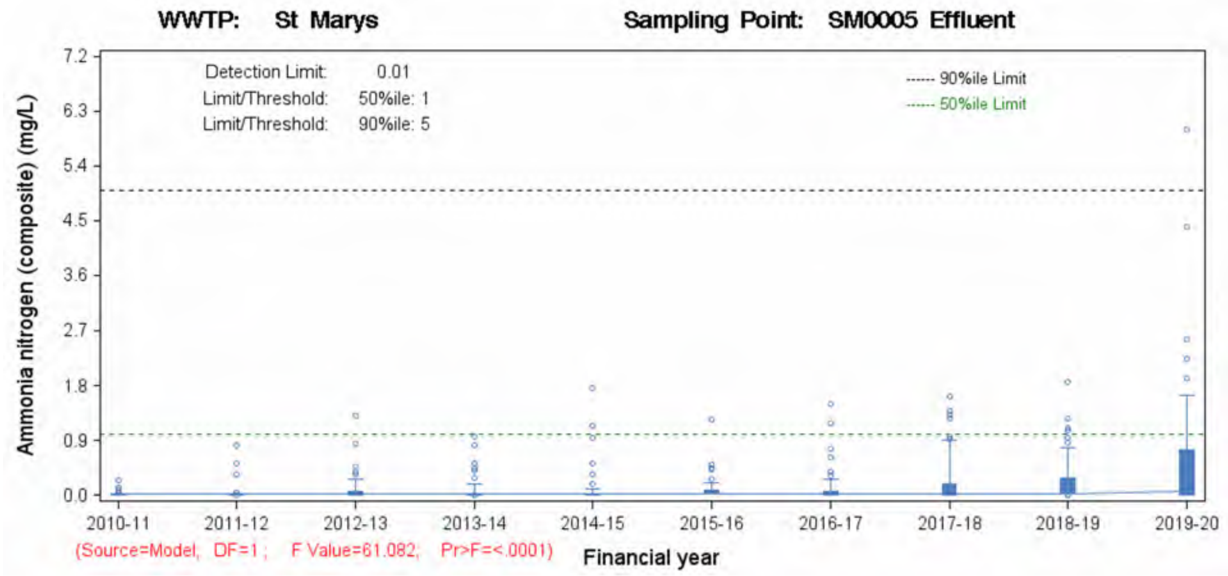
All concentration and load limits in the discharge from St Marys WWTP were within the EPL limits during the 2019-20 period. The annual total phosphorus aggregate load discharged from the South Creek plants (Quakers Hill, Riverstone and St Marys WWTPs) was exceeded during the 2019-20 monitoring period. The cause of this exceedance was related to the significant rain event in early February 2020, which had a considerable impact on increased flows and loads from the plants. All process and chemical dosing units were operating according to the unit process guidelines at the time of the rain event for all three plants.

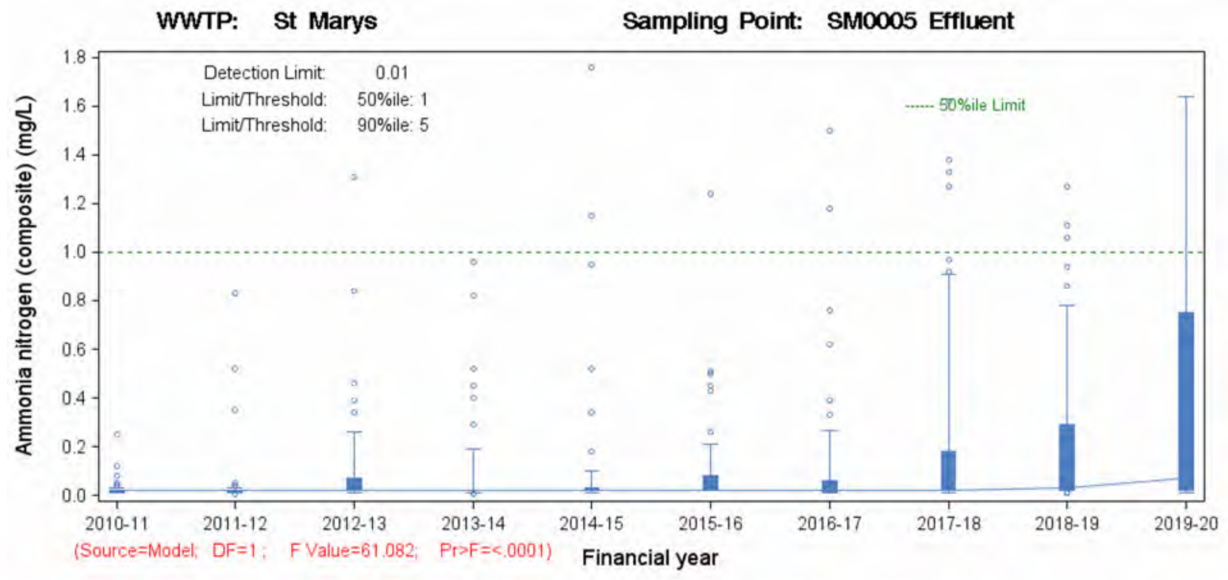
Statistical analysis identified a significant increasing trend in ammonia nitrogen and total nitrogen concentrations in St Marys WWTP discharges in 2019-20 in comparison to earlier nine years. Generally, the pollutant loads were steady and followed a pattern similar to the rainfall and flow to the plant and were well below the load limits.

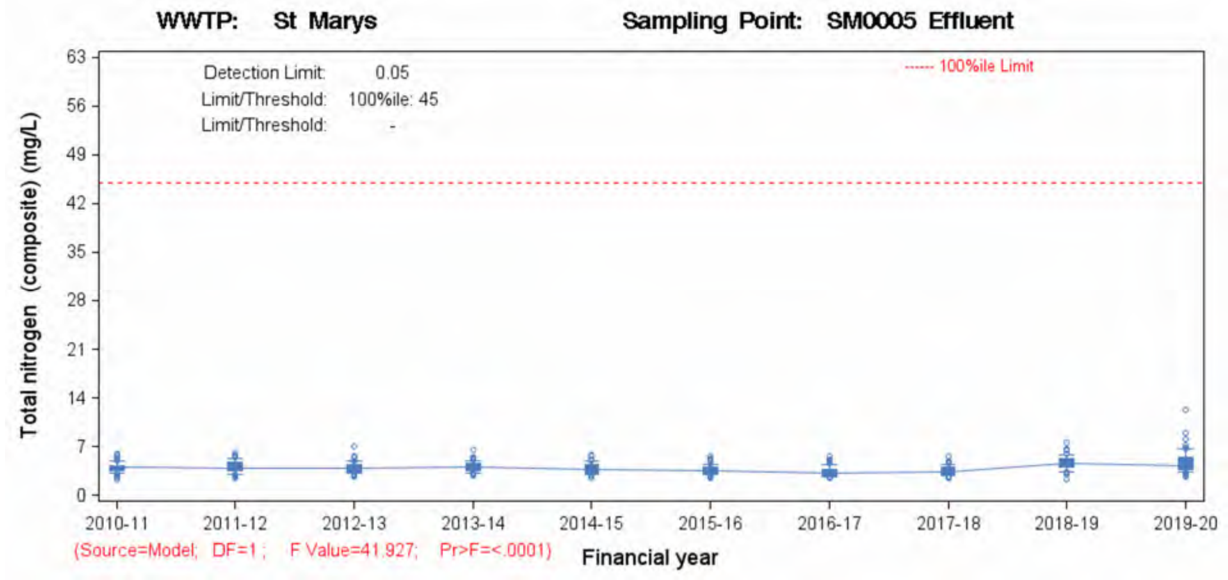
St Marys WWTP is part of a $550 million Lower South Creek Treatment Program, that will provide new and upgraded wastewater infrastructure to support an additional 500,000 people in Sydney's north west by 2040.

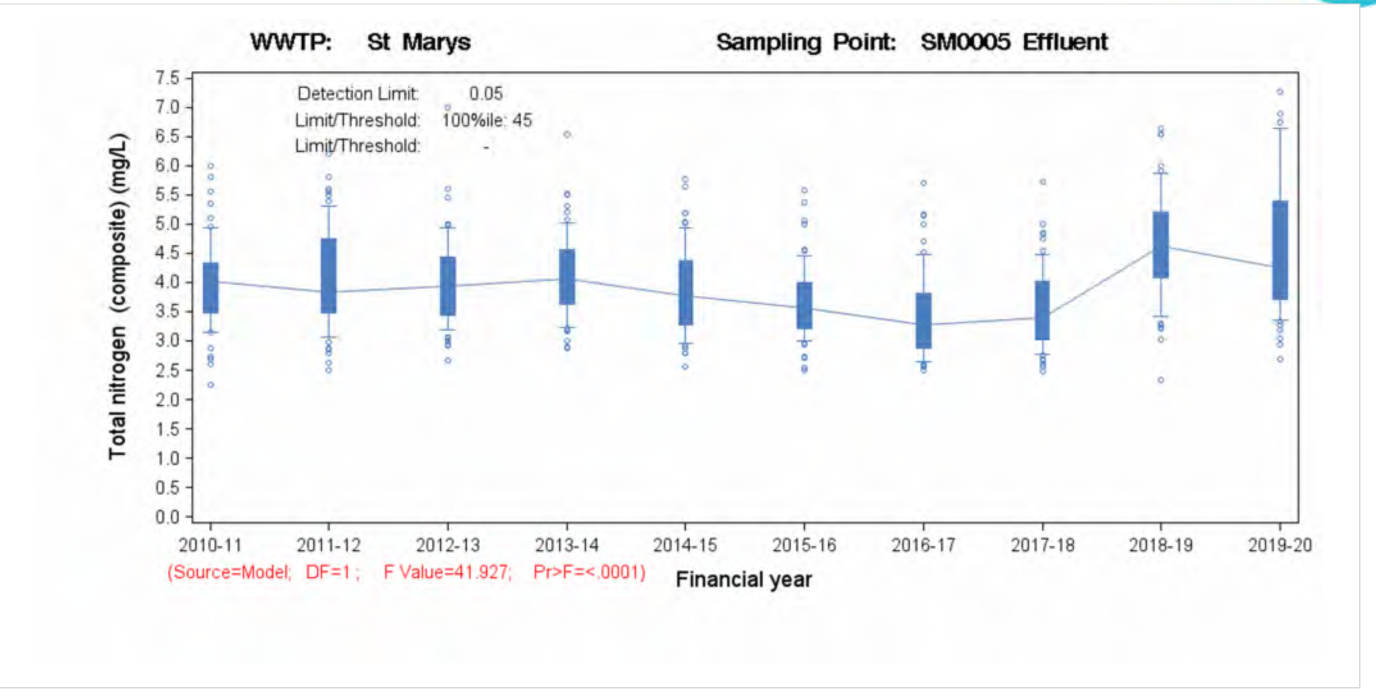





WWTP: St Marys
Sampling Point: SM0005 Effluent
Detection Limit: 0.01
Limit/Threshold: 50%ile: 1
Limit/Threshold: 90%ile: 5
------ 90%ile Limit
------ 50%ile Limit
Ammonia nitrogen (composite) (mg/L)
7.2
6.3
5.4
4.5
3.6
2.7
1.8
0.9
0.0
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=61.082; Pr>F=<.0001)
Financial year


WWTP: St Marys
Sampling Point: SM0005 Effluent
Detection Limit: 0.01
Limit/Threshold: 50%ile: 1
Limit/Threshold: 90%ile: 5
------ 50%ile Limit
Ammonia nitrogen (composite) (mg/L)
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=61.082; Pr>F=<.0001)
Financial year


WWTP: St Marys
Sampling Point: SM0005 Effluent
Detection Limit: 0.05
Limit/Threshold: 100%ile: 45
Limit/Threshold: -
------ 100%ile Limit
Total nitrogen (composite) (mg/L)
63
56
49
42
35
28
21
14
7
0
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=41.927; Pr>F=<.0001)
Financial year



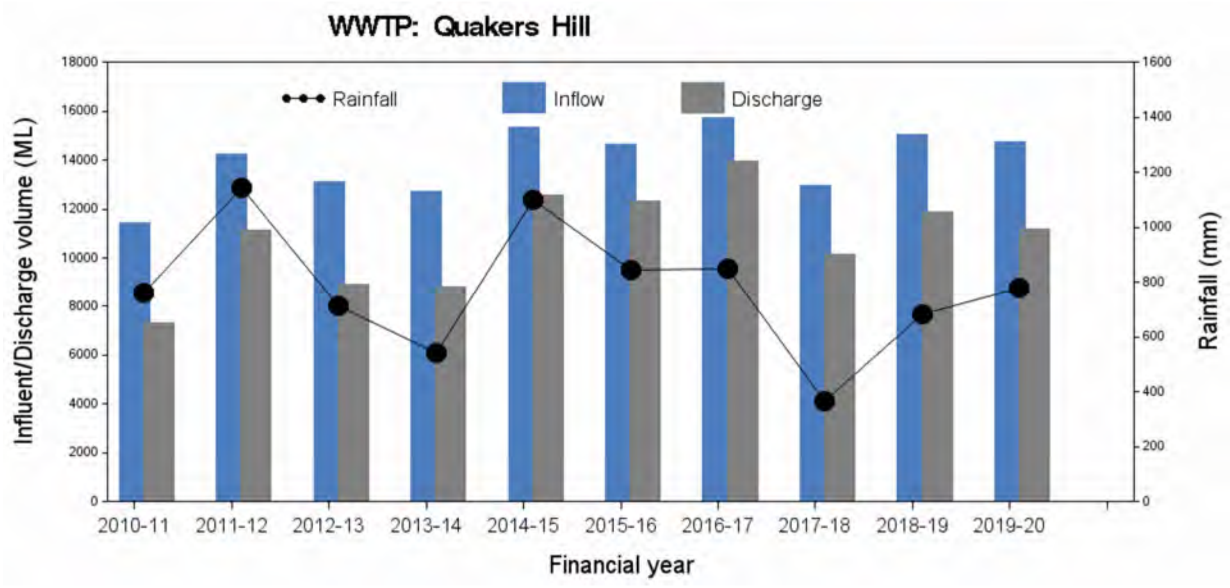
WWTP: St Marys
Sampling Point: SM0005 Effluent
Detection Limit: 0.05
Limit/Threshold: 100%ile: 45
Limit/Threshold: -
Total nitrogen (composite) (mg/L)
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=41.927; Pr>F=<.0001)
Financial year

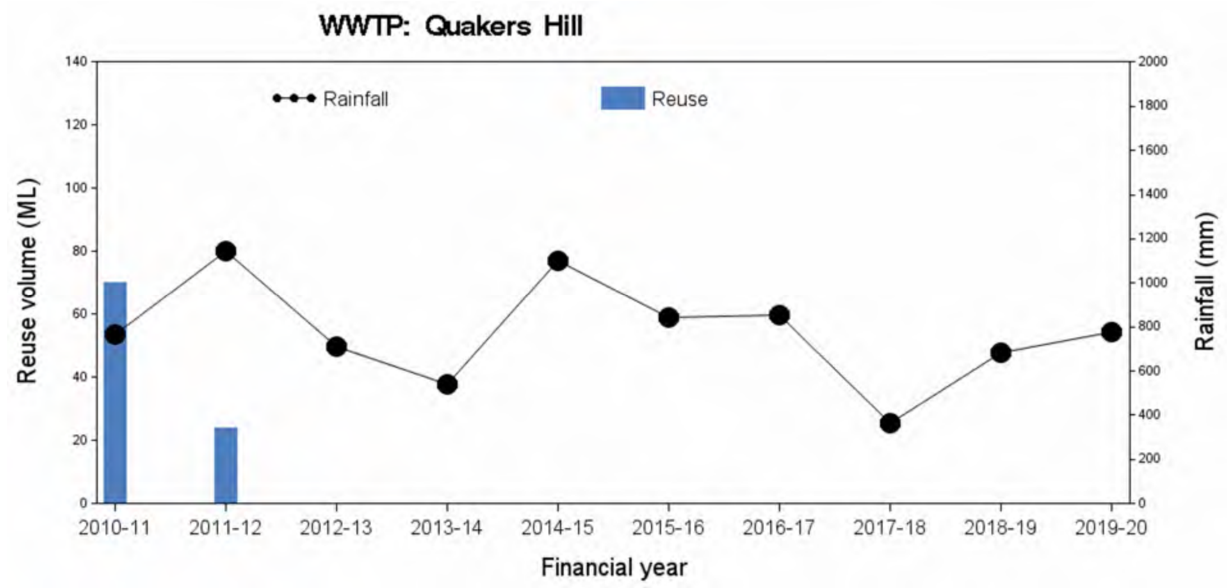
4.2.9 Quakers Hill WWTP

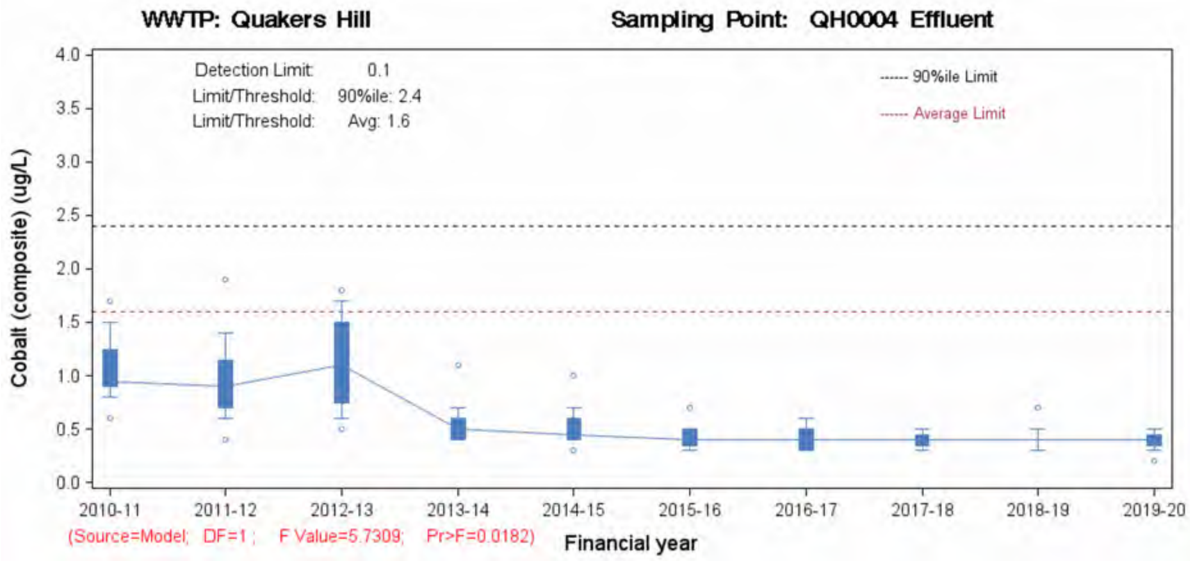
All concentration and load limits in the discharge from Quakers Hill WWTP were within the EPL limits during the 2019-20 period. The annual total phosphorus aggregate load discharged from the South Creek plants (Quakers Hill, Riverstone and St Marys WWTPs) was exceeded during the 2019-20 monitoring period. The cause of this exceedance was related to the significant rain event in early February 2020, which had a considerable impact on increased flows and loads recorded by the plants. All process and chemical dosing units were operating according to the unit process guidelines at the time of the rain event for all three plants.

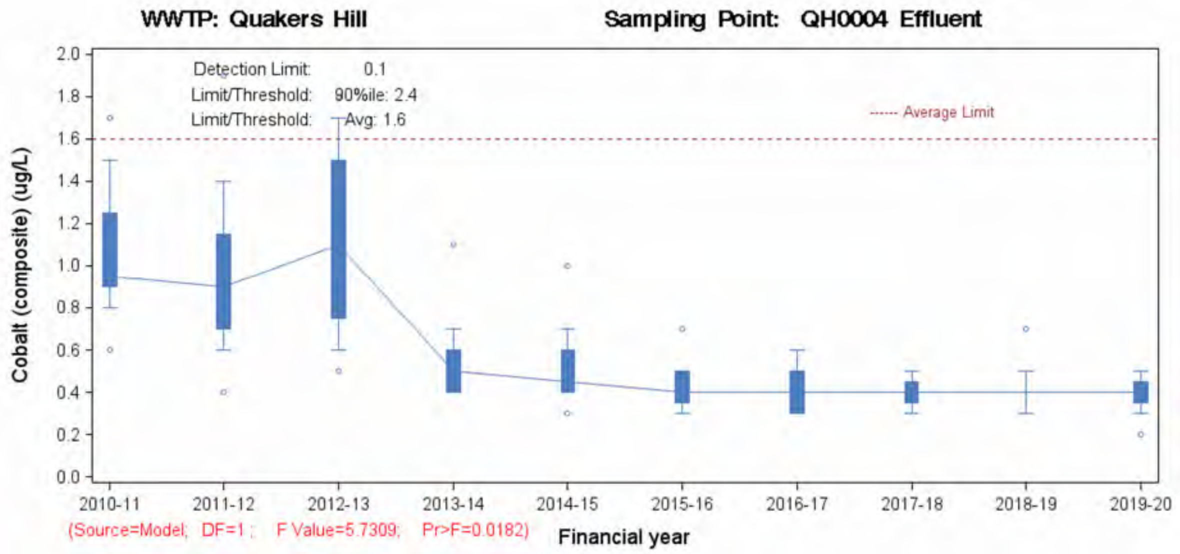
Quakers Hill WWTP is part of a $550 million Lower South Creek Treatment Program, that will provide new and upgraded wastewater infrastructure to support an additional 500,000 people in Sydney's north west by 2040

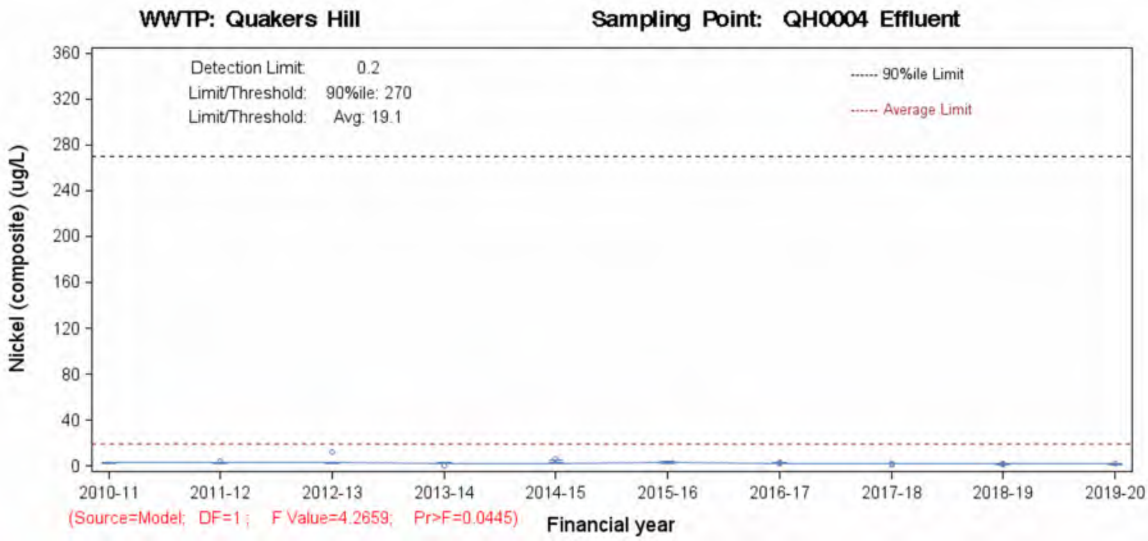
Statistical analysis identified significant decreasing trends in cobalt and nickel concentrations in Quakers Hill WWTP discharges in 2019-20 in comparison to earlier nine years.



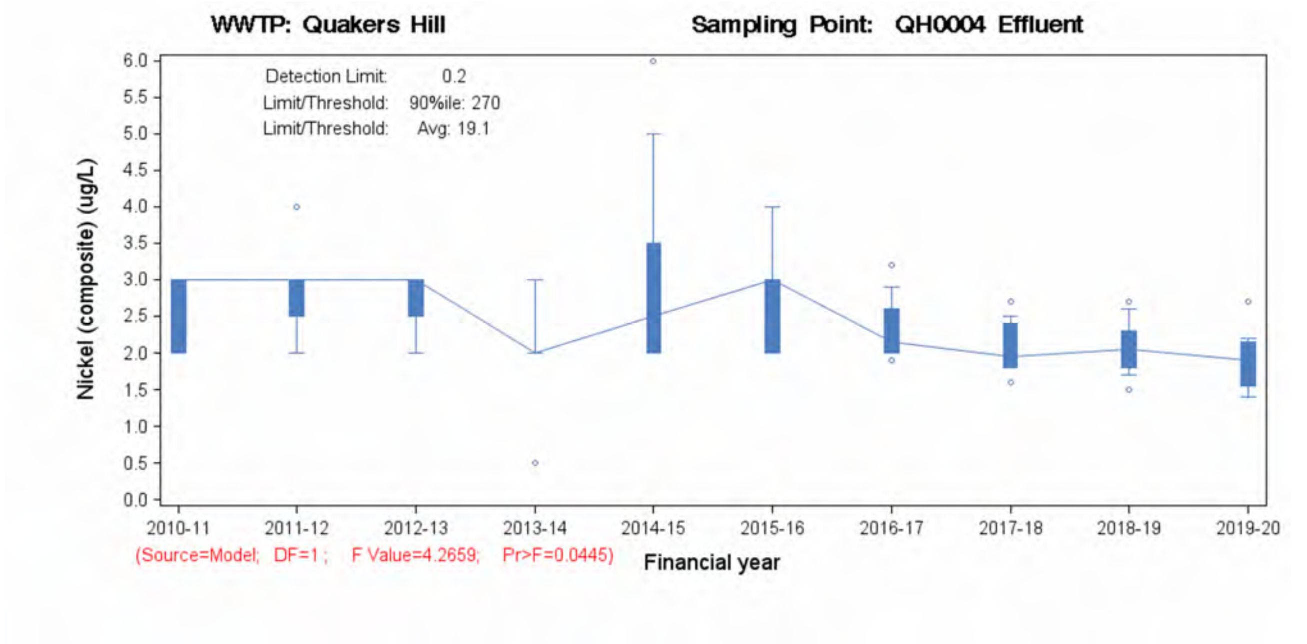








Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.



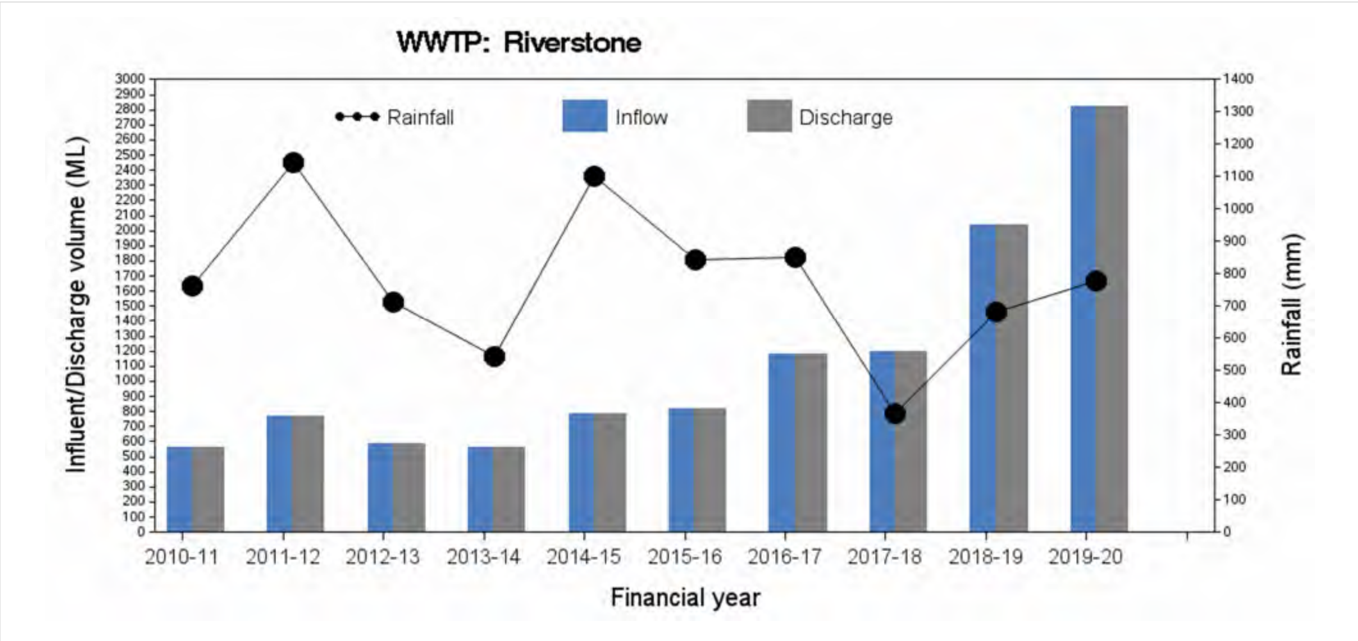
Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.

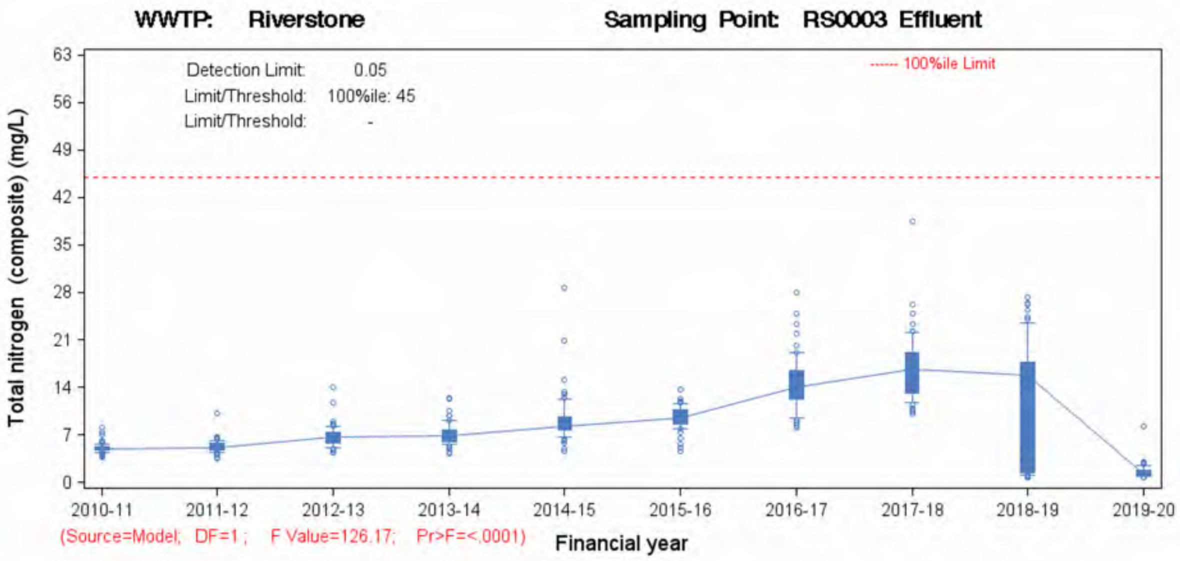
4.2.10 Riverstone WWTP

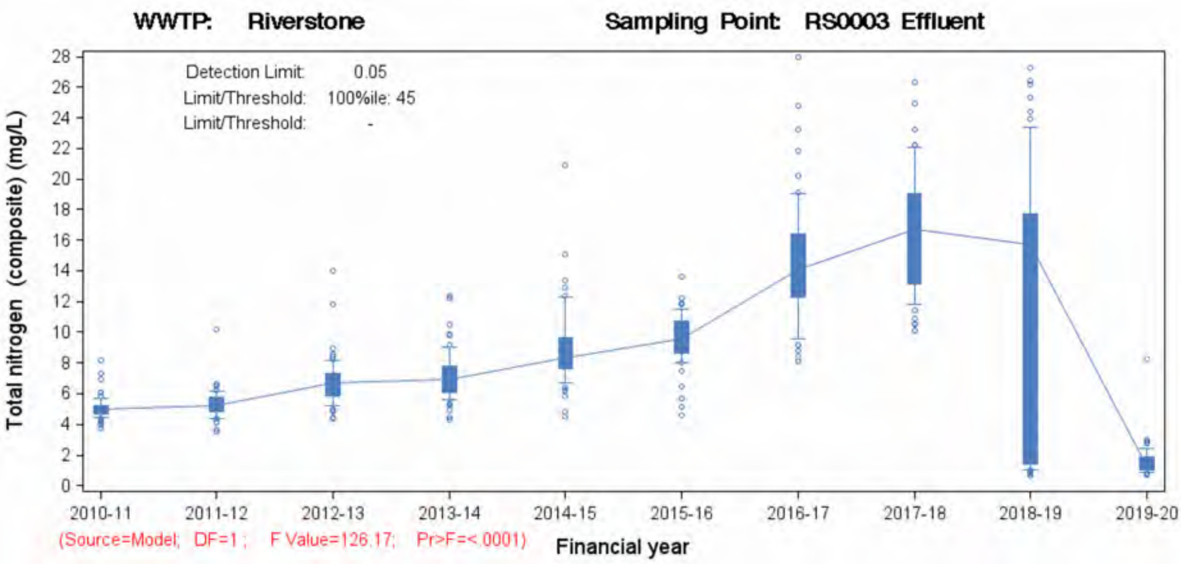
All concentration and load limits in the discharge from Riverstone WWTP were within the EPL limits during the 2019-20 period. The annual total phosphorus aggregate load discharged from the South Creek plants (Quakers Hill, Riverstone and St Marys WWTPs) was exceeded during the 2019-20 monitoring period. The cause of this exceedance was related to the significant rain event in early February 2020, which had a considerable impact on increased flows and loads recorded by the plants. All process and chemical dosing units were operating according to the unit process guidelines at the time of the rain event for all three plants. Riverstone WWTP saw an increase in inflows and subsequent loads during the second half of 2020, possibly due to the COVID-19 pandemic with more people working from home.

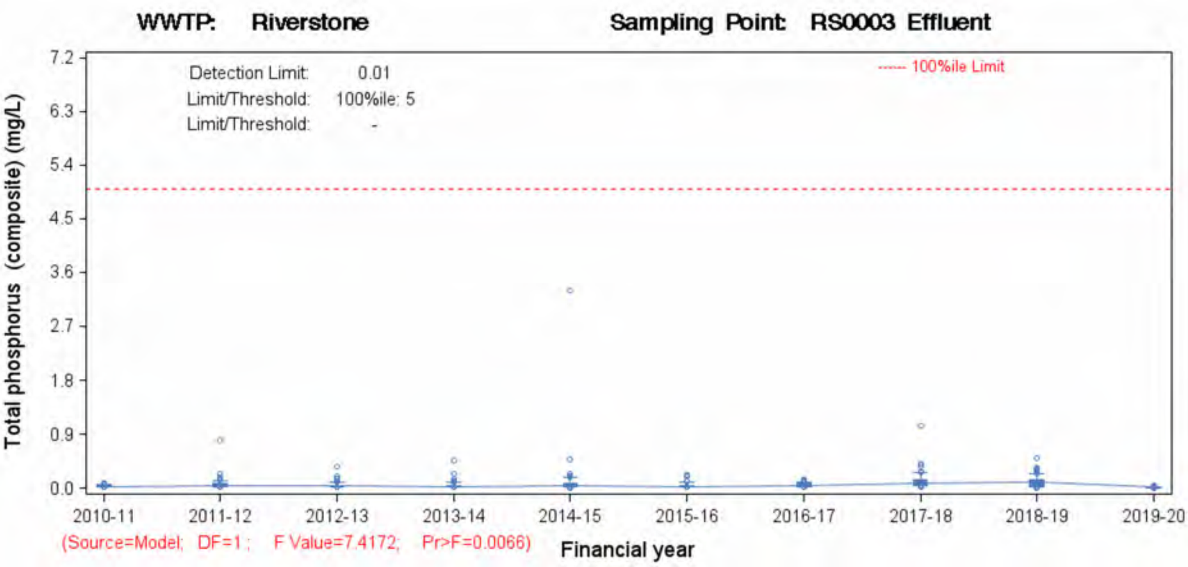
Statistical analysis identified significantly decreasing trends in total nitrogen, total phosphorus, cobalt and nickel concentrations in Riverstone WWTP discharges in 2019-20 in comparison to earlier nine years.

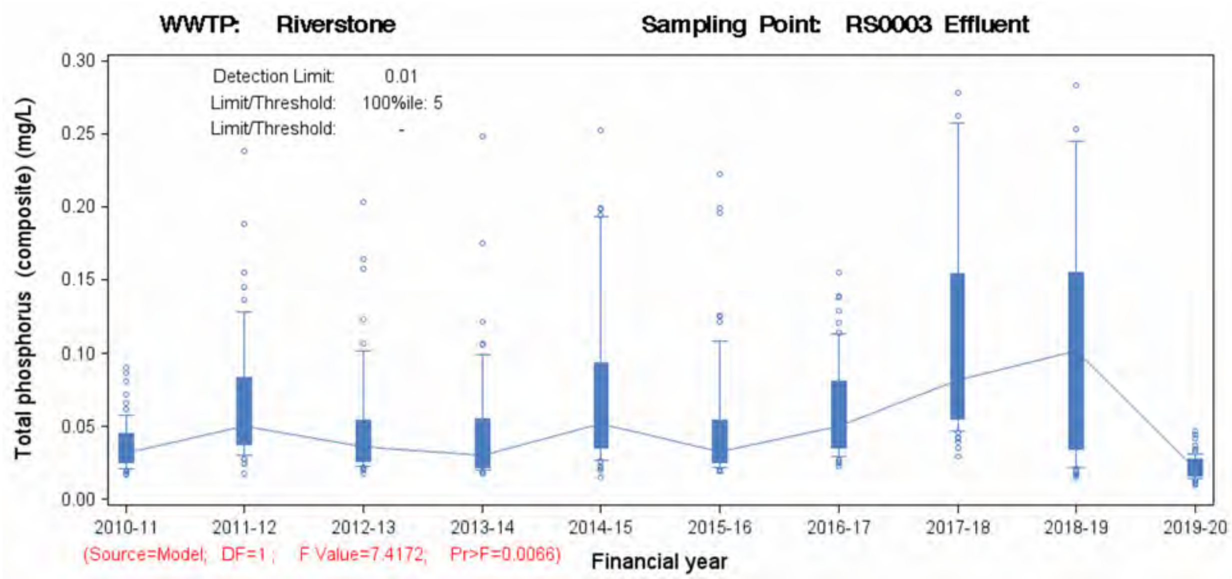
Riverstone WWTP underwent a major upgrade in early 2019 as part of a $550 million Lower South Creek Treatment Program, that provided new and upgraded wastewater infrastructure to support an additional 500,000 people in Sydney's north west by 2040. Since commissioning, nutrient concentrations and loads have been significantly lower as plant operations were optimised and returned to consistent operating conditions.

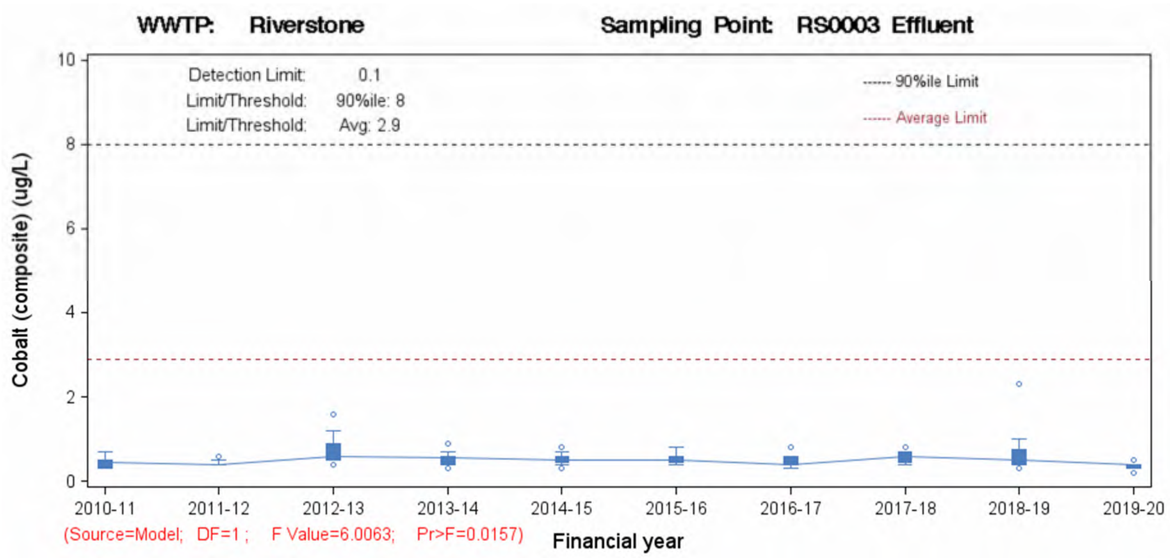


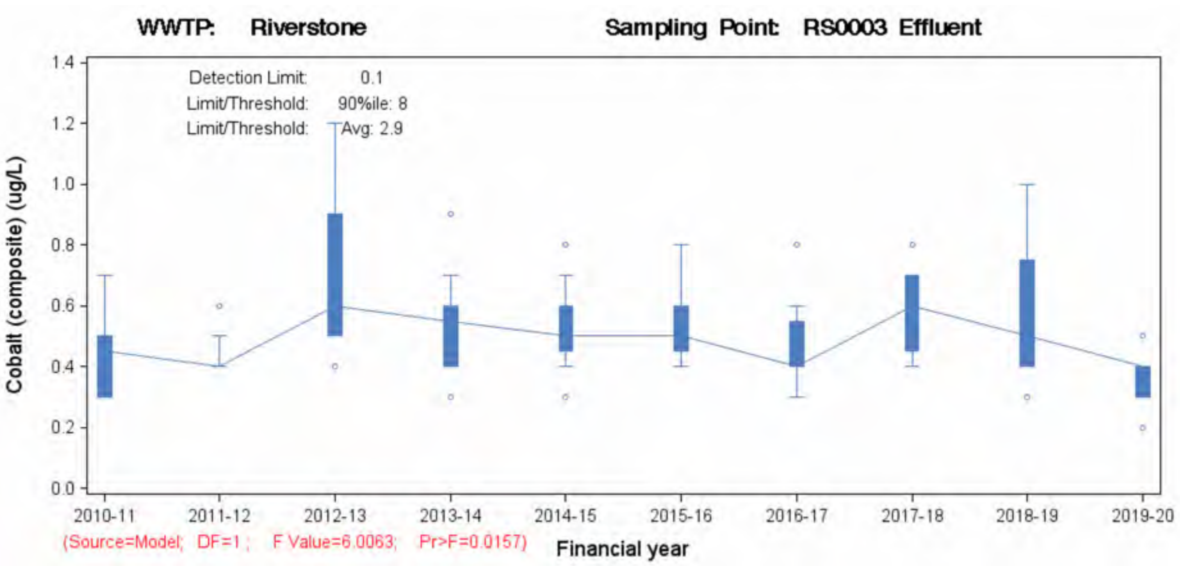

WWTP: Riverstone
Sampling Point: RS0003 Effluent
Detection Limit: 0.05
Limit/Threshold: 100%ile: 45
Limit/Threshold: -
------ 100%ile Limit
Total nitrogen (composite) (mg/L)
63
56
49
42
35
28
21
14
7
0
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=126.17; Pr>F=<.0001)
Financial year

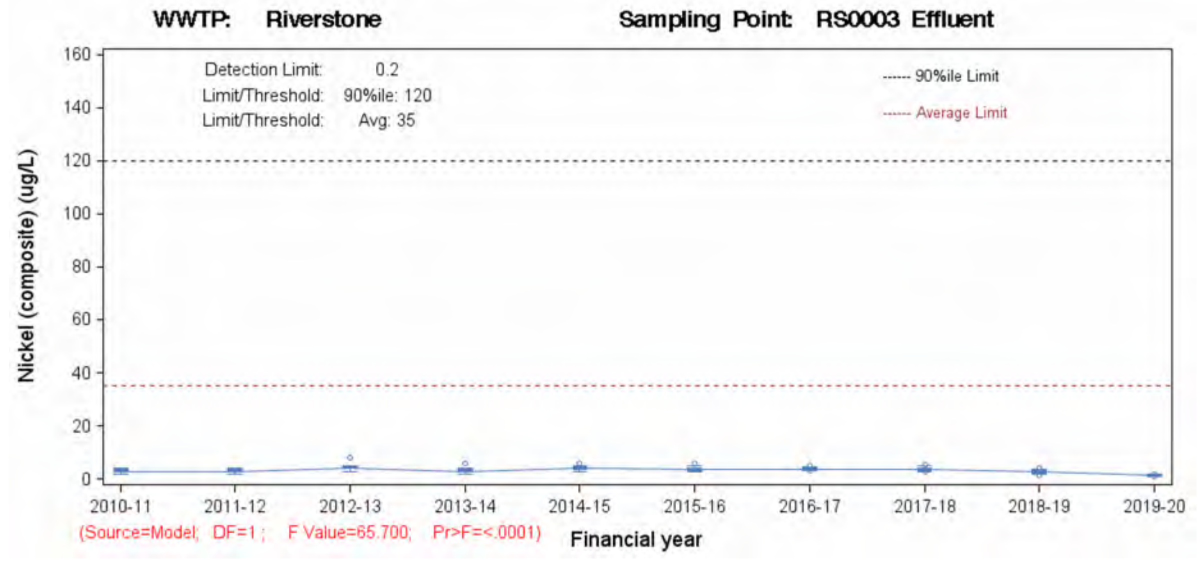

WWTP: Riverstone
Sampling Point: RS0003 Effluent
Detection Limit: 0.05
Limit/Threshold: 100%ile: 45
Limit/Threshold: -
Total nitrogen (composite) (mg/L)
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=126.17; Pr>F=<.0001)
Financial year


WWTP: Riverstone
Sampling Point: RS0003 Effluent
Detection Limit: 0.01
Limit/Threshold: 100%ile: 5
Limit/Threshold: -
------ 100%ile Limit
Total phosphorus (composite) (mg/L)
7.2
6.3
5.4
4.5
3.6
2.7
1.8
0.9
0.0
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=7.4172; Pr>F=0.0066)
Financial year

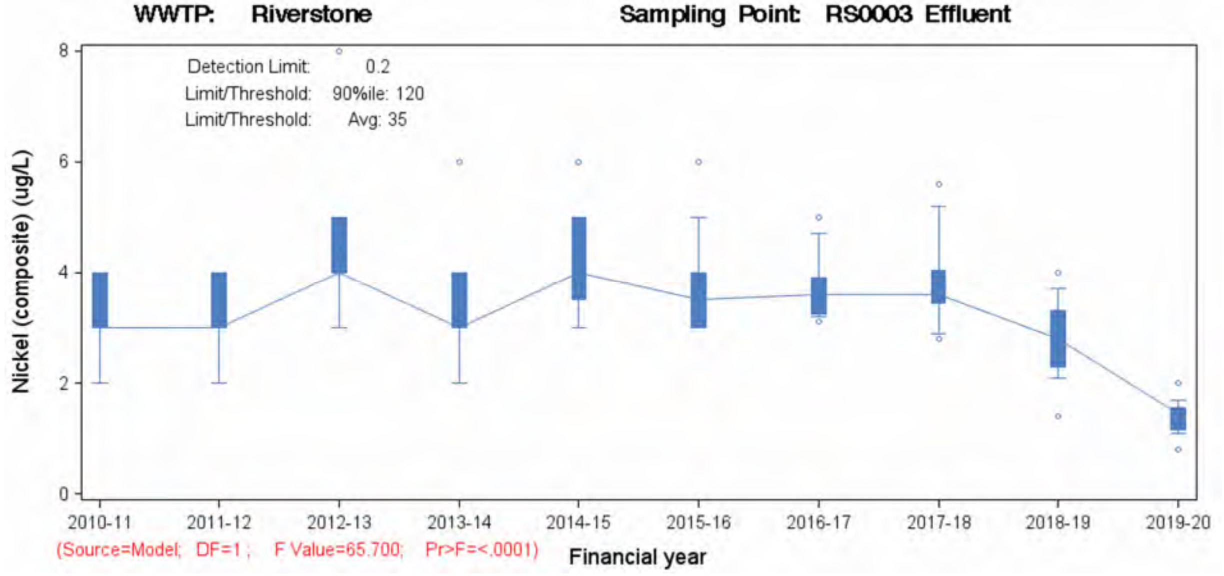

WWTP: Riverstone
Sampling Point: RS0003 Effluent
Detection Limit: 0.01
Limit/Threshold: 100%ile: 5
Limit/Threshold: -
Total phosphorus (composite) (mg/L)
0.30
0.25
0.20
0.15
0.10
0.05
0.00
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=7.4172; Pr>F=0.0066)
Financial year


WWTP: Riverstone
Sampling Point: RS0003 Effluent
Detection Limit: 0.1
Limit/Threshold: 90%ile: 8
Limit/Threshold: Avg: 2.9
------ 90%ile Limit
------ Average Limit
Cobalt (composite) (ug/L)
10
8
6
4
2
0
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=6.0063; Pr>F=0.0157)
Financial year


WWTP: Riverstone
Sampling Point: RS0003 Effluent
Detection Limit: 0.1
Limit/Threshold: 90%ile: 8
Limit/Threshold: Avg: 2.9
Cobalt (composite) (ug/L)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=6.0063; Pr>F=0.0157)
Financial year



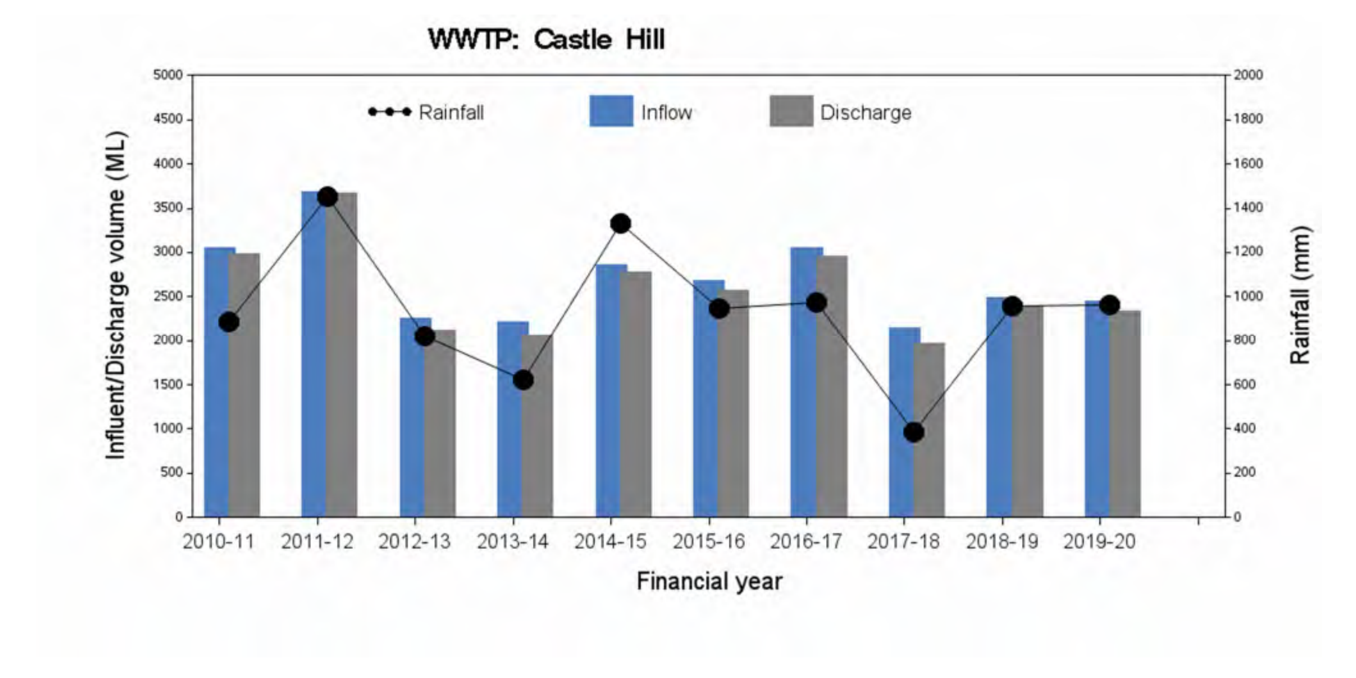
Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17

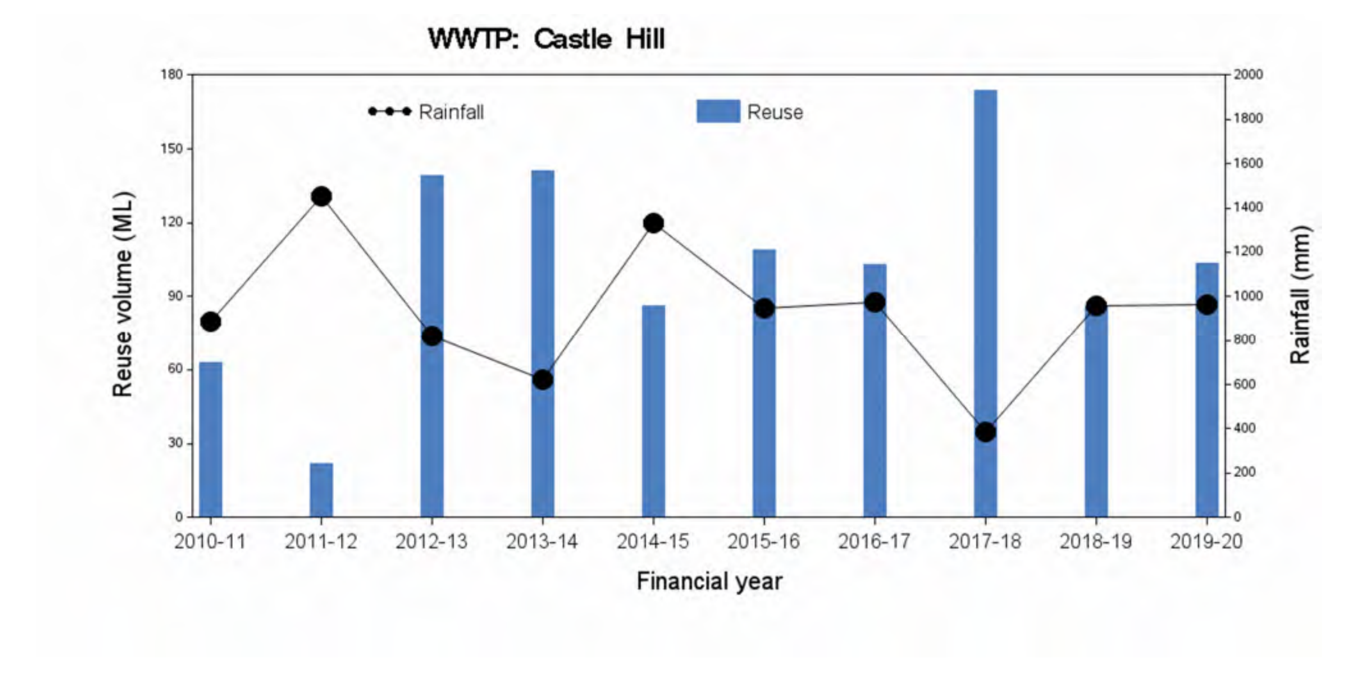


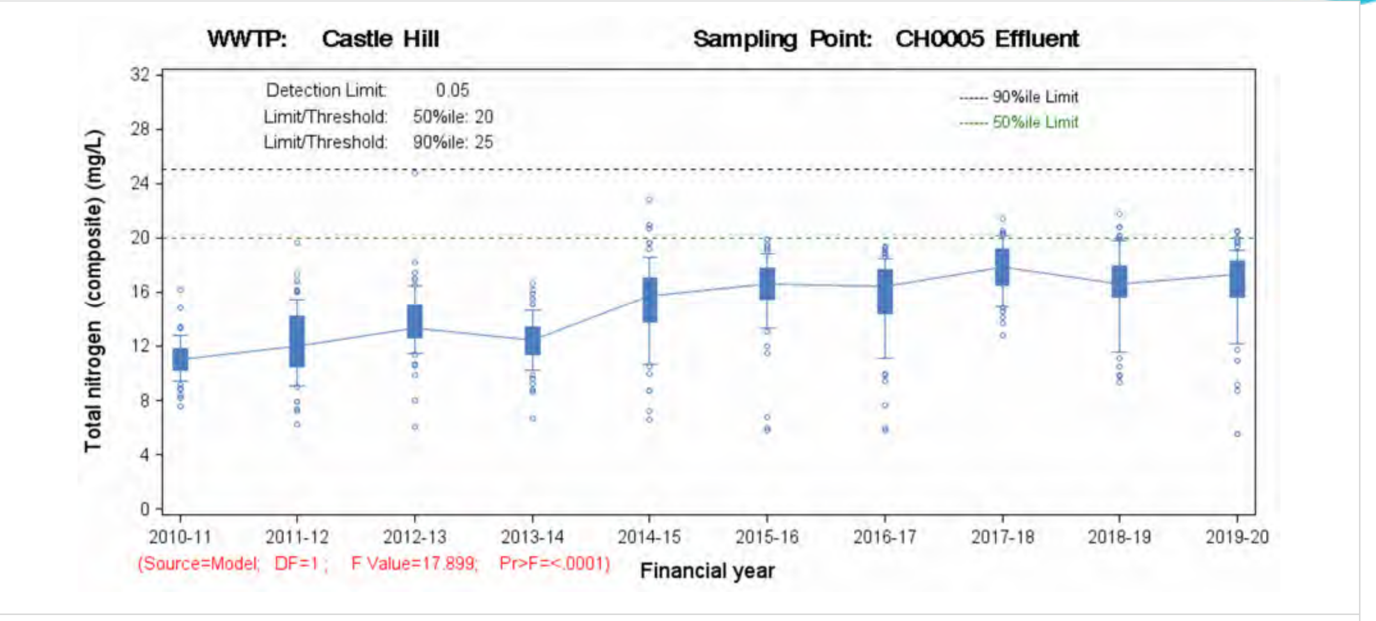
Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17

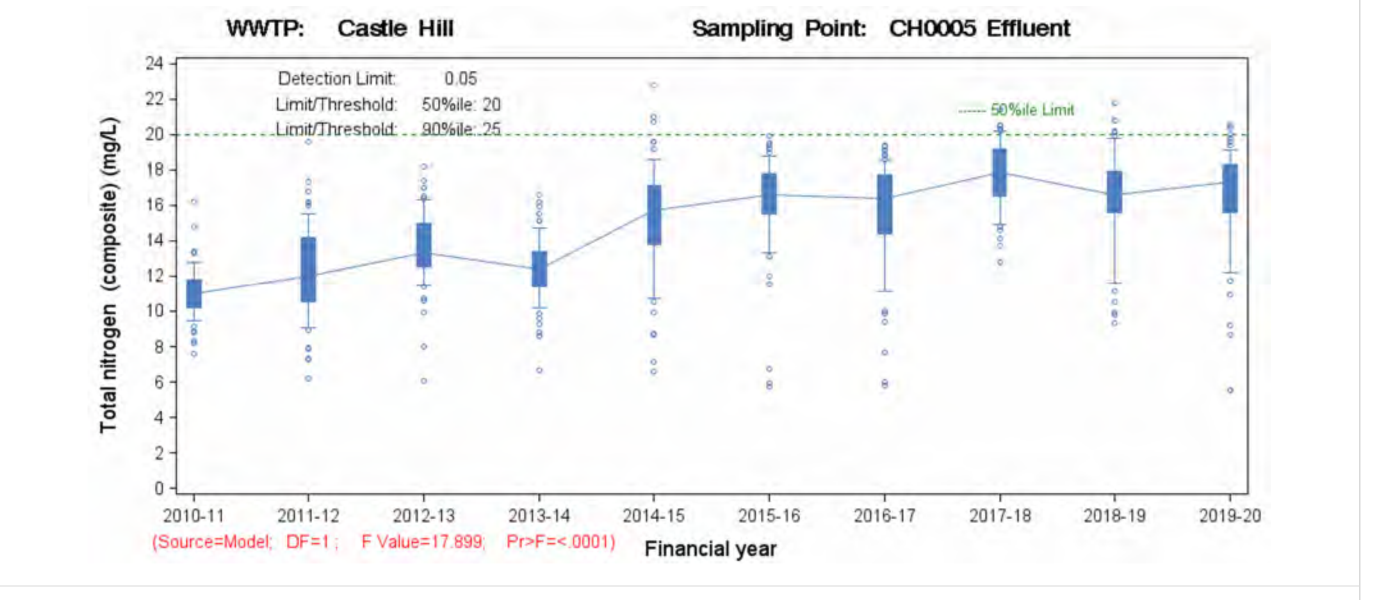
4.2.11 Castle Hill WWTP

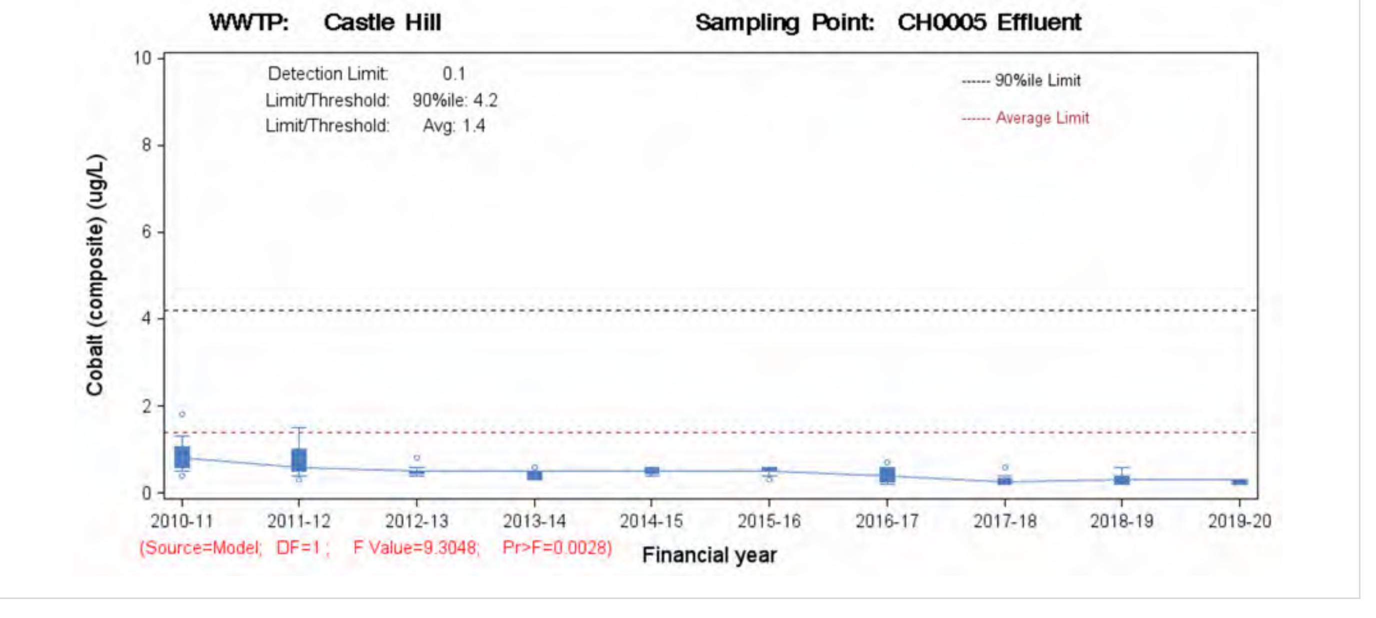
All concentration and load limits in the discharge from Castle Hill WWTP were within the EPL limits during the 2019-20 period. Statistical analysis identified significantly increasing trends in total nitrogen, copper and zinc concentrations. The plant has been operating normally, with increasing trends possibly linked to loads from rainfall events and trade waste customers. Like St Marys, the significant rain event in early February 2020 had a considerable impact on loads recorded by Castle Hill WWTP. A significantly decreasing trend in cobalt concentration was also identified.

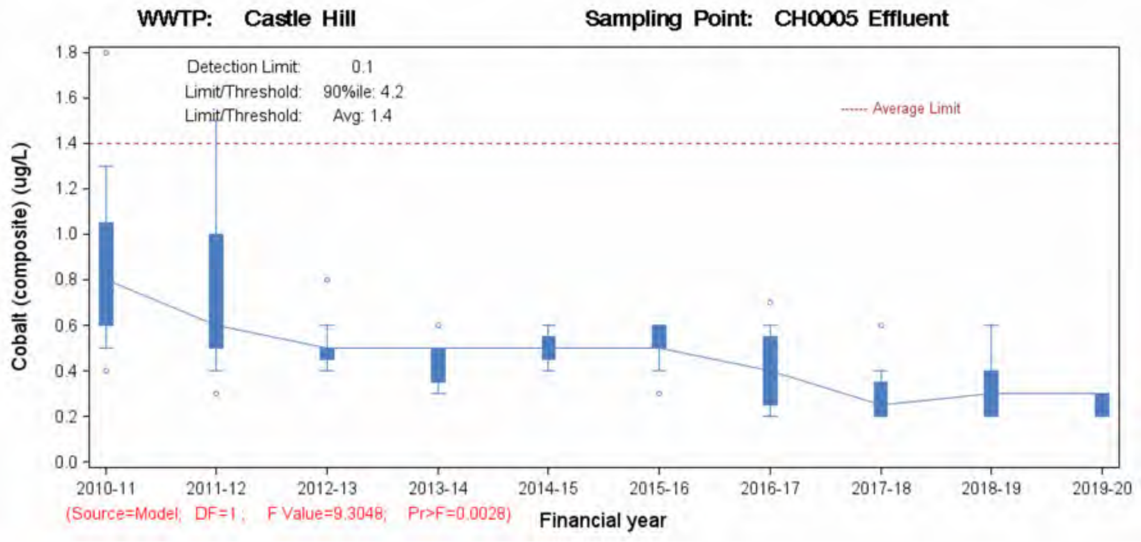


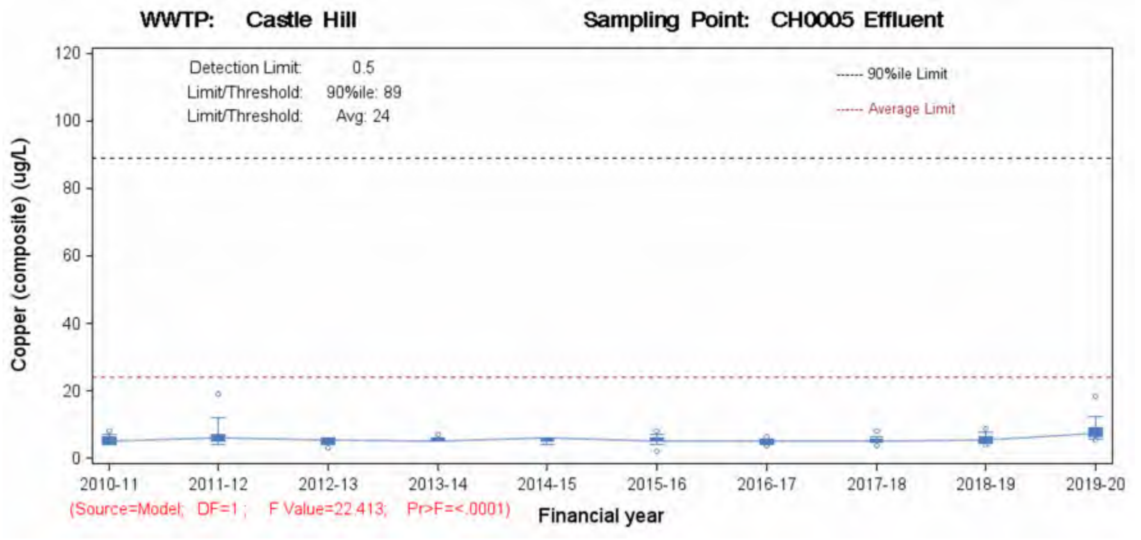



WWTP: Castle Hill
Sampling Point: CH0005 Effluent
Detection Limit: 0.05
Limit/Threshold: 50%ile: 20
Limit/Threshold: 90%ile: 25
------ 90%ile Limit
------ 50%ile Limit
Total nitrogen (composite) (mg/L)
Financial year
(Source=Model; DF=1 ; F Value=17.899; Pr>F=<.0001)

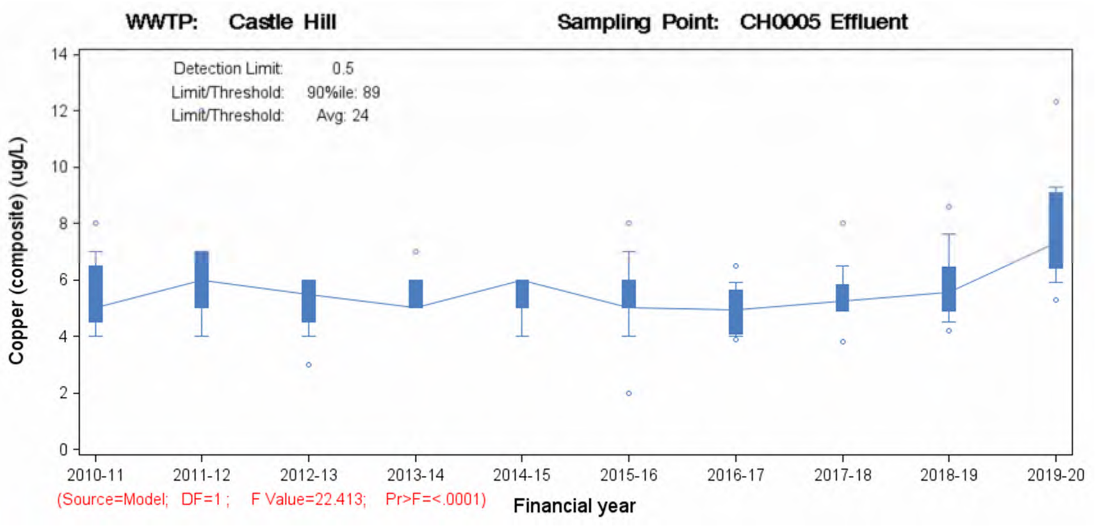

WWTP: Castle Hill
Sampling Point: CH0005 Effluent
Detection Limit: 0.05
Limit/Threshold: 50%ile: 20
Limit/Threshold: 90%ile: 25
------ 50%ile Limit
Total nitrogen (composite) (mg/L)
Financial year
(Source=Model; DF=1 ; F Value=17.899; Pr>F=<.0001)


WWTP: Castle Hill
Sampling Point: CH0005 Effluent
Detection Limit: 0.1
Limit/Threshold: 90%ile: 4.2
Limit/Threshold: Avg: 1.4
------ 90%ile Limit
------ Average Limit
Cobalt (composite) (ug/L)
Financial year
(Source=Model; DF=1 ; F Value=9.3048; Pr>F=0.0028)

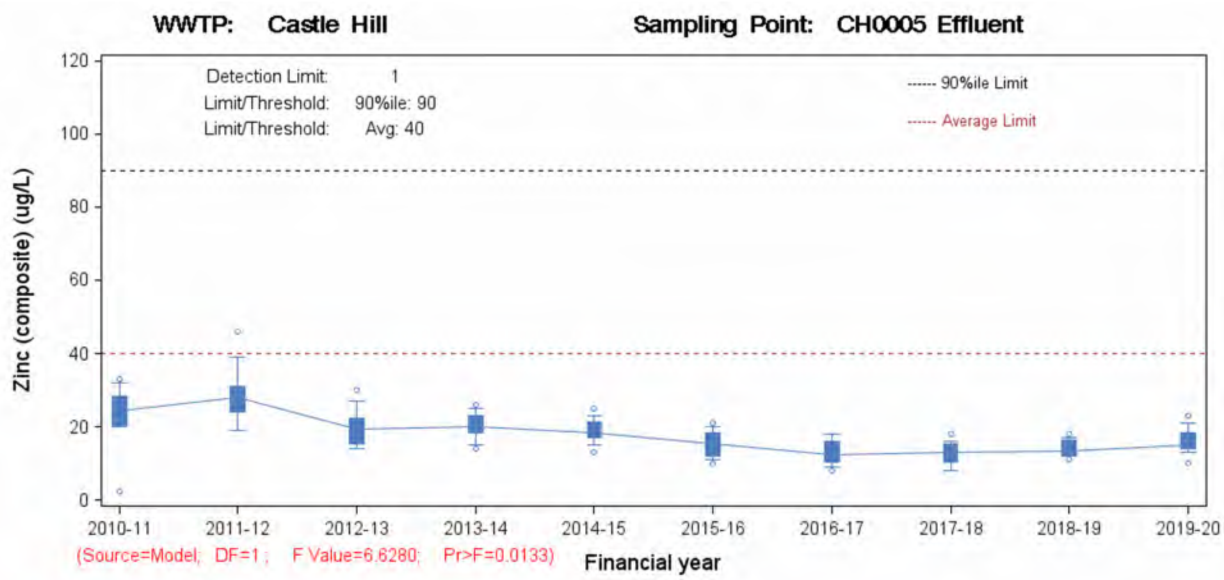




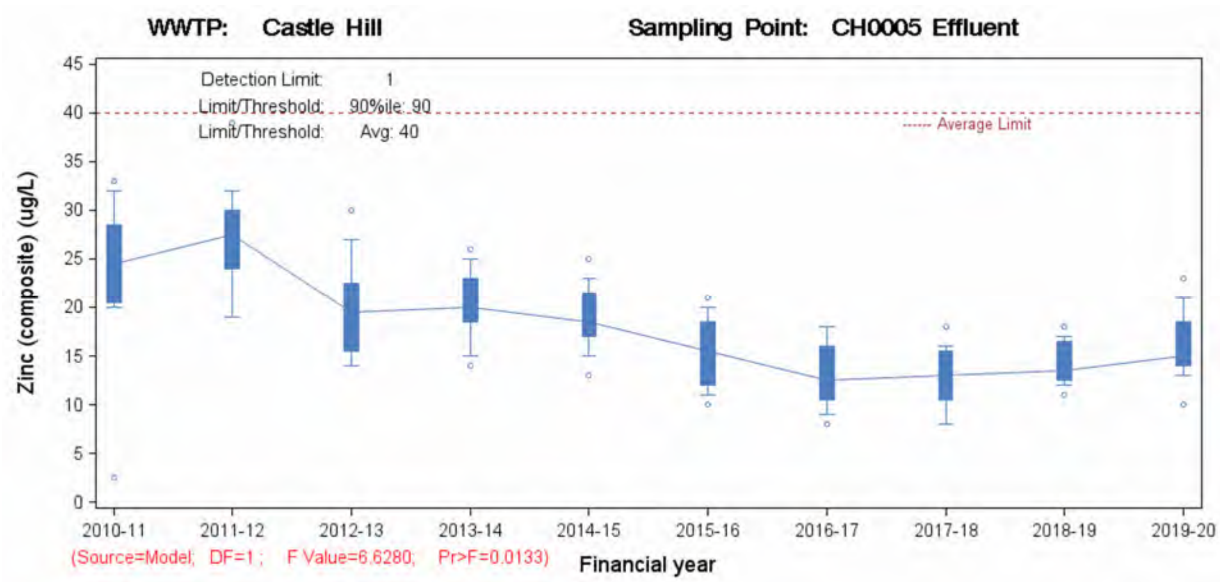
Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17



Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17



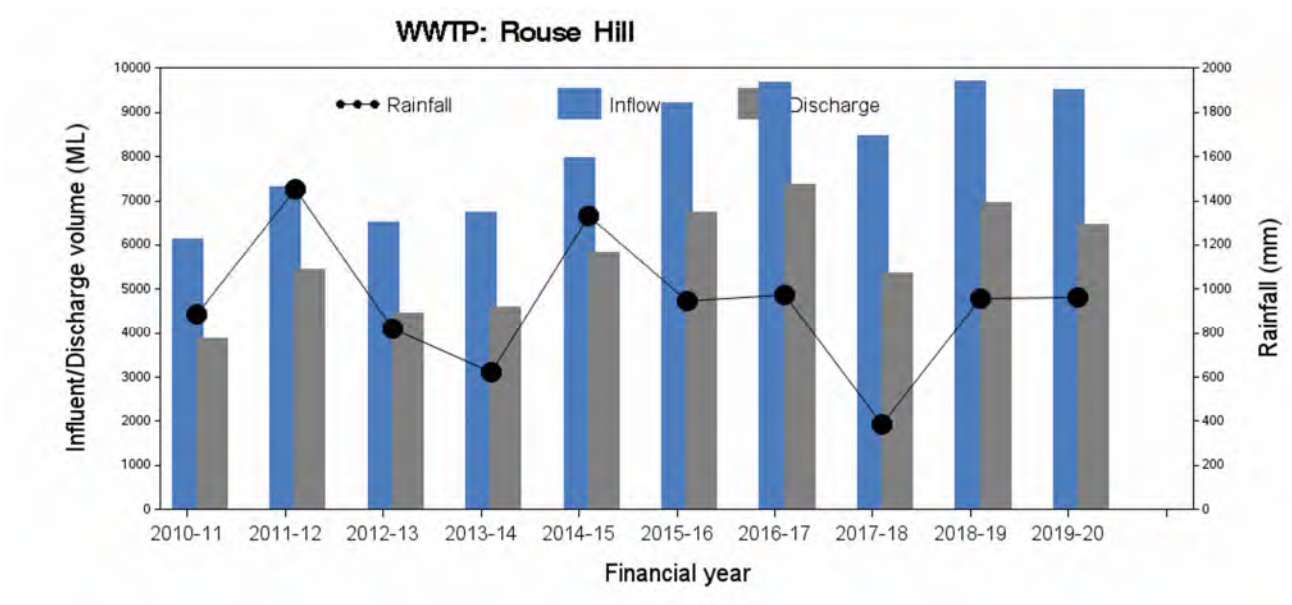
Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17

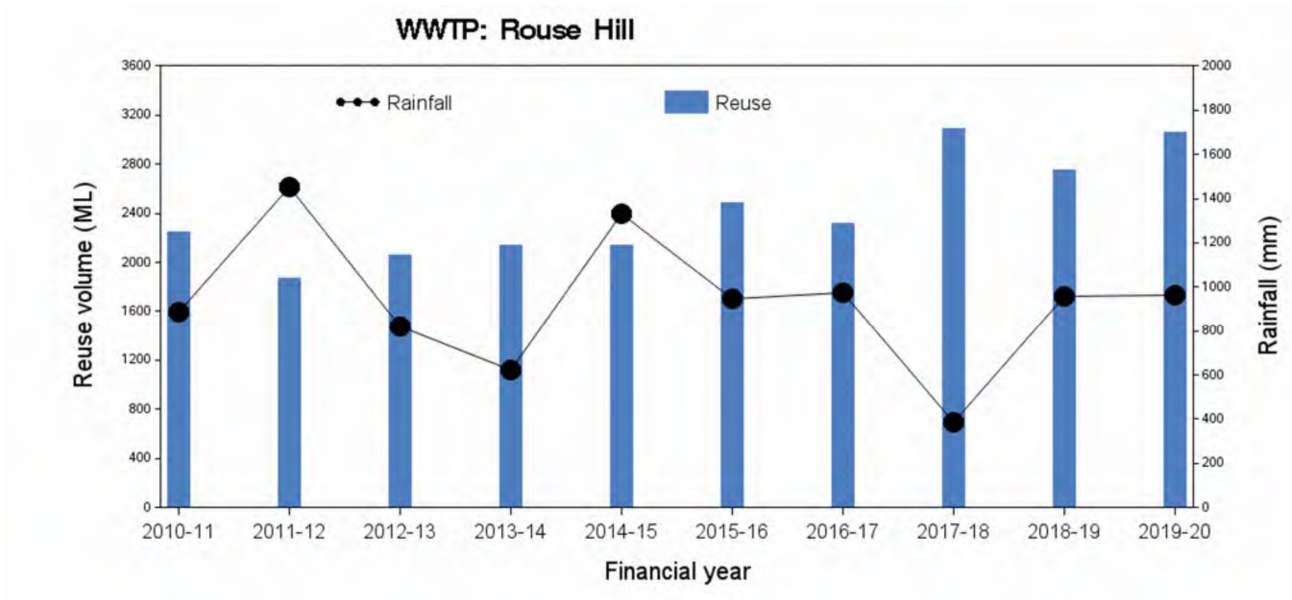


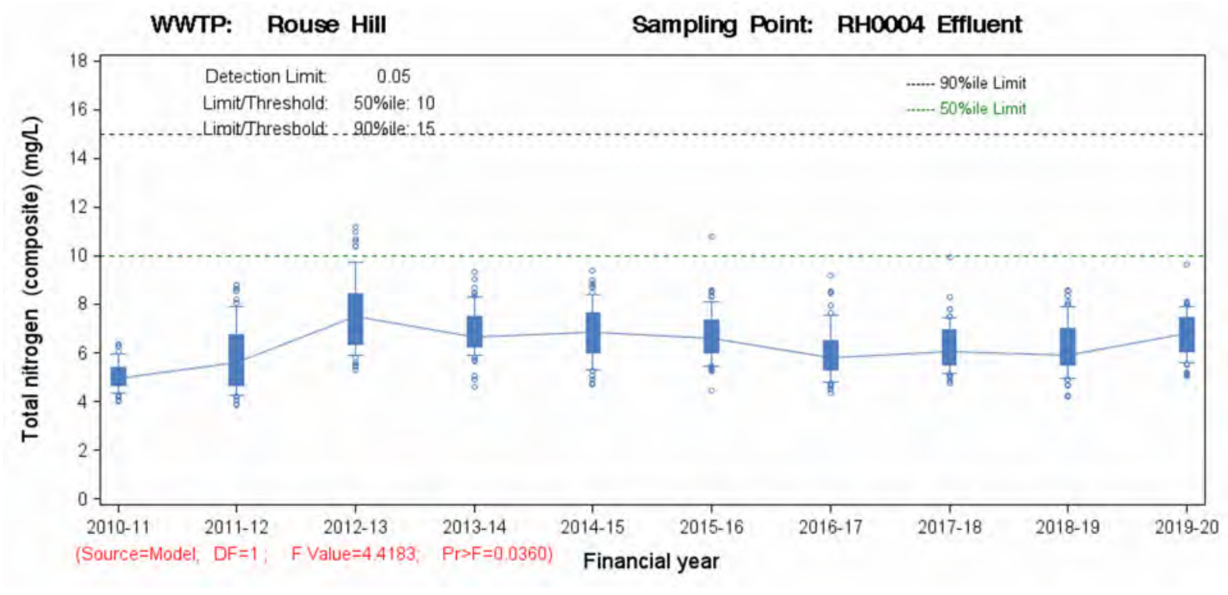
Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17

4.2.12 Rouse Hill WWTP

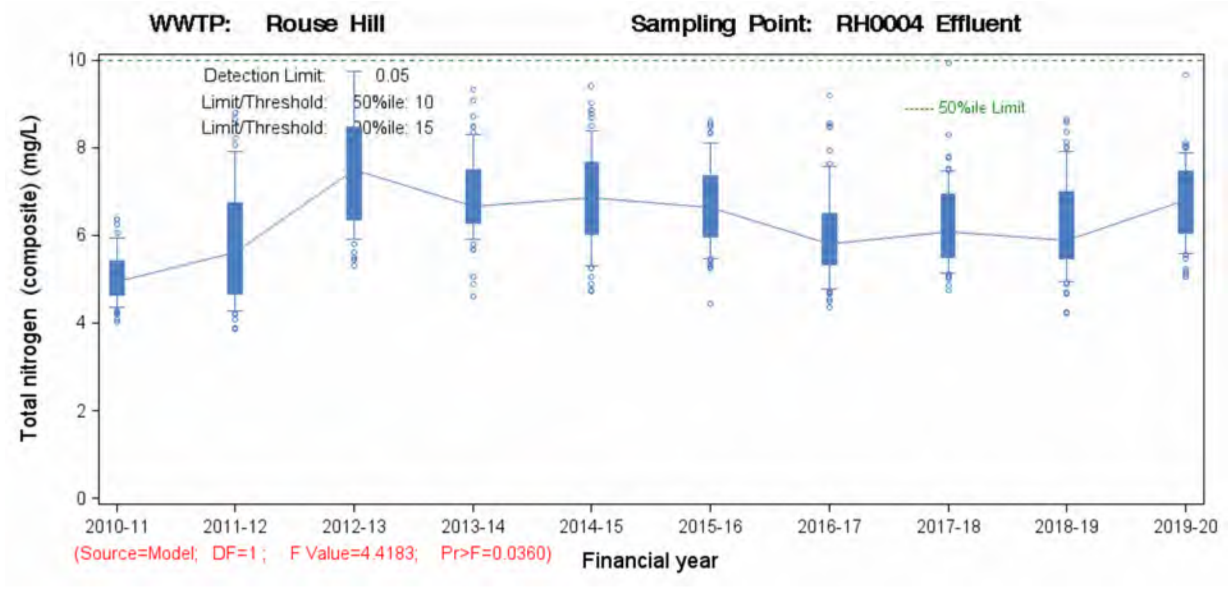
All concentration and load limits in the discharge from Rouse Hill WWTP were within the EPL limits during the 2019-20 period. Statistical analysis identified a significantly increasing trend in total nitrogen and aluminium concentrations, and decreasing trends in total phosphorus and copper concentrations. The plant has been operating normally, with increasing trends linked to the population growth within the catchment area (population growth from 100,730 in 2016-17 to 114,390 in 2019-20). Like Castle Hill, the significant rain event in early February 2020 had a considerable impact on loads recorded by Rouse Hill WWTP. In addition, an increase in flows and subsequent loads was observed during the second half of 2020, possibly due to the COVID-19 pandemic with more people working from home.



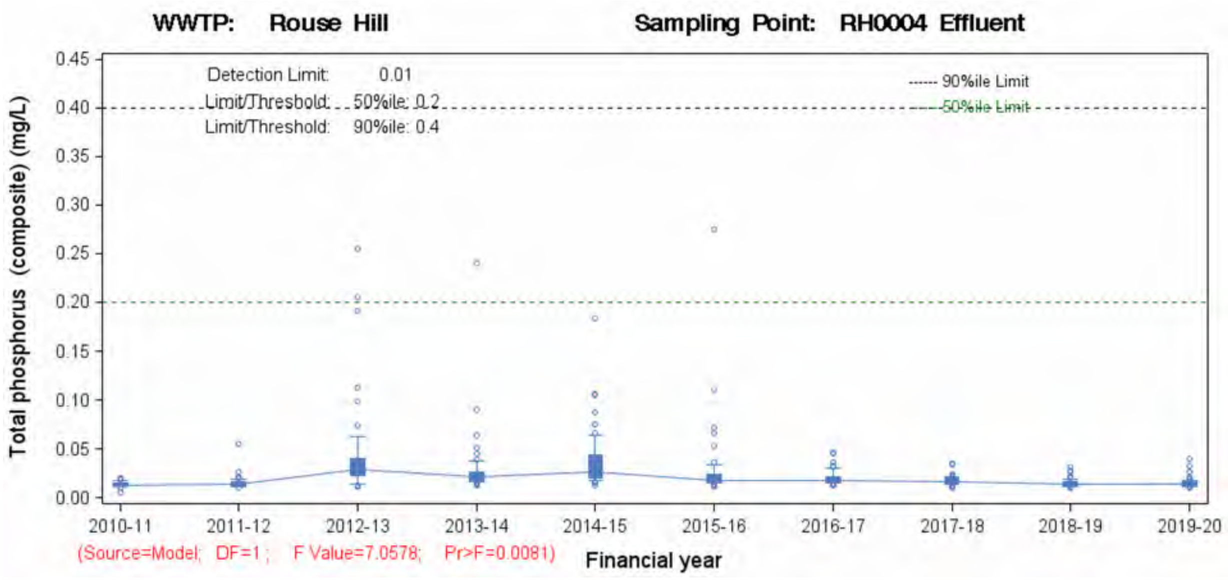




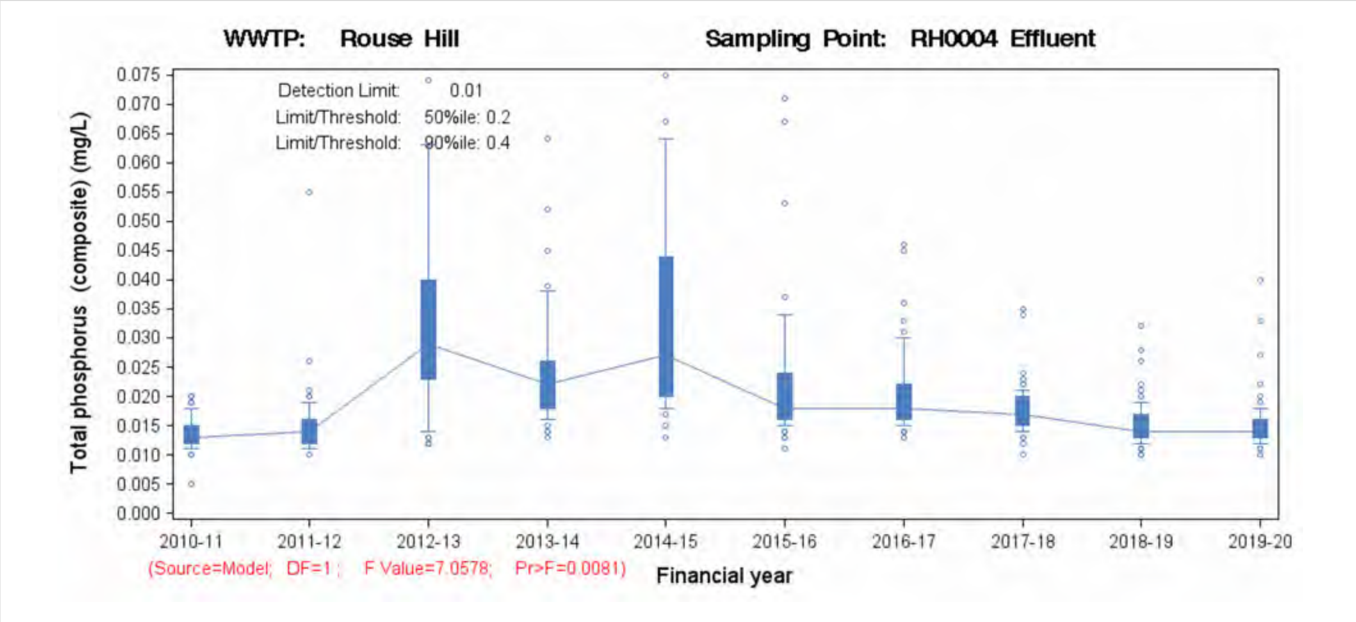
WWTP: Rouse Hill
Sampling Point: RH0004 Effluent
Detection Limit: 0.05
Limit/Threshold: 50%ile: 10
Limit/Threshold: 90%ile: 15
------ 90%ile Limit
------ 50%ile Limit
Total nitrogen (composite) (mg/L)
18
16
14
12
10
8
6
4
2
0
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=4.4183; Pr>F=0.0360)
Financial year

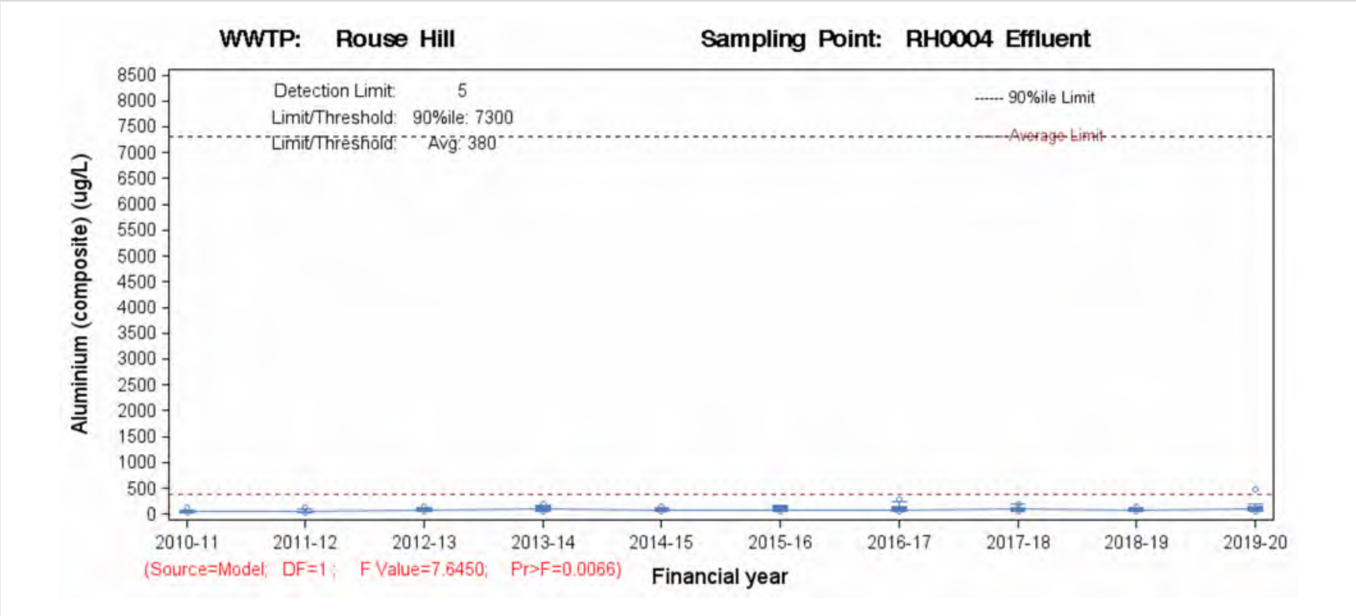


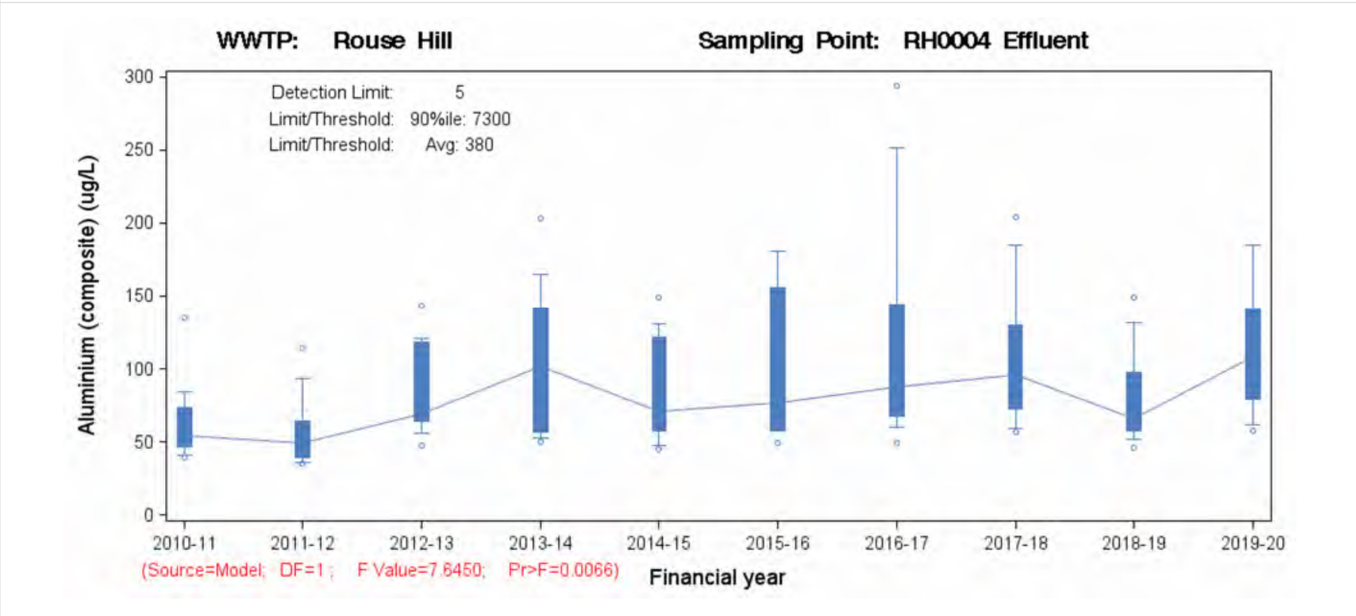
WWTP: Rouse Hill
Sampling Point: RH0004 Effluent
Detection Limit: 0.05
Limit/Threshold: 50%ile: 10
Limit/Threshold: 90%ile: 15
------ 50%ile Limit
Total nitrogen (composite) (mg/L)
10
8
6
4
2
0
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=4.4183; Pr>F=0.0360)
Financial year

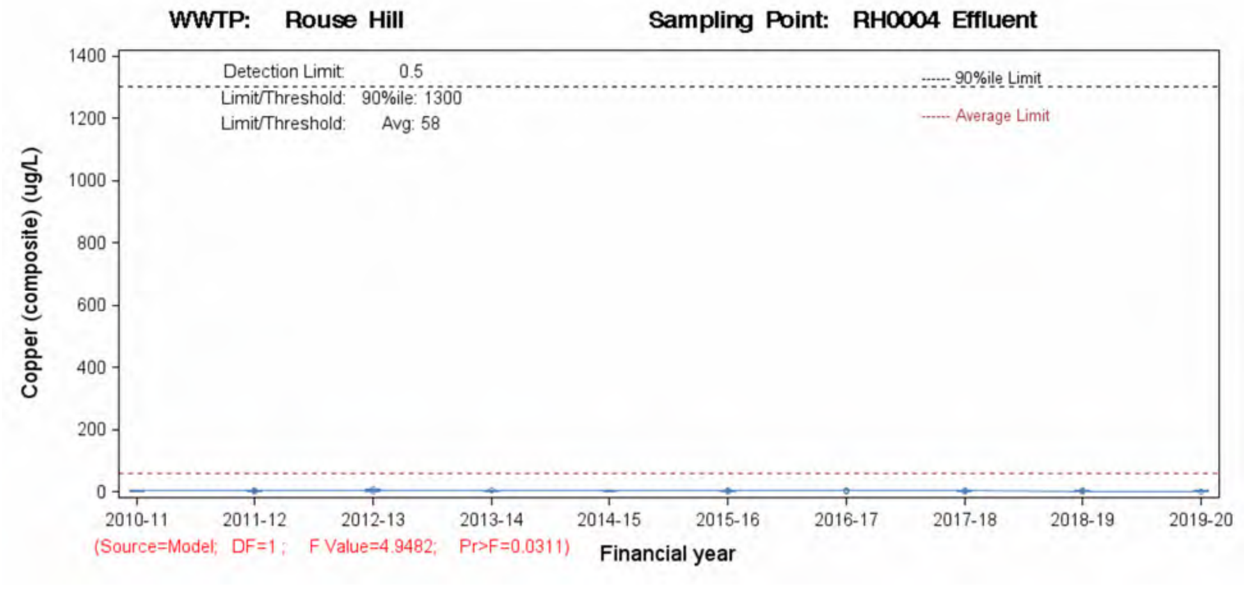


WWTP: Rouse Hill
Sampling Point: RH0004 Effluent
Detection Limit: 0.01
Limit/Threshold: 50%ile: 0.2
Limit/Threshold: 90%ile: 0.4
------ 90%ile Limit
------ 50%ile Limit
Total phosphorus (composite) (mg/L)
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=7.0578; Pr>F=0.0081)
Financial year

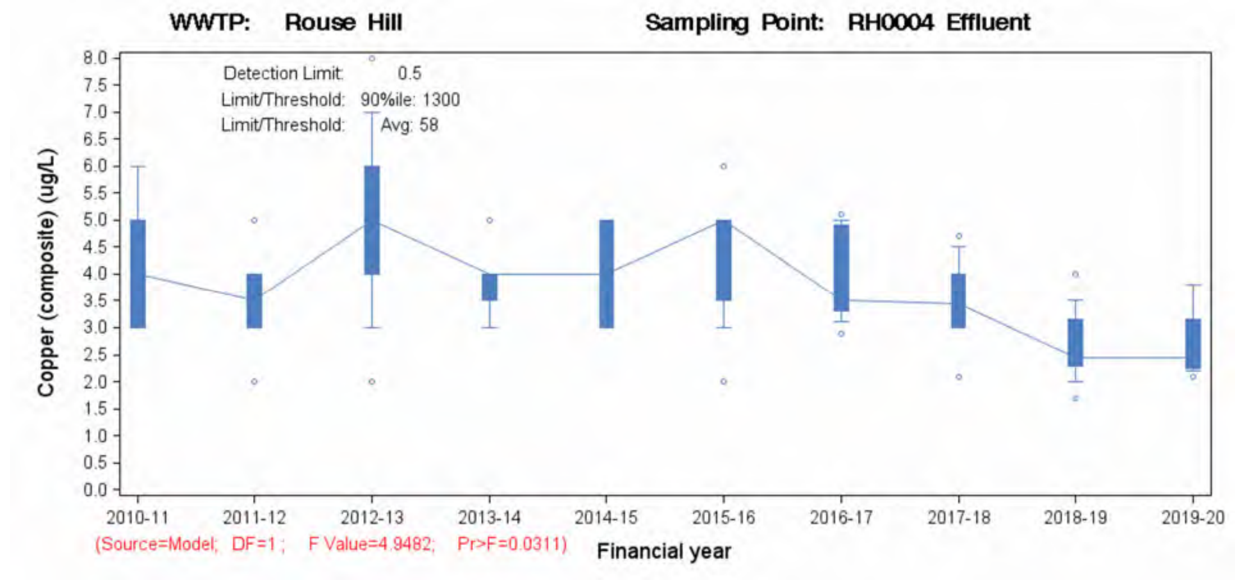

WWTP: Rouse Hill
Sampling Point: RH0004 Effluent
Detection Limit: 0.01
Limit/Threshold: 50%ile: 0.2
Limit/Threshold: 90%ile: 0.4
Total phosphorus (composite) (mg/L)
0.000 0.005 0.010 0.015 0.020 0.025 0.030 0.035 0.040 0.045 0.050 0.055 0.060 0.065 0.070 0.075
2010-11 2011-12 2012-13 2013-14 2014-15 2015-16 2016-17 2017-18 2018-19 2019-20
(Source=Model; DF=1 ; F Value=7.0578; Pr>F=0.0081)
Financial year


WWTP: Rouse Hill
Sampling Point: RH0004 Effluent
Detection Limit: 5
Limit/Threshold: 90%ile: 7300
Limit/Threshold: Avg: 380
------ 90%ile Limit
------ Average Limit
Aluminium (composite) (ug/L)
0 500 1000 1500 2000 2500 3000 3500 4000 4500 5000 5500 6000 6500 7000 7500 8000 8500
2010-11 2011-12 2012-13 2013-14 2014-15 2015-16 2016-17 2017-18 2018-19 2019-20
(Source=Model; DF=1 ; F Value=7.6450; Pr>F=0.0066)
Financial year


WWTP: Rouse Hill
Sampling Point: RH0004 Effluent
Detection Limit: 5
Limit/Threshold: 90%ile: 7300
Limit/Threshold: Avg: 380
Aluminium (composite) (ug/L)
0 50 100 150 200 250 300
2010-11 2011-12 2012-13 2013-14 2014-15 2015-16 2016-17 2017-18 2018-19 2019-20
(Source=Model; DF=1 ; F Value=7.6450; Pr>F=0.0066)
Financial year



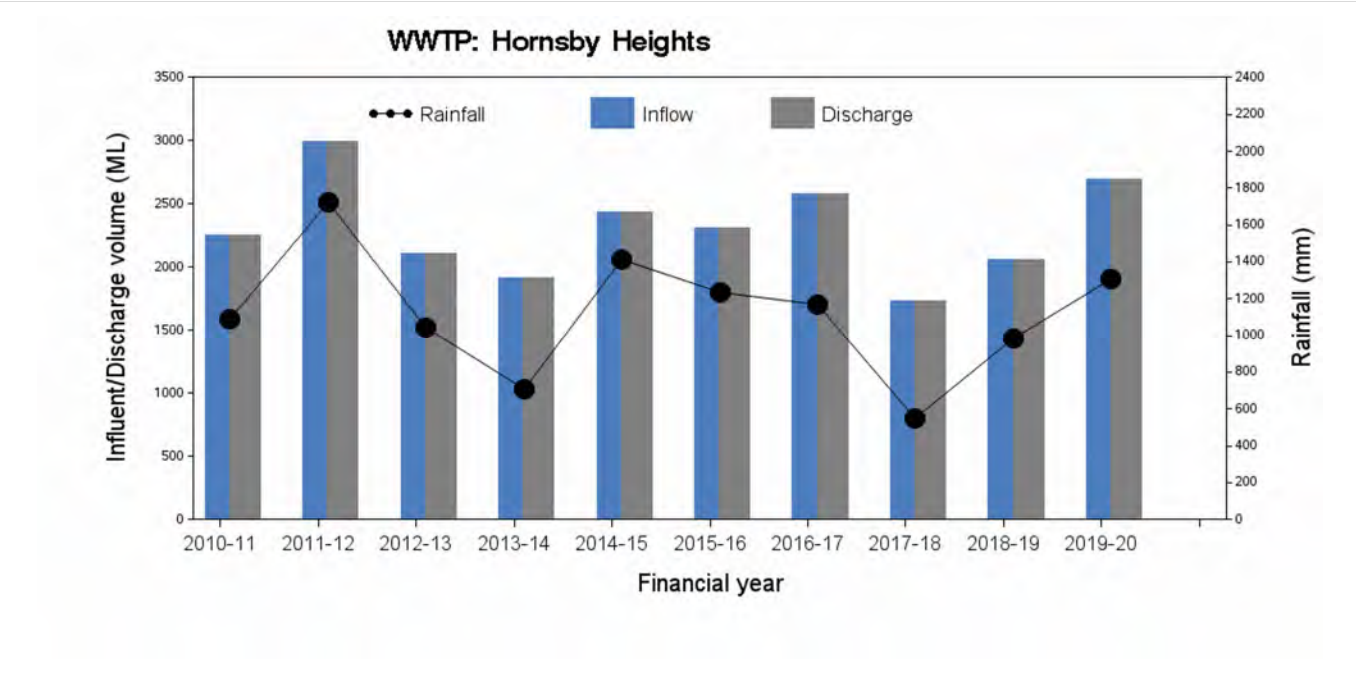
Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17

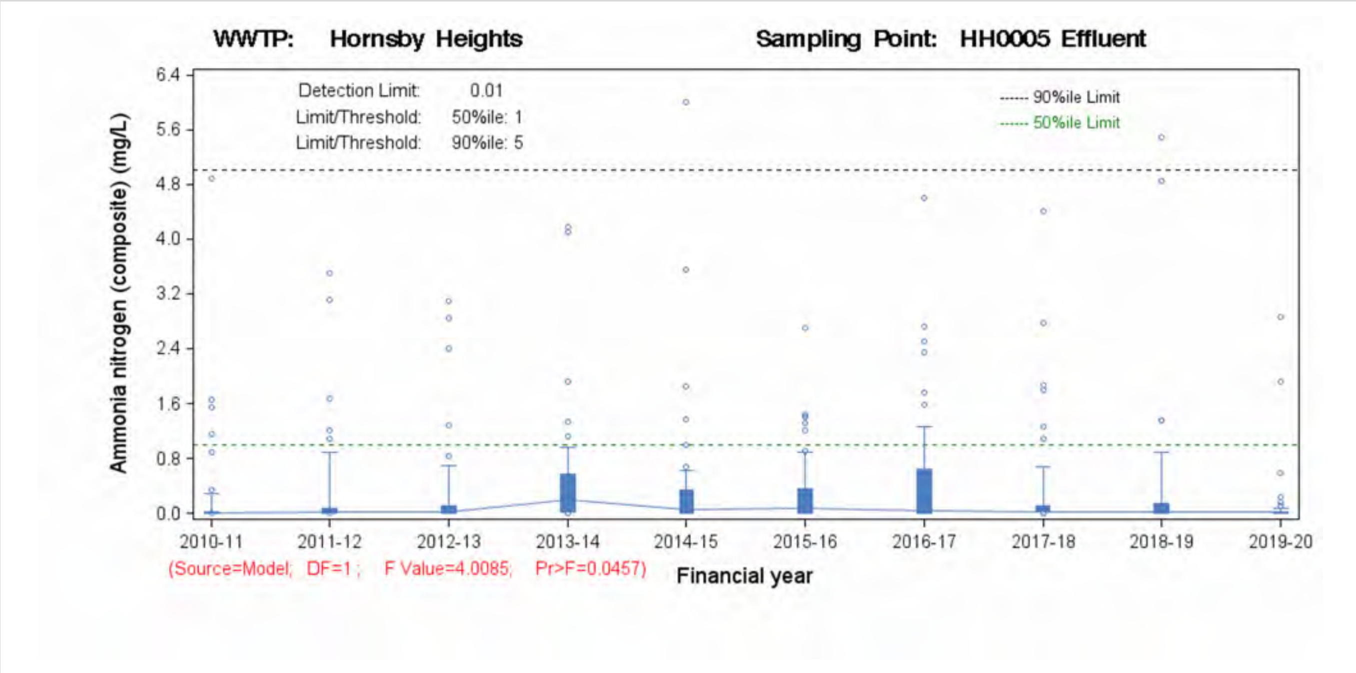


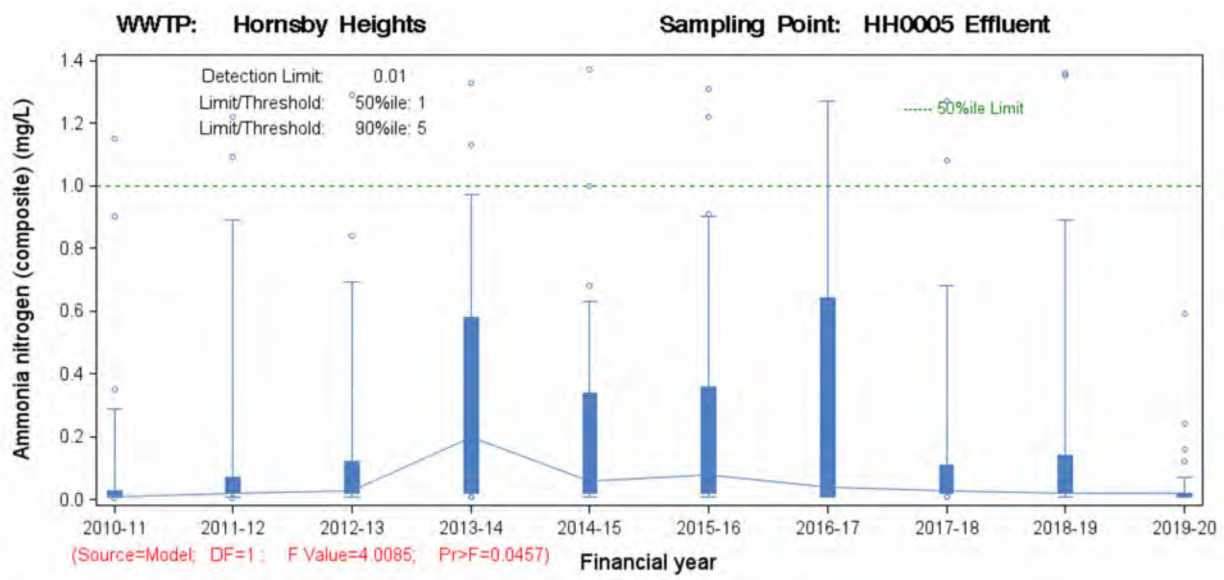
Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17

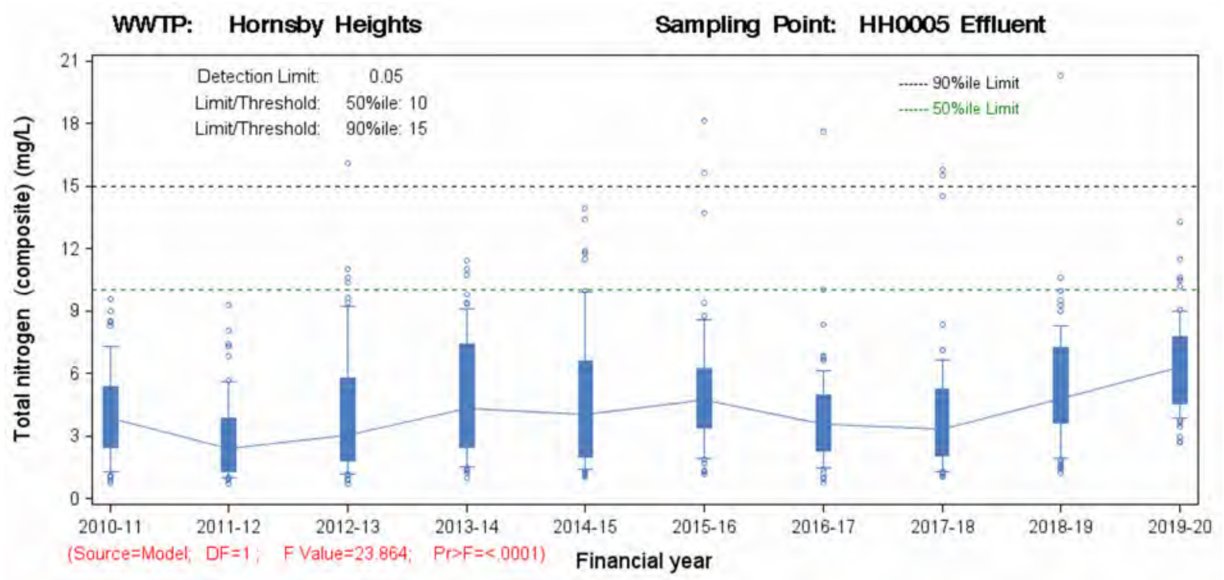
4.2.13 Hornsby Heights WWTP

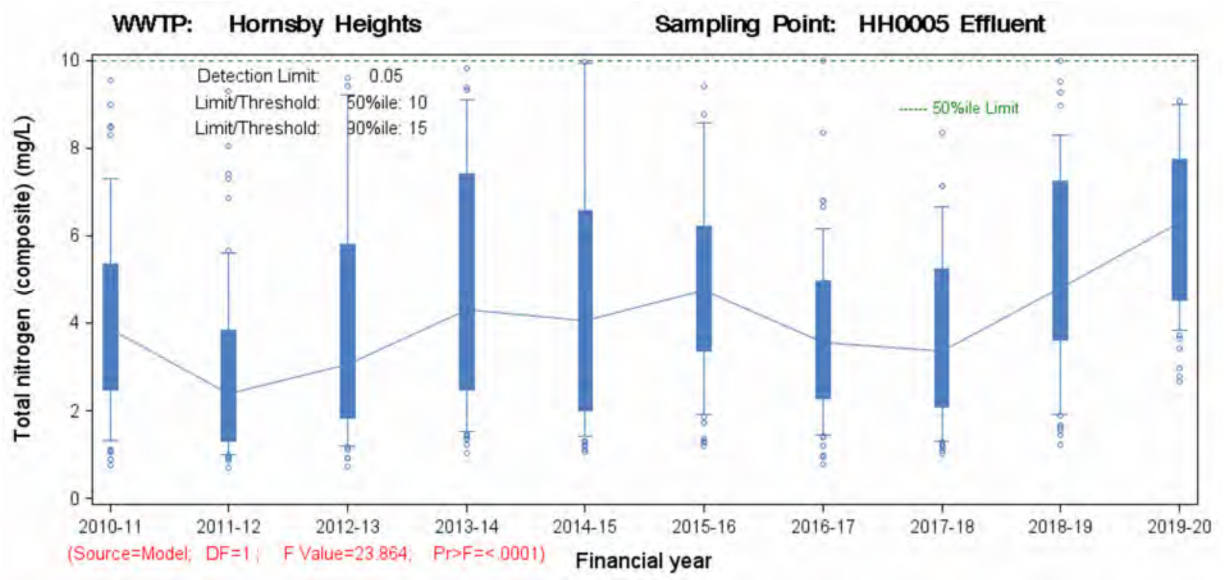
All concentration and load limits in the discharge from Hornsby Heights WWTP were within the EPL limits during the 2019-20 period. Statistical analysis identified a significantly increasing trend in total nitrogen concentration. This increasing trend is associated to a recently improved BOD removal process from a major trade waste source within the plant catchment, which subsequently has had an impact of the plant's nitrogen removal efficiency. Sydney Water are investigating further options to improve nitrogen removal at Hornsby Heights WWTP, including future plant upgrades. Hornsby Heights WWTP saw an increase in inflows and subsequent loads during the second half of 2020, possibly due to the COVID-19 pandemic with more people working from home. A significant decreasing trend was observed in ammonia nitrogen and cobalt concentrations.

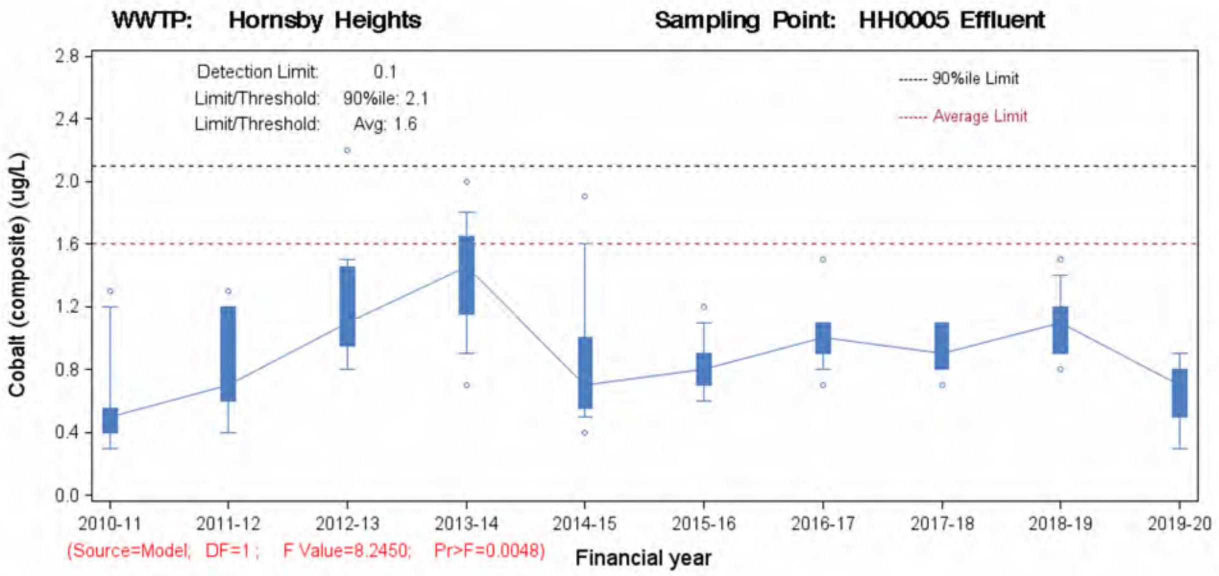




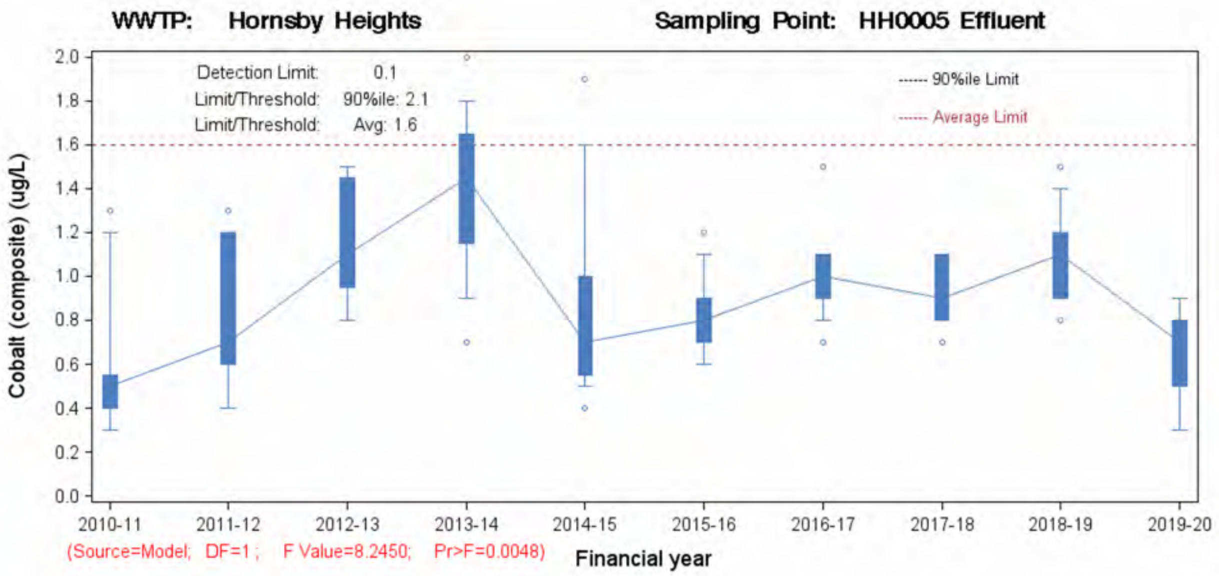

WWTP: Hornsby Heights
Sampling Point: HH0005 Effluent
Detection Limit: 0.01
Limit/Threshold: 50%ile: 1
Limit/Threshold: 90%ile: 5
50%ile Limit
Ammonia nitrogen (composite) (mg/L)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=4.0085; Pr>F=0.0457)
Financial year


WWTP: Hornsby Heights
Sampling Point: HH0005 Effluent
Detection Limit: 0.05
Limit/Threshold: 50%ile: 10
Limit/Threshold: 90%ile: 15
90%ile Limit
50%ile Limit
Total nitrogen (composite) (mg/L)
0
3
6
9
12
15
18
21
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=23.864; Pr>F=<.0001)
Financial year


WWTP: Hornsby Heights
Sampling Point: HH0005 Effluent
Detection Limit: 0.05
Limit/Threshold: 50%ile: 10
Limit/Threshold: 90%ile: 15
50%ile Limit
Total nitrogen (composite) (mg/L)
0
2
4
6
8
10
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=23.864; Pr>F=<.0001)
Financial year



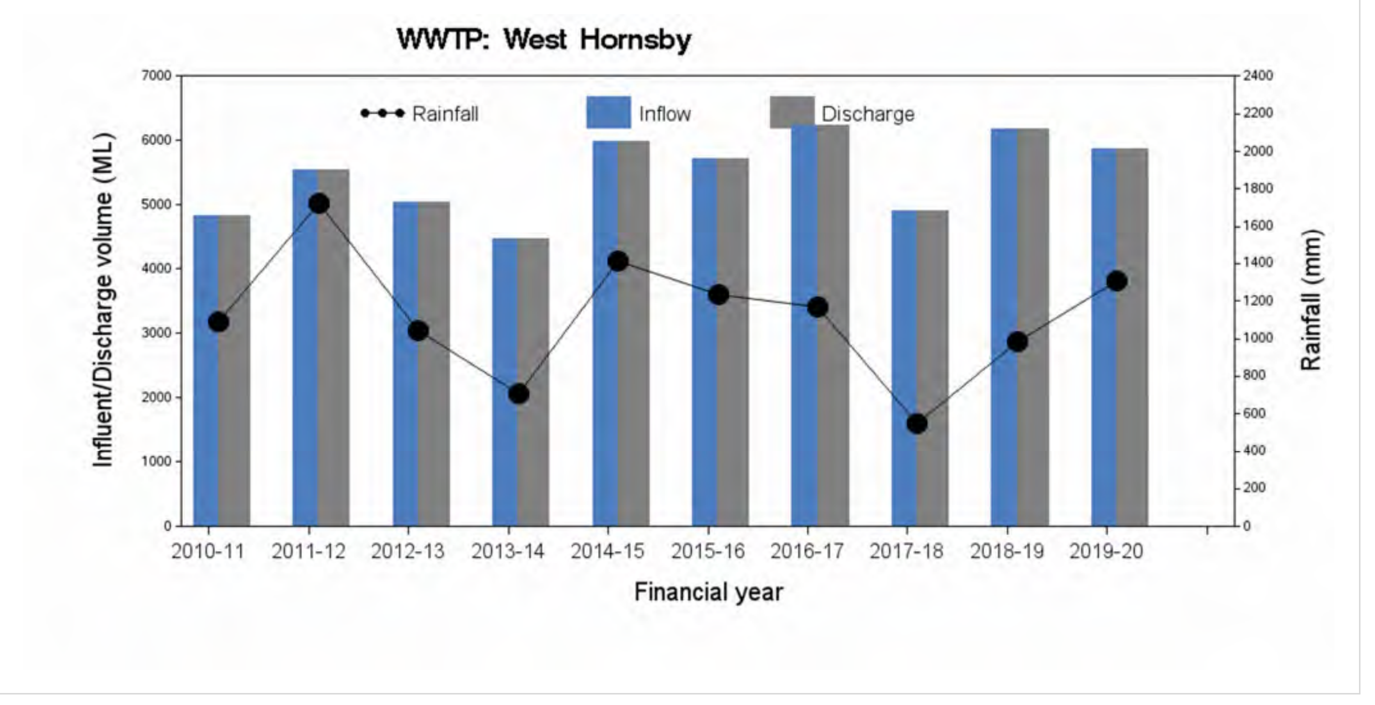
WWTP: Hornsby Heights
Sampling Point: HH0005 Effluent
Detection Limit: 0.1
Limit/Threshold: 90%ile: 2.1
Limit/Threshold: Avg: 1.6
------ 90%ile Limit
------ Average Limit
Cobalt (composite) (ug/L)
2.8
2.4
2.0
1.6
1.2
0.8
0.4
0.0
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=8.2450; Pr>F=0.0048)
Financial year



WWTP: Hornsby Heights
Sampling Point: HH0005 Effluent
Detection Limit: 0.1
Limit/Threshold: 90%ile: 2.1
Limit/Threshold: Avg: 1.6
------ 90%ile Limit
------ Average Limit
Cobalt (composite) (ug/L)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=8.2450; Pr>F=0.0048)
Financial year

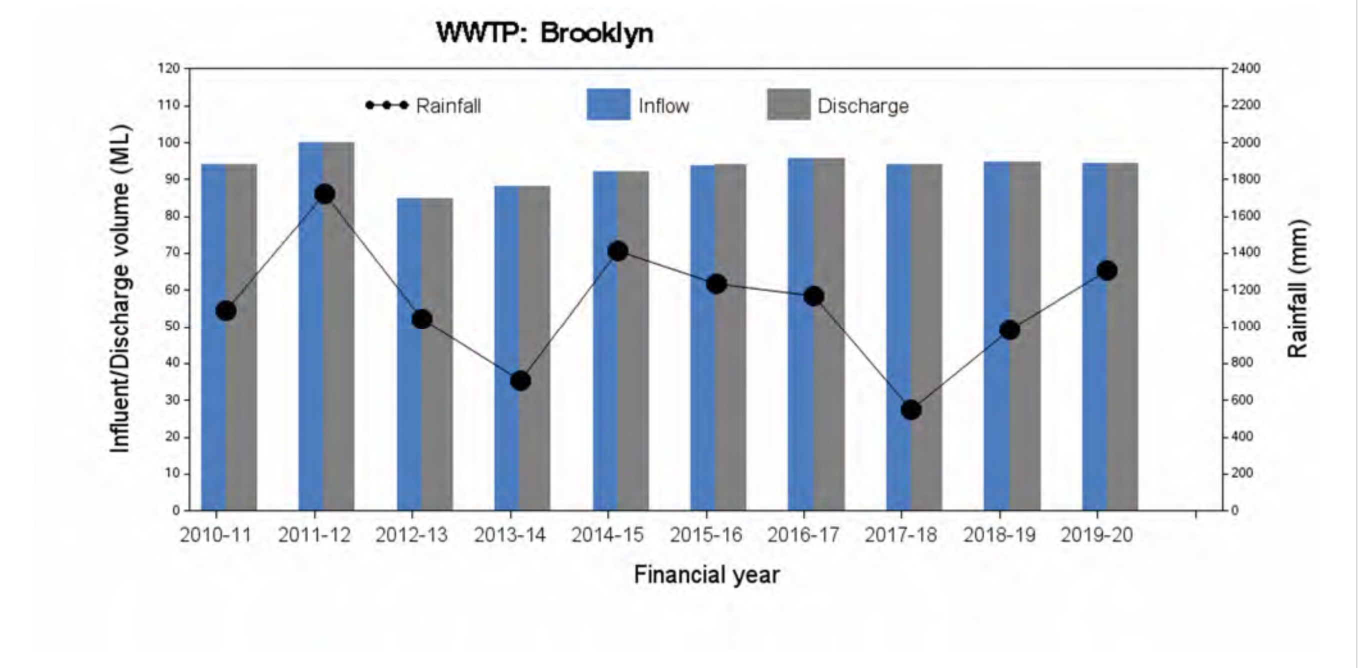
4.2.14 West Hornsby WWTP

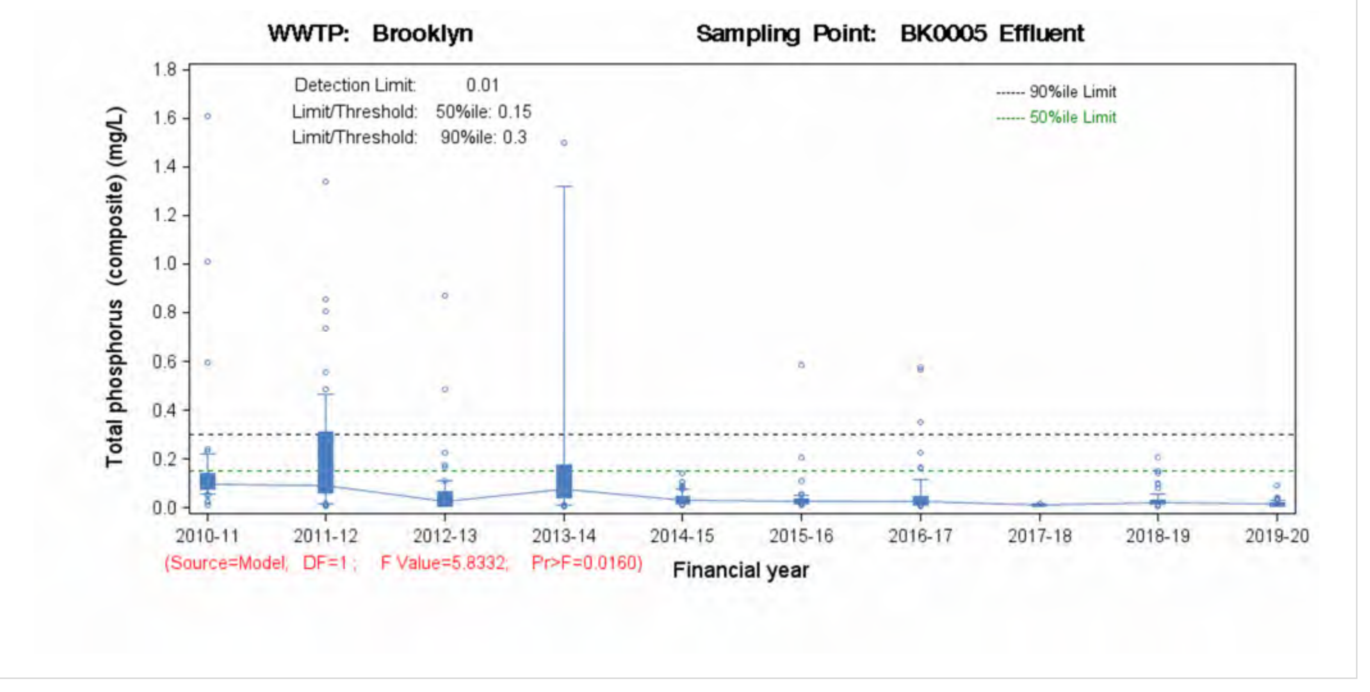
All concentration and load limits in the discharge from West Hornsby WWTP were within the EPL limits during the 2019-20 period. No significant trends were identified during 2019-20 when compared to earlier years. West Hornsby WWTP saw an increase in inflows and subsequent loads during the second half of 2020, possibly due to the COVID-19 pandemic with more people working from home.

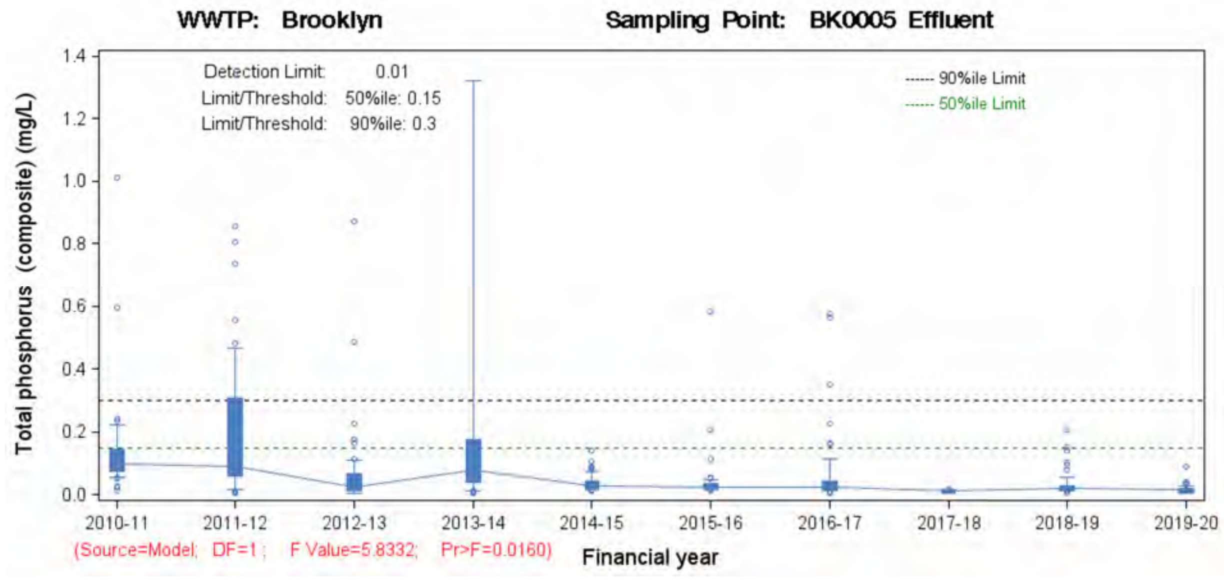


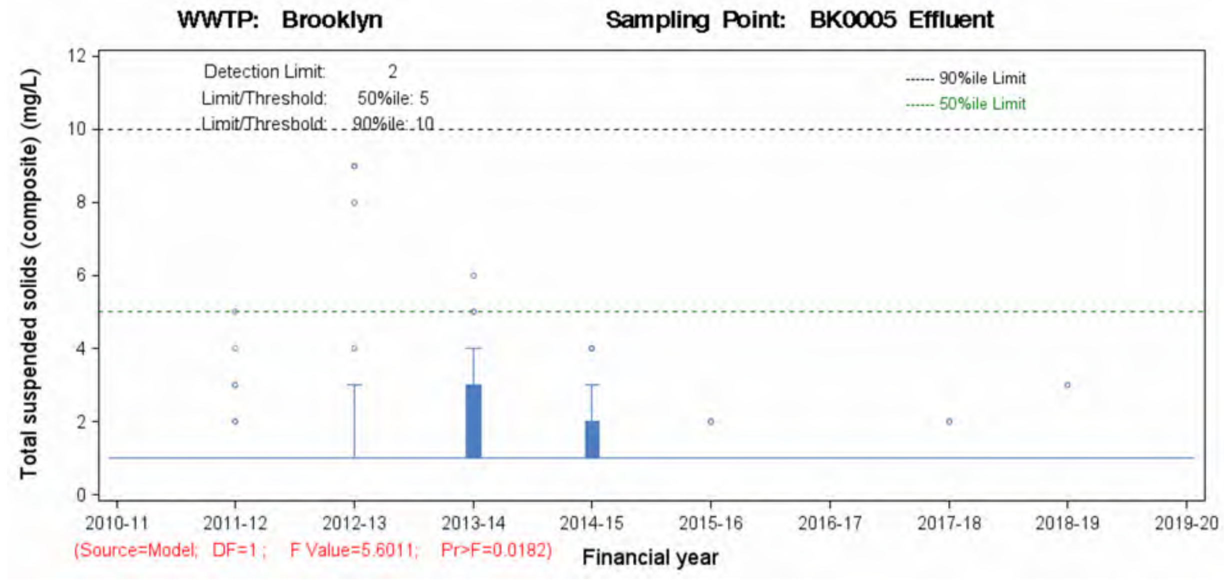
4.2.15 Brooklyn WWTP

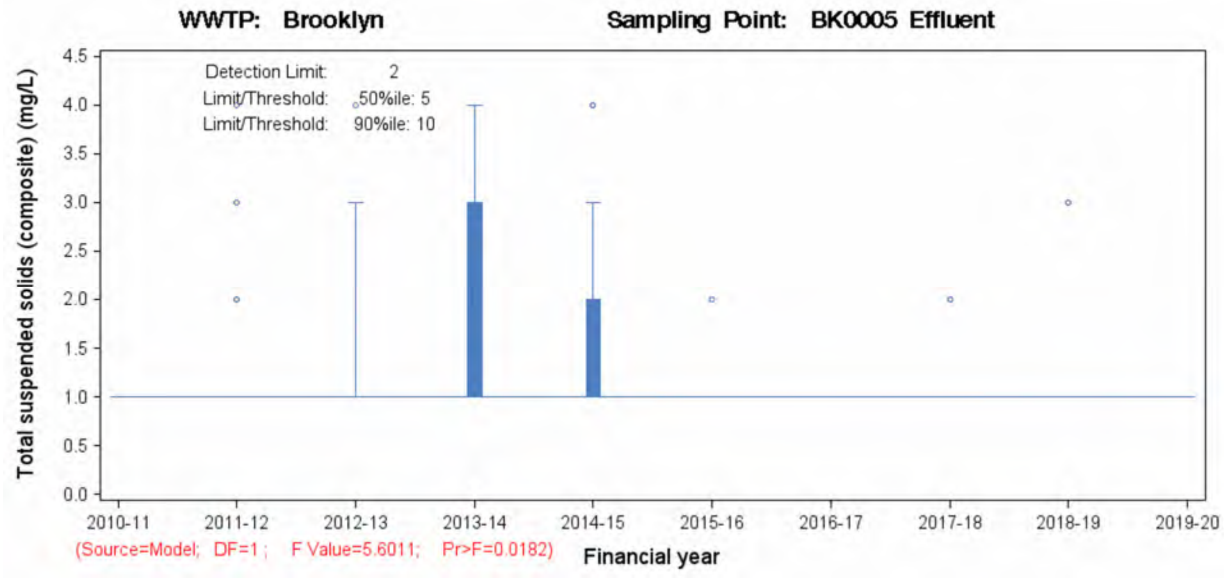
All concentration and load limits in the discharge from Brooklyn WWTP were within the EPL limits during the 2019-20 period. Statistical analysis identified a significant decreasing trend in total phosphorus and total suspended solids concentrations.






WWTP: Brooklyn
Sampling Point: BK0005 Effluent
Detection Limit: 0.01
Limit/Threshold: 50%ile: 0.15
Limit/Threshold: 90%ile: 0.3
------ 90%ile Limit
------ 50%ile Limit
Total phosphorus (composite) (mg/L)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=5.8332; Pr>F=0.0160)
Financial year


WWTP: Brooklyn
Sampling Point: BK0005 Effluent
Detection Limit: 2
Limit/Threshold: 50%ile: 5
Limit/Threshold: 90%ile: 10
------ 90%ile Limit
------ 50%ile Limit
Total suspended solids (composite) (mg/L)
12
10
8
6
4
2
0
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=5.6011; Pr>F=0.0182)
Financial year


WWTP: Brooklyn
Sampling Point: BK0005 Effluent
Detection Limit: 2
Limit/Threshold: 50%ile: 5
Limit/Threshold: 90%ile: 10
Total suspended solids (composite) (mg/L)
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=5.6011; Pr>F=0.0182)
Financial year

4.3 Wastewater overflows and leakage

Wastewater overflows can occur under dry or wet weather conditions. Ocean systems have higher overflow frequencies and volume because they are much larger systems.

The dry weather wastewater leakage detection program is undertaken to locate leakage points from the reticulated wastewater system and to enable repair of faulty assets.

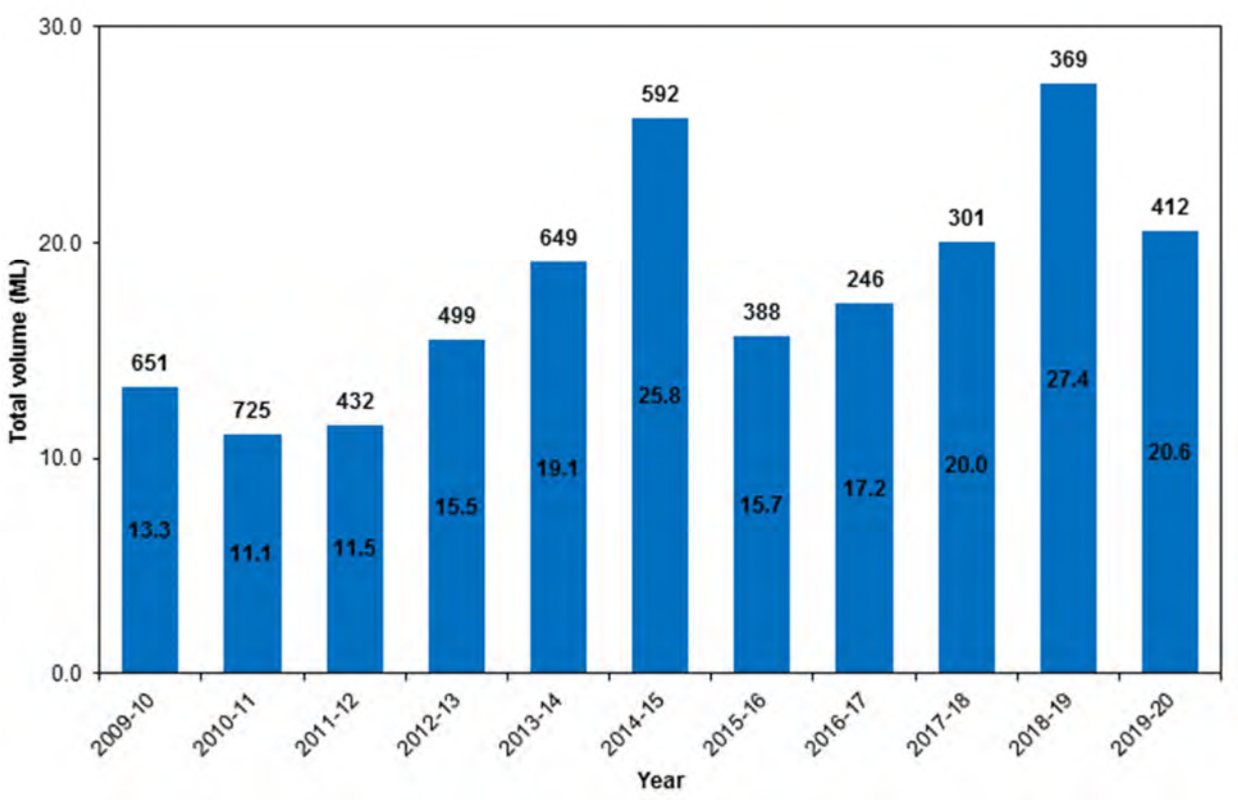
4.3.1 Dry weather overflows

Dry weather overflow trends

Eight wastewater treatment systems draining to the ocean WWTPs were responsible for a total dry weather overflow volume of 20.6 ML in 2019-20 (Figure 4-1). Further details on recent dry weather overflow data including 2019-20, by each ocean wastewater system is presented in Volume 2 Appendix E (Table E-1 and Table-E-2).

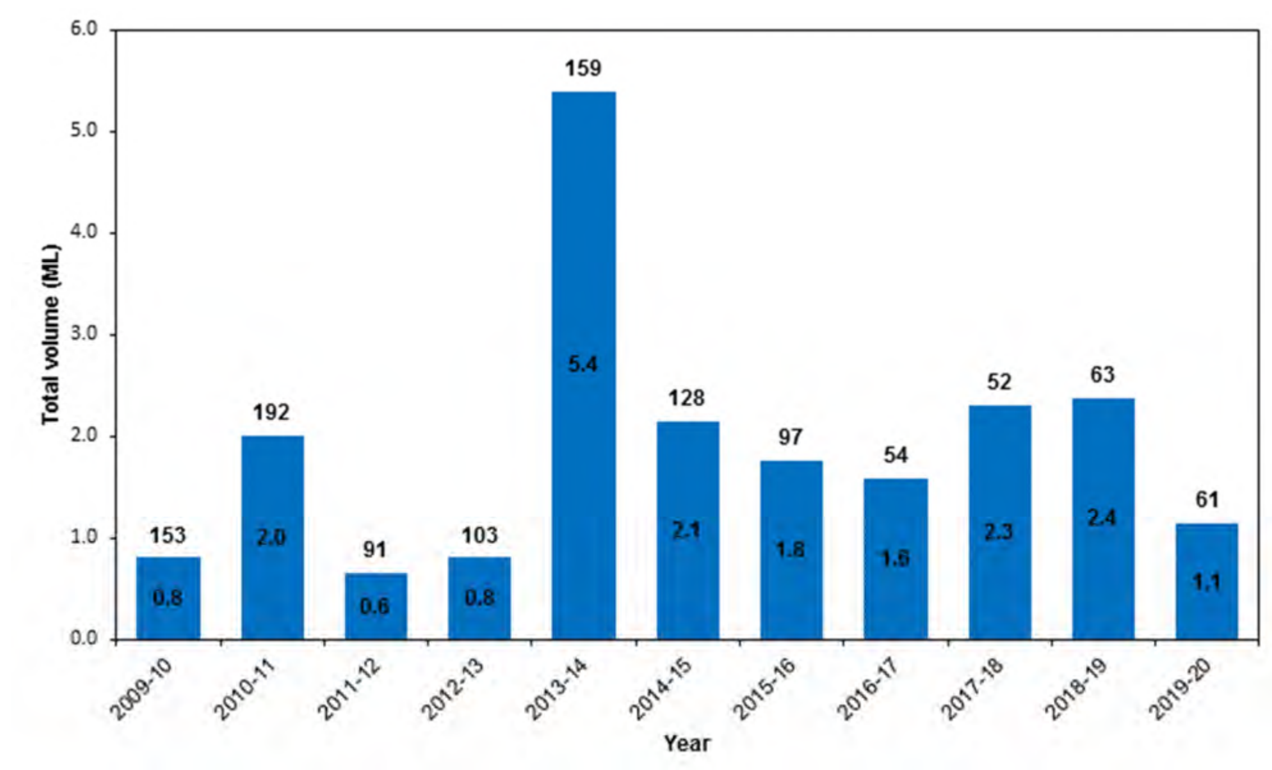
The two largest systems of North Head and Malabar were responsible for 85% of total volume of dry weather overflows (North Head 39%, Malabar 46%). The total volume of dry weather overflows from the ocean systems decreased in 2019-20 (25%) compared to the previous year (2018-19). However, the total number of overflow incidents has increased by 12% in the same period.

Twelve large inland wastewater system networks were responsible for a total dry weather overflow volume of 1.1 ML in 2019-20 (Figure 4-2). Three major inland wastewater system contributed 47% of this total dry weather overflow volume (Penrith 16%, St Marys 17% and Rouse Hill 14%). The total volume of dry weather overflows in inland systems decreased by 52% in 2019-20 compared to the previous year (2018-19). The number of incidents were also slightly lower.



Note: number of overflow events per year is shown at the top of each bar, volume (ML) at the middle of bar

Figure 4-1 Previous ten years of dry weather overflow volumes in ocean WWTP catchments



Note: number of overflow events per year is shown at the top of each bar, volume (ML) at the middle of bar

Figure 4-2 Previous ten years of dry weather overflow volumes in inland WWTP catchments

Dry weather overflow performance (EPL)

Dry weather overflow volumes are measured when an incident is reported to Sydney Water. The total number of overflows and the overflow volume are estimated by each Sewer Catchment Area Management Plan (SCAMP) and the proportion that reaches the receiving waters is reported via annual returns for each EPL.

Twelve wastewater systems have EPL specified limits on the number of dry weather overflow incidents reaching the waterways (Clause 7.4). In 2019-20 seven of these systems exceeded their respective limits.

Each SCAMP has EPL target on number of dry weather overflows reaching the waterways. Out of 215 SCAMPs with a target in EPLs, 135 were under or equal to their target and the remaining 80 areas exceeded their respective licence targets.

In 2019-20, Sydney Water experienced 17,428 blockages across all of its wastewater networks in relation to dry weather overflows (Sydney Water 2020a). The total number of wastewater overflows reaching waterways that resulted from these blockages was 473 (about 2.7%).

The overall trends in number of wastewater systems and SCAMPs that have exceeded their respective dry weather incident target limits were higher in 2019-20 compared to last four reporting years (2015-16 to 2018-19).

In 2019-20, most of the blockage occurred in small diameter pipes because of tree root entry. Altogether, 48.3% of the total blockages were caused by tree roots entering through cracks, joints and private sewers. Other causes of blockages were debris (18.1%), soft chokes due to residual solids/ wet wipes/sanitary products (17.7%) and consolidations of fats from households pouring down the sink (7.4%). A more detailed performance of dry weather overflow volume and frequency by each of the SCAMPs and wastewater systems in relation to compliance limits are presented in a separate report (Sydney Water 2020a).

This report also included detailed strategies or action lists by Sydney Water to reduce the increased volume and frequencies of dry weather overflows. The key initiatives or improvement strategies that were undertaken in 2019-20 as scheduled investigations, works and activities are:

- Improved CCTV cameras/surveillance: Inspection of pipes after overflows reaching to water to minimise repeat occurrence from the same asset
- Preventative waterway program Level 2 (Tractor CCTV): Condition assessment of pipes likely to block and overflow to waters, significant obstructions cleared by jetting using same contract resources
- Preventive waterway program Level 1 (Maintenance hole inspection and CCTV): Condition assessment of pipes and maintenance structures likely to block and overflow to waters (proactive program). Push-rod CCTV camera used. Follow-on cleaning by exception and breakdown maintenance process used to address significant blockages in pipes and structures

A list of proposed investigations and follow on works is planned for 2020-21 to minimise the dry weather overflows.

In summary Sydney Water will continue to monitor the performance and the progress of the new condition assessment tactics during 2020-21. This new approach aims to inspect far greater length of sewer and high flow reticulation sewer main per annum. The focus will be to target poor performing wastewater systems and SCAMPS not meeting licence targets in 2019-20.

4.3.2 Wet weather overflows

Modelled occurrence and volume of wet weather overflows

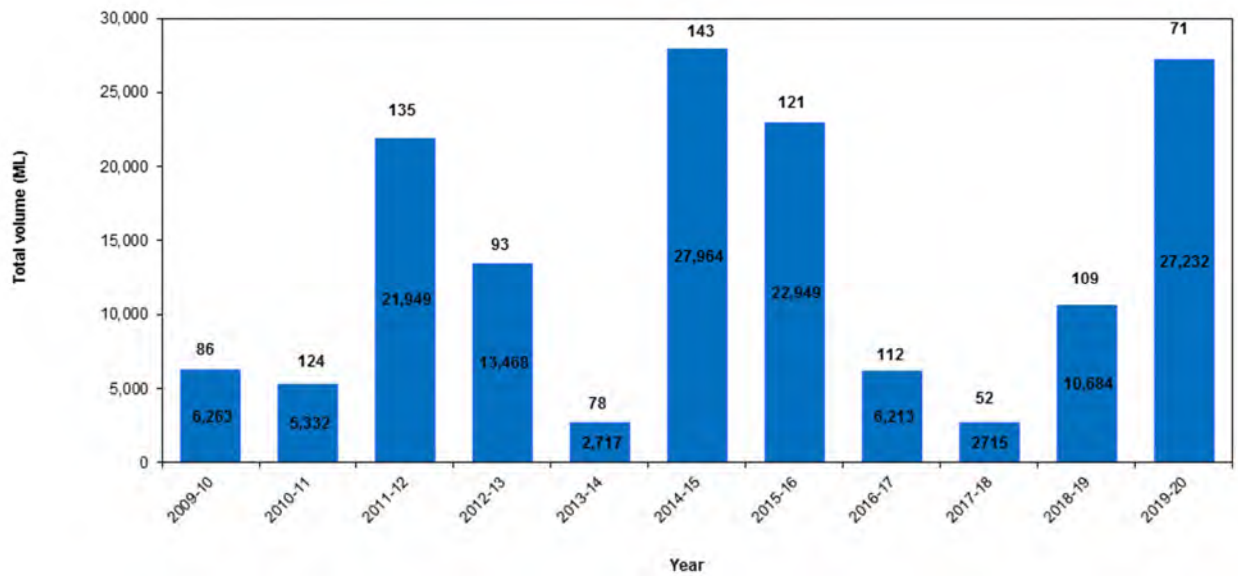
Each year, the wastewater system's wet weather overflow performance (system performance) is compared against the benchmark year system performance or target system performance, to determine if any deterioration has occurred. Sydney Water has developed hydraulic sewer models that are calibrated yearly using strategic sewer and rainfall gauging of the systems (calibrated using ten years of data) and are a requirement of our EPLs. These models allow a direct comparison of system performance between periods of differing rainfall.

Wet weather wastewater overflows occur when the capacity of the network is overloaded. To estimate the volume of these overflows, a model is run based on an established protocol, the 'Trunk Wastewater System Model` Update, Re-calibration and Annual Reporting Procedure'.

The total number of wet weather overflow events refers to the total number of individual overflow events from all overflow locations (mostly designated emergency relief structures) for all wastewater systems.

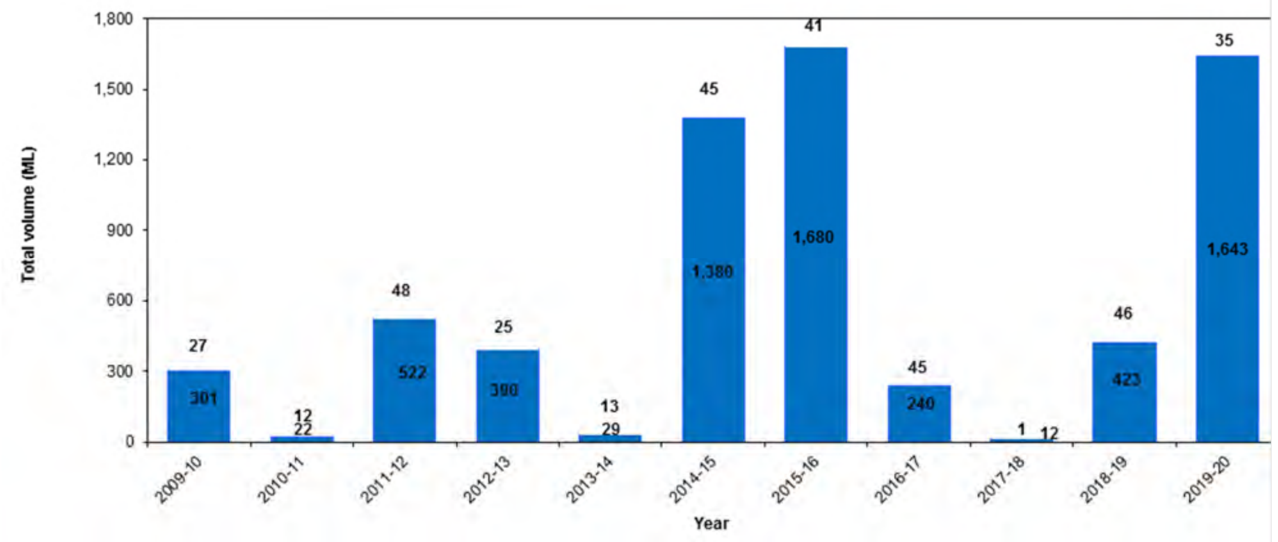
The trends in wet weather overflow frequency or number of incidents decreased in 2019-20 compared to last year (2018-19). However, the volume from both the ocean and inland systems notably increased in 2019-20 following three successive years of comparatively low volumes (Figure 4-3 and Figure 4-4). The increases in wet weather overflow discharge volume from previous year (2018-19) from the ocean and inland system were 155% and 288%, respectively. This was partly due to above average rainfall in 2019-20.

Further details on the recent wet weather overflow data including 2019-20, by each ocean wastewater system is presented in Volume 2 Appendix E (Table E-3 and Table E-4).



Note: number of overflow events per year is shown at the top of each bar, volume at the middle of bar

Figure 4-3 Previous ten years of modelled wet weather overflow volumes by all ocean wastewater systems



Note: number of overflow events per year is shown at the top of each bar, volume at the middle or lower right of bar

Figure 4-4 Previous ten years of modelled wet weather overflow volumes by all inland wastewater systems

Wet weather overflow performance

Of the 23 wastewater treatment system models Sydney Water maintains, three system models were assessed as non-compliant with condition L7.1 during 2019-20 (Table 4-3). Thirteen wastewater treatment systems complied with EPL conditions L7.2 or O4.8(c) and O4.9. Two systems (Picton and Brooklyn-Dangar Island systems) don't have condition L7.2 or O4.9 and hence were not assessed for EPL compliance conditions. The remaining seven systems did not comply with either full or partial treatment conditions for wet weather overflows (Table 4-3). The reason for these non-compliances were investigated individually to prevent re-occurrences. Detail of the mitigation measures and progress was reported via the Annual Sewage Treatment System Performance Report - Wet Weather Overflow (Sydney Water 2020b).

Table 4-3 List of wet weather overflow non-compliances by EPL clause (2019-20)

Wastewater system EPL Clause	Non-compliant systems
L7.1 Ongoing use and development of a high-quality Hydraulic System Sewer model.	Wollongong, Shellharbour and Malabar
L7.2 Wet weather overflow limits	North Richmond, Wallacia, Shellharbour, St Marys, Wollongong and Rouse Hill
O4.8 (c) Comparison of modelled wet weather overflows	Malabar
O4.9 Wet weather partial treatment discharges	Fairfield (Malabar)

4.3.3 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 211 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).

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 had the potential to cause the high faecal coliform result. Due to the time involved in completing the desktop investigations and the delay between an exceedance result occurring and a desktop investigation being completed, 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 2019-20 there were 232 routine site visits for the DWLP across Sydney, Blue Mountains and the Illawarra. Of the 211 SCAMPs, 17 annually monitored sites were dry or ponded at the time of sampling indicating no dry weather leaks. Forty sites (19%) exceeded the 10,000 cfu/100 mL faecal coliform threshold at least once during the year, and 154 sites (73%) had faecal coliform results below the threshold. Figure 4-5 shows the pattern of compliance for the last ten years. All years have been compared against the EPL faecal coliform threshold (10,000 cfu/100 mL). Over the past ten years, the percentage of sites exceeding the threshold has ranged from 10% (2016-17) to 21% (2018-19).

Figure 4-6 displays a map of ranked SCAMP performances for the last ten 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 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 six SCAMPs that exceeded most often were Camperdown (77%), Edgecliff (76%), South Sydney (70%), Homebush (69%), Ashfield (68%) and Summer Hill (65%), identified by the dark orange regions. Eight SCAMPs exceeded 40-65% of the time (pale orange regions; Liverpool (59%), Glenfield (57%), Bexley (48%), Bankstown (47%), Kogarah (47%), Leichhardt (44%), Manly (42%) and Alexandria (41%). Thirty sites exceeded 20-40% of the time (pale yellow regions), 69 sites exceeded 1- 20% of the time (pale green regions) and 98 SCAMPs were consistently below the threshold (dark green regions) and have never recorded an exceedance.

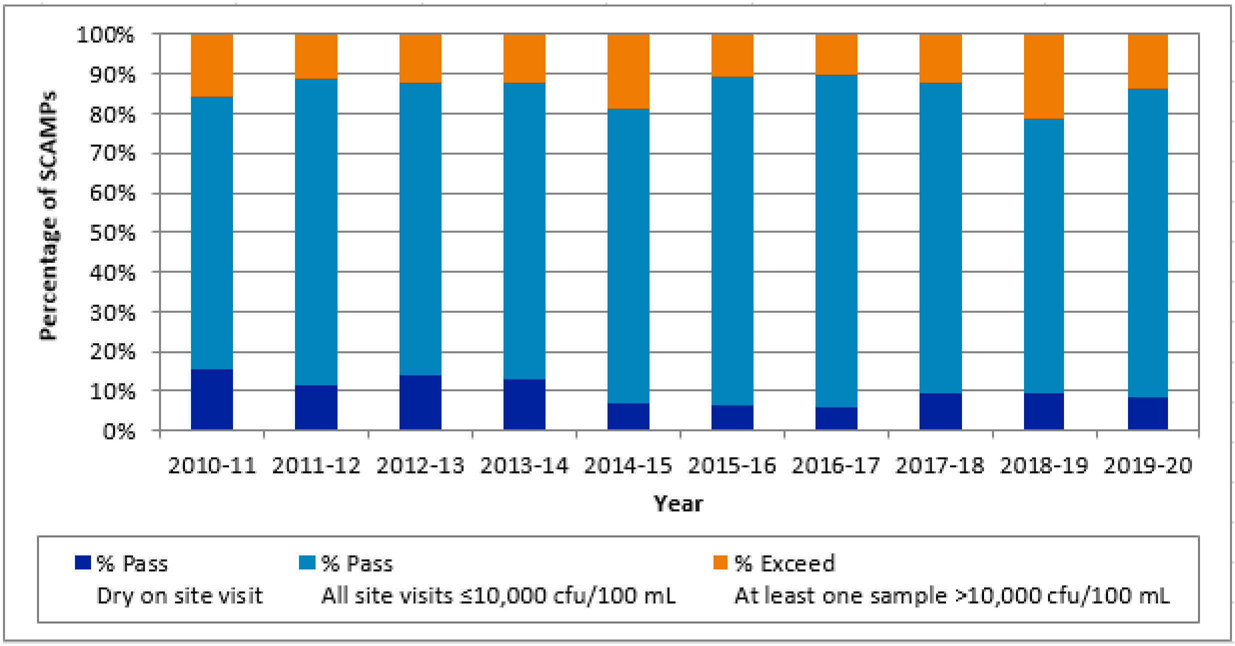
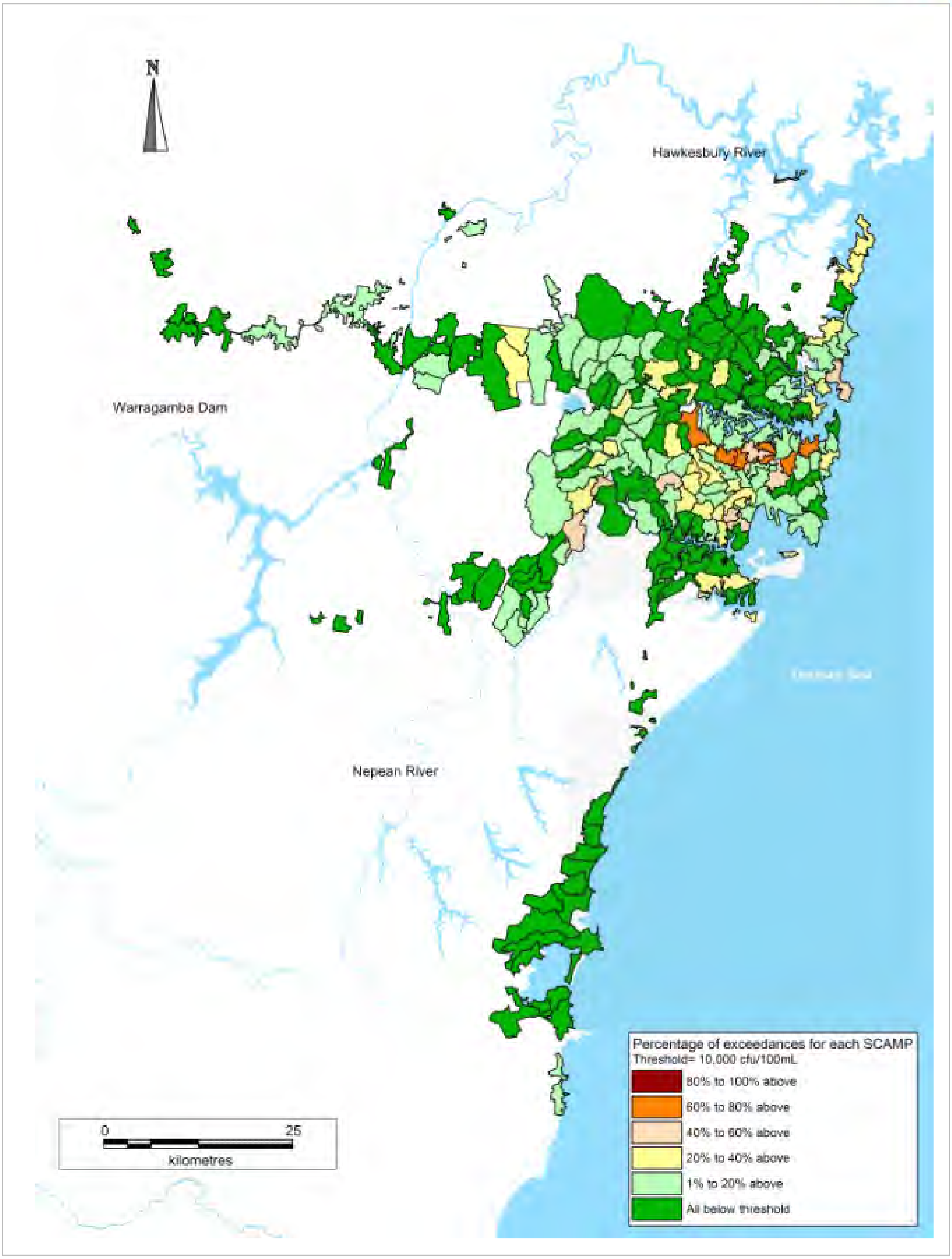


Figure 4-5 Percentage of SCAMP samples that were below (passed) or exceeded the faecal coliform threshold of 10,000 cfu/100 mL between 2010 and 2020

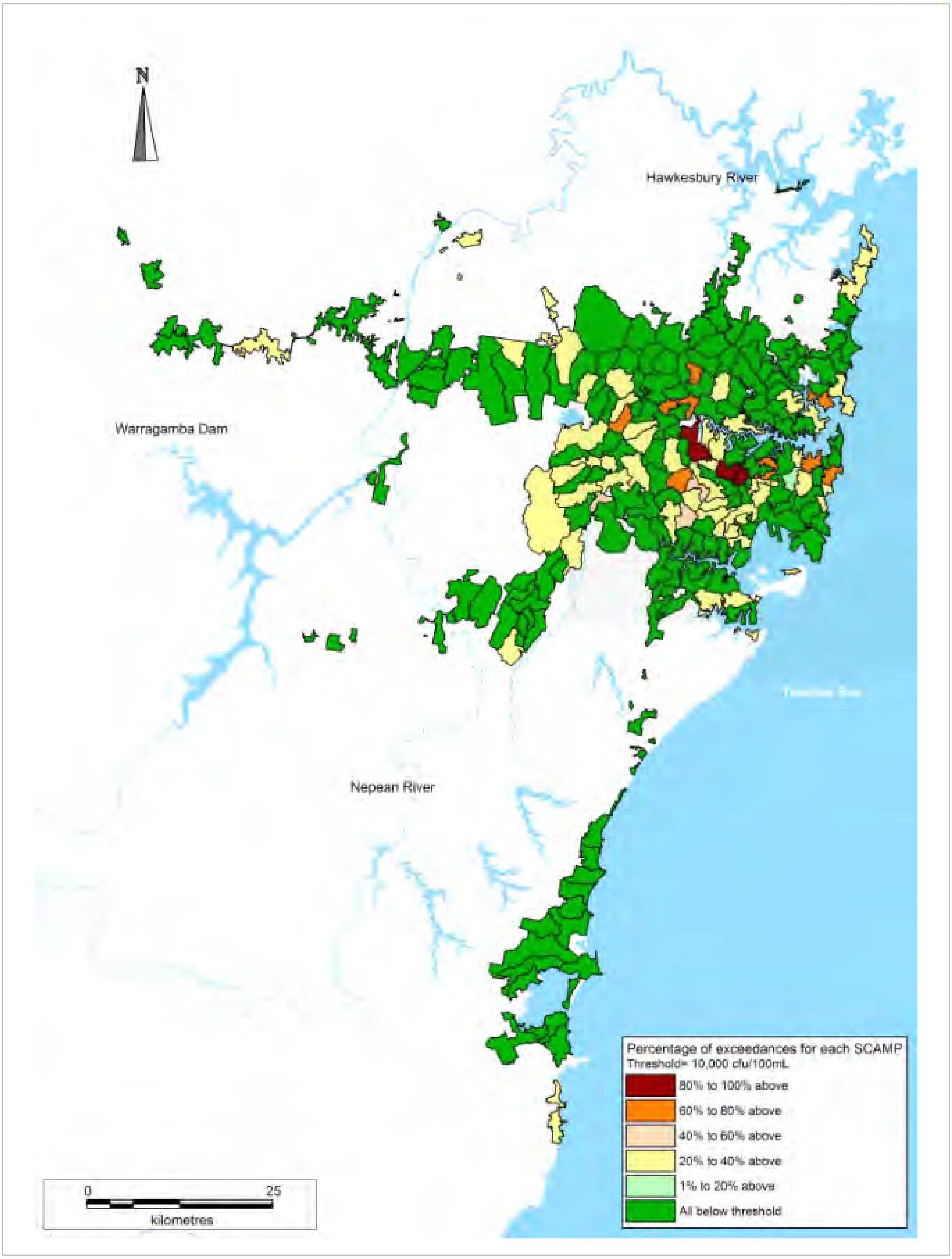
Figure 4-7 ranks the performance of SCAMPs over the most recent three years of the program. In general, the inner city and inner west regions of Sydney remained the key focus areas for the program and recorded the most exceedances. The three SCAMPs that exceeded most often were Homebush (88%), Ashfield (83%) and Summer Hill (83%), identified by the dark red regions. Areas of increased exceedances ranked above 60% include Edgecliff, Bondi Beach, Camperdown, Greenacre, Balgowlah Heights, Dundas, Epping and South Wentworthville (dark orange). Less significant increases were also evident at SCAMPs in the south-west, inner-west, northern beaches, north shore and north-west areas of Sydney (pale yellow regions). Similar to the ten-year exceedance trends, the areas experiencing the greatest exceedances tend to be the areas with the oldest wastewater infrastructure. In the last three years, 147 SCAMPs have recorded no exceedances at all. The SCAMPs that have increased exceedances in the last three years generally represent the catchments with current and ongoing source detection investigations. Source detection work in 2019-20 identified approximately 31 individual leakage issues associated with Sydney Water assets including private and illegal wastewater-stormwater connections. The significant findings from the SCAMPs where these faults were identified are detailed in Table 4-4. Additionally, special investigations completed outside of the DWLP routine monitoring program were responsible for the identification and rectification of several faults. Investigations in the Homebush and Ashfield SCAMP's are ongoing. Potential sources of contamination have been identified, however subsequent sampling identified ongoing issues requiring further rectification and investigation.

Internet of Things (IoT) devices are planned in sensitive environmental areas to detect wastewater blockages and react before they become an overflow. Under this program, 23 designed overflow points in the Chatswood SCAMP are planned to be monitored by overflow sensors.



Note: Each site is only counted once per year. If it was sampled multiple times and was always below the threshold it is counted as a pass. If it was sampled multiple times and failed the threshold at least once, it is counted as an exceedance.

Figure 4-6 Percentage of exceedances for each SCAMP over the last ten years of the DWLP, including 2019-20 data



Note: Each site is only counted once per year. If it was sampled multiple times and was always below the threshold it is counted as a pass. If it was sampled multiple times and failed the threshold at least once, it is counted as an exceedance.

Figure 4-7 Percentage of exceedances for each SCAMP over last three years of the DWLP, including 2019-20 data

Table 4-4 SCAMP catchment investigation findings and status for the 2019-20 period

SCAMP	Outcome of investigations	Fault status	Investigation status
Bondi Beach	Routine sampling identified sewer leak. Multiple catchment investigations between March and April 2020 identified the source in Hall Street, Bondi.	Networks facilitated containment and pump out downstream of Campbell Pde above Gross Pollutant Trap. Dig, repair and patching of line completed. Council notified of damage to stormwater.	Investigation closed
	CCTV investigations confirmed sewer leaking into stormwater and several major issues with Sydney Water sewers and Council stormwater.		
Camperdown	Catchment investigations completed in July 2019 indicated sewer leakage at several upstream sites. CCTV investigation in July 2019 identified location of leaks.	Reactive sewer lining completed in Victory Lane, Camperdown.	Open Investigations ongoing
	Odour complaint in December 2019 near Harold Park traced to potential leak upstream to Bell Lane, Glebe. CCTV identified multiple sewer line displacements, dye testing confirmed sewer leaking to stormwater. This investigation also identified an un-mapped and damaged junction entering sewer at southern end of Bell Lane.	Rectification works completed February 2020.	
	Further investigations in March 2020 found results remained above threshold. Source traced to an area around Hampshire St, Church St and Victory Ln consisting of defective junctions, displaced joints and fractures.	Rectification works including concrete grinding, lining, dredging and relining.	
	Investigation of underground stormwater identified potential sewer leak on Albion St, Annandale.	Still under investigation.	
Edgecliff	Investigations found sewer in stormwater, civil crew located a fault in Comber Street.	Comber St fault repaired.	Open Investigations ongoing
	Catchment investigations in December 2019 and March 2020 indicated ongoing sewer leakage upstream of Boundary St, Paddington. CCTV conducted in June 2020 at Kidman Ln, Paddington found multiple fractures and displacements, bulging liner restricting flow and two damaged manholes.	Reactive sewer relining completed, damaged maintenance holes repaired and bulging liner repaired robotically.	
Ashfield	Catchment investigations in November 2019 identified a private leak on a joint house sewer line at 61-67 Heighway Ave, Croydon, which was flowing into stormwater easement	Owner of 67 Heighway Ave notified and private plumber rectified the damage.	Open Investigations ongoing

SCAMP	Outcome of investigations	Fault status	Investigation status
	for the properties. Further testing located a damaged private sewer at 67 Heighway Ave.		
	Verification sampling in February 2020 indicated ongoing leakage in the same stormwater easement. Dye testing in February & March 2020 indicated a second private fault at 69 Heighway Ave. Subsequent investigations indicate that issues are ongoing in this catchment.	Owner of 69 Heighway Ave notified, plumber rectified the damage.	
Belmore	Catchment investigations in July and November 2019 indicated potential intermittent leaks. This lead to further investigations in December 2019 and January 2020 with dye testing which identified a collapsed sewer and storm water at 66 Second Ave, Campsie.	Canterbury-Bankstown Council advised of storm water damage and need of repair. Private repairs completed.	Open Investigations ongoing
	Further catchment investigations in April 2020 found elevated faecal coliform results. Continued investigations in May 2020 to investigate the source.		
Campsie	Catchment investigations conducted in May and June 2020 returned elevated faecal coliform results, but source is yet to be located.	No rectification action at this time.	Open Investigations ongoing
Greenacre	Rectification work for previous faults was completed in July 2019. Catchment investigations in November 2019 and routine sample from January 2020 found evidence of sewer leak. Sewer detection dogs identified sewage coming from storm water outlet on east side of Juno Pde, which was confirmed by faecal coliform analysis. A private fault on Yerrick Rd was requested to be fixed on 12/9/19. Investigations found that the private fault on Yerrick St was still ongoing. Council notified of the issue.	Private fault still ongoing. Council has been notified.	Open Investigations ongoing
	The sewer detection dogs also detected another inflow at Defoe St which was traced to storm water pit at the corner of Robinson St North and Defoe St. Subsequent CCTV in February 2020 found a significant break in the sewer as well as several sections of displacement and defective junctions.	Robinson St North repair works completed in February 2020.	

SCAMP	Outcome of investigations	Fault status	Investigation status
	CCTV conducted near 9 Juno Pde in May 2020 found defective junctions and a break in the sewer line.	Juno Pde repair works completed in May & June 2020	
Homebush	Multiple catchment investigations were completed between July & October 2019. Multiple point sources of pollution were identified at 90-95 The Crescent, Homebush. Council notified that the property did not have a sufficient trade waste management system. A sewer leak entering storm water was also identified at the same property. Another private fault was also identified at 1-9 Kanoona Ave, Homebush and Council notified.	Strathfield Council agreed to manage both faults and issued rectification notices to property management. Council gave 14 days to rectify sewer leak. Confirmed that private fault at 1-9 Kanoona Ave was rectified.	Open Investigations ongoing
	Investigations in April & May 2020 found three separate private leakage issues. Leakage identified in storm water adjacent to Bates St, Homebush. A second suspected leak coming from Flemington Markets, with multiple storm water inflows returning high range bacteriological results. A third was identified entering Cox's Ck beneath Eco-farms market 167-173 Parramatta Rd, Homebush. Strathfield Council notified of all three leaks.	Council notified.	
	CCTV & dye testing in May 2020 identified damage on customer junction at 12 Bates St. Dye testing at this property confirmed a sewer leak present. Following the repair of the junction, dye testing showed a leak still existed and property owner was notified, as was Strathfield Council.	Property owner and Council notified. Strathfield Council agreed to manage rectification.	
Kensington	Investigations on April & May 2020 found point sources of sewage contamination. The horse stables at Randwick Racecourse were the source of pollution. Randwick Council was notified.	Randwick Council confirmed that works at the Racecourse are underway to reduce faecal contamination of storm water.	Open Investigations ongoing
Kingsgrove	Routine sample (January 2020) and resample, both exceeded the faecal coliform threshold. An overflow from an Environmental Response job was found to be the source of these exceedances. Investigations in January 2020 could not find evidence of leaks. In May 2020, all sample results were below threshold.	No rectification works. Found to be related to Environmental Response job.	Investigation Closed

SCAMP	Outcome of investigations	Fault status	Investigation status
Liverpool	Routine sampling in February 2020 and resample in March 2020 identified results above the faecal coliform threshold. Investigations observed pulp on substrate at stormwater outlet near the routine site. Follow up investigation sites returned results below threshold, including the routine site.	No rectification action at this time.	Investigation Closed
Summer Hill	Continuing investigations found a private sewer leak at the Meriton apartment complex on Hudson St, Lewisham. Further investigations in August 2019 confirmed the location and building management were notified. Private plumber reported a cross-connection of sewer and storm water.	Tree roots cleared from customer junctions at end of laneway to Seaview St. Private plumber rectified cross connection; also jet blasted and cleaned the pipe and Stormwater Quality Improvement Device pits.	Open Investigations ongoing
	Multiple investigations between September 2019 and April 2020 indicated ongoing sources of sewage contamination upstream.	No rectification action	
Sydenham	Routine sample in April 2020 and resample from May 2020 exceeded the faecal coliform threshold. Investigations are yet to commence.	No rectification action	Open Investigations ongoing
Balgowlah Heights	Routine sample in August 2019 exceeded threshold. Subsequent investigations confirmed sewage entering stormwater between Glade St & Ernest St, Balgowlah Heights. CCTV identified moderate displacement of sewer in Glade St. The investigation also identified a sewer overflow from manhole, which was contained, cleared and cleaned up.	No rectification action	Open Investigations ongoing
	CCTV in January 2020 identified significant damage to several sections of sewer in Ernest St. Multiple emergency patches were installed and a customer junction was found full of tree roots, with jetting to clear the roots arranged.	Emergency patches installed on four assets. Tree roots removed from junction.	
	Investigations in March 2020 confirmed leaks upstream of Ernest St. This was traced to stormwater line downstream of Nolan Pl. CCTV and dye testing was conducted in May 2020 which identified a private leak at 10 Nolan Pl. The owner engaged a private	Private plumber confirmed & rectified collapsed sewer & storm water services at 10 Nolan Pl. Two patches to be installed.	

SCAMP	Outcome of investigations	Fault status	Investigation status
	plumber to rectify the fault. Two sections of sewer were found to require patches.		
Epping	Routine sample in July 2019 confirmed ongoing issue in this SCAMP. CCTV investigation were conducted within a housing complex at 13 Carlingford Rd. Significant fracturing was found in the Sydney Water sewer. Repairs were completed and verification testing showed unresolved sources of sewage intrusion. June 2020 - all repair works had been completed and samples confirmed that this fault had been rectified. However, sample from the routine site indicated a potential new leak within the catchment.	Fractured assets were patched; other damaged assets were dug up and repaired.	Open Investigations ongoing
Holroyd	Routine sampling in July 2019 exceeded the threshold. While conducting the resample, a cracked sewer line discharging into the creek was discovered. This was managed by the Environmental Response project.	Managed by ER project	Open Investigations ongoing
	Investigation in October and November 2019 indicated an upstream sewage leak. In December 2019 a private sewer leak near Dressler Court, Merrylands, was identified which was referred to Cumberland Council. Further investigations in February and May 2020 have progressed the focus towards Newman St.	Private leak in Dressler Court referred to Cumberland Council	
Richmond	Routine sampling in March 2020 identified a potential sewer leak. Investigations, including CCTV, in April and May 2020, identified a sewer leak from the base of a council storm water easement at Faithful St, Richmond. A choke in the sewer line was also identified and cleared. Work orders have been raised for lining the sewer main and jetting customer junctions.	Choke cleared in May 2020. Work orders raised for installing a patch liner to repair a leak and to undertake junction jetting.	Open Investigations ongoing
Blackett	Routine sampling in February 2020 identified a potential sewer leak. Investigations in May 2020 have indicated an ongoing issue further up the catchment.	Investigation is ongoing.	Open Investigations ongoing

4.4 State of ocean environment

4.4.1 Ocean receiving waters

Out of eight chemicals assessed in 2019-20, only the modelled copper concentrations in the receiving waters at the edge of the mixing zones of all three deepwater ocean outfalls exceeded the ANZG (2018) guideline for protection of 95% of marine species. A summary of results can be found in Volume 2 Appendix F.

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 Simson 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).

4.4.2 Ocean sediment program

The current 2020 assessment year data has been analysed together with previous assessment years data from 2002, 2005, 2008, 2011, 2014 and 2016 with outcomes presented in the Ocean Sediment Program 2020 Assessment Year Report.

4.5 State of coastal environment

4.5.1 Harbour and beaches

Based on the assessment of the dry weather Beachwatch data there were 156 individual exceedances identified as having *Enterococci* levels above the ANZECC (2000) primary contact recreational guideline (>35 cfu/100mL) (Volume 2: Appendix H; Table H-5). Seventy five out of the 114 Beachwatch sites recorded one or more exceedance in dry weather during the 2019-20 period (Volume 2, Appendix H, Table H-1).

A desktop investigation was conducted for each of the 156 dry weather Beachwatch exceedances to determine a likely explanation for the elevated *Enterococci* levels. The investigation focused on assessing data collected at sites sampled under the Environmental Response (ER) and Dry Weather Leakage Program (DWLP) projects. 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 sewage 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 156 Beachwatch exceedances. Any site sampled under the ER or DWLP that met the above criteria and occurred within 7 days prior and 7 days after the Beachwatch exceedance was deemed to have a potential impact.

Using the above methodology for 2019-20, wastewater overflows may have impacted *Enterococci* levels at 12 of the 75 Beachwatch sites (Narrabeen Lagoon at Birdwood Park, Gymea Bay Baths, Brighton Le Sands Baths, Bronte Beach, Clifton Gardens, Coogee Beach, Davidson Reserve, Frenchmans Bay, Gunnamatta Bay Baths, Kyeemagh Baths, Rose Bay Beach and Tamarama Beach) (Table 4-6).

Table 4-6 Short-listed beaches, harbours and estuarine monitoring sites with possible pollution from wastewater overflows during 2019-20

Site name	Sampling date	*Enterococci* (>35 cfu/100mL)	Conductivity (µS/cm)	Comments
Sydney Beaches				
Bronte Beach	24/01/2020	38	54200	There were no incidents during the 7 days prior to the Beachwatch exceedance. One ER incident occurred on 28/01/2020 and the sample collected from Bronte Beach was above the primary contact threshold. It is unknown if there was any ongoing impact prior to the ER incident notification on 28/01/2020 that may have contributed to the Beachwatch exceedance.
Coogee Beach	4/09/2019	70	53900	One ER incident occurred on 04/09/2019 with a potential to impact Beachwatch results collected on the same day. A sample was collected from the stormwater outlet at the northern end of Coogee Beach that exceeded the primary contact threshold. However, a sample collected from the swimming area was below the primary contact threshold.
Narrabeen Lagoon (Birdwood Park)	18/06/2020	36	49800	One ER incident occurred on 18/06/2020 with the potential to impact Beachwatch results collected on the same day. The sample was collected in a stormwater gully that flows into Mullet Creek, and is approx. 1.6 km upstream of the Beachwatch site.
Tamarama Beach	16/10/2019	120	54100	One ER incident occurred on 2/10/2019 which had the potential to impact Beachwatch results on 16/10/2019. Samples taken from the stormwater outlet at the southern end of Tamarama beach exceeded Primary contact threshold, however, samples collected at the northern end of the beach were below threshold.
Illawarra Beaches				
NA				
Sydney Harbours and Estuaries				
Brighton Le Sands Baths	24/02/2020	150	43800	One ER incident occurred on 22/02/2020 which had the potential to impact Beachwatch results on 24/02/2020. Due to the natural direction of flow being parallel to the beach and flowing away from the Beachwatch site, it is unlikely that this incident contributed to the exceedance.

Site name	Sampling date	*Enterococci* (>35 cfu/100mL)	Conductivity (µS/cm)	Comments
Clifton Gardens	24/01/2020	64	54200	One ER incident occurred on 14/01/2020 which had the potential to impact Beachwatch results on 24/01/2020.
Davidson Reserve	20/03/2020	44	40300	One ER incident occurred on 19/03/2020 which had the potential to impact Beachwatch results on 20/03/2020. The nearest sample was collected at Roseville Marina, approx. 850 m downstream of the Beachwatch site. It is also noted that there was 17.6 mm of rain on 17/03/2020, which may have contributed to the exceedance.
Frenchmans Bay	14/11/2019	58	54100	One ER incident occurred on 08/11/2019 which had the potential to impact Beachwatch results on 14/11/2019. Samples collected from Yarra Bay Beach exceeded the primary contact threshold, however, samples that were collected closer to Frenchmans Bay were below the threshold.
Gunnamatta Bay Baths	26/02/2020	44	49400	One ER incident occurred on 21/02/2020 which had the potential to impact Beachwatch results on 26/02/2020.
Gymea Bay Baths	26/02/2020	44	43000	One ER incident occurred on 11/02/2020 which had the potential to impact Beachwatch results on 26/02/2020. Sampling on 23/02/2020 showed results above the primary contact threshold.
Kyeemagh Baths	28/01/2020	98	52600	One ER incident occurred on 05/02/2020 which had the potential to impact Beachwatch results on 28/01/2020. Samples collected at Muddy Creek approx. 1.6 km upstream of Beachwatch site were above the primary contact threshold. It is unclear when this incident started and if it contributed to the Beachwatch exceedance.
Rose Bay Beach	04/05/2020	140	53800	One ER incident occurred on 28/04/2020 which had the potential to impact Beachwatch results on 04/05/2020. Samples collected along Rose Bay beach were above the primary contact threshold.

4.5.2 Chlorophyll-*a* trends at estuarine sites

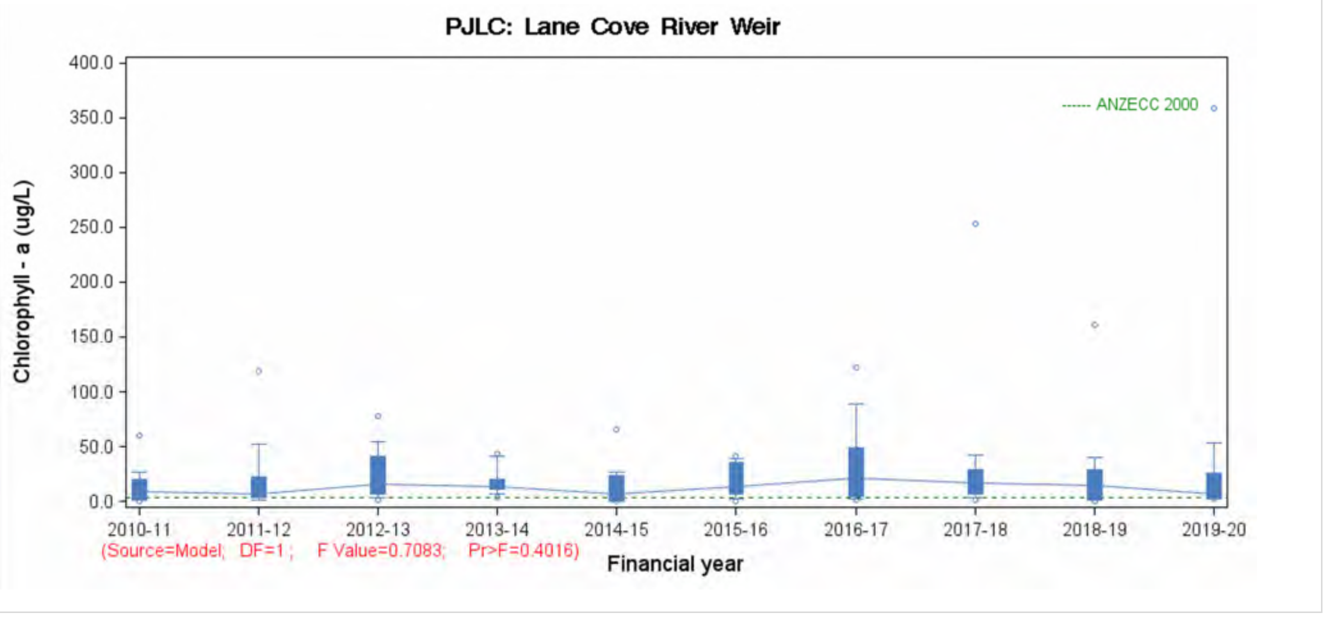
The yearly trends in chlorophyll-*a* at all estuarine monitoring sites are presented in Volume 2 Appendix I.

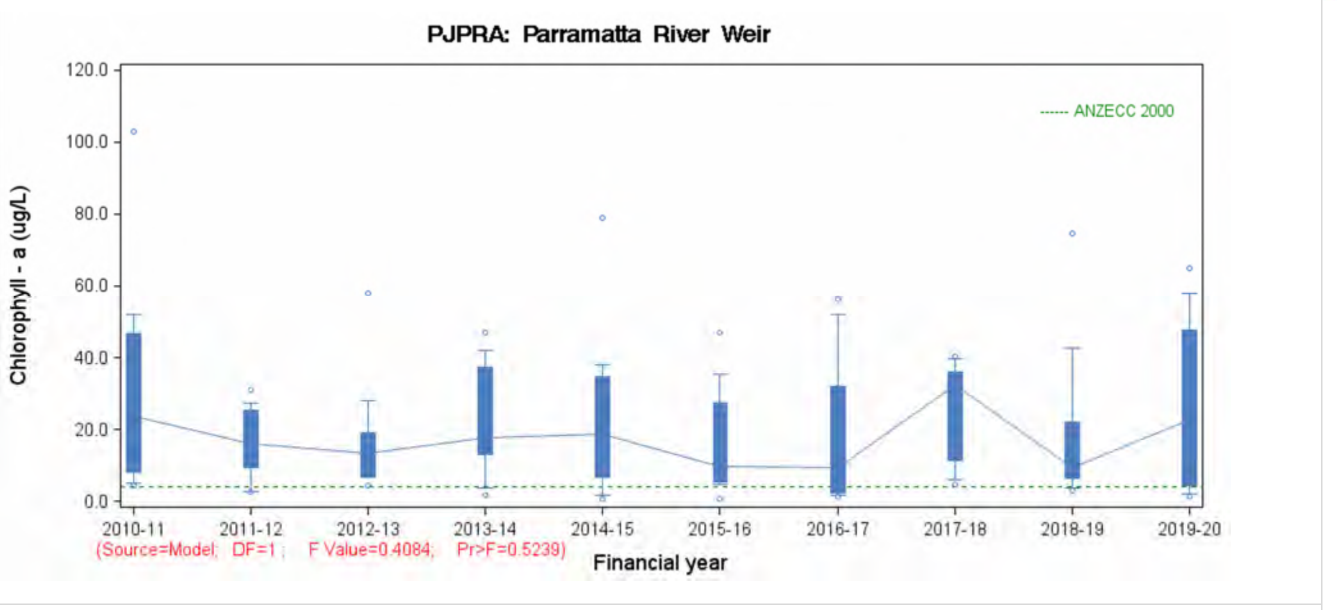
Statistical analysis confirmed that the 2019-20 chlorophyll-*a* at one Upper Georges River site (downstream of Harris Creek, GR19) was significantly higher than the previous nine years. The trends in chlorophyll-*a* concentrations were steady at all other 15 estuarine sites.

Generally, the upstream river sites had higher chlorophyll-*a* concentrations than the sites closer to the mouth of each estuary. The 2019-20 median chlorophyll-*a* concentrations at six such upstream sites were significantly higher than the ANZECC (2000) guideline limit.

A maximum chlorophyll-*a* concentration of 432.2 µg/L was recorded at Alexandria Canal, an upstream tributary of Cooks River (CR04A) in June 2020. The Lane Cove River Weir (PJLC) also recorded an elevated chlorophyll-*a* maxima of 357.9 µg/L in December 2019. The four other sites with 2019-20 median chlorophyll-*a* concentrations higher than the guideline were in the upper reaches of Parramatta River (PJPRA and PJ015) and Georges River (GR22 and GR19).

As expected chlorophyll-*a* concentrations were lower at Sydney Harbour sites compared to other upstream estuarine sites in 2019-20. Median chlorophyll-*a* concentrations at these sites were less than the ANZECC guideline limit.




PJPRA: Parramatta River Weir
------ ANZECC 2000
Chlorophyll - a (ug/L)
120.0
100.0
80.0
60.0
40.0
20.0
0.0
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
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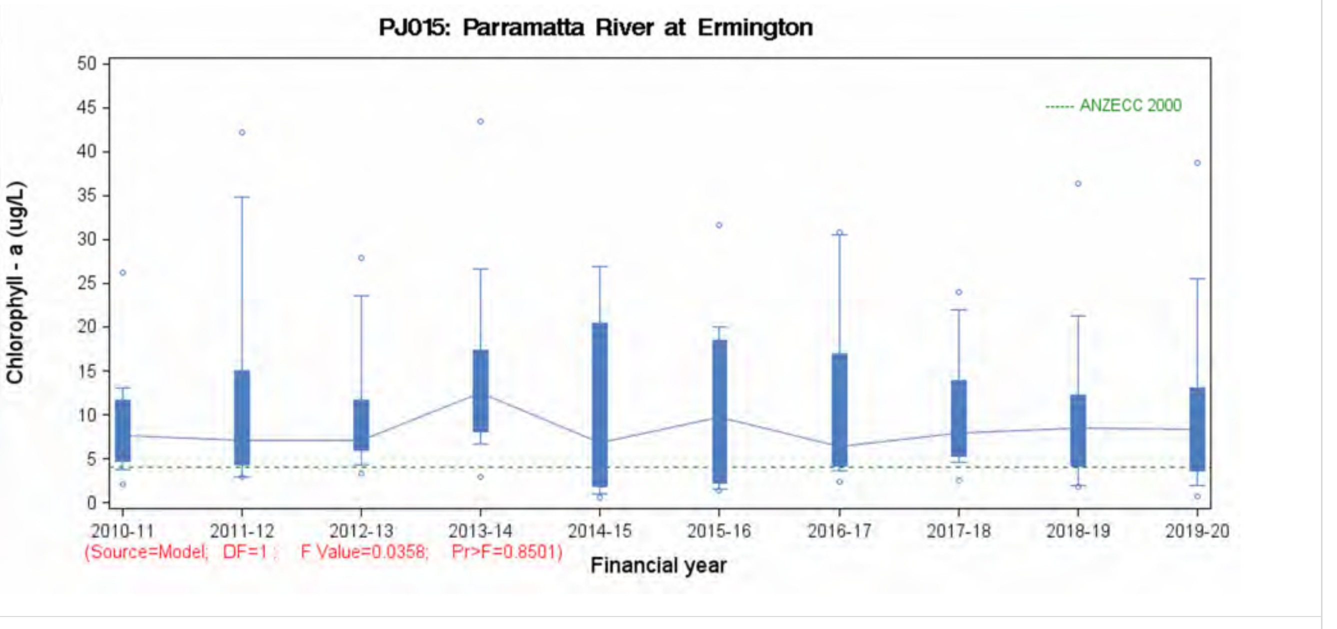
Financial year


PJ015: Parramatta River at Ermington
------ ANZECC 2000
Chlorophyll - a (ug/L)
50
45
40
35
30
25
20
15
10
5
0
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
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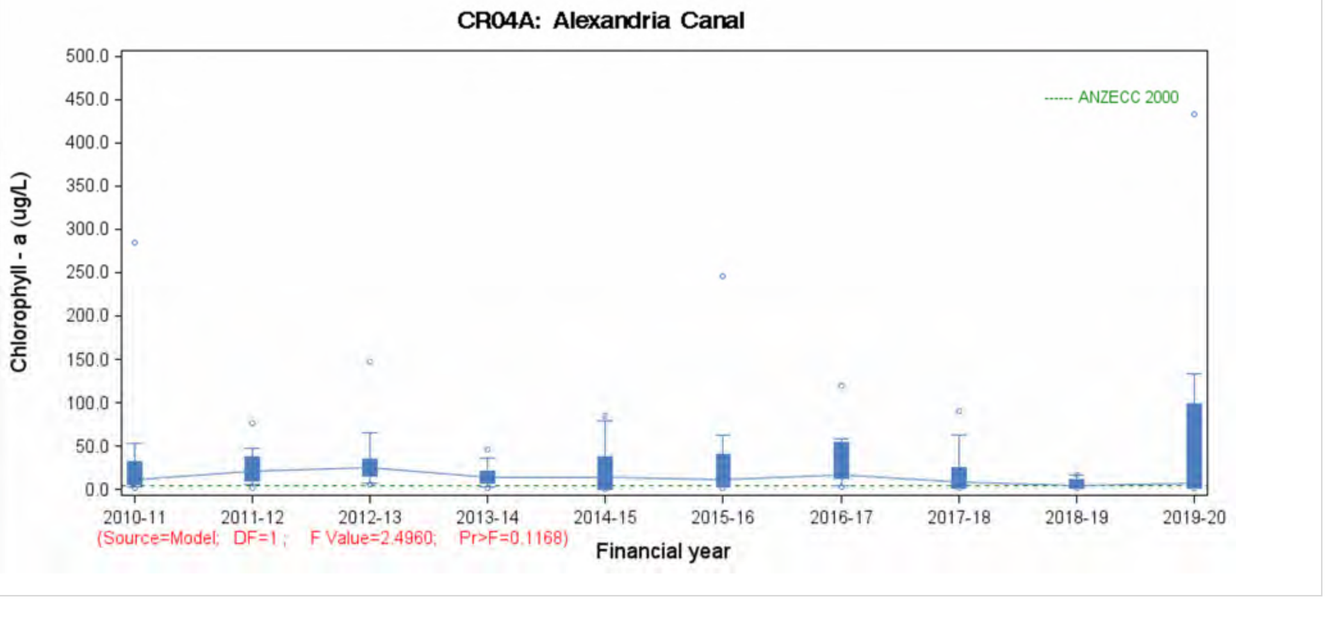
Financial year


CR04A: Alexandria Canal
------ ANZECC 2000
Chlorophyll - a (ug/L)
500.0
450.0
400.0
350.0
300.0
250.0
200.0
150.0
100.0
50.0
0.0
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
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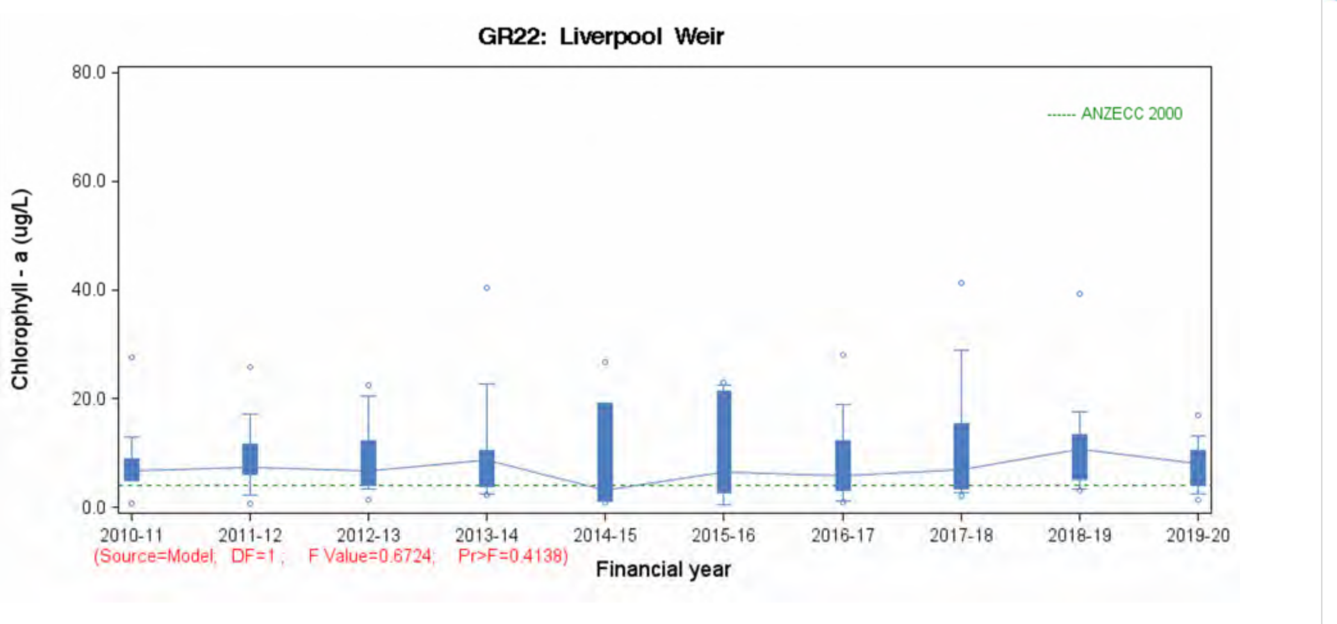
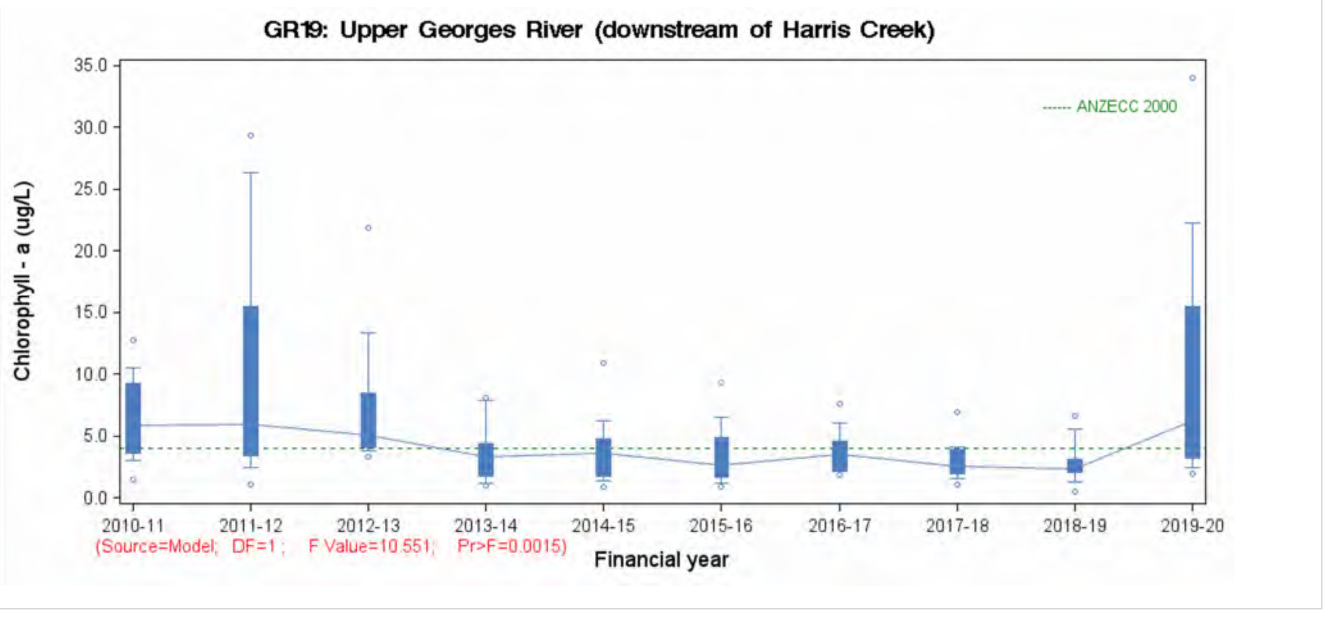
Financial year


GR22: Liverpool Weir
ANZECC 2000
Chlorophyll - a (ug/L)
80.0
60.0
40.0
20.0
0.0
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=0.6724; Pr>F=0.4138)
Financial year


GR19: Upper Georges River (downstream of Harris Creek)
ANZECC 2000
Chlorophyll - a (ug/L)
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=10.551; Pr>F=0.0015)
Financial year

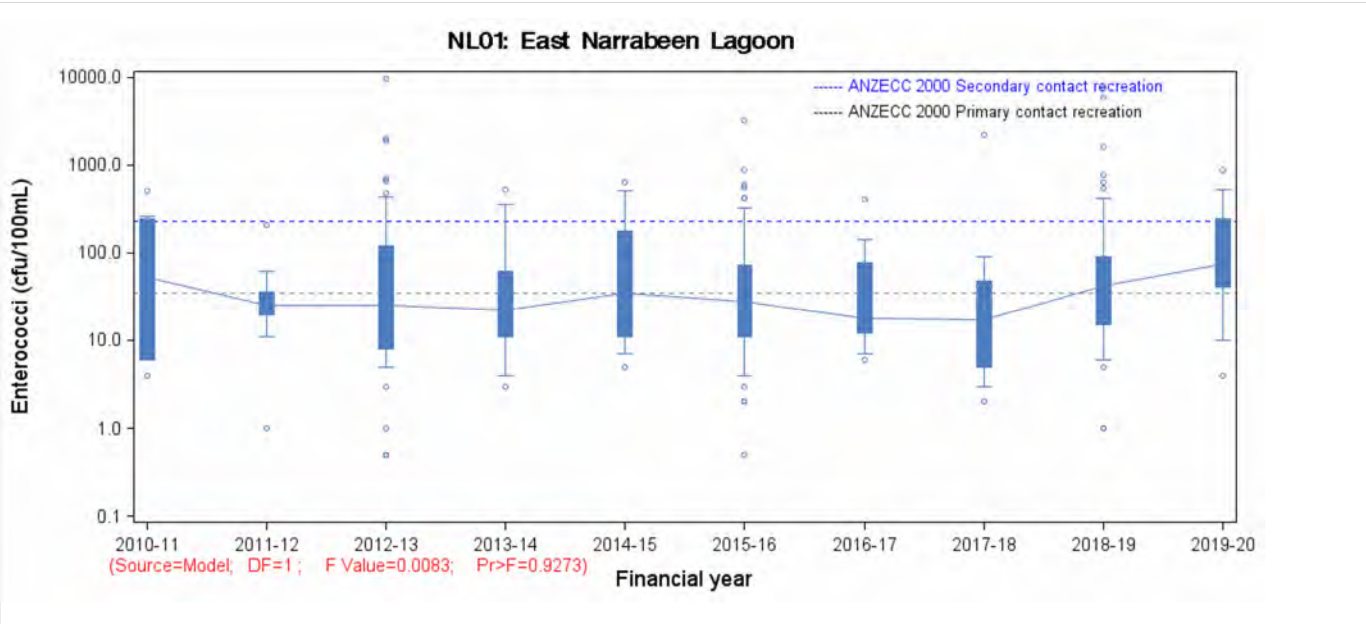
4.5.3 Water quality trends in lagoons

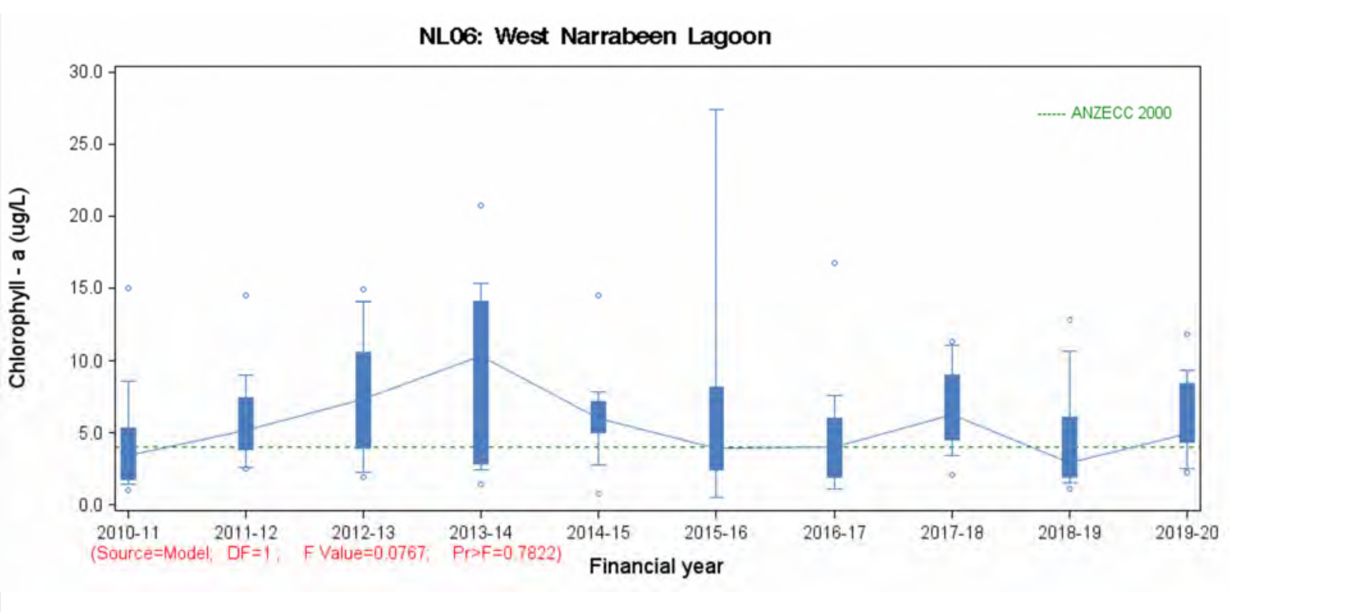
The yearly trends in conductivity, chlorophyll-*a* and *Enterococci* results at seven lagoon monitoring sites are presented in Volume 2 Appendix J.

There were no increasing/decreasing trends found in chlorophyll-*a* and conductivity results in 2019-20 at any lagoon sites. The *Enterococci* densities increased significantly at Dee Why lagoon (DW01) in 2019-20 compared to previous nine years. No significant trends in *Enterococci* were recorded at any other lagoon site.

The 2019-20 median chlorophyll-*a* concentrations exceeded the ANZECC (2000) guideline at West Narrabeen lagoon (NL06). The median chlorophyll-*a* concentrations were lower than the guideline at all other 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 tend to accelerate algal growth if other conditions are also favourable. Chlorophyll-*a* reached a maximum of 26.7 µg/L at Upper Manly Lagoon (ML03, March 2020) and 27.8 µg/L at Dee Why Lagoon (July 2019).

The median *Enterococci* level exceeded the ANZECC (2000) secondary contact recreation guideline at Curl Curl Lagoon (CC01) and Upper Manly Lagoon (ML03). The median *Enterococci* exceeded the primary contact recreation guideline at three other lagoon sites (East Narrabeen NL01, Mouth Manly ML01 and Dee Why DW01).




NL06: West Narrabeen Lagoon
ANZECC 2000
Chlorophyll - a (ug/L)
30.0
25.0
20.0
15.0
10.0
5.0
0.0
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
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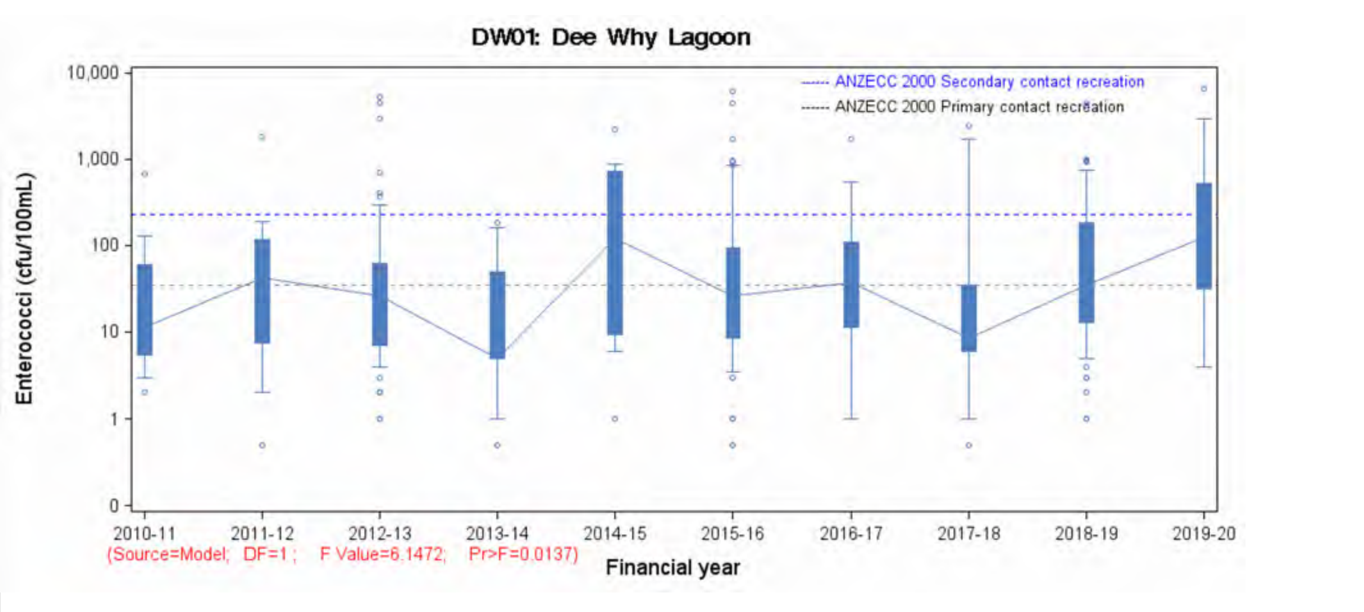
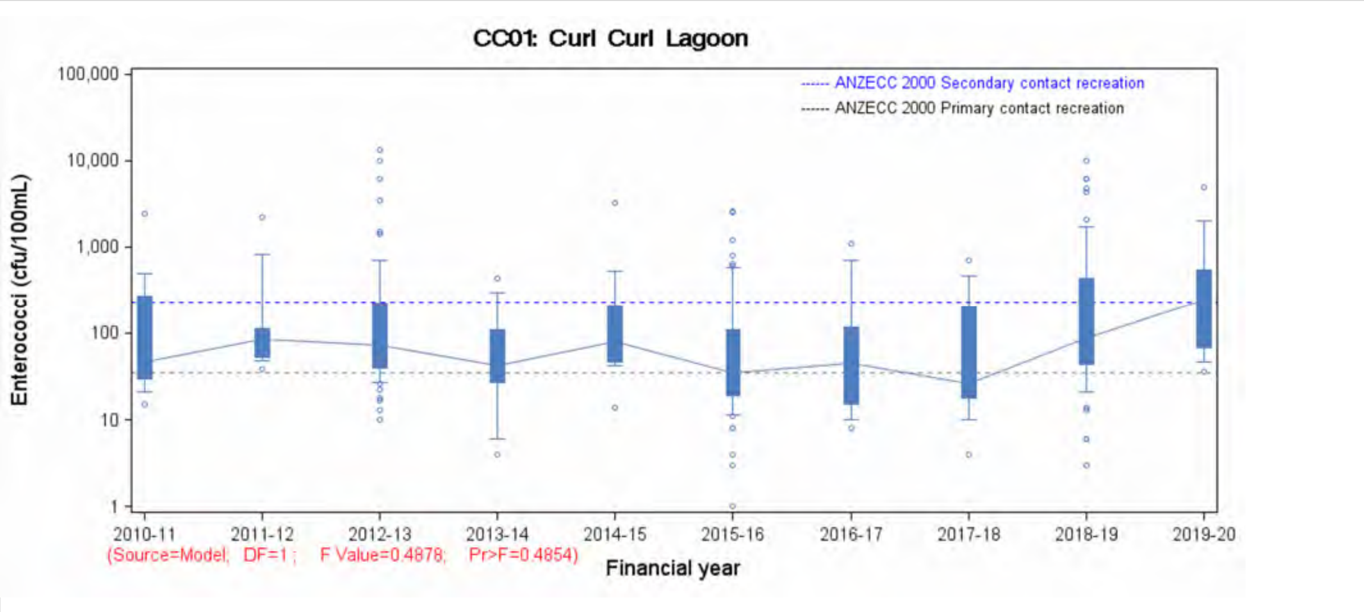
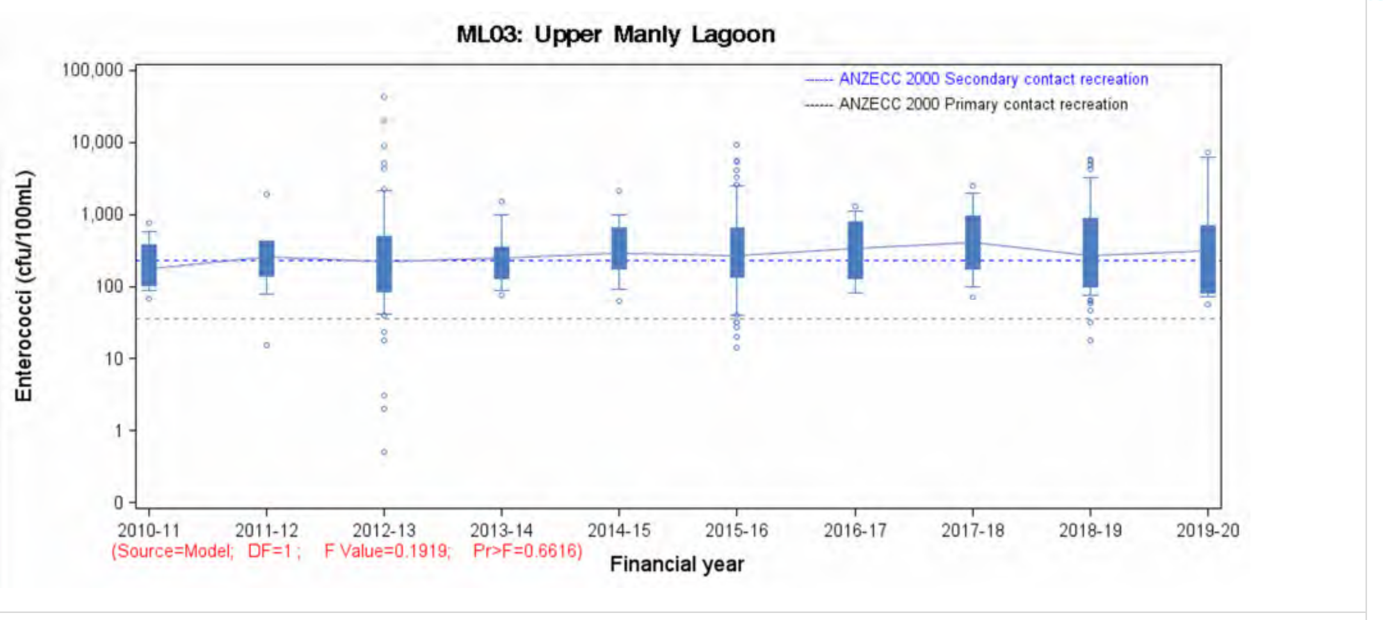
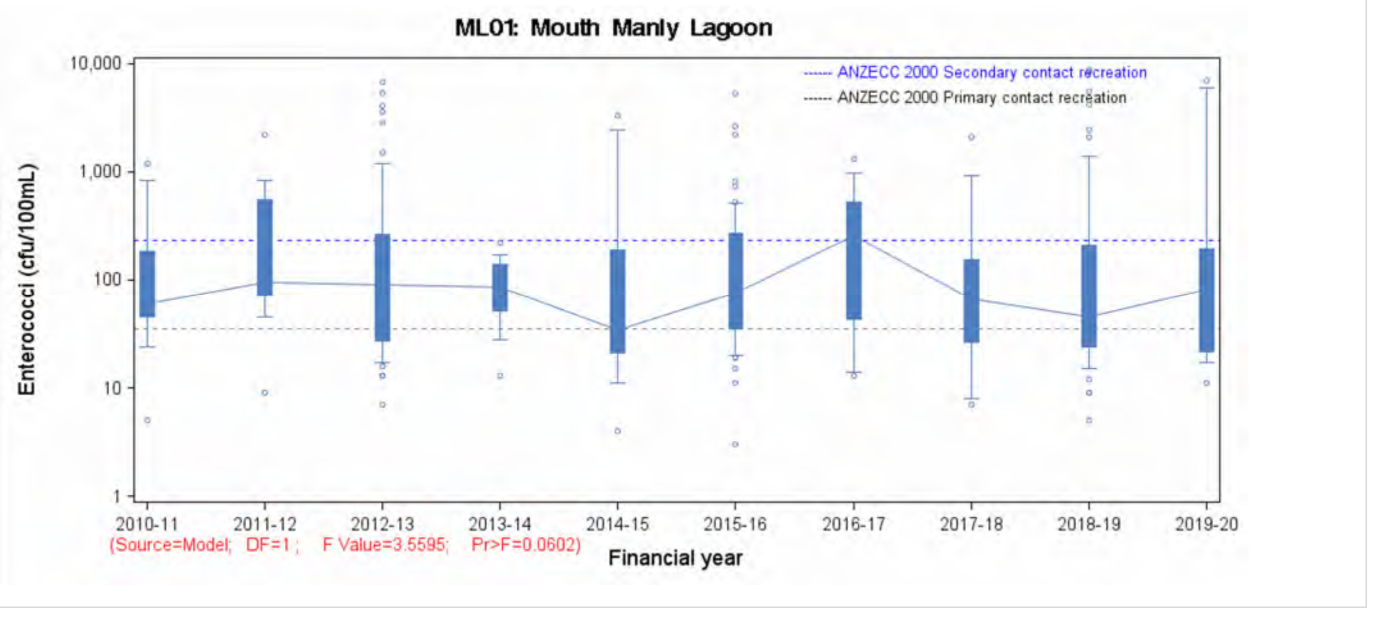
Financial year


DW01: Dee Why Lagoon
ANZECC 2000 Secondary contact recreation
ANZECC 2000 Primary contact recreation
Enterococci (cfu/100mL)
10,000
1,000
100
10
1
0
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=6.1472; Pr>F=0.0137)
Financial year


CC01: Curl Curl Lagoon
ANZECC 2000 Secondary contact recreation
ANZECC 2000 Primary contact recreation
Enterococci (cfu/100mL)
100,000
10,000
1,000
100
10
1
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=0.4878; Pr>F=0.4854)
Financial year


ML03: Upper Manly Lagoon
ANZECC 2000 Secondary contact recreation
ANZECC 2000 Primary contact recreation
Enterococci (cfu/100mL)
100,000
10,000
1,000
100
10
1
0
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=0.1919; Pr>F=0.6616)
Financial year


ML01: Mouth Manly Lagoon
ANZECC 2000 Secondary contact recreation
ANZECC 2000 Primary contact recreation
Enterococci (cfu/100mL)
10,000
1,000
100
10
1
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=3.5595; Pr>F=0.0602)
Financial year

4.5.4 Shoreline outfall program – Intertidal communities

Assessment of the 2008 to 2019 monitoring data from the Shellharbour WWTP and two control sites indicated a relatively stable equilibrium in the rocky-intertidal community structure (Volume 2 Appendix K). 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 WWTP as the community assemblage at the outfall site was very similar to the control site 1 over the 2008 to 2019 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).

4.5.5 Intertidal communities of Sydney's estuaries

Intertidal rock platform communities

The comparison of control sites to other intertidal rock platform sites indicated test sites had similar results in 2019 to the last few years. Test sites in the higher salinity zone were grouped near or within the range of variation recorded for higher salinity control sites. Sites in the lower salinity zone were well separated in most cases from the recorded range of variation for the lower salinity control sites. This suggests the 2019 community structure in the lower salinity zone at most sites was impaired with the exception of the improving trends for the Hawthorn Canal arm of Iron Cove (PJ082) and three of the Georges river sites (GR15 Woronora River, GR115 Kyle Bay and GR175 Edith Bay) (Volume 2 Appendix L).

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 undertaken 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 2019-20, Georges River site GR01 (Cooks River downstream Muddy Creek) and GR085 (Quibray Bay) had statistically higher barnacle settling in the higher salinity zone while the Georges River site GR15 (Woronora River) also had statistically higher barnacle settling in the lower salinity zone (Volume 2: Appendix L).

4.6 State of riverine environment

4.6.1 Hawkesbury-Nepean River water quality and algae

The receiving water quality was assessed via monitoring key water quality and algae analytes at 13 sites along the Hawkesbury-Nepean River from the upstream freshwater reaches of the Hawkesbury-Nepean River at Maldon to the downstream Hawkesbury River at Leets Vale. Another five sites were monitored at four major tributaries, South Creek, Cattai Creek, Colo River and Berowra Creek. Temporal trend plots for all these sites by each analyte are included in Volume 2 (Appendix M).

The water quality of the Hawkesbury-Nepean River varied considerably between the upstream and downstream reaches and tributaries in 2019-20. The water quality was also outside the ANZECC 2000 guidelines for key nutrient analytes and chlorophyll-*a* concentrations at many of these sites, particularly downstream of the Souk Creek confluence. The Hawkesbury River downstream of South Creek widens and receives agricultural/urbanised nutrient run-offs and discharges from multiple WWTPs.

Statistical analysis found that oxidised nitrogen and total nitrogen increased significantly in 2019-20 at all 12 main-stream river sites from the upstream control site of Nepean River at Maldon Weir (N92) to downstream Sackville Ferry, Hawkesbury River (N26). Of the five tributary sites, these nitrogen analytes also increased significantly at the lower Colo River site (N2202).

The 2019-20 median total nitrogen concentrations exceeded the ANZECC (2000) guideline at 17 monitoring sites including the upstream control site at Maldon Weir (N92) to downstream Berowra Creek (NB11). The only exception was the downstream reference site at Lower Colo River (N2202), despite showing a significant increase. Median oxidised nitrogen concentrations also exceeded the guideline at 16 out of 18 sites of the Hawkesbury-Nepean River and tributaries. The median ammonia nitrogen concentrations exceeded the ANZECC (2000) guideline at six sites.

Total phosphorus concentrations increased significantly in 2019-20 compared to the previous nine years at Berowra Creek, Off Square Bay (NB11). The trends in total phosphorus were steady at all other 17 sites. Filterable total phosphorus concentrations were stable at all 18 monitoring sites.

The 2019-20 median total phosphorus concentrations exceeded the ANZECC (2000) guideline at four sites on the Hawkesbury River downstream of South Creek and at three tributary sites (South Creek, Cattai Creek and one upstream Berowra Creek site).

Chlorophyll-*a* trends were mostly steady, with improvements or decreasing concentrations at two Upper Nepean River sites: Sharpes Weir (N75) and Penrith Weir (N57). However, in line with increasing concentrations of nitrogen analytes, chlorophyll-*a* increased significantly at the reference site of Colo River (2019-20) in comparison to the previous nine years, although remained below the ANZECC (2000) guideline of 3 μg/L. Total algal biovolume increased significantly at Smith Road, Nepean River (N48A) and blue-green algal biovolume increased at lower Colo River (N2202). Both total and blue-green algal biovolume increased significantly at Sackville Ferry (N26) in 2019-20. No other significant trend in toxic blue-green algal biovolume or counts was found at any site.

The 2019-20 median chlorophyll-*a* concentrations exceeded the ANZECC (2000) guideline at 15 out of 18 sites from upstream Nepean River at Wallacia Bridge (N67) to downstream Berowra Creek, Off Square Bay (NB11). The three exceptions were the upstream control site of Nepean River at Maldon Weir, Sharpes Weir (N75) and reference site at Colo River (N2202).

During 2019-20, the median counts of the potentially toxic blue green algae *Microcystis* was less than the Amber alert (NHMRC) at all sites. The actual *Microcystis* counts were higher than the Amber alert level on three occasions only. Two of these samples were from the lower Hawkesbury River at Sackville Ferry (N26) and Leets Vale (N18). The third sample was from the reference site at Colo River (N2202).

Conductivity increased significantly at 13 out of the 18 sites from upstream control site of the Nepean at Maldon Weir (N92) to downstream Colo River (N2202) in 2019-20.

Dissolved oxygen saturation decreased or deteriorated at two sites, Nepean River at Penrith Weir (N57) and Hawkesbury River at North Richmond (N42). Both dissolved oxygen concentrations and percent saturation increased or improved at Lower Cattai Creek (NC11A). Dissolved oxygen concentrations also improved or increased at Berowra Creek, Off Square Bay (NB11).

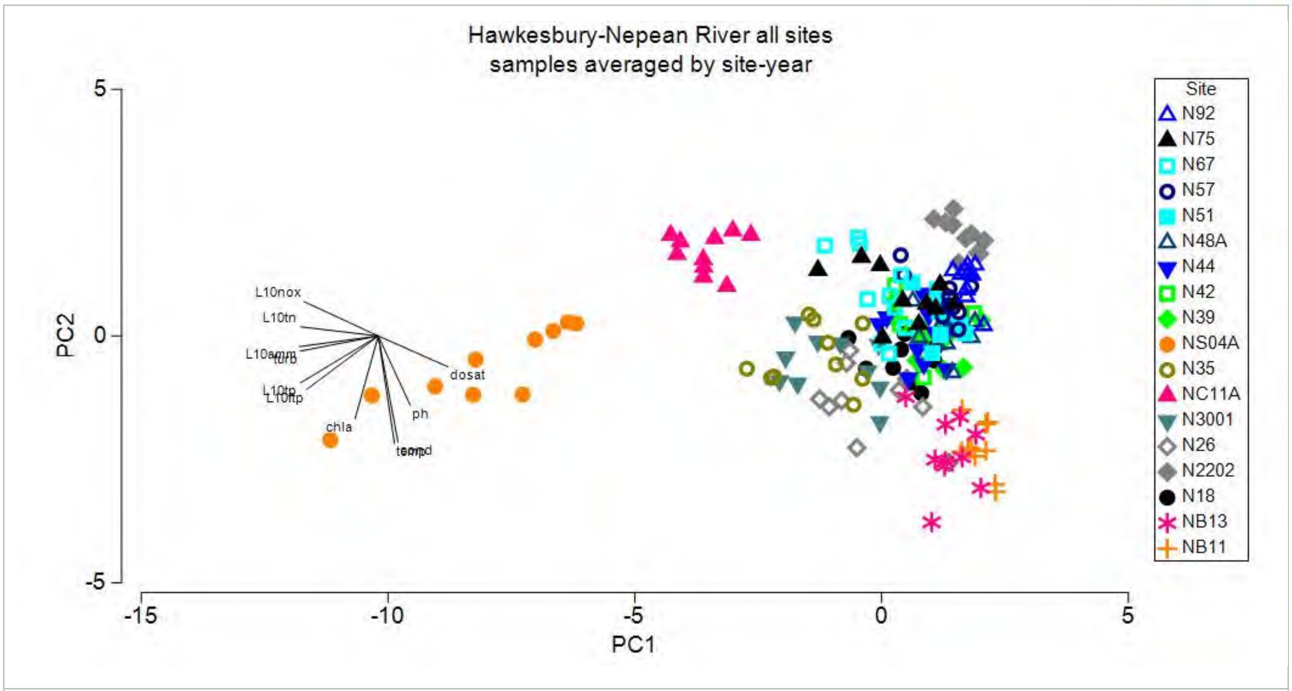
Median dissolved oxygen saturation was less than the lower guideline limit at two tributary sites (South Creek and Cattai Creek).

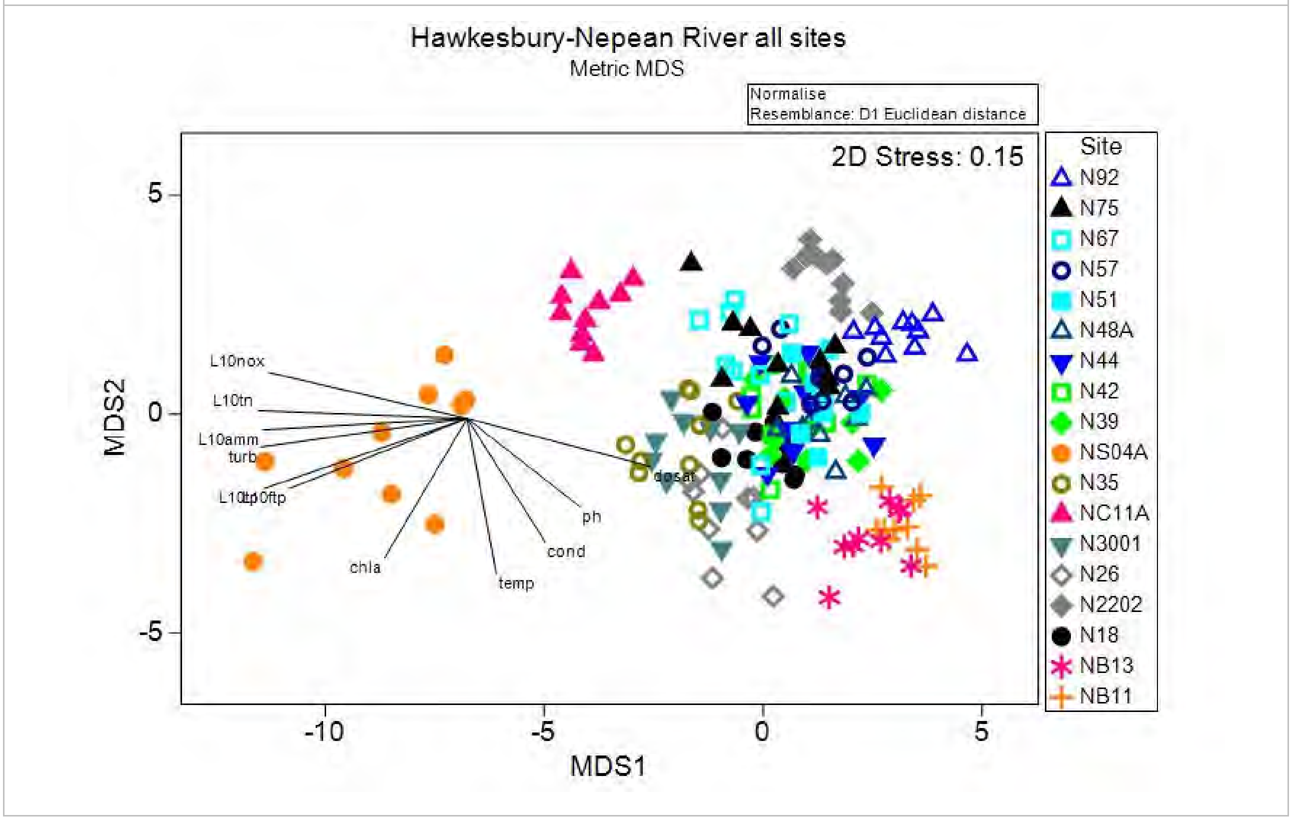
pH increased significantly at two sites, upstream control site at Maldon Weir (N92) and Sackville Ferry (N26). No significant trend in water temperature and turbidity results was found at any site.

The water clarity was good at most of monitoring sites as indicated by very low median turbidity that often dropped below the lower guideline limits (10 out of 18 sites).

An overview of the Hawkesbury-Nepean River receiving water data for all 18 sites is provided under multivariate analysis of all water quality analytes together. Correlation based Principal Component Analysis (PCA) was run based on normalised Euclidean distance. The first two Principal Component axes (PCs) accounted for 69% of the variation in the dataset. To check that the amount of variation explained under the PCA ordination provided an adequate view, the PCA ordination pattern was compared to a metric MDS ordination plot. A metric MDS that fitted all data into two dimensions showed a suitable fit (stress) measurement of 0.15, which suggested this was an adequate view of the data. As the outputted patterns from both ordination techniques were in agreement, this helped to confirm the view that was presented by the first two PCs of the PCA was acceptable.

These ordinations suggested the lower South Creek site (NS04A) was relatively nutrient enriched (far left-hand side of the ordination plots) compared to the other 17 sites. Based on PCA analysis, the lower Cattai Creek site (NC11A) is distinctly showing deviation with higher nutrient concentrations from other sites. Sites with relatively low nutrient water quality were the two control sites, the Nepean River at Maldon Weir (N92) and the lower Colo River (N2202) situated at the top right-hand side of each ordination plot. Higher conductivity sites were represented by those in the salt water zone of the Berowra estuary (NB13 and NB11) at the bottom right hand side of ordination plots. Sites situated between these extremities of the plots vary in water quality. Sites located further downstream in the river were positioned in the ordination plot toward the centre of the plot suggesting they had higher levels of nutrients than those physically situated further upstream toward Maldon Weir at Picton, which were displayed in the ordination plot closer to the Maldon Weir and Colo river site samples. Inspection of Eigenvector output of the PCA indicated PC1 predominantly represented nutrients while PC2 represented conductivity, temperature, pH and chlorophyll-*a*.


Hawkesbury-Nepean River all sites
samples averaged by site-year
PC2
PC1
L10nox
L10tn
L10amm
turb
L10tp
L10ftp
chla
ph
temp
cond
dosat
Site
N92
N75
N67
N57
N51
N48A
N44
N42
N39
NS04A
N35
NC11A
N3001
N26
N2202
N18
NB13
NB11


Hawkesbury-Nepean River all sites
Metric MDS
Normalise
Resemblance: D1 Euclidean distance
2D Stress: 0.15
MDS2
MDS1
L10nox
L10tn
L10amm
turb
L10tp
L10ftp
chla
temp
cond
ph
dosat
Site
N92
N75
N67
N57
N51
N48A
N44
N42
N39
NS04A
N35
NC11A
N3001
N26
N2202
N18
NB13
NB11

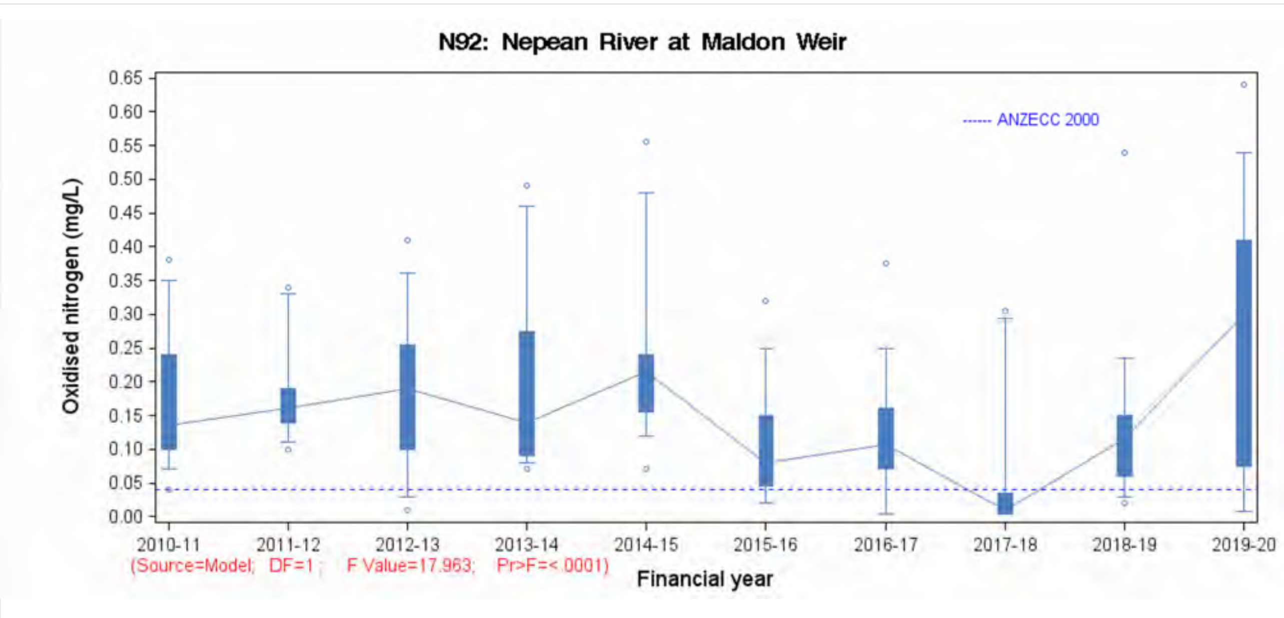
N92: Nepean River at Maldon Weir

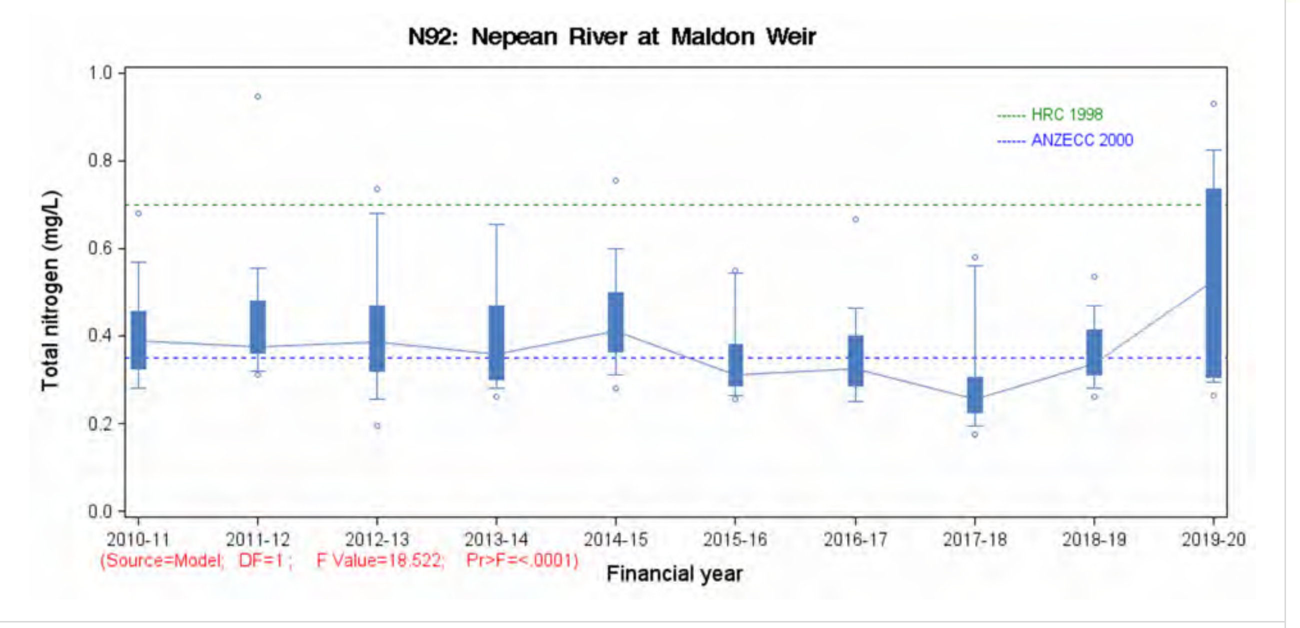
Maldon Weir (N92) is a control site for the inland Hawkesbury-Nepean River receiving water quality monitoring program as it is located upstream of all inland wastewater systems. The water quality at Maldon Weir is influenced by upstream rural catchment factors, Tahmoor colliery and environmental flows released from the upstream water storage dams of Nepean, Avon and Cordeaux since 2010.

Statistical analysis confirmed that the water quality condition of Nepean River at Maldon Weir has deteriorated in 2019-20 for four key analytes. Oxidised nitrogen and total nitrogen increased sharply in 2019-20 in comparison to the previous nine years indicating nitrogen enrichment from upstream diffuse and point (Tahmoor colliery) sources. These two nitrogen compounds also exceeded their respective ANZECC 2000 guideline limits. This trend is unusual for this control site without much catchment influence historically and also benefited from the low nutrient environmental releases from the Upper Nepean dams. Investigation by Western Sydney University in early 2020 identified elevated levels of nitrogen downstream of Tahmoor colliery compared to upstream (Hannam 2020 and Hair 2020). In addition, further investigation into the yearly data identified that the high concentrations of nutrients were mostly related to wet weather events from February to June 2020.

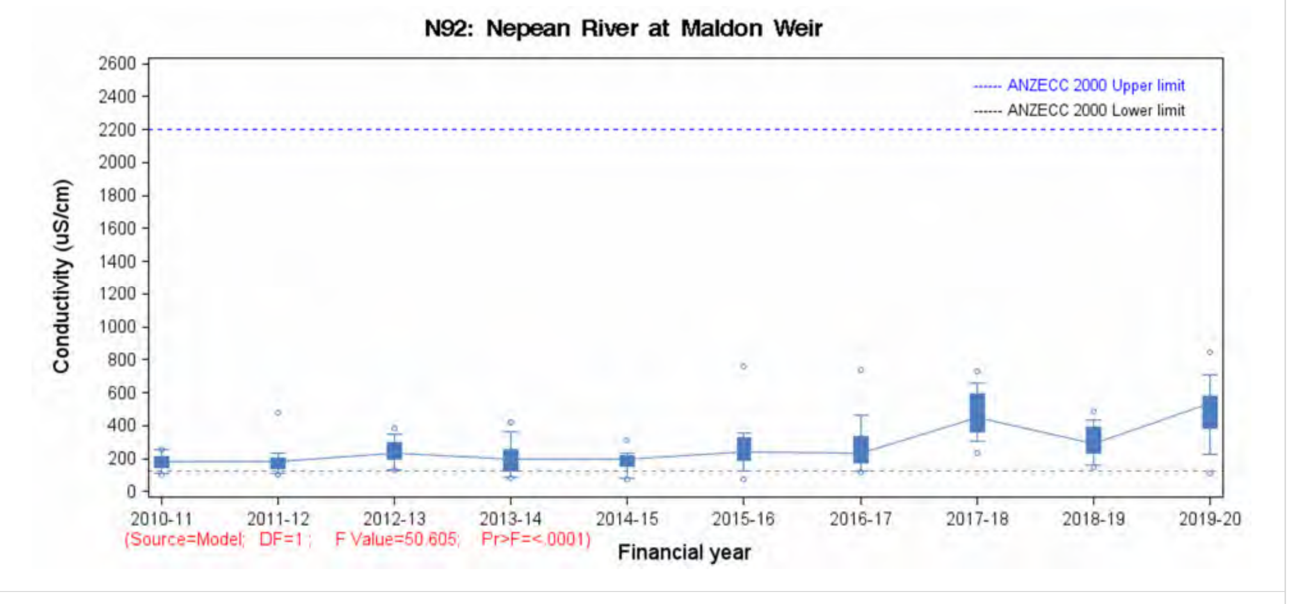
The trend in conductivity and pH values for this control site also showed significantly increasing trends in the latest year. Turbidity was low, with the median value less than the ANZECC guideline range of 6 - 50 NTU for lowland rivers.

In 2019-20, none of the samples collected from this site qualified for full algal counting. The maximum chlorophyll-*a* concentration was 5.0 µg/L, that is below the algal counting threshold of 7.0 µg/L.

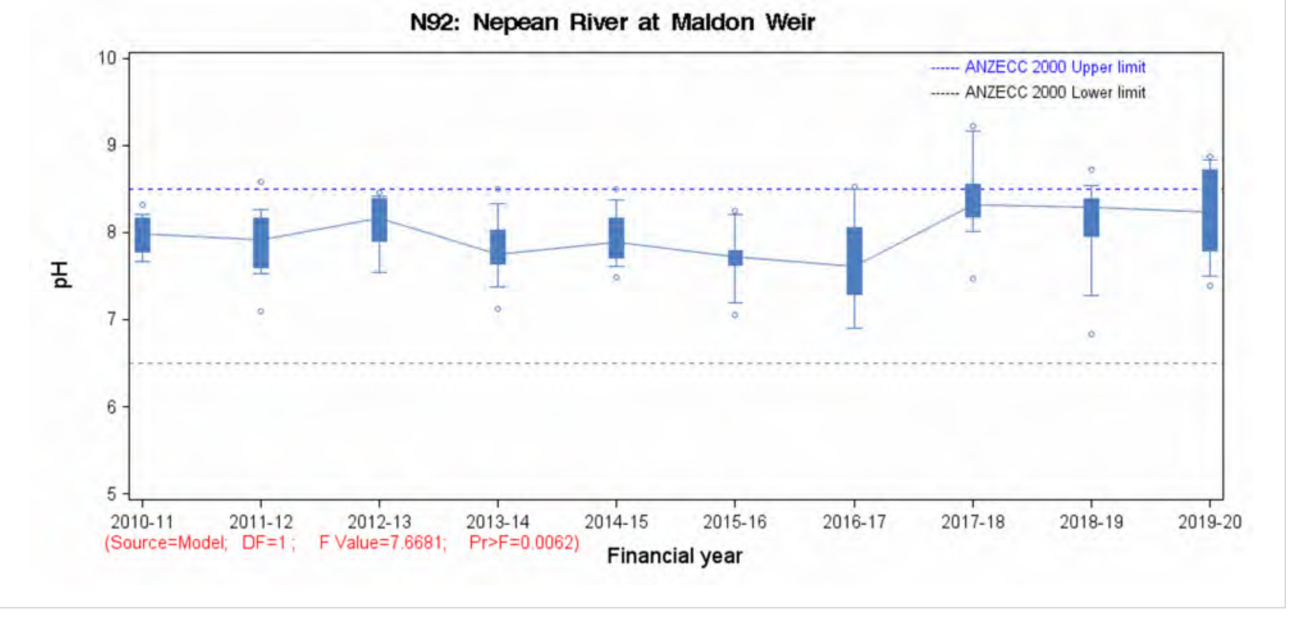




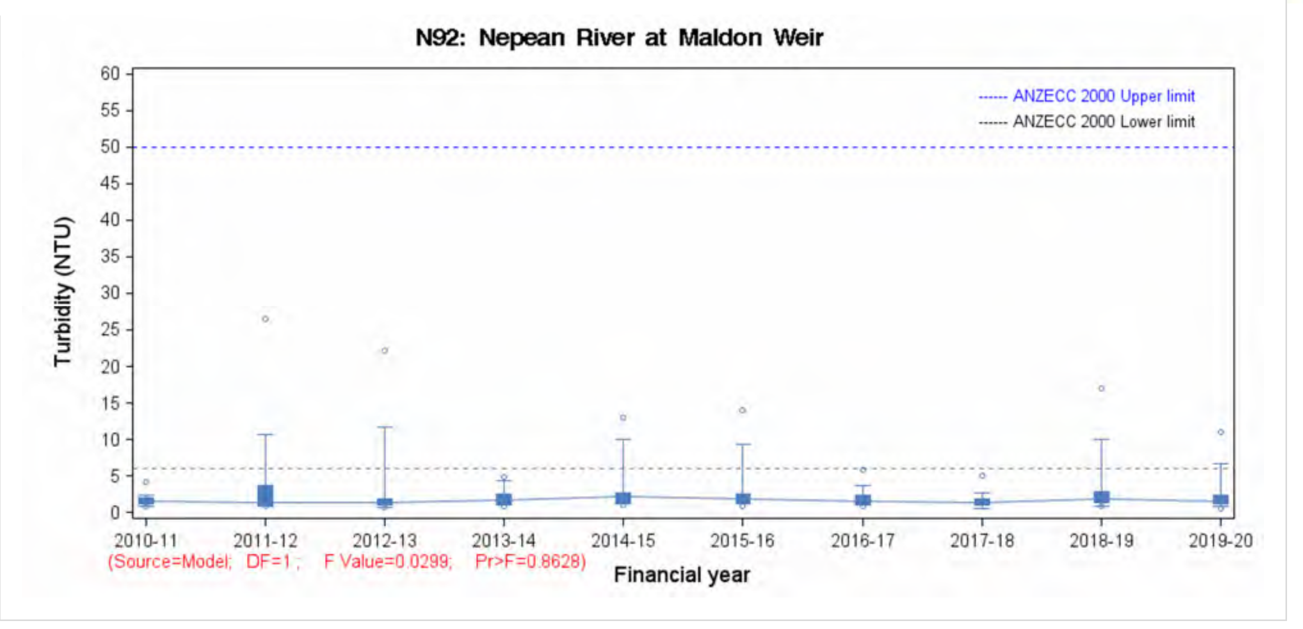
N92: Nepean River at Maldon Weir
Total nitrogen (mg/L)
HRC 1998
ANZECC 2000
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=18.522; Pr>F=<.0001)
Financial year



N92: Nepean River at Maldon Weir
Conductivity (uS/cm)
ANZECC 2000 Upper limit
ANZECC 2000 Lower limit
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=50.605; Pr>F=<.0001)
Financial year



N92: Nepean River at Maldon Weir
pH
ANZECC 2000 Upper limit
ANZECC 2000 Lower limit
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=7.6681; Pr>F=0.0062)
Financial year


N92: Nepean River at Maldon Weir
ANZECC 2000 Upper limit
ANZECC 2000 Lower limit
Turbidity (NTU)
60
55
50
45
40
35
30
25
20
15
10
5
0
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=0.0299; Pr>F=0.8628)
Financial year

N75: Nepean River at Sharpes Weir

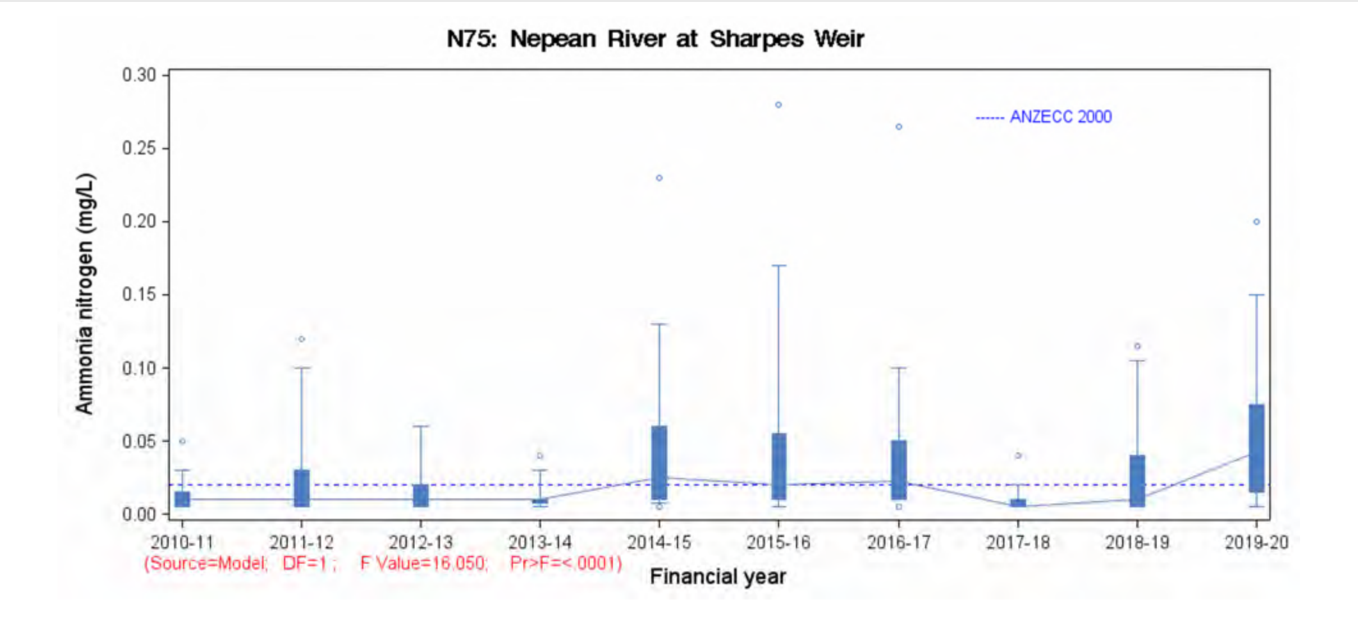
The Nepean River at Sharpes Weir (N75) is located immediately downstream of Matahil Creek, which receives treated wastewater from the West Camden WWTP. Further upstream of this site is the Picton WWTP which discharges during wet weather under a precautionary discharge condition specified in the EPL for the Picton WWTP.

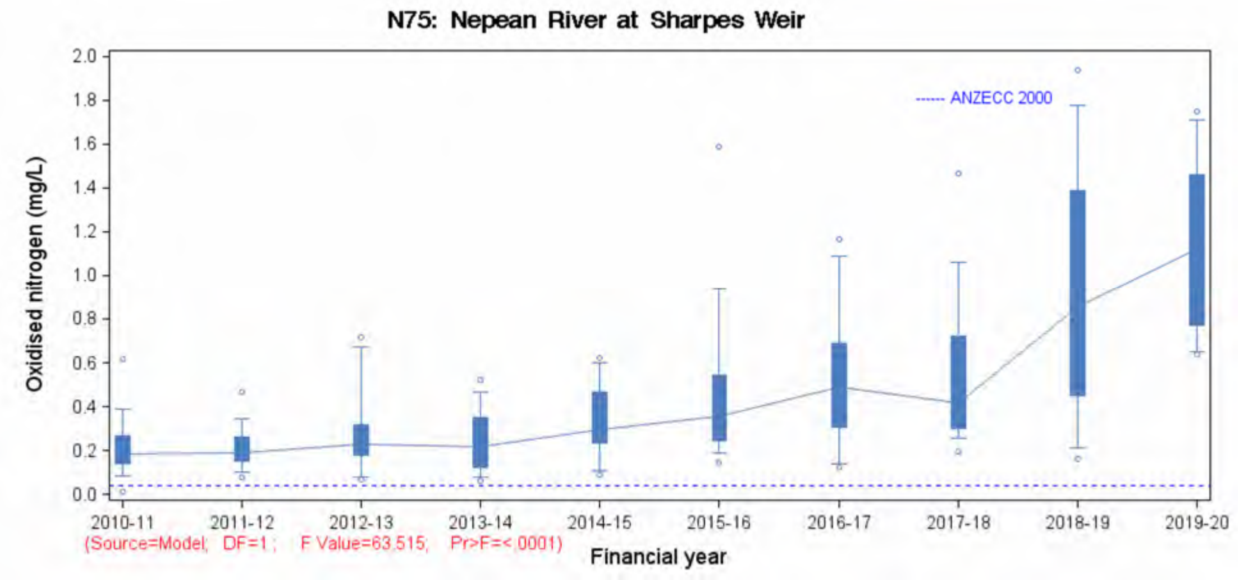
Statistical analysis confirmed that ammonia nitrogen, oxidised nitrogen, total nitrogen and conductivity levels were significantly higher in 2019-20 compared to the previous nine years results. Median concentrations of these nitrogen analytes were above the respective ANZECC (2000) guideline values. Despite this increasing trend in nitrogen analyte concentrations, the trend in chlorophyll-a concentration was significantly lower in the latest year and the median concentration was within the ANZECC (2000) guideline.

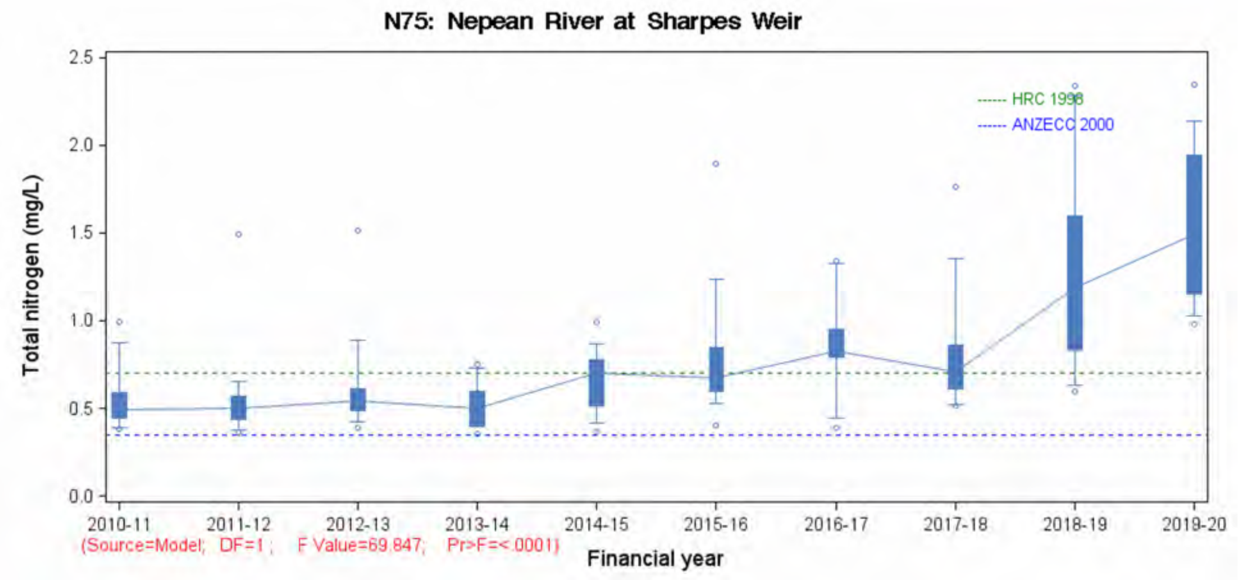
Only two out of 17 samples collected from Sharpes Weir (N75) had a chlorophyll-*a* concentration above 7.0 µg/L which triggered algal analysis. Maximum chlorophyll-*a* was 9.4 µg/L on 12 March 2020 when flagellated monad algae were dominant. No potentially toxic blue-green algae were identified at this site last year (2019-20).

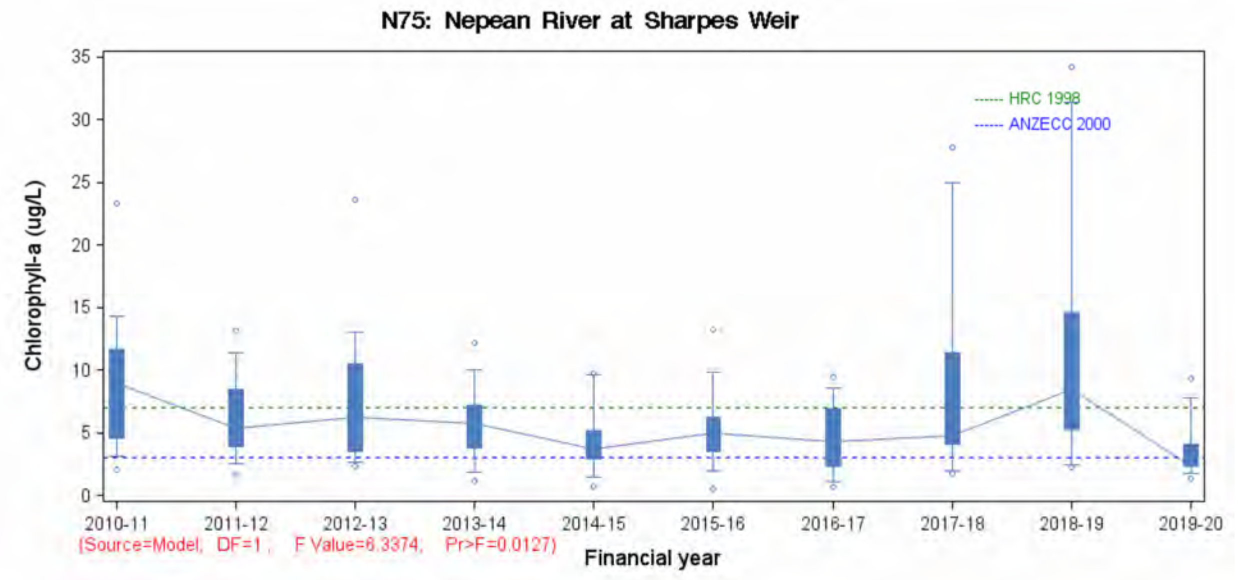
Conductivity levels showed significantly increasing trends in the latest year. Turbidity was low with the median value less than the ANZECC 2000 guideline range of 6 – 50 NTU for lowland rivers.

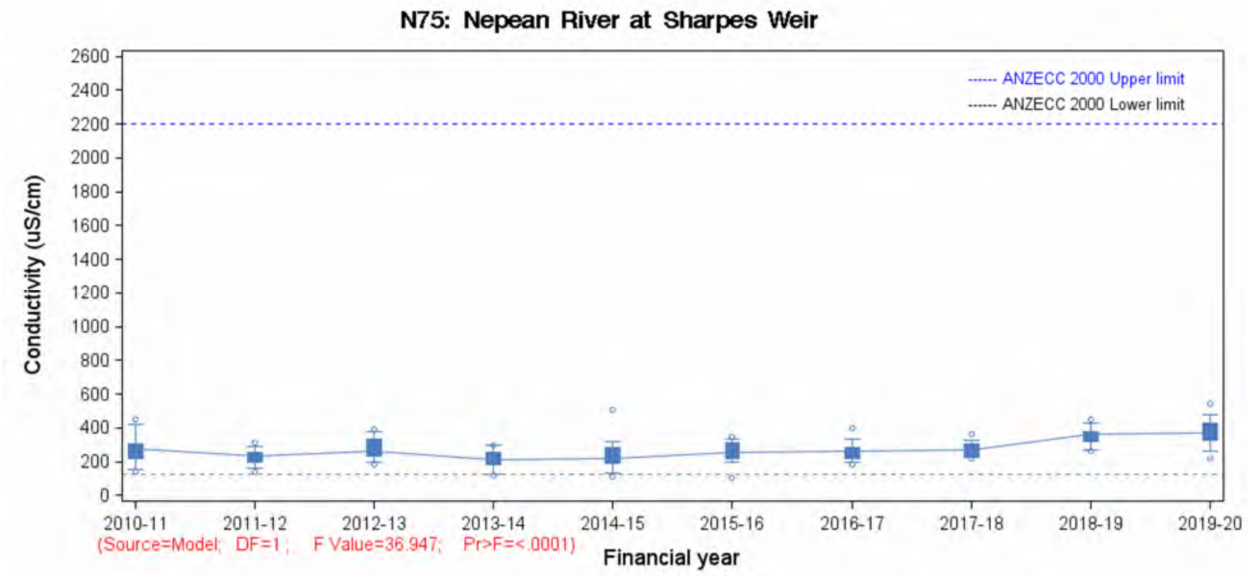
There were no other significant trends and/or exceptions (median values higher than the guideline limits) for any other water quality or algae analyte in 2019-20.

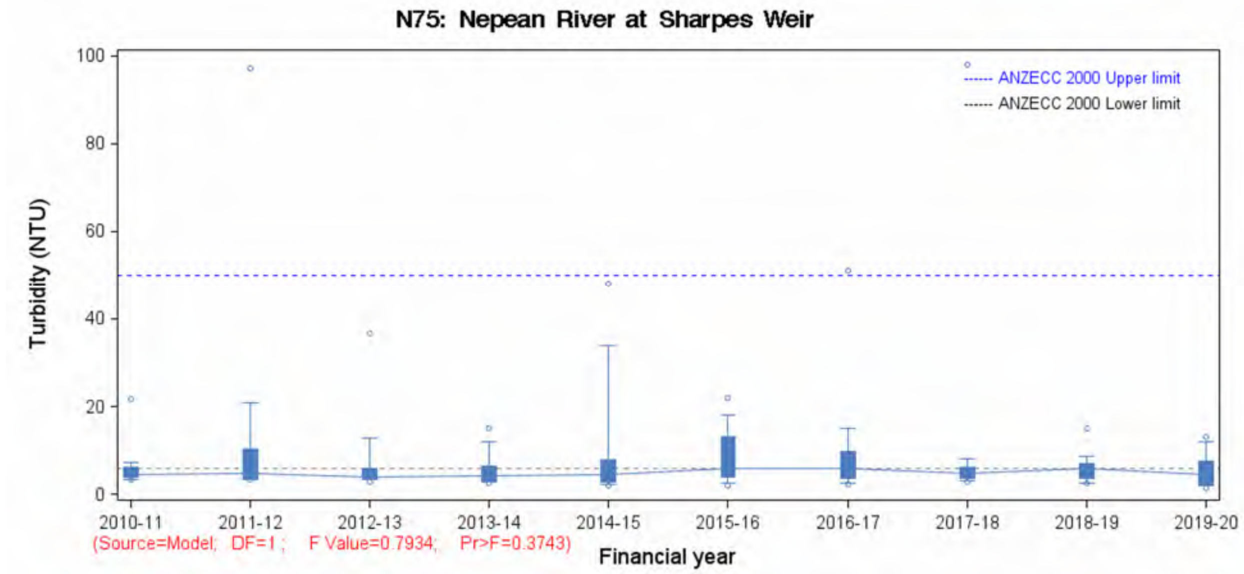



N75: Nepean River at Sharpes Weir
Oxidised nitrogen (mg/L)
ANZECC 2000
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=63.515; Pr>F=<.0001)
Financial year


N75: Nepean River at Sharpes Weir
Total nitrogen (mg/L)
HRC 1998
ANZECC 2000
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=69.847; Pr>F=<.0001)
Financial year


N75: Nepean River at Sharpes Weir
Chlorophyll-a (ug/L)
HRC 1998
ANZECC 2000
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=6.3374; Pr>F=0.0127)
Financial year


N75: Nepean River at Sharpes Weir
Conductivity (uS/cm)
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
------ ANZECC 2000 Upper limit
------ ANZECC 2000 Lower limit
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=36.947; Pr>F=<.0001)
Financial year


N75: Nepean River at Sharpes Weir
Turbidity (NTU)
100
80
60
40
20
0
------ ANZECC 2000 Upper limit
------ ANZECC 2000 Lower limit
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=0.7934; Pr>F=0.3743)
Financial year

N67: Nepean River at Wallacia Bridge

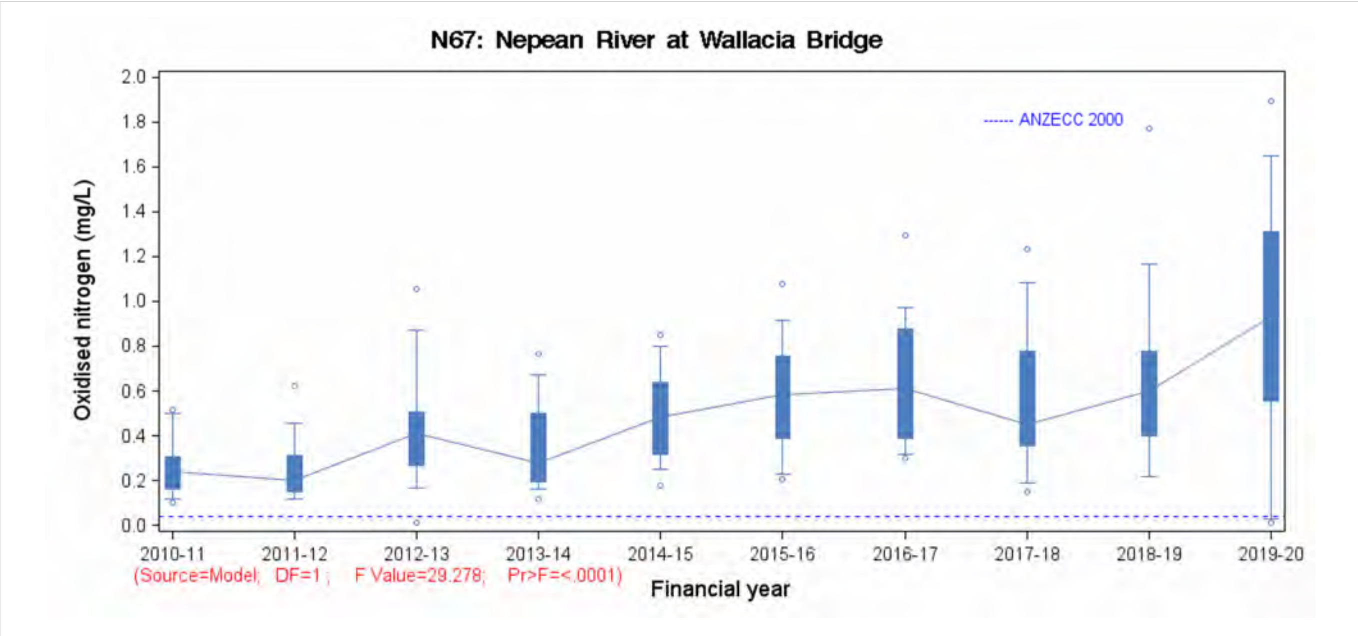
The Nepean River at Wallacia Bridge (N67) is about 30 km downstream of Sharpes Weir (N75) and 4 km upstream of the Warragamba River confluence. The area in between is primarily a natural, undeveloped catchment.

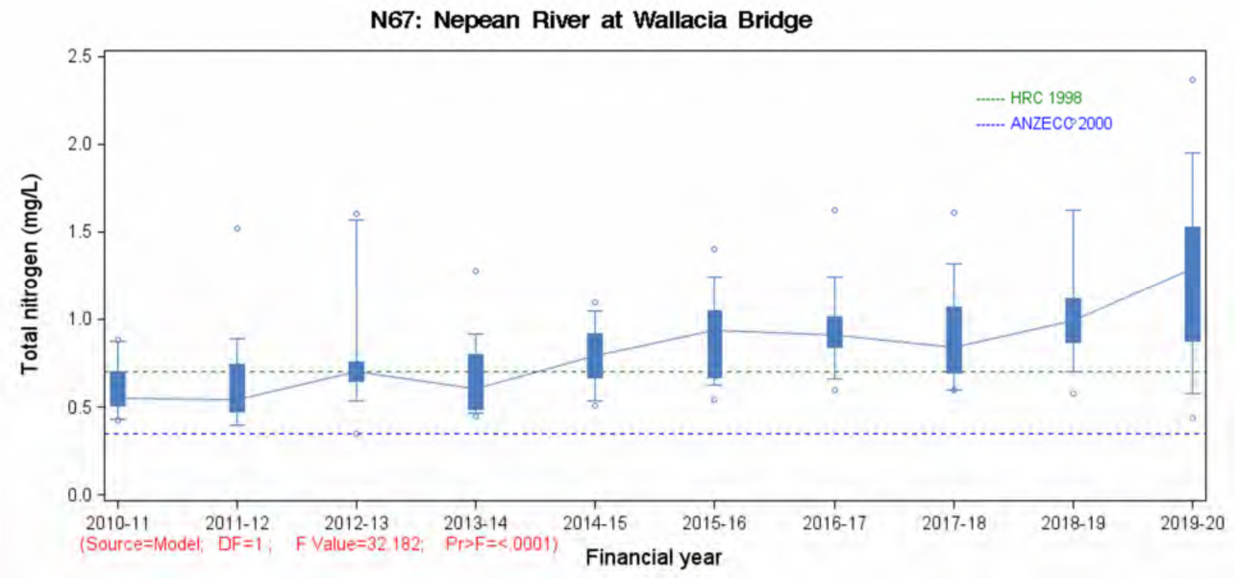
Analysis of the water quality data from N67 showed a significant increase in oxidised nitrogen and total nitrogen in 2019-20 compared to the previous nine years. Conductivity levels also showed significantly increasing trends in the latest year.

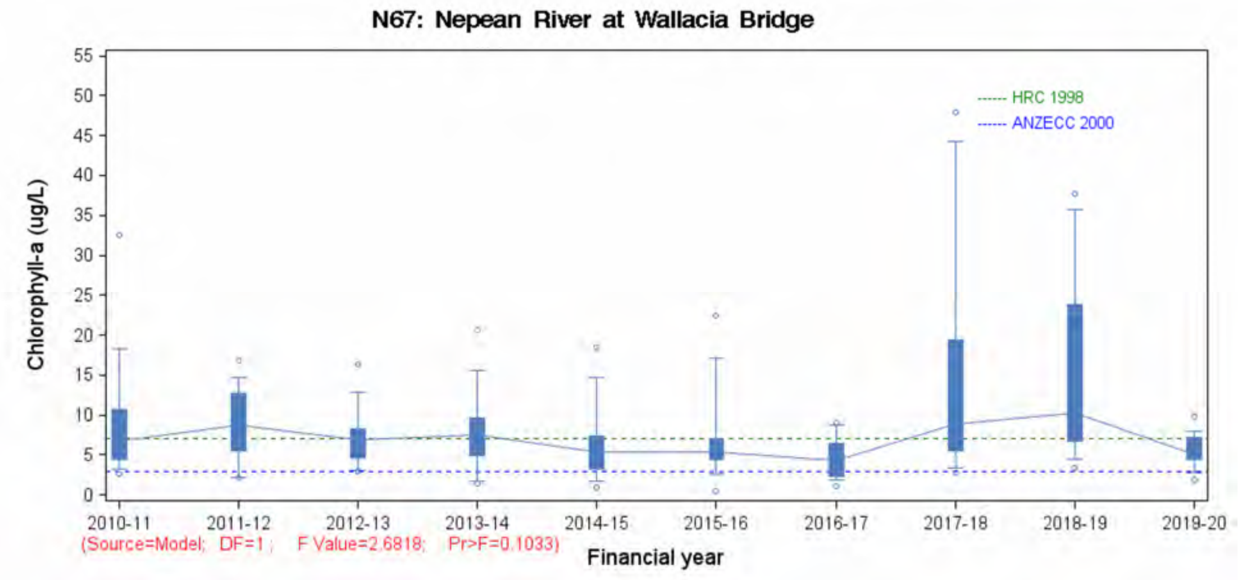
Six out of 17 samples qualified for an algal count when chlorophyll-*a* was higher than 7.0 μg/L. Chlorophyll-*a* concentrations reached as high as 9.8 μg/L on 10 January 2020, when algal biovolume was dominated by flagellated monads (*Cryptophyta* and *Euglenophyta*). Blue-green algae were in high counts (although low biovolume), including the presence of potentially toxic species *Microcystis* (351 cells/mL).

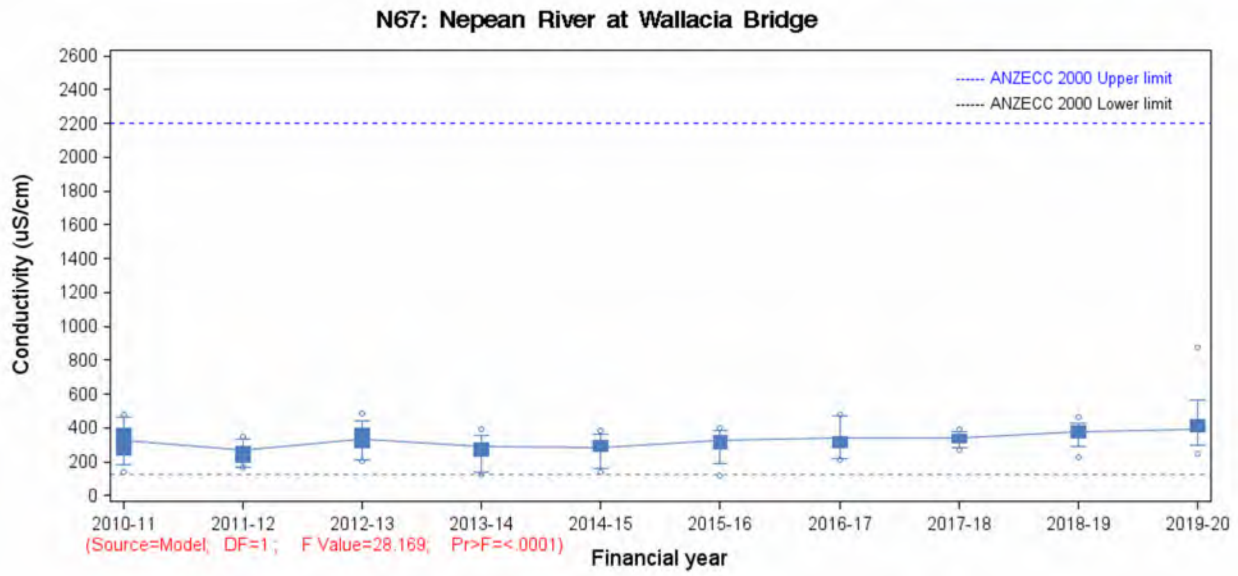
In the 2019-20 period, the median oxidised nitrogen, total nitrogen and chlorophyll-*a* concentrations exceeded the respective ANZECC (2000) guidelines.

There were no other significant trends and/or exceptions (median values higher than the guideline limits) for any other water quality or algae analyte in 2019-20.




N67: Nepean River at Wallacia Bridge
HRC 1998
ANZECC 2000
Total nitrogen (mg/L)
0.0
0.5
1.0
1.5
2.0
2.5
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=32.182; Pr>F=<.0001)
Financial year


N67: Nepean River at Wallacia Bridge
HRC 1998
ANZECC 2000
Chlorophyll-a (ug/L)
0
5
10
15
20
25
30
35
40
45
50
55
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=2.6818; Pr>F=0.1033)
Financial year


N67: Nepean River at Wallacia Bridge
ANZECC 2000 Upper limit
ANZECC 2000 Lower limit
Conductivity (uS/cm)
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=28.169; Pr>F=<.0001)
Financial year

N57: Nepean River at Penrith Weir

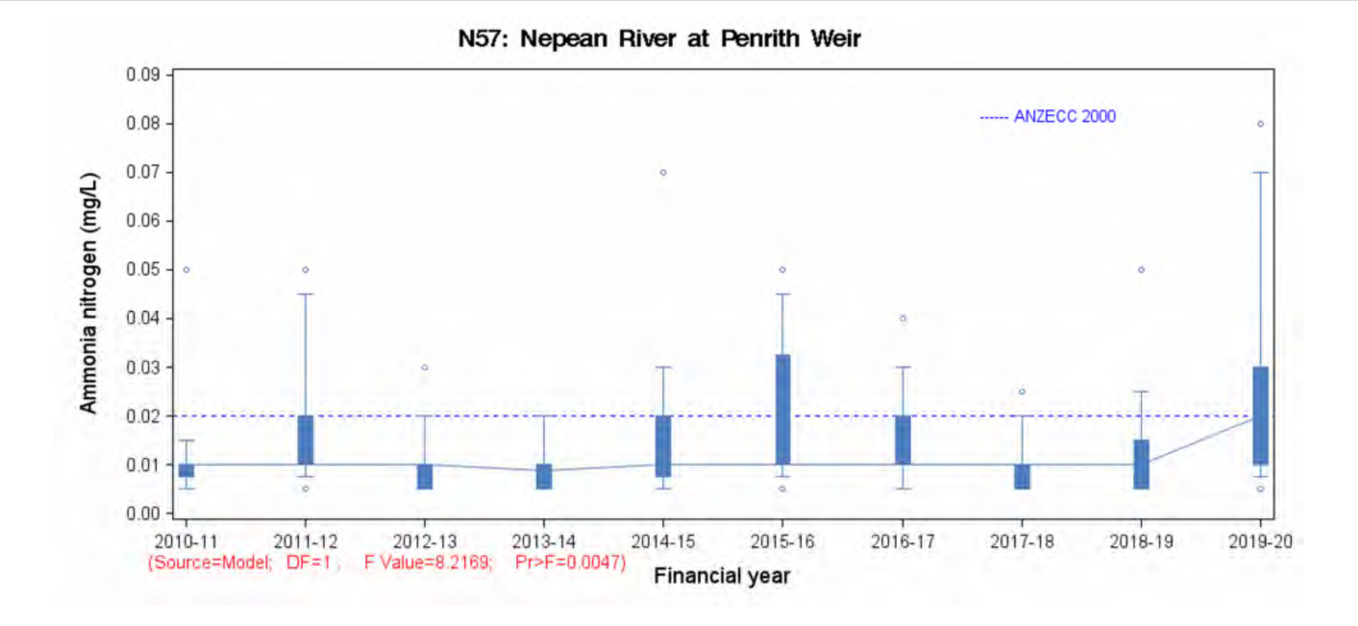
The Nepean River at Penrith Weir (N57) is 21 km downstream of Wallacia Bridge (N67). The immediate upstream catchment is largely undeveloped. The Warragamba River joins the Nepean River about 18 km upstream of Penrith Weir. The Warragamba River receives discharges from Wallacia WWTP and environmental flow releases from Warragamba Dam.

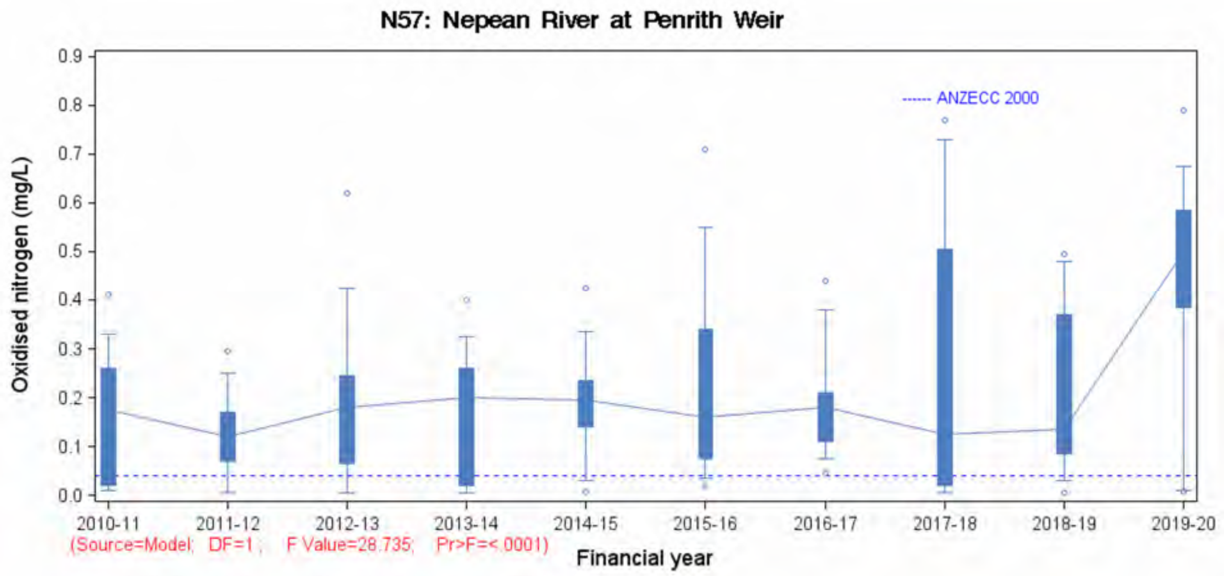
Statistical analysis confirmed that ammonia nitrogen, oxidised nitrogen and total nitrogen concentrations increased significantly at Penrith Weir (N57) in 2019-20 in comparison to the previous nine years (2010-19). Conductivity also significantly increased and dissolved oxygen saturation decreased (deteriorated) at this site.

The chlorophyll-*a* concentration decreased significantly in 2019-20 at this site. Two out of 17 samples qualified for an algal count with chlorophyll-*a* higher than 7.0 µg/L. Potentially toxic blue-green alga *Dolichospermum* was detected once on 15 August 2019 in low counts (245 cells/mL).

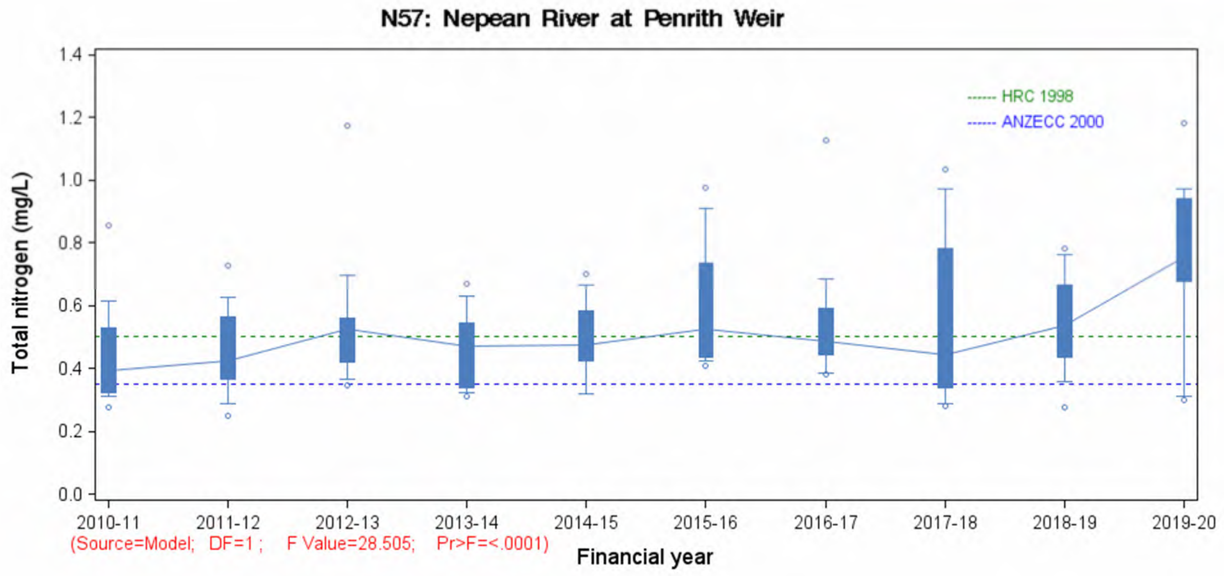
In the 2019-20 period, the median oxidised nitrogen, total nitrogen and chlorophyll-*a* concentrations exceeded the respective ANZECC (2000) guidelines. Median turbidity was low and below the ANZECC (2000) lower guideline limit.

There were no other significant trends and/or exceptions (median values higher than the guideline limits) for any other water quality or algae analyte in 2019-20.

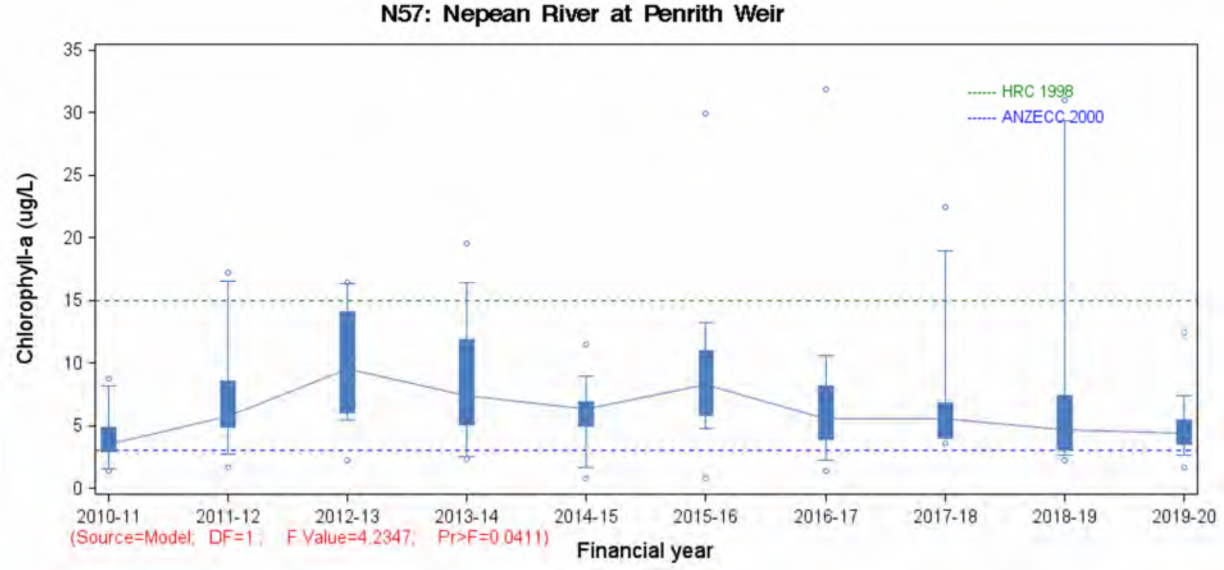




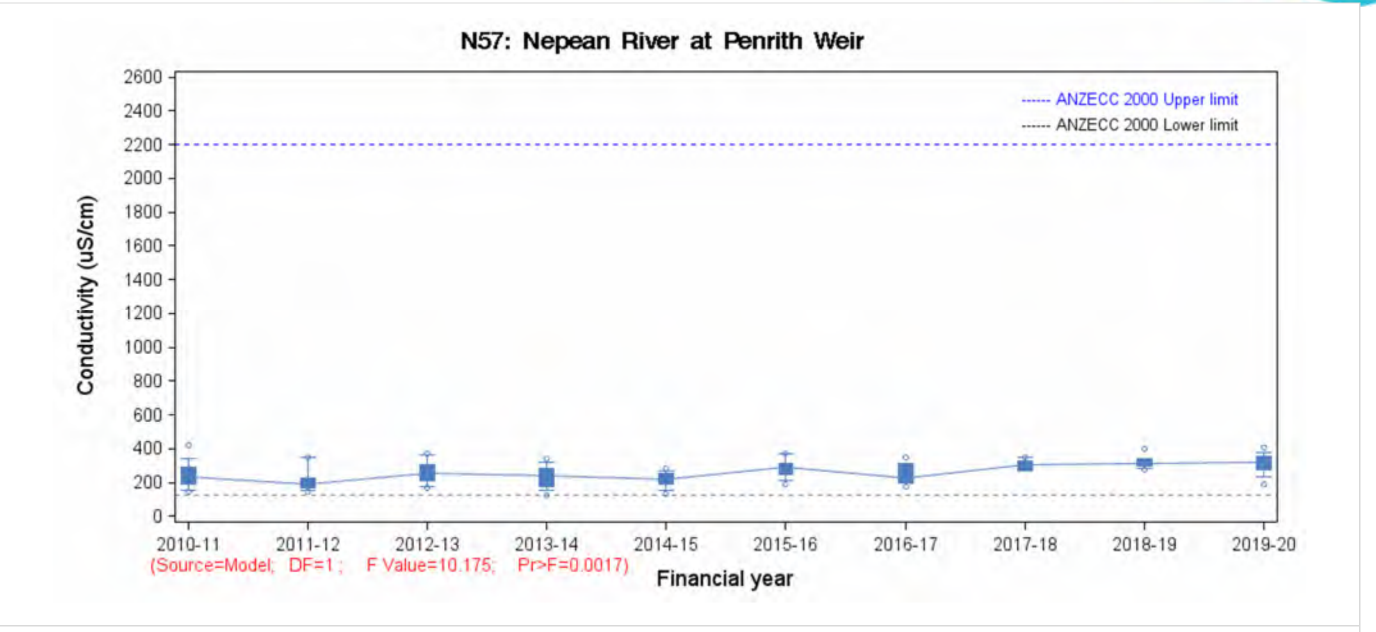
N57: Nepean River at Penrith Weir
Oxidised nitrogen (mg/L)
ANZECC 2000
2010-11 2011-12 2012-13 2013-14 2014-15 2015-16 2016-17 2017-18 2018-19 2019-20
(Source=Model; DF=1 ; F Value=28.735; Pr>F=<.0001)
Financial year

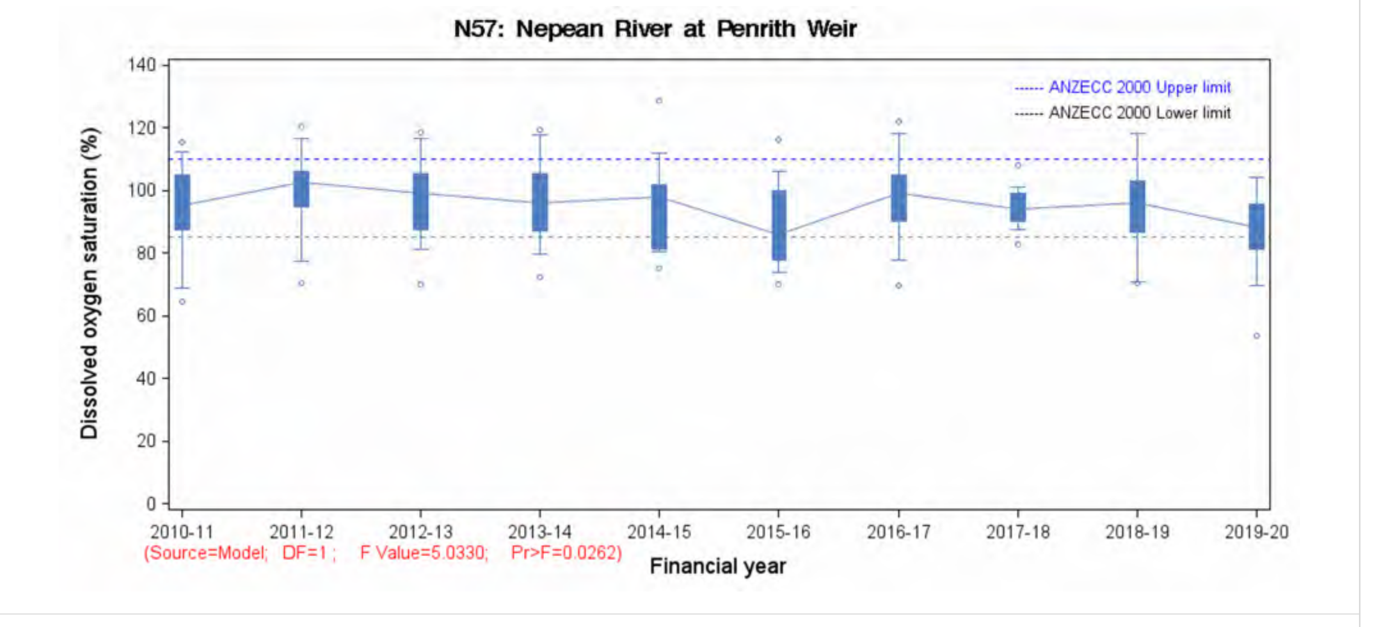


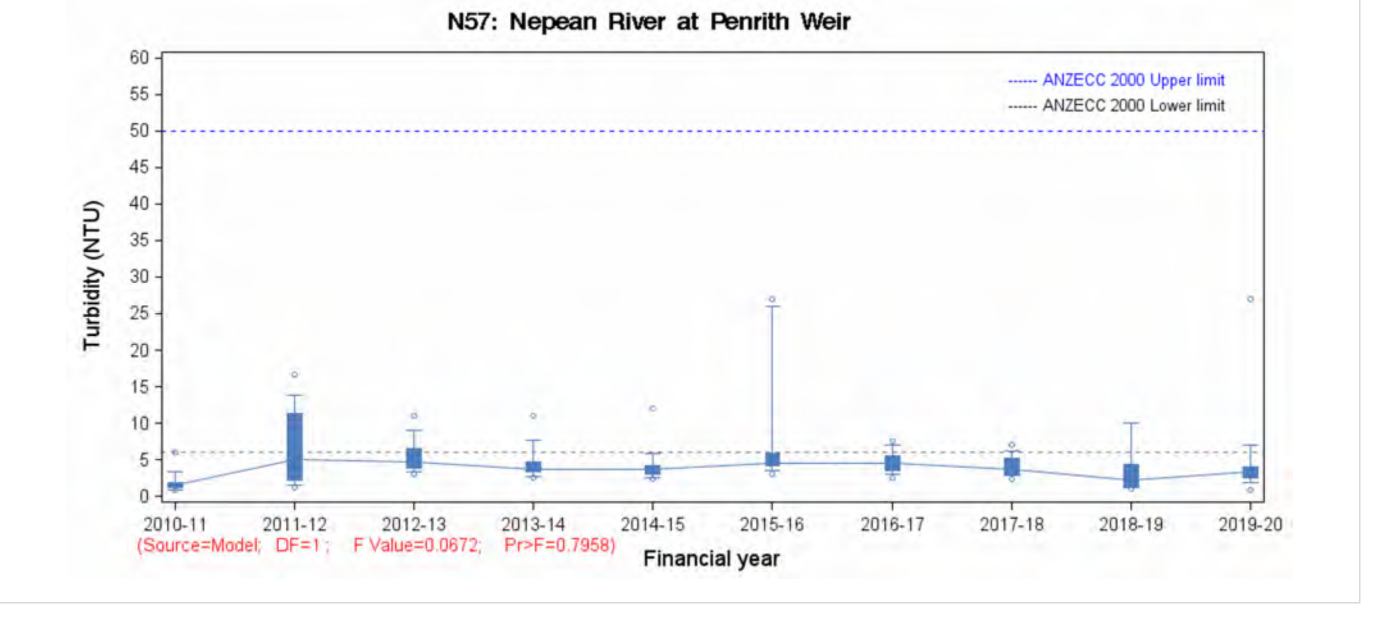
N57: Nepean River at Penrith Weir
Total nitrogen (mg/L)
HRC 1998
ANZECC 2000
2010-11 2011-12 2012-13 2013-14 2014-15 2015-16 2016-17 2017-18 2018-19 2019-20
(Source=Model; DF=1 ; F Value=28.505; Pr>F=<.0001)
Financial year



N57: Nepean River at Penrith Weir
Chlorophyll-a (ug/L)
HRC 1998
ANZECC 2000
2010-11 2011-12 2012-13 2013-14 2014-15 2015-16 2016-17 2017-18 2018-19 2019-20
(Source=Model; DF=1 ; F Value=4.2347; Pr>F=0.0411)
Financial year


N57: Nepean River at Penrith Weir
Conductivity (uS/cm)
ANZECC 2000 Upper limit
ANZECC 2000 Lower limit
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=10.175; Pr>F=0.0017)
Financial year


N57: Nepean River at Penrith Weir
Dissolved oxygen saturation (%)
ANZECC 2000 Upper limit
ANZECC 2000 Lower limit
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=5.0330; Pr>F=0.0262)
Financial year


N57: Nepean River at Penrith Weir
Turbidity (NTU)
ANZECC 2000 Upper limit
ANZECC 2000 Lower limit
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=0.0672; Pr>F=0.7958)
Financial year

N51: Nepean River opposite Fitzgeralds Creek

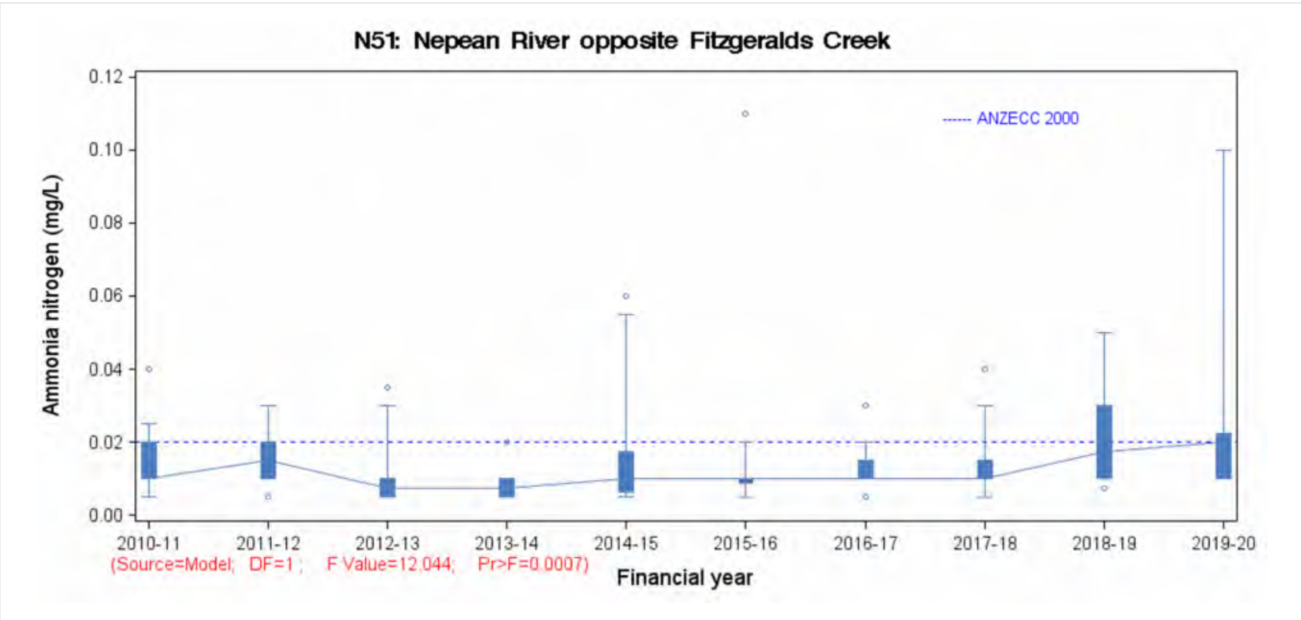
The Nepean River site opposite Fitzgeralds Creek (N51) is about 5 km downstream of Penrith Weir. Penrith WWTP discharges treated wastewater effluent to Boundary Creek, a small tributary entering the Nepean River below Penrith Weir. Boundary Creek also receives highly treated recycled water from the St Marys Advanced Water Treatment Plant (AWTP). Discharges from the AWTP commenced in 2010, that may have improved 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.

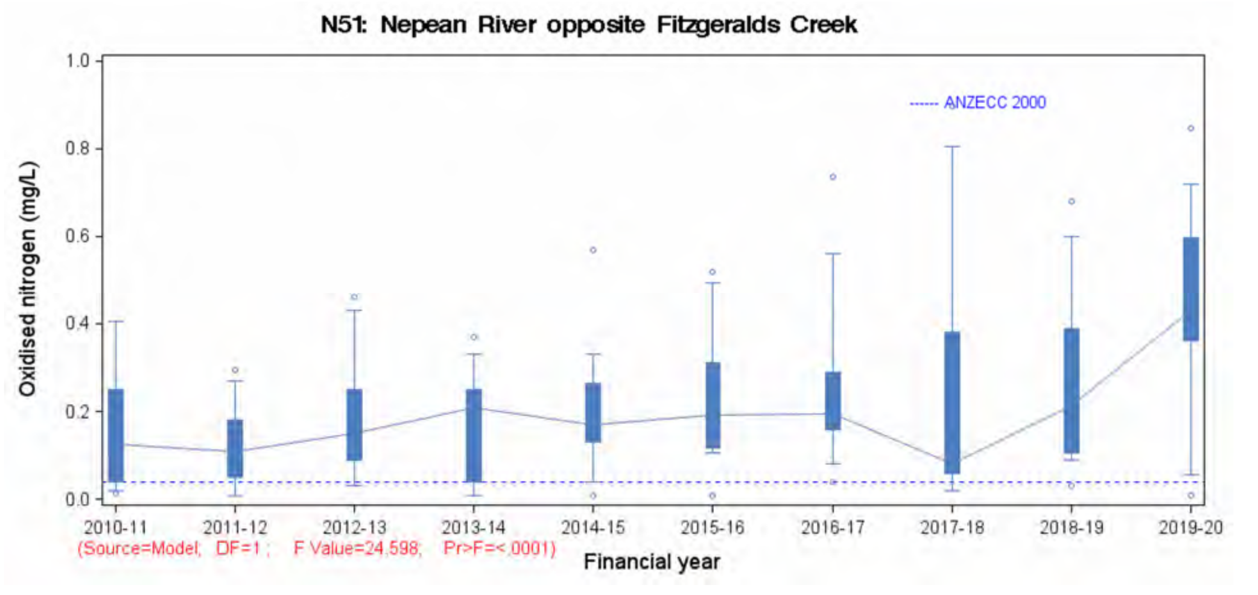
Statistical analysis confirmed that ammonia nitrogen, oxidised nitrogen, total nitrogen and conductivity levels/concentrations were significantly higher in 2019-20 compared to the previous nine years results.

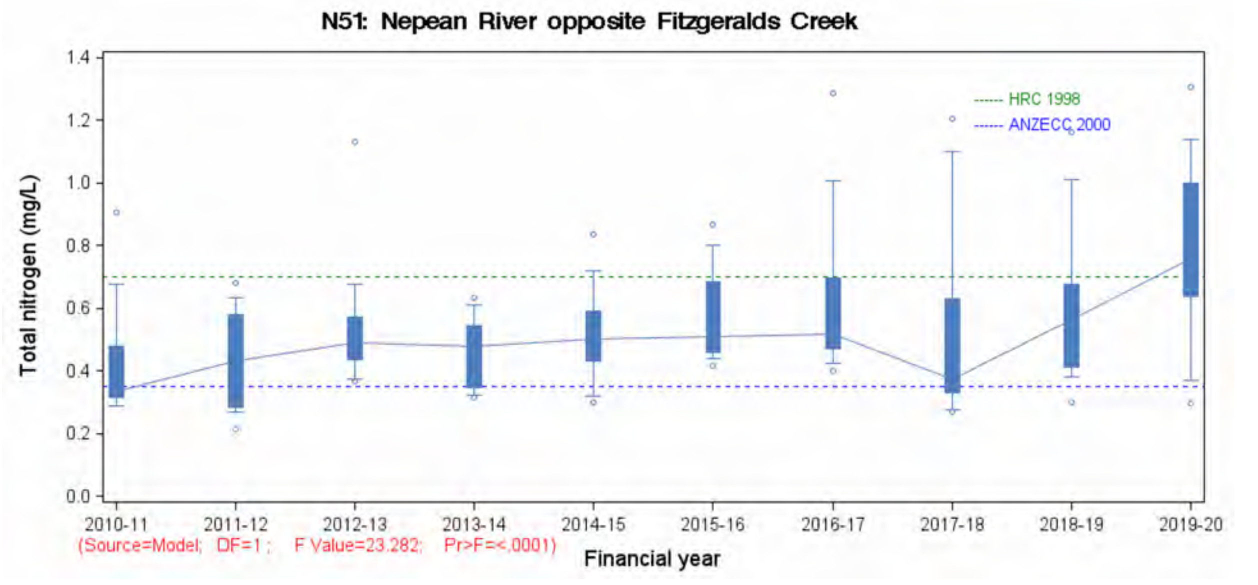
Chlorophyll-*a* concentrations were stable at this site with three of the 16 samples qualified for algal counting with a chlorophyll-*a* above 7.0 µg/L. Algal biovolume was low with no toxigenic blue-green algae detected in any sample.

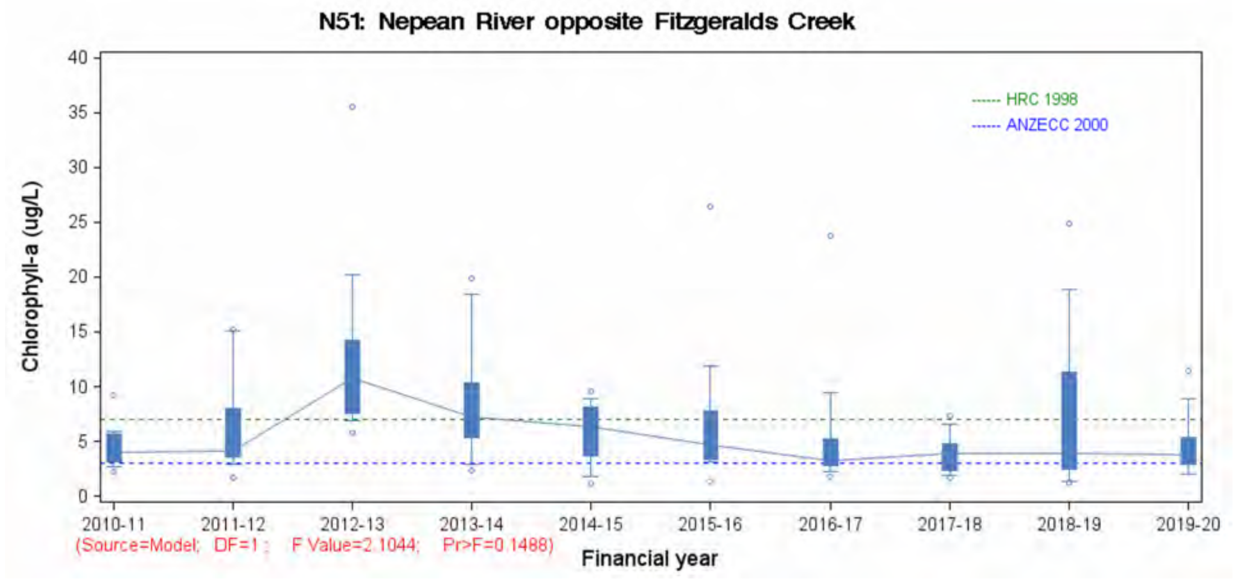
In the 2019-20 period, the median oxidised nitrogen, total nitrogen and chlorophyll-*a* concentrations exceeded the respective ANZECC (2000) guidelines. Median turbidity was low and below the ANZECC (2000) lower guideline limit.

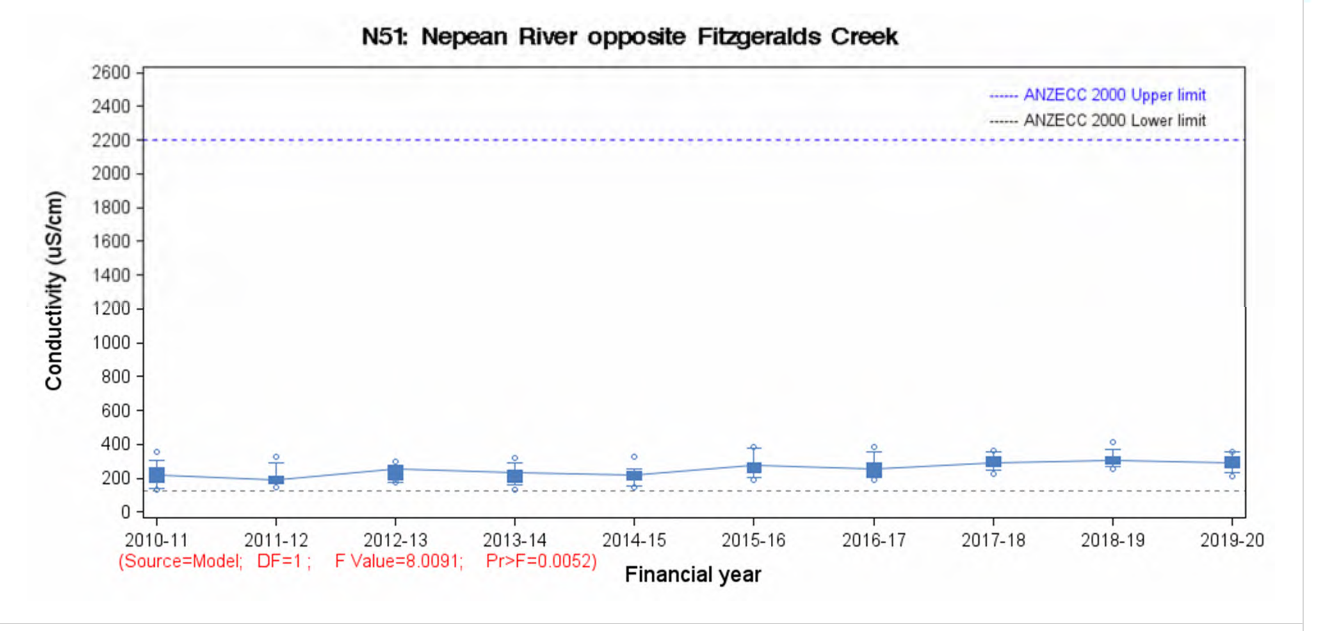
There were no other significant trends and/or exceptions (median values higher than the guideline limits) for any other water quality or algae analyte in 2019-20.

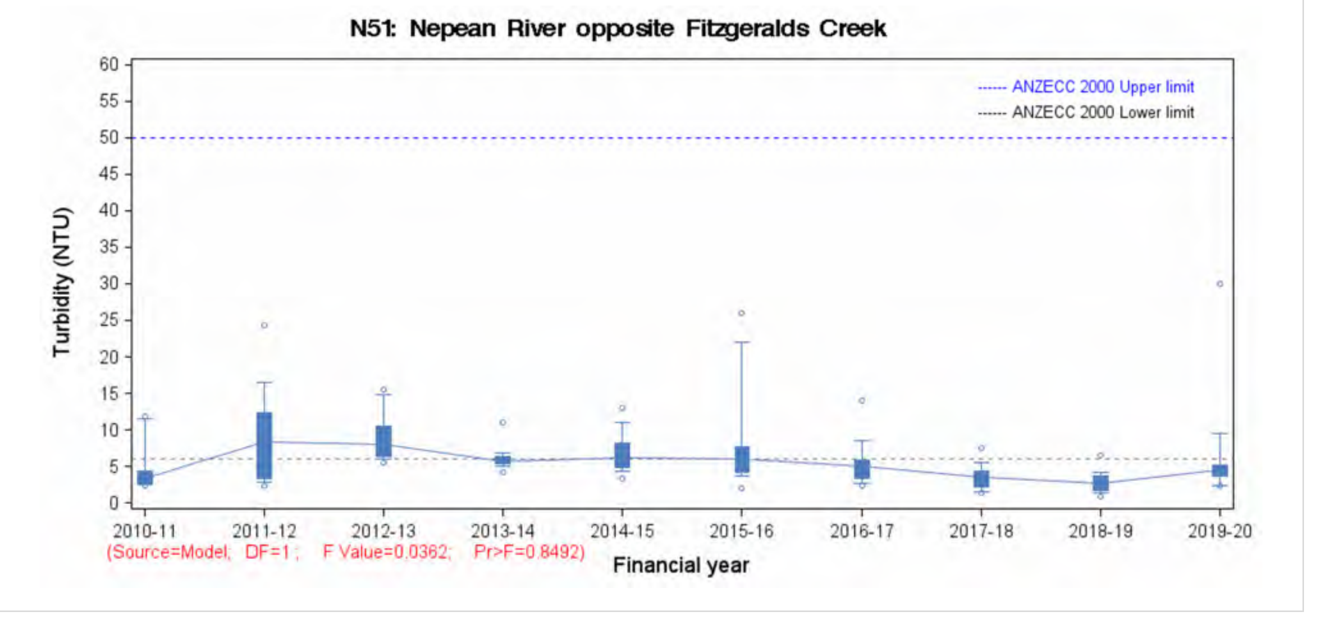



N51: Nepean River opposite Fitzgeralds Creek
Oxidised nitrogen (mg/L)
ANZECC 2000
(Source=Model; DF=1 ; F Value=24.598; Pr>F=<.0001)
Financial year


N51: Nepean River opposite Fitzgeralds Creek
Total nitrogen (mg/L)
HRC 1998
ANZECC 2000
(Source=Model; DF=1 ; F Value=23.282; Pr>F=<.0001)
Financial year


N51: Nepean River opposite Fitzgeralds Creek
Chlorophyll-a (ug/L)
HRC 1998
ANZECC 2000
(Source=Model; DF=1 ; F Value=2.1044; Pr>F=0.1488)
Financial year


N51: Nepean River opposite Fitzgeralds Creek
------ ANZECC 2000 Upper limit
------ ANZECC 2000 Lower limit
Conductivity (uS/cm)
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=8.0091; Pr>F=0.0052)
Financial year


N51: Nepean River opposite Fitzgeralds Creek
------ ANZECC 2000 Upper limit
------ ANZECC 2000 Lower limit
Turbidity (NTU)
60
55
50
45
40
35
30
25
20
15
10
5
0
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=0.0362; Pr>F=0.8492)
Financial year

N48A: Nepean River at Smith Road

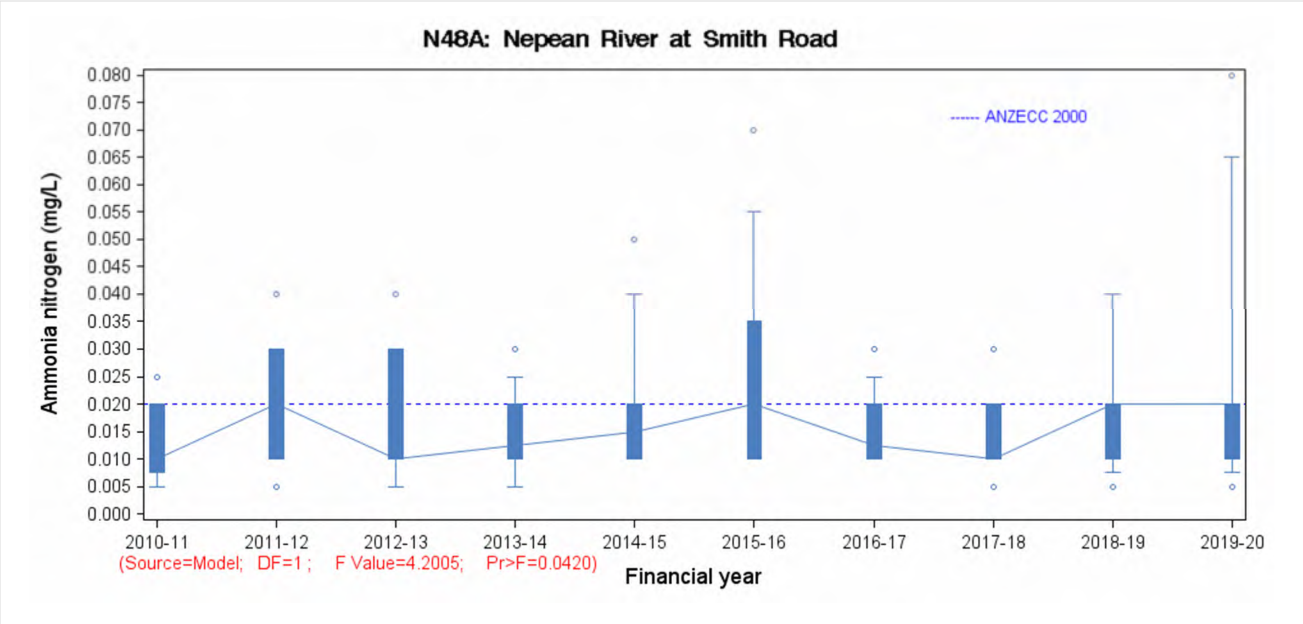
The Nepean River site at Smith Road (N48A) is a further 5 km downstream from the Fitzgeralds Creek site (N51). There are no wastewater discharges from Sydney Water WWTPs in the vicinity of this site other than the upstream Penrith WWTP. This site often contains submerged macrophyte beds with the occasional floating macrophyte species.

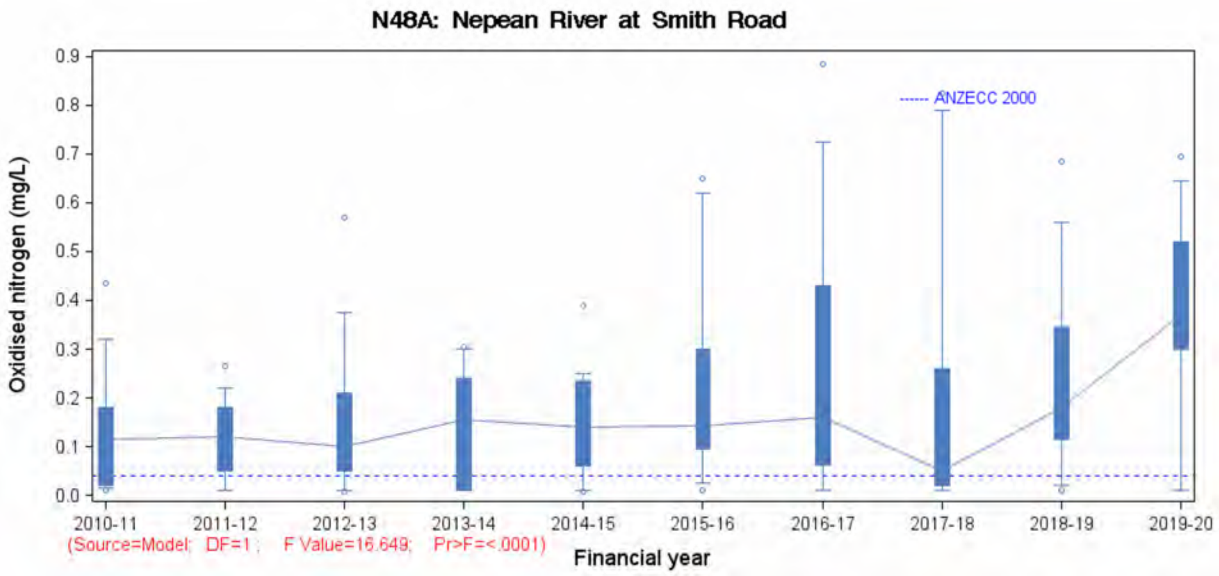
The water quality condition of this site deteriorated significantly with increased levels of ammonia nitrogen, oxidised nitrogen, total nitrogen and total algal biovolume in 2019-20 compared to the previous nine years.

Six out of 17 samples qualified for algal counting with chlorophyll-*a* concentrations higher than 7 µg/L. Chlorophyll-*a* concentrations reached as high as 41.1 µg/L at this site on 10 January 2020, when a potentially toxic blue-green alga *Phormidium* was identified in high counts (14,200 cells/mL).

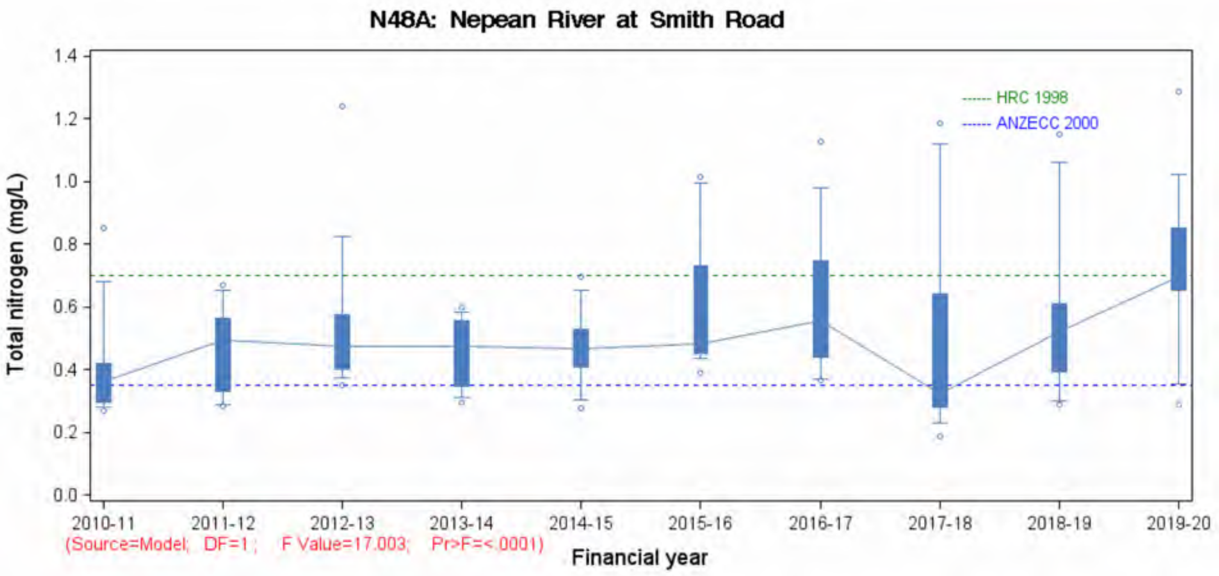
In the 2019-20 period, the median ammonia nitrogen, oxidised nitrogen, total nitrogen and chlorophyll-*a* concentrations exceeded the respective ANZECC (2000) guideline at this site. Median turbidity was low and below the ANZECC (2000) lower guideline limit.

There were no other significant trends and/or exceptions (median values higher than the guideline limits) for any other water quality or algae analyte in 2019-20.

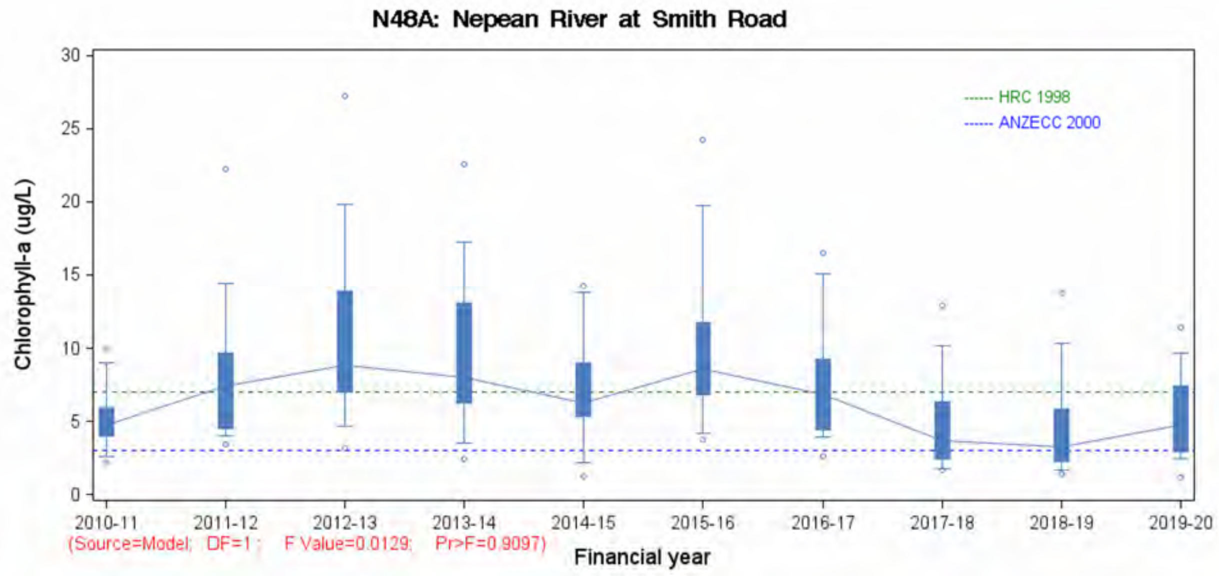




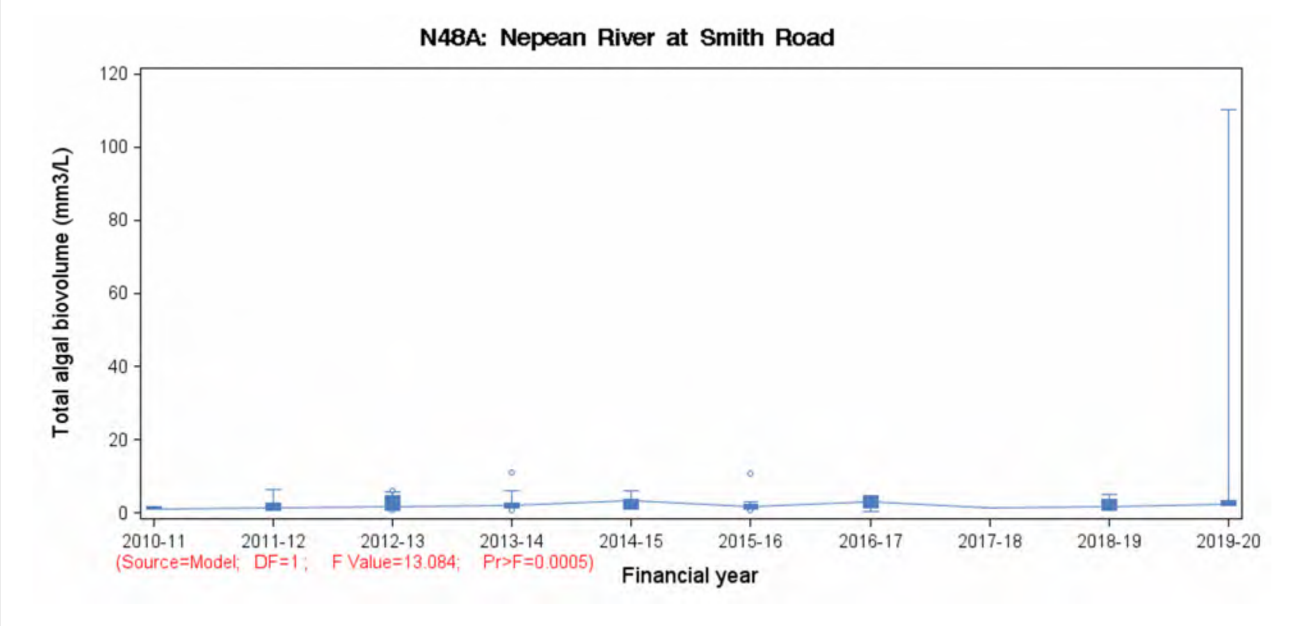
N48A: Nepean River at Smith Road
Oxidised nitrogen (mg/L)
ANZECC 2000
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=16.649; Pr>F=<.0001)
Financial year

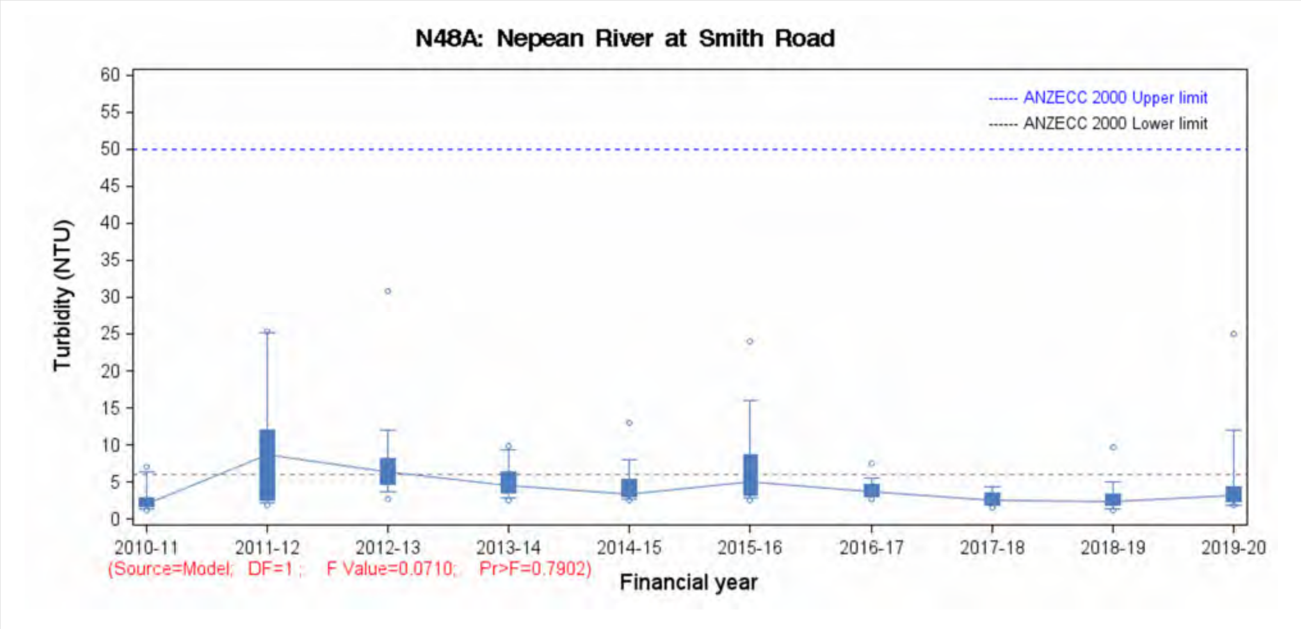


N48A: Nepean River at Smith Road
Total nitrogen (mg/L)
HRC 1998
ANZECC 2000
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=17.003; Pr>F=<.0001)
Financial year



N48A: Nepean River at Smith Road
Chlorophyll-a (ug/L)
HRC 1998
ANZECC 2000
0
5
10
15
20
25
30
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=0.0129; Pr>F=0.9097)
Financial year


N48A: Nepean River at Smith Road
Total algal biovolume (mm3/L)
120
100
80
60
40
20
0
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=13.084; Pr>F=0.0005)
Financial year


N48A: Nepean River at Smith Road
------ ANZECC 2000 Upper limit
------ ANZECC 2000 Lower limit
Turbidity (NTU)
60
55
50
45
40
35
30
25
20
15
10
5
0
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=0.0710; Pr>F=0.7902)
Financial year

N44: Nepean River at Yarramundi Bridge

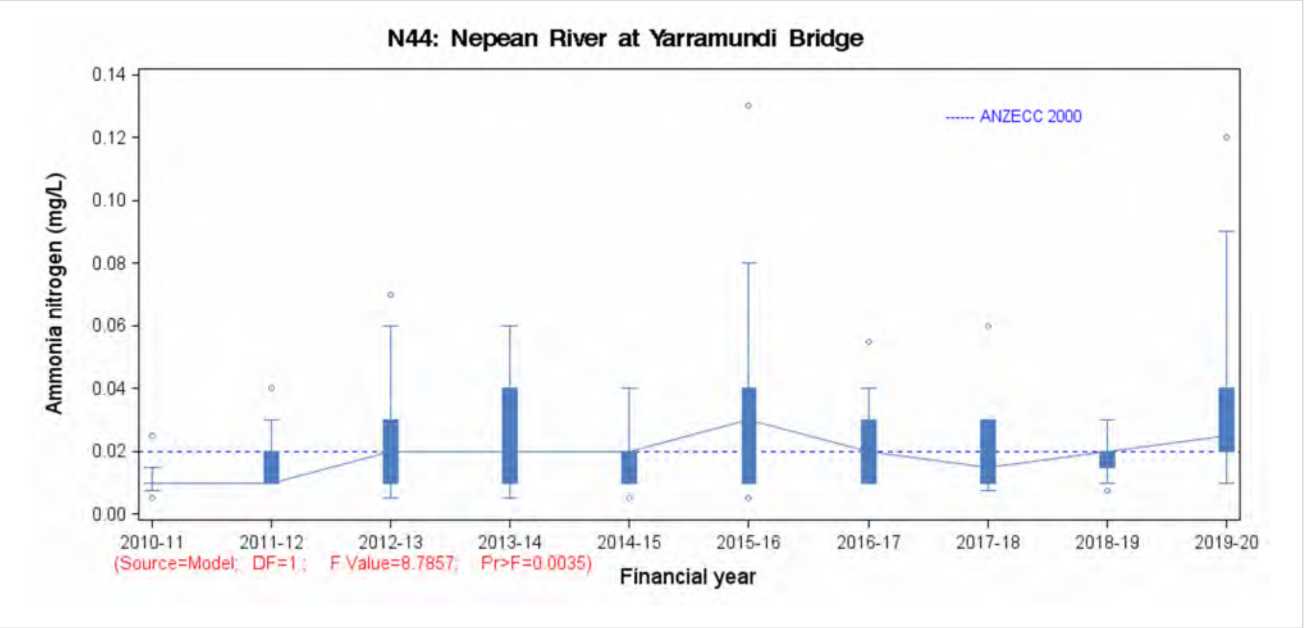
The Nepean River at Yarramundi Bridge (N44) is located just before the confluence with the Grose River. The site is situated downstream of Winmalee lagoon where Winmalee WWTP discharges treated wastewater. Yarramundi is the freshwater upper tidal limit for the Hawkesbury-Nepean River.

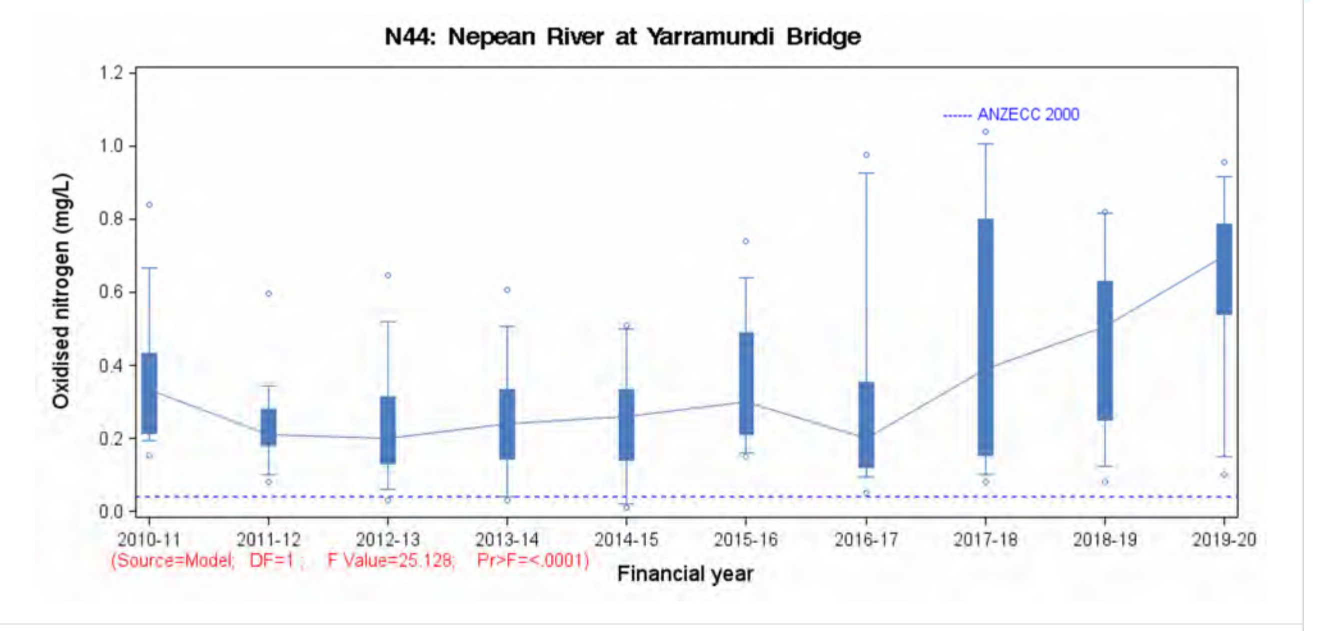
The water quality of the Nepean River at Yarramundi Bridge showed significantly increased concentrations of ammonia nitrogen, oxidised nitrogen and total nitrogen in 2019-20. Despite elevated concentrations of nitrogen analytes, chlorophyll-*a* concentrations remained steady at this site. Six out of the 17 samples exceeded a chlorophyll-*a* concentration of 7μg/L which triggered algal analysis in 2019-20. Algal populations were mixed with no potentially toxic blue-green algae present in any sample.

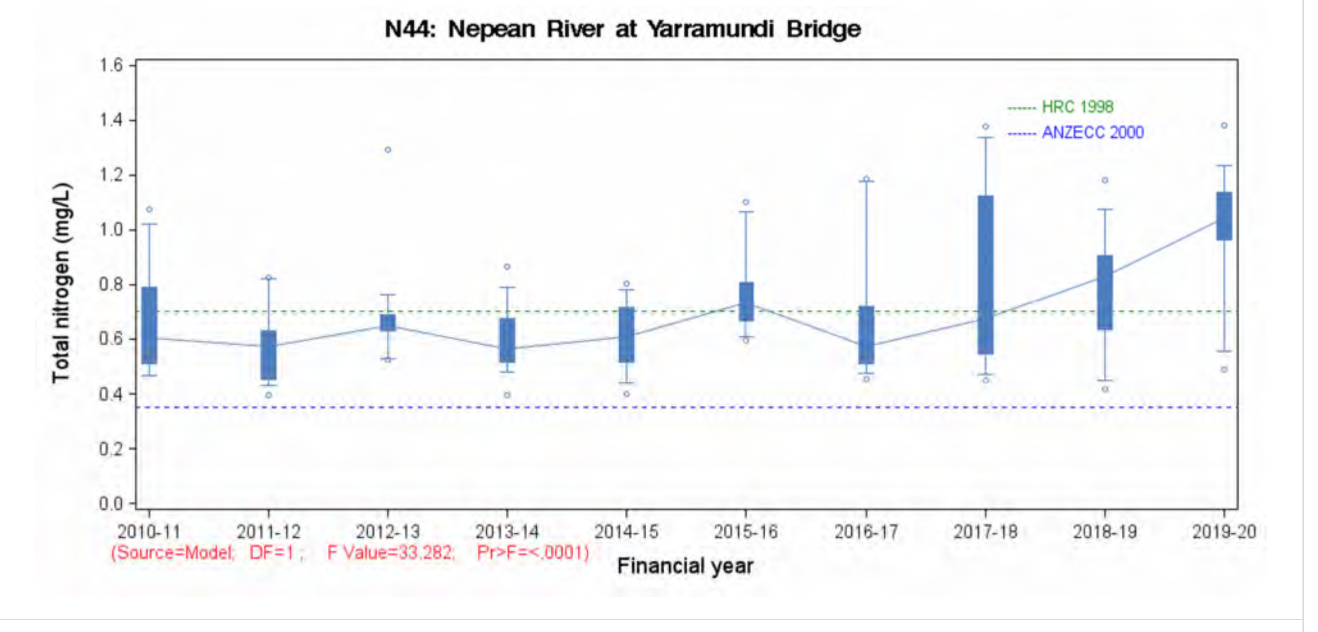
Among physico-chemical analytes, conductivity was significantly higher in 2019-20 compared to previous years.

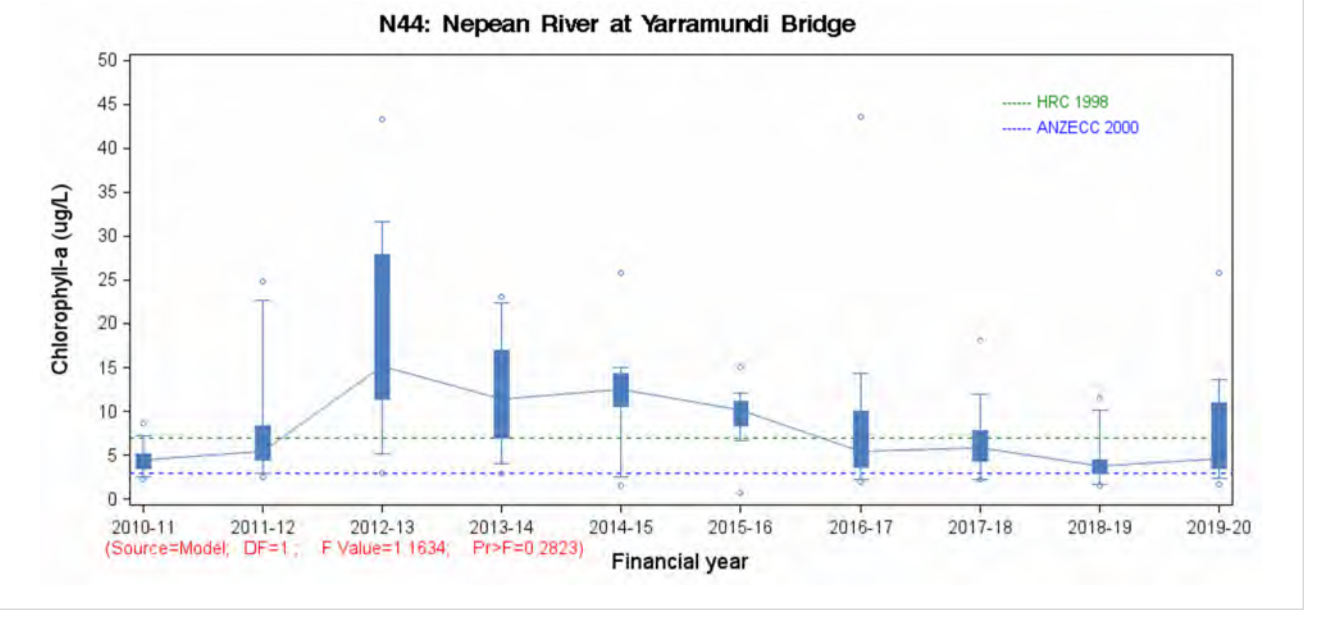
In the 2019-20 period, the median ammonia nitrogen, oxidised nitrogen, total nitrogen and chlorophyll-*a* concentrations exceeded the ANZECC (2000) guidelines. Median turbidity was low and below the ANZECC (2000) lower guideline limit.

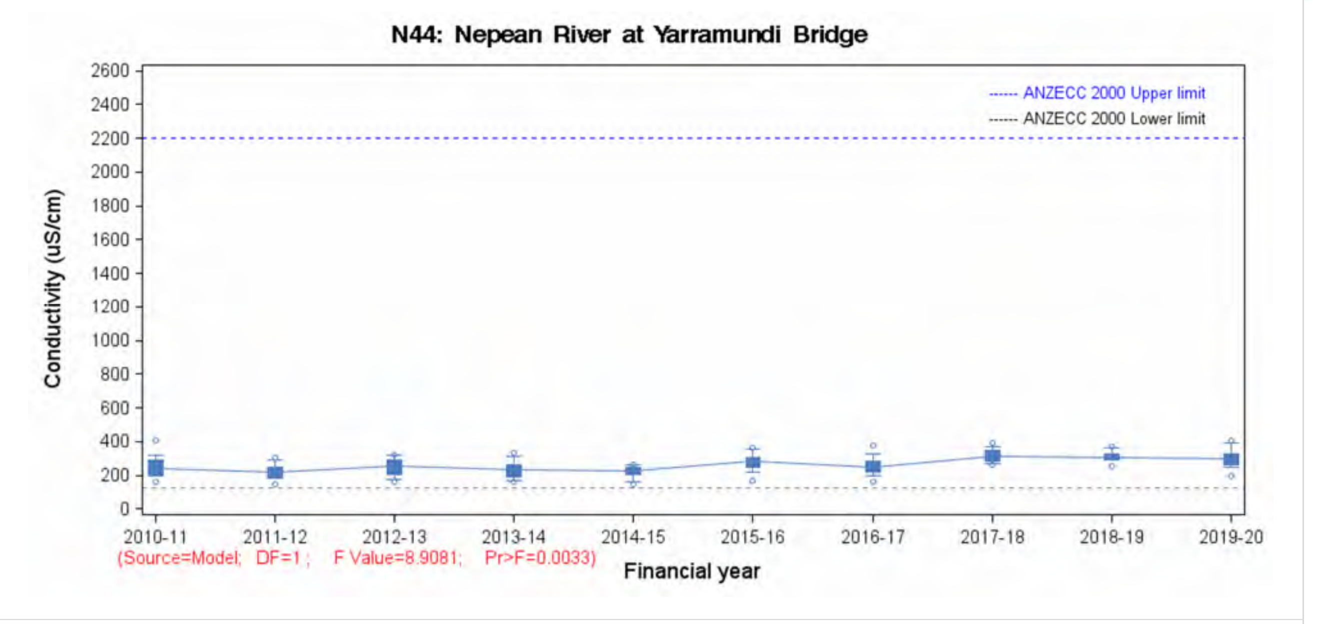
There were no other significant trends and/or exceptions (median values higher than the guideline limits) for any other water quality or algae analyte in 2019-20.

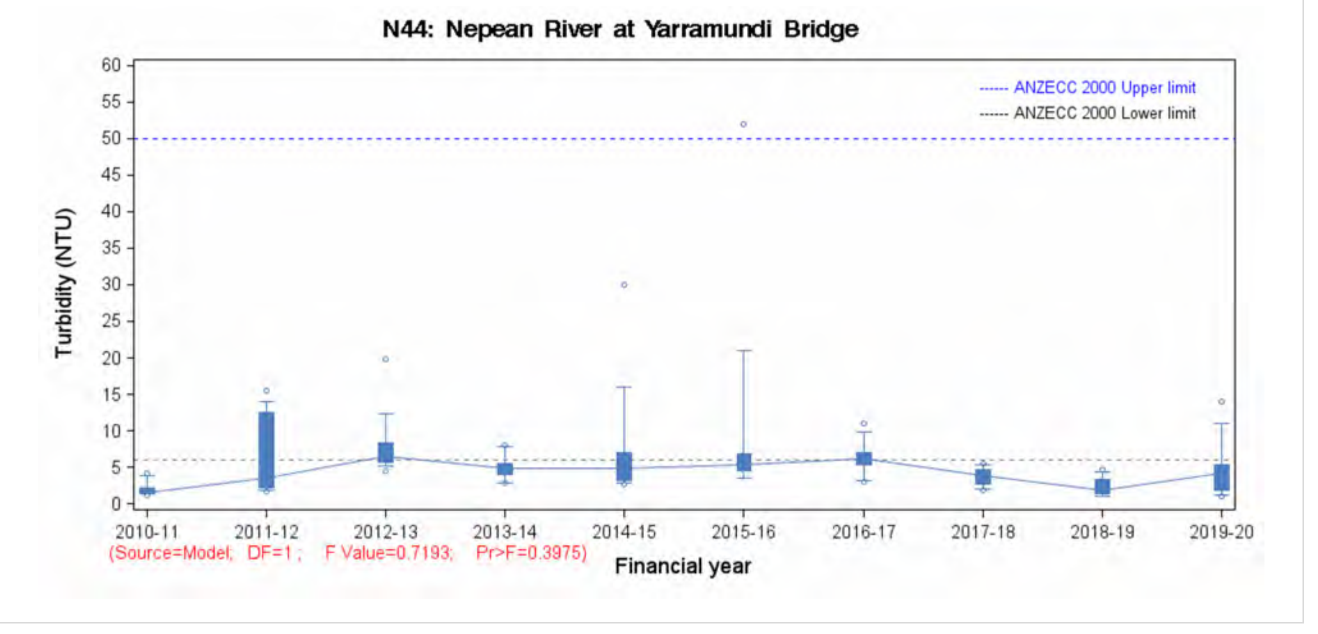



N44: Nepean River at Yarramundi Bridge
Oxidised nitrogen (mg/L)
ANZECC 2000
1.2
1.0
0.8
0.6
0.4
0.2
0.0
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=25.128; Pr>F=<.0001)
Financial year


N44: Nepean River at Yarramundi Bridge
Total nitrogen (mg/L)
HRC 1998
ANZECC 2000
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=33.282; Pr>F=<.0001)
Financial year


N44: Nepean River at Yarramundi Bridge
Chlorophyll-a (ug/L)
HRC 1998
ANZECC 2000
50
45
40
35
30
25
20
15
10
5
0
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=1.1634; Pr>F=0.2823)
Financial year


N44: Nepean River at Yarramundi Bridge
Conductivity (uS/cm)
ANZECC 2000 Upper limit
ANZECC 2000 Lower limit
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=8.9081; Pr>F=0.0033)
Financial year


N44: Nepean River at Yarramundi Bridge
Turbidity (NTU)
ANZECC 2000 Upper limit
ANZECC 2000 Lower limit
60
55
50
45
40
35
30
25
20
15
10
5
0
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=0.7193; Pr>F=0.3975)
Financial year

N42: Hawkesbury River at North Richmond

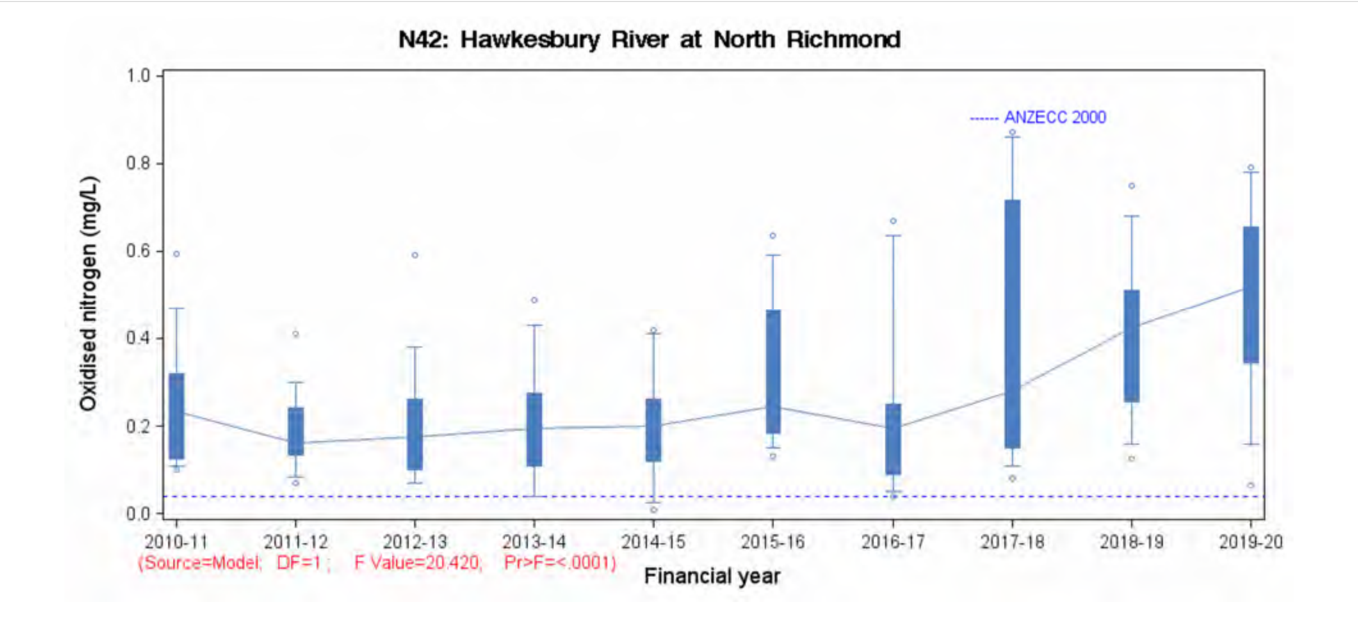
The Hawkesbury River at North Richmond (N42) is the uppermost site of the Hawkesbury River, located immediately downstream of the confluence with the Grose River. The river widens and deepens from this point. There are established beds of exotic submerged macrophytes in the vicinity of this site.

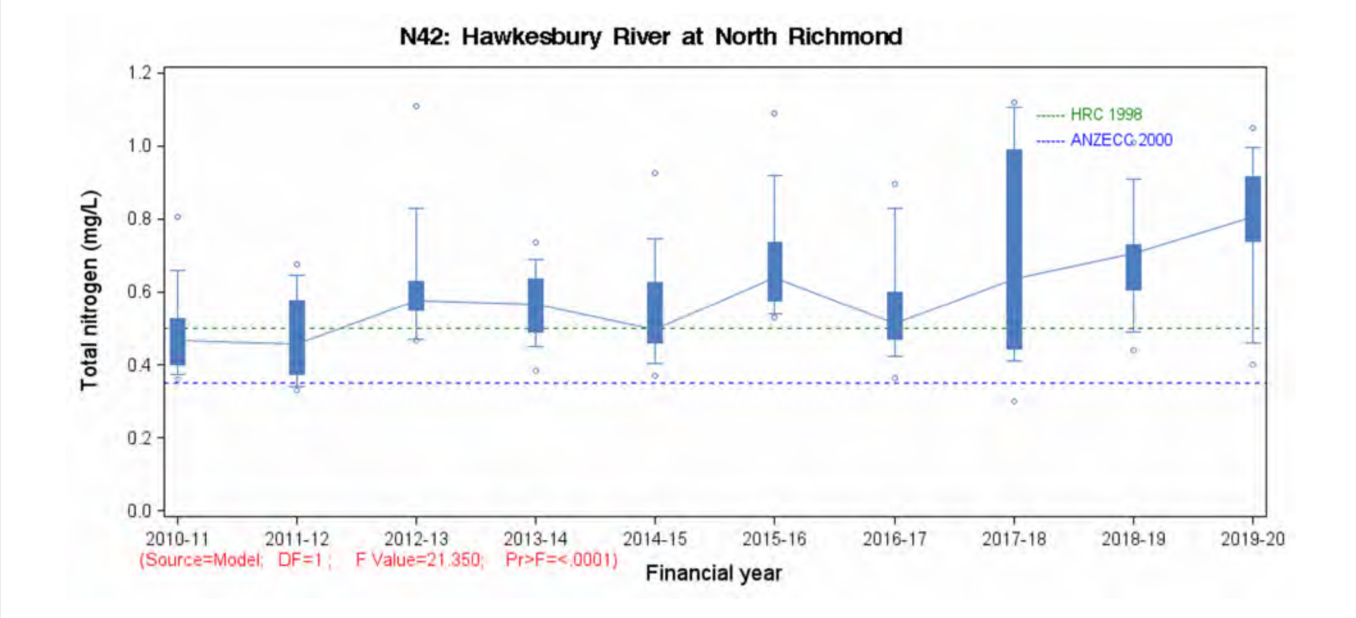
Oxidised nitrogen and total nitrogen significantly increased at North Richmond (N42) in 2019-20 in comparison to previous nine years. No significantly increasing/decreasing trends were identified in ammonia nitrogen, filterable total phosphorus, total phosphorus and chlorophyll-*a* concentrations in 2019-20. Six of the 17 samples exceeded a chlorophyll-*a* concentration of 7 µg/L, triggering algal analysis. Chlorophyll-*a* at North Richmond (N42) reached a maximum of 22.0 µg/L in February 2020. The algal population was mixed with no potentially toxic blue-green algae present in any sample.

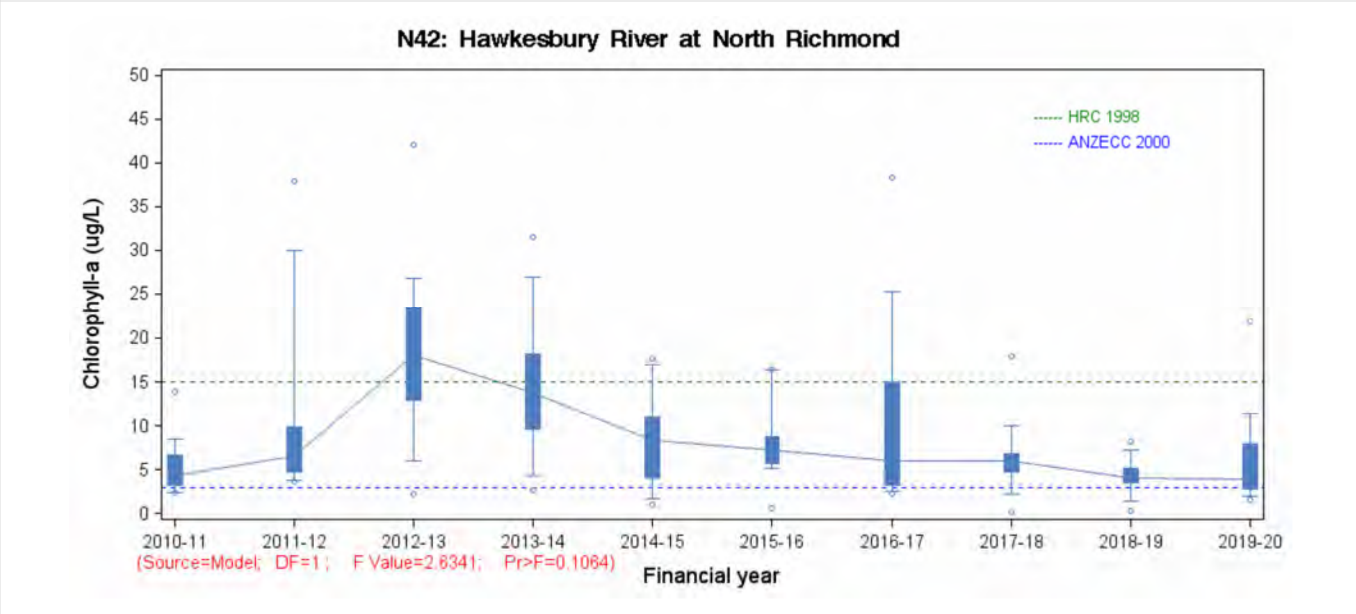
Among the physico-chemical analytes, conductivity was significantly higher and dissolved oxygen saturation lower/deteriorated in 2019-20.

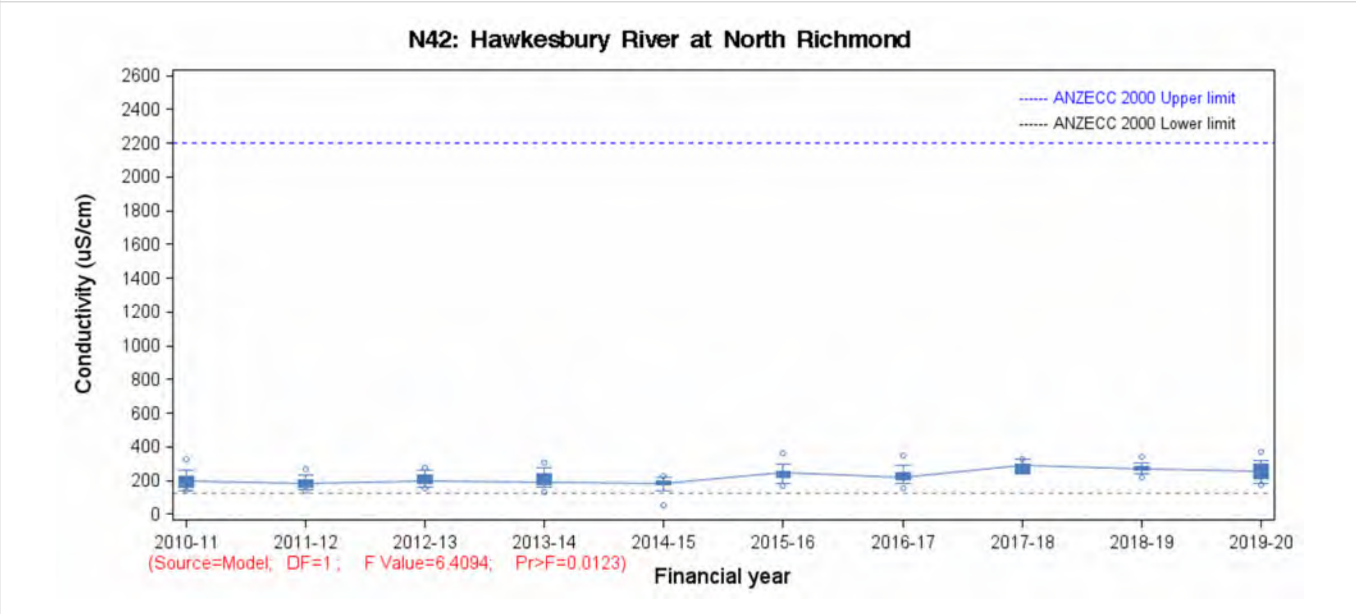
In the 2019-20 period, the median oxidised nitrogen, total nitrogen and chlorophyll-*a* concentrations exceeded the respective ANZECC (2000) guidelines. Median turbidity was very low and below the ANZECC (2000) lower guideline limit.

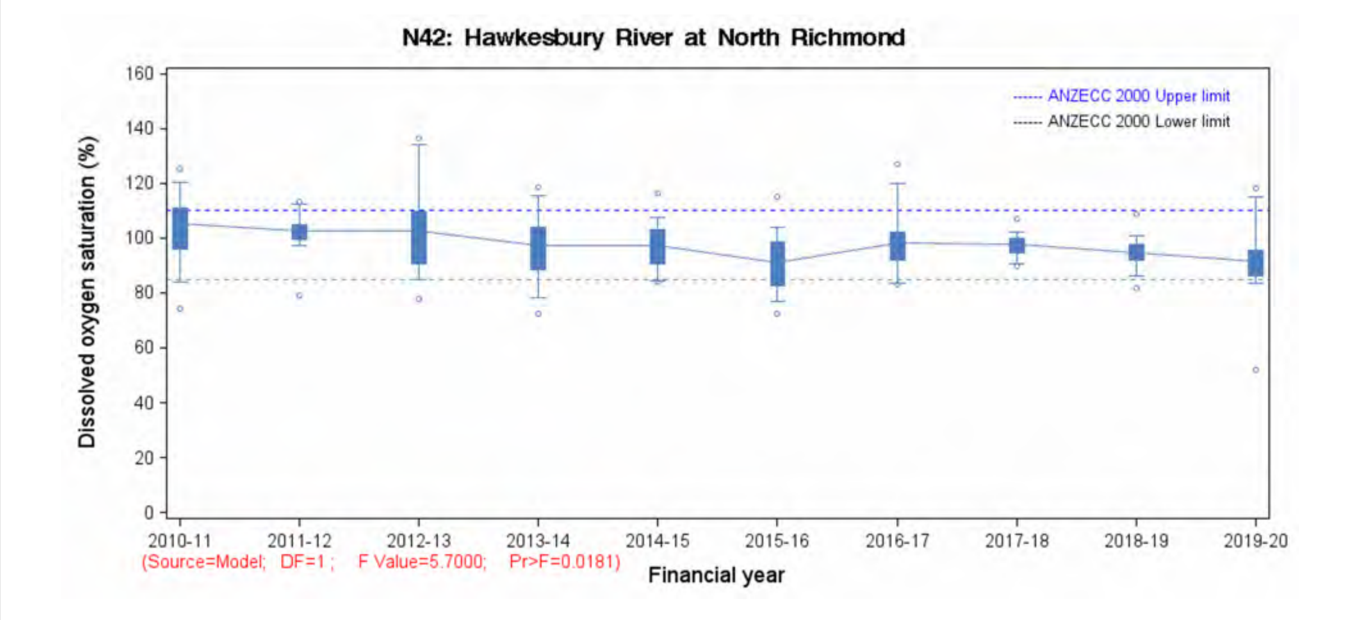
There were no other significant trends and/or exceptions (median values higher than the guideline limits) for any other water quality or algae analyte in 2019-20.

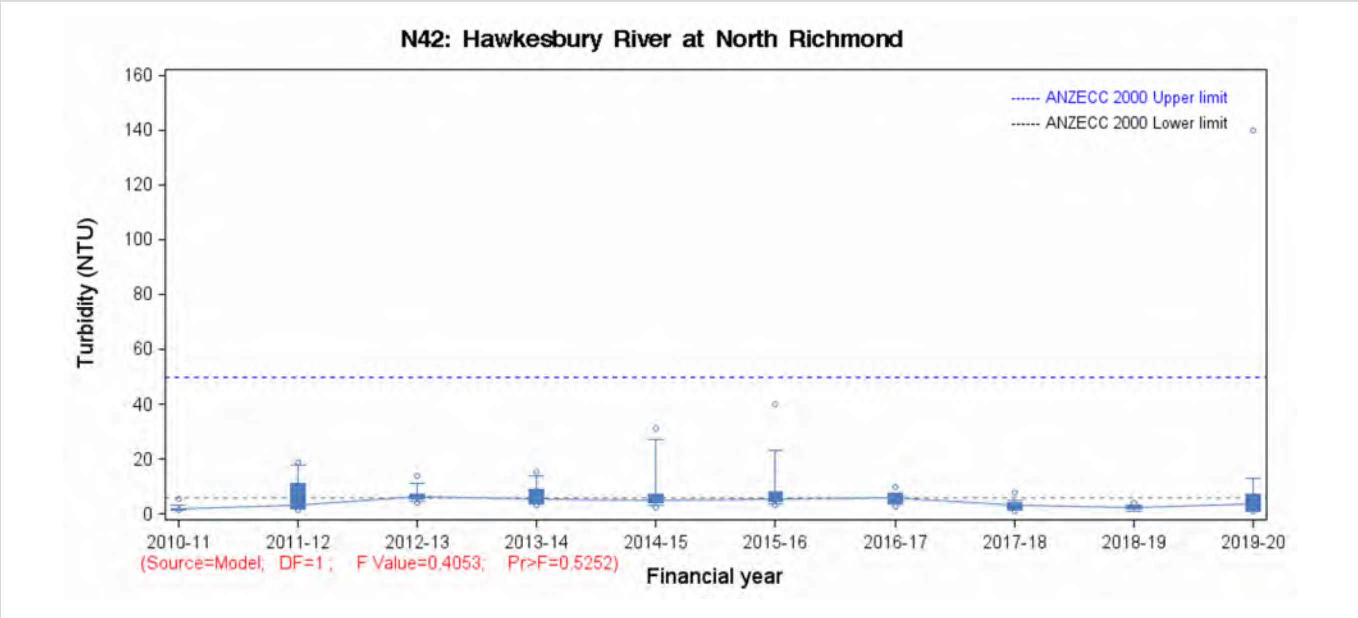



N42: Hawkesbury River at North Richmond
Total nitrogen (mg/L)
HRC 1998
ANZECC 2000
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=21.350; Pr>F=<.0001)
Financial year


N42: Hawkesbury River at North Richmond
Chlorophyll-a (ug/L)
HRC 1998
ANZECC 2000
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=2.6341; Pr>F=0.1064)
Financial year


N42: Hawkesbury River at North Richmond
Conductivity (uS/cm)
ANZECC 2000 Upper limit
ANZECC 2000 Lower limit
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=6.4094; Pr>F=0.0123)
Financial year


N42: Hawkesbury River at North Richmond
ANZECC 2000 Upper limit
ANZECC 2000 Lower limit
Dissolved oxygen saturation (%)
160
140
120
100
80
60
40
20
0
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=5.7000; Pr>F=0.0181)
Financial year


N42: Hawkesbury River at North Richmond
ANZECC 2000 Upper limit
ANZECC 2000 Lower limit
Turbidity (NTU)
160
140
120
100
80
60
40
20
0
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=0.4053; Pr>F=0.5252)
Financial year

N39: Hawkesbury River at Freemans Reach

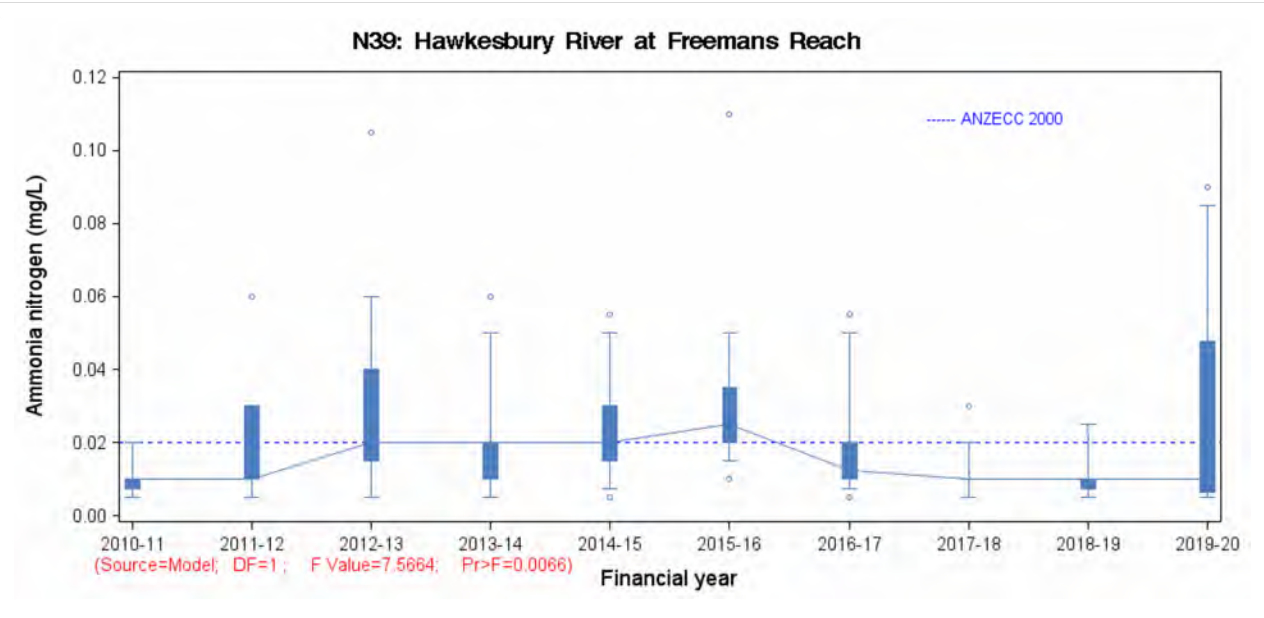
The Hawkesbury River at Freemans Reach (N39) is located approximately 7 km downstream from North Richmond. North Richmond WWTP discharge small volumes of treated wastewater via Redbank Creek, into the Hawkesbury River upstream from N39.

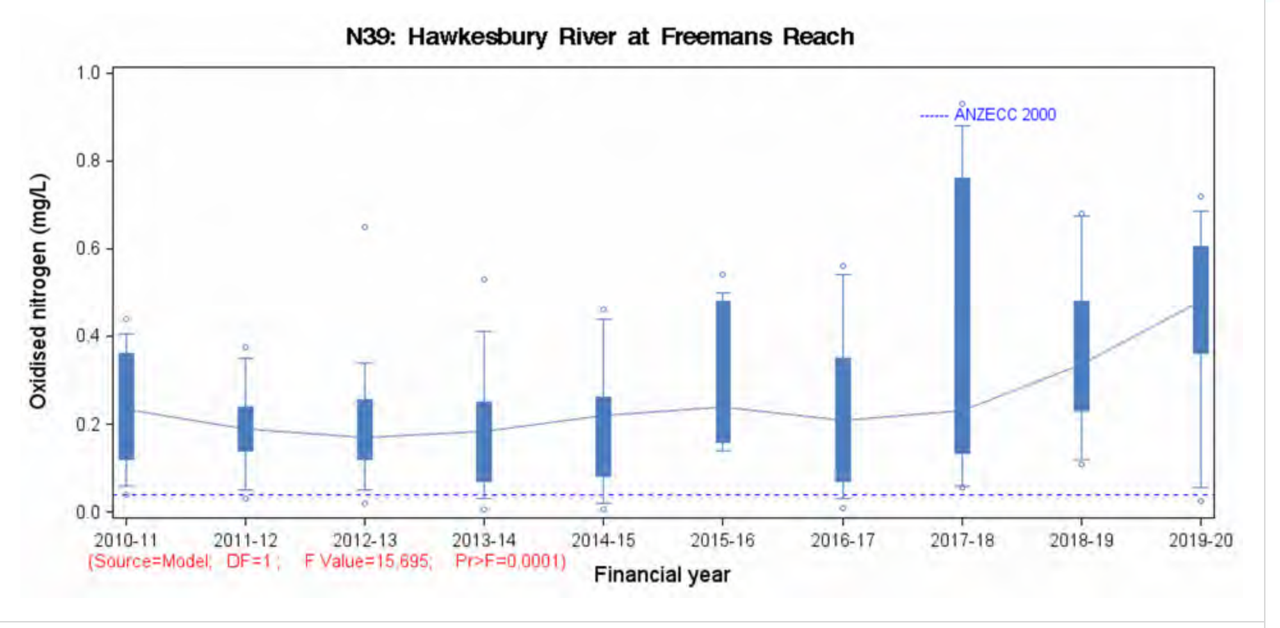
There was a significant increase in ammonia nitrogen, oxidised nitrogen and total nitrogen at Freemans Reach in 2019-20. Filterable total phosphorus, total phosphorus and chlorophyll-*a* concentrations were steady in 2019-20. Three of the 17 samples exceeded a chlorophyll-*a* concentration of 7 µg/L, triggering algal analysis in 2019-20. Chlorophyll-*a* reached a peak of 31.4 µg/L on 21 February 2020. The algal population of this sample was dominated by flagellated monads in high counts (*Cryptomonas* 6,035 cells/mL) and potentially toxic blue-green alga *Microcystis* was also present in moderate counts (1,120 cells/mL).

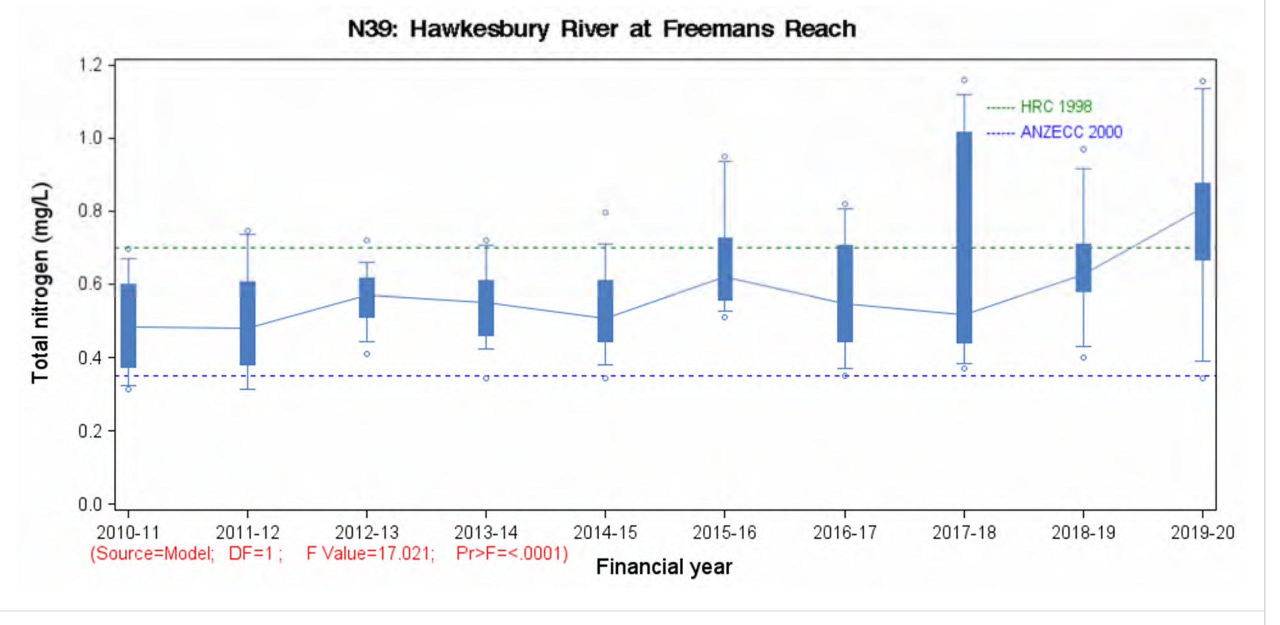
Among the physico-chemical analytes, conductivity was significantly higher in 2019-20. All other water quality and algae analytes were not significantly different in 2019-20.

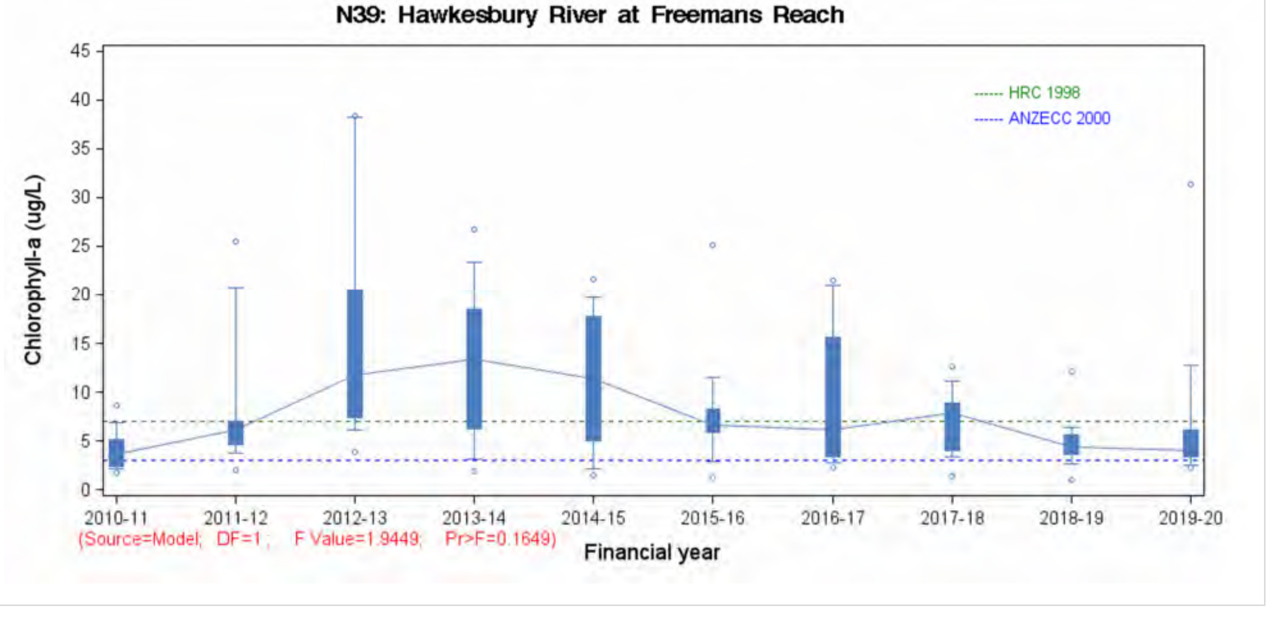
In the 2019-20 period, the median oxidised nitrogen, total nitrogen and chlorophyll-*a* concentrations exceeded the respective ANZECC (2000) guidelines. Median turbidity was low and below the ANZECC (2000) lower guideline limit.

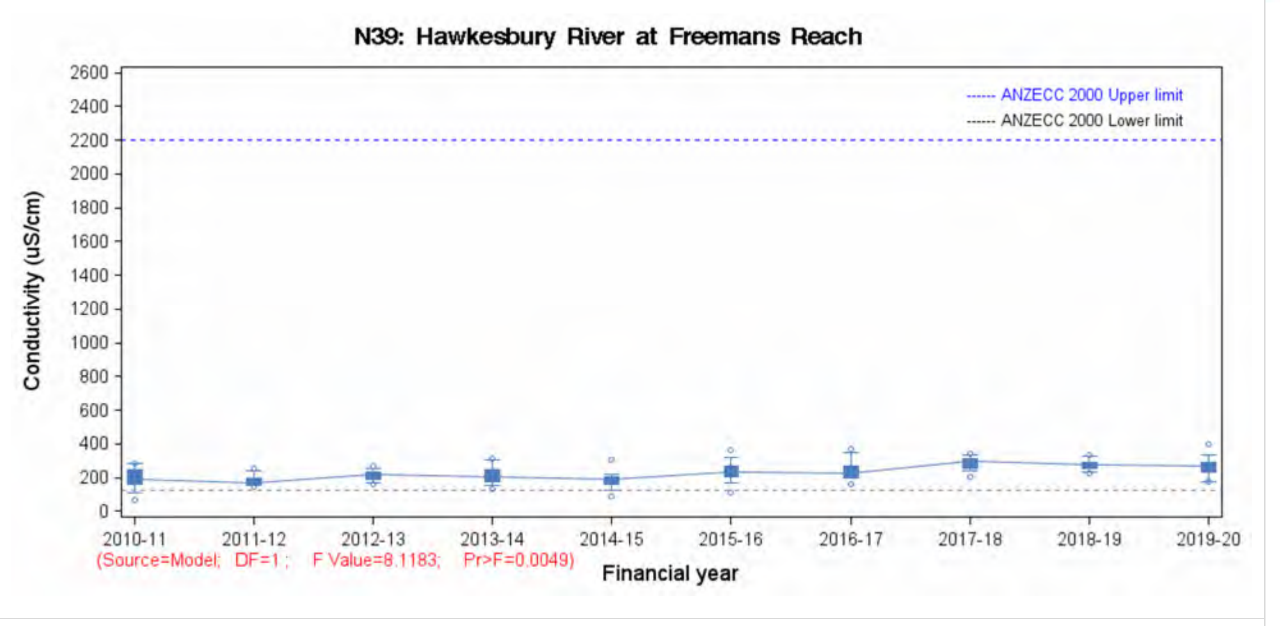
There were no other significant trends and/or exceptions (median values higher than the guideline limits) for any other water quality or algae analyte in 2019-20.



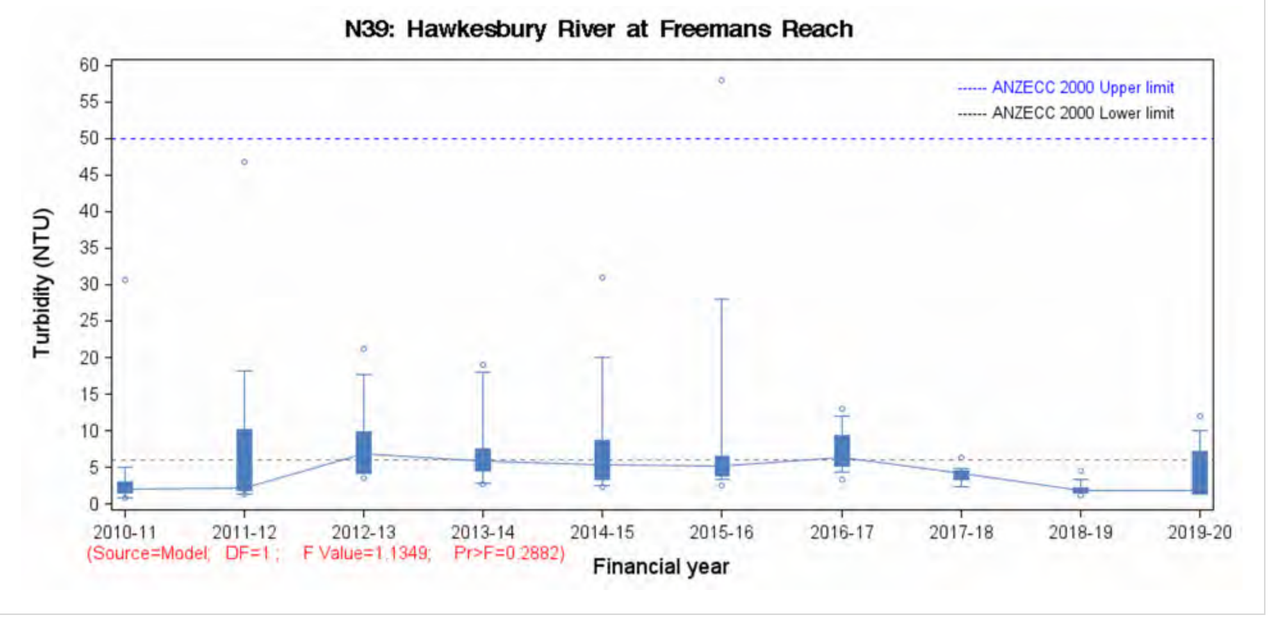

N39: Hawkesbury River at Freemans Reach
ANZECC 2000
Oxidised nitrogen (mg/L)
1.0
0.8
0.6
0.4
0.2
0.0
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=15.695; Pr>F=0.0001)
Financial year


N39: Hawkesbury River at Freemans Reach
HRC 1998
ANZECC 2000
Total nitrogen (mg/L)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=17.021; Pr>F=<.0001)
Financial year


N39: Hawkesbury River at Freemans Reach
HRC 1998
ANZECC 2000
Chlorophyll-a (ug/L)
45
40
35
30
25
20
15
10
5
0
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=1.9449; Pr>F=0.1649)
Financial year



N39: Hawkesbury River at Freemans Reach
Conductivity (uS/cm)
------ ANZECC 2000 Upper limit
------ ANZECC 2000 Lower limit
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=8.1183; Pr>F=0.0049)
Financial year



N39: Hawkesbury River at Freemans Reach
Turbidity (NTU)
------ ANZECC 2000 Upper limit
------ ANZECC 2000 Lower limit
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=1.1349; Pr>F=0.2882)
Financial year

NS04A: Lower South Creek at Fitzroy Bridge

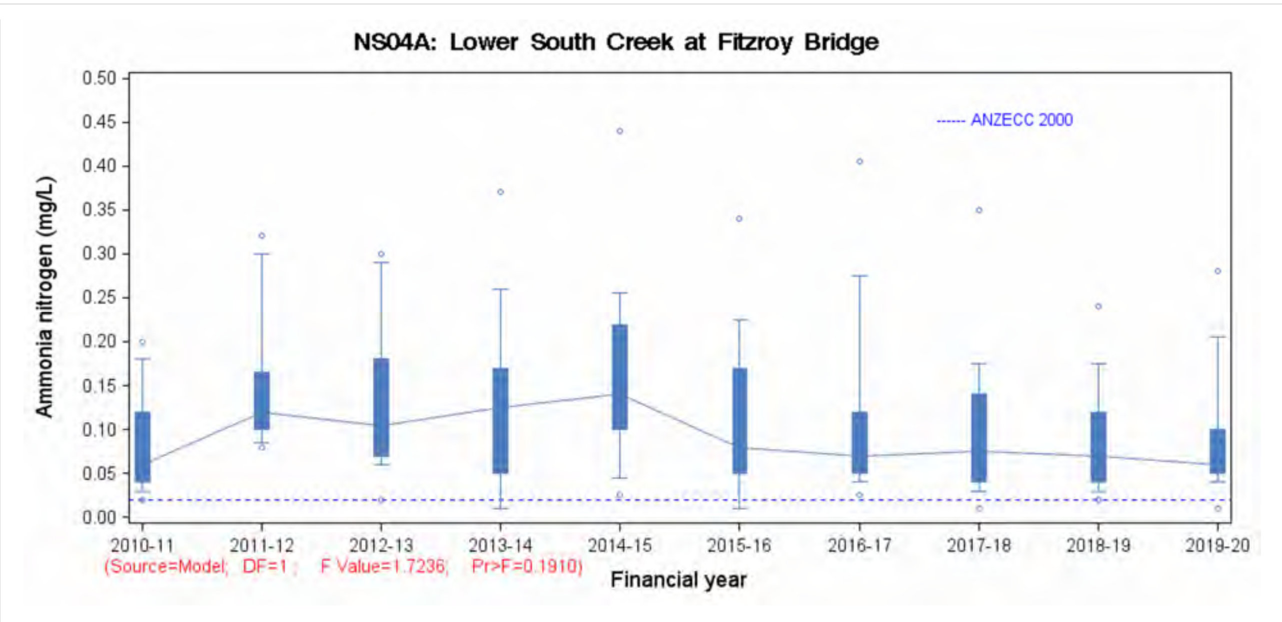
South Creek is one of the major tributaries to the Hawkesbury River. It originates at Narellan and travels 64 km before entering the Hawkesbury River at Windsor. The land along South Creek is used for rural applications including grazing and market gardening and, intensive agriculture such as poultry farming. It also has both urban and industrial land uses. South Creek and its tributaries receive tertiary treated wastewater discharges from three Sydney Water WWTPs (St Marys, Riverstone and Quakers Hill) and two council WWTPs (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 the South Creek before meeting the river.

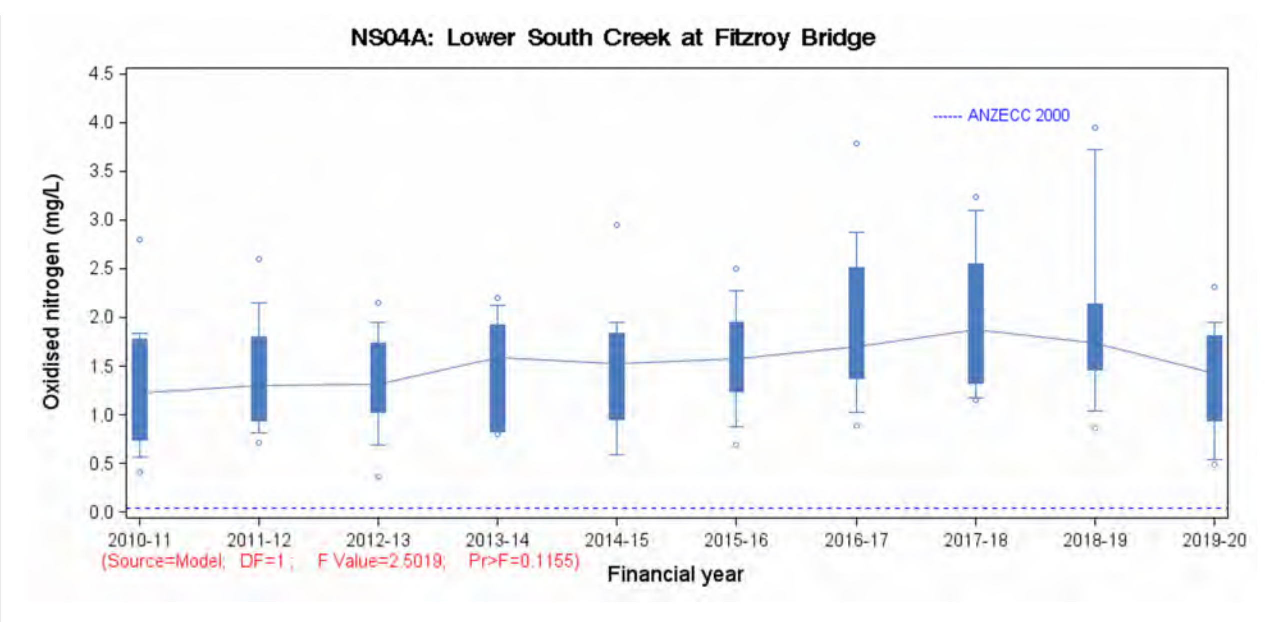
The water quality and algae condition at the lower South Creek site remained steady in 2019-20 with no significantly increasing or decreasing trends found in any of the analytes.

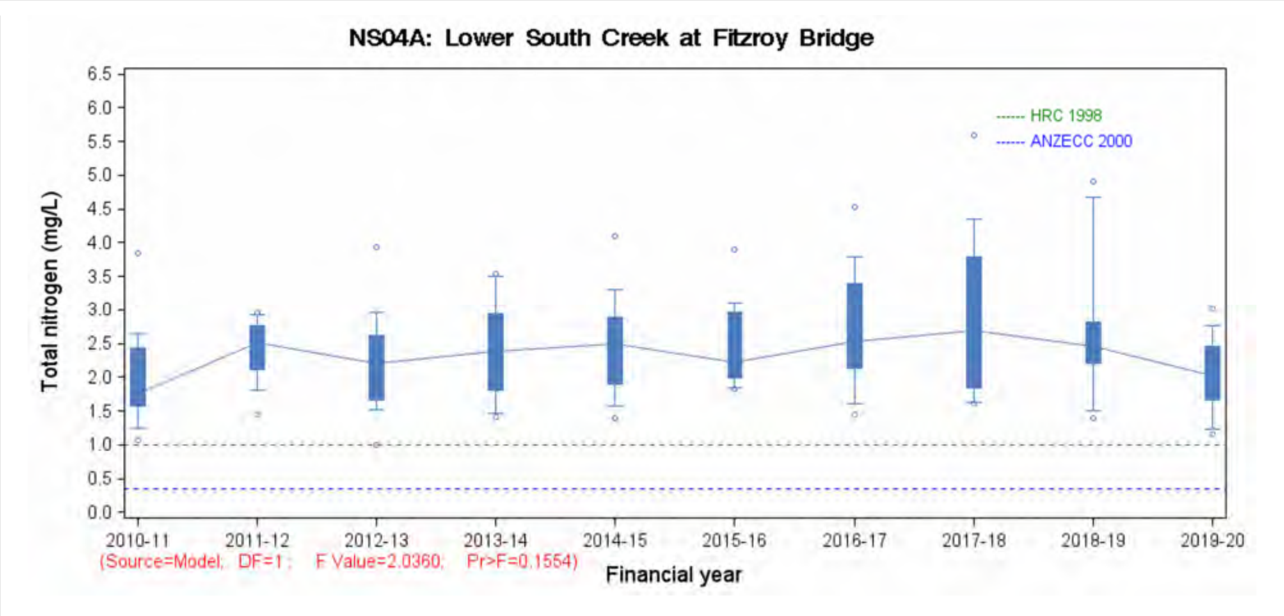
Chlorophyll-*a* and algal analytes were stable at this site in 2019-20. Three of the 17 samples exceeded a chlorophyll-*a* concentration of 7µg/L which triggered algal analysis in 2019-20. The maximum chlorophyll-*a* concentration of 12.4 µg/L was recorded on 12 August 2019. Miscellaneous diatoms were dominant in this sample. No potentially toxic blue-green algae were found in any of the three samples.

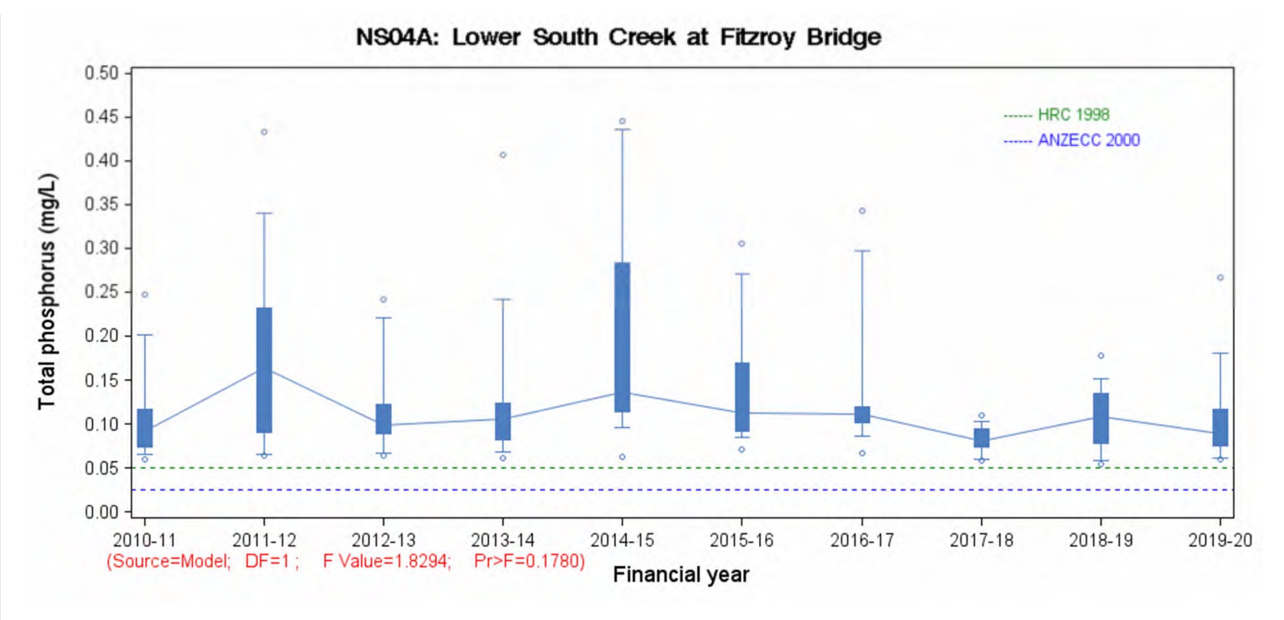
In the 2019-20 period, the median ammonia nitrogen, total nitrogen, total phosphorus and chlorophyll-*a* concentrations in South Creek exceeded the respective ANZECC (2000) guidelines. The dissolved oxygen saturation was low, with the median saturation level lower than the lower guideline limit (ANZECC 2000).

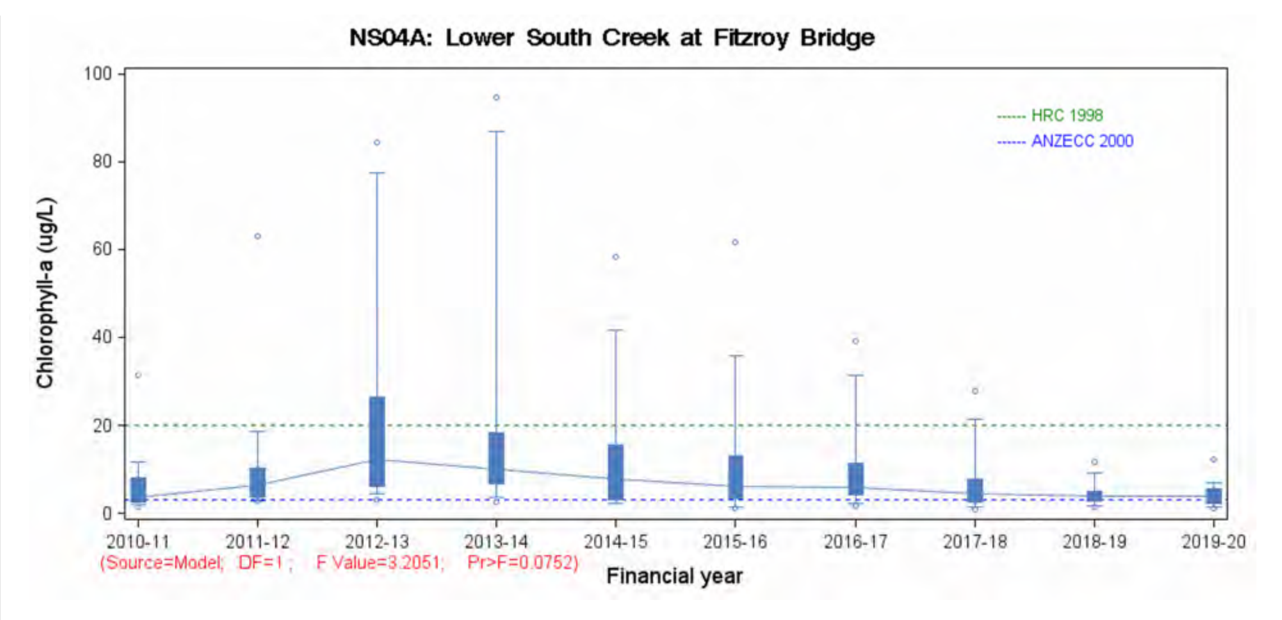
There were no other significant trends and/or exceptions (median values higher than the guideline limits) for any other water quality or algae analyte in 2019-20.



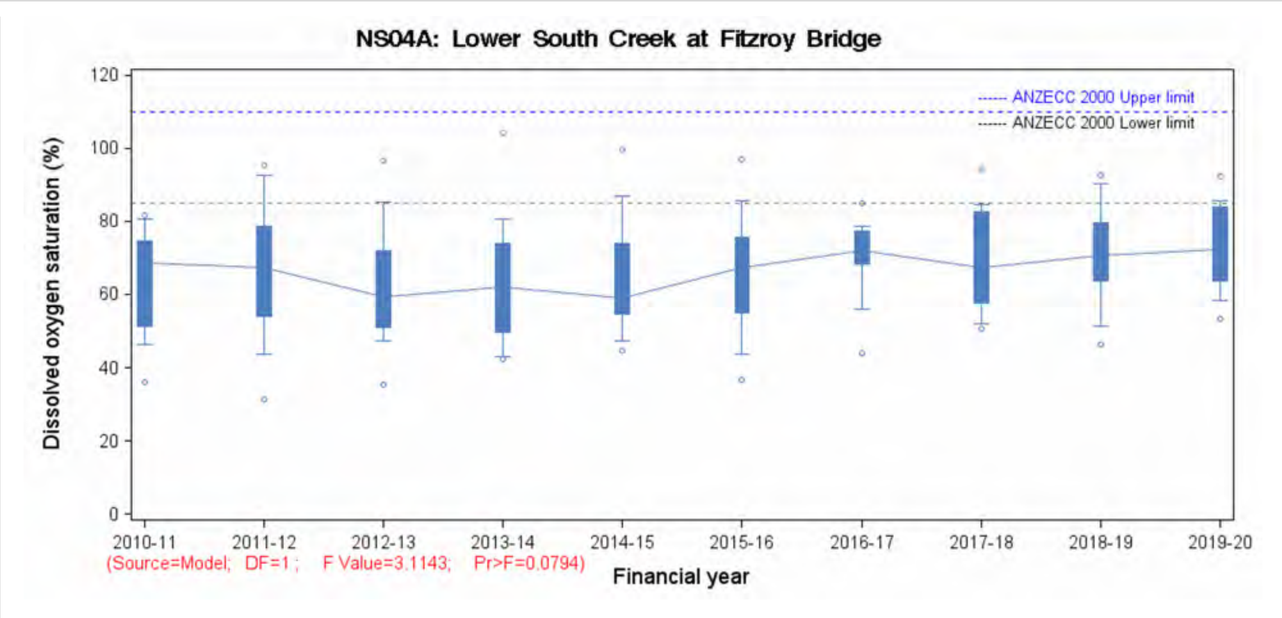

NS04A: Lower South Creek at Fitzroy Bridge
ANZECC 2000
Oxidised nitrogen (mg/L)
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=2.5019; Pr>F=0.1155)
Financial year


NS04A: Lower South Creek at Fitzroy Bridge
HRC 1998
ANZECC 2000
Total nitrogen (mg/L)
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=2.0360; Pr>F=0.1554)
Financial year


NS04A: Lower South Creek at Fitzroy Bridge
HRC 1998
ANZECC 2000
Total phosphorus (mg/L)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=1.8294; Pr>F=0.1780)
Financial year



NS04A: Lower South Creek at Fitzroy Bridge
HRC 1998
ANZECC 2000
Chlorophyll-a (ug/L)
100
80
60
40
20
0
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=3.2051; Pr>F=0.0752)
Financial year



NS04A: Lower South Creek at Fitzroy Bridge
ANZECC 2000 Upper limit
ANZECC 2000 Lower limit
Dissolved oxygen saturation (%)
120
100
80
60
40
20
0
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=3.1143; Pr>F=0.0794)
Financial year

N35: Hawkesbury River at Wilberforce

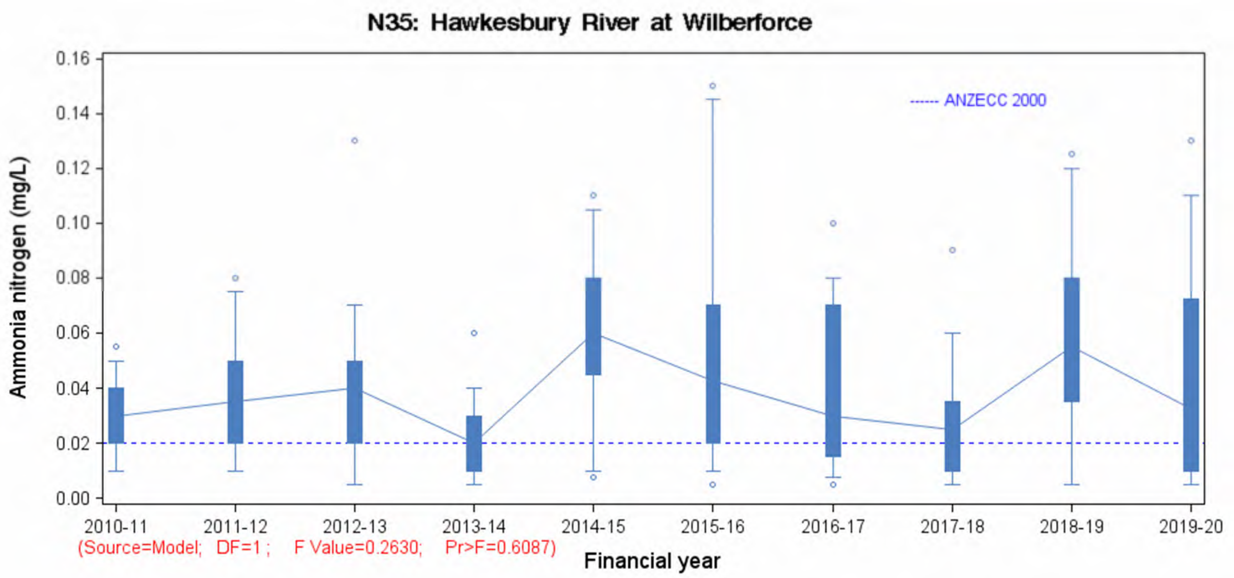
The Hawkesbury River site at Wilberforce (N35) is located about 5 km downstream of the confluence with the South Creek. Water quality at this site is affected by the quality and magnitude of flows coming from South Creek. Historically, there have been water quality concerns at this site due to elevated nutrient concentrations, chlorophyll-*a* and algal blooms, especially potentially toxic blue-green algal blooms. The width and depth of the river, combined with the high nutrients, tidal influence and high residence time has made it prone to algal blooms in the past.

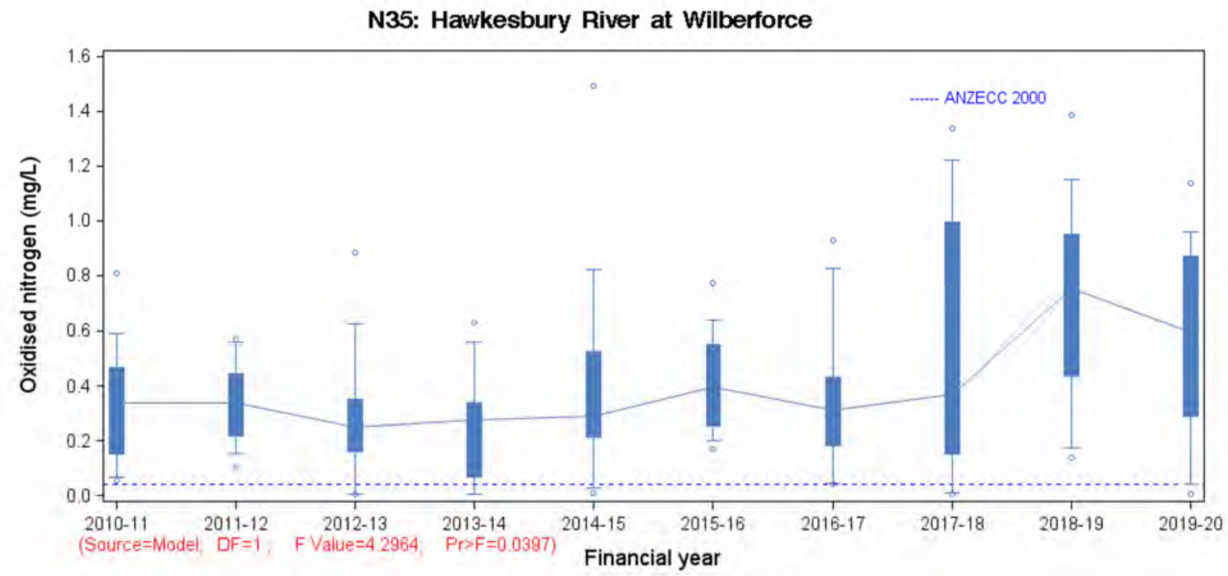
In 2019-20, oxidised nitrogen, total nitrogen and conductivity levels/concentrations were significantly higher at Wilberforce compared to earlier years. The trends in all other analytes were steady.

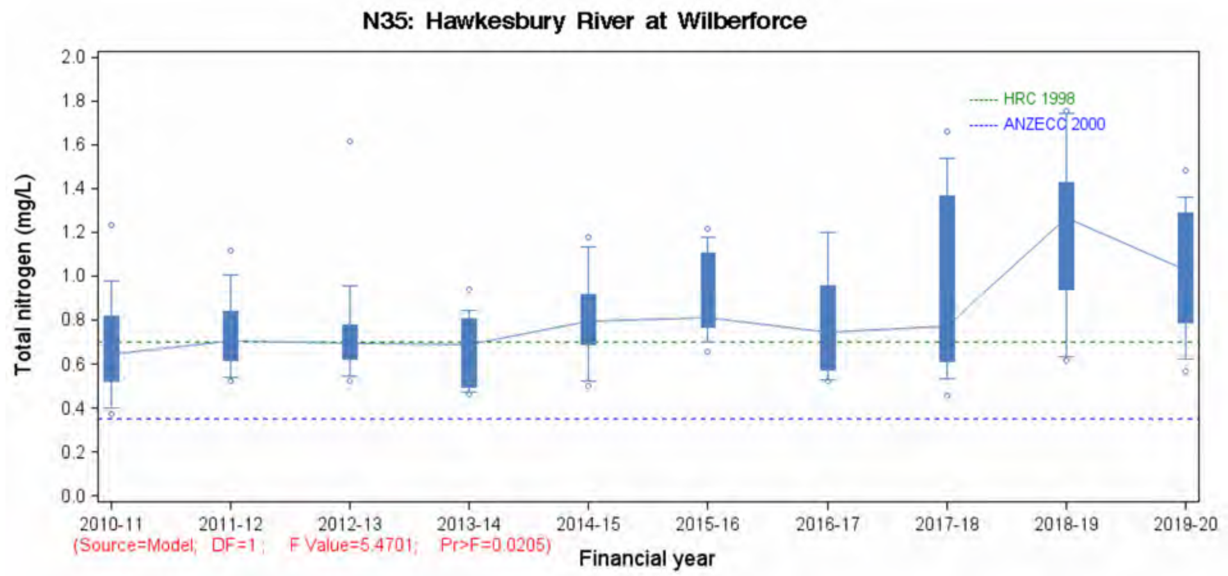
The majority of the samples (12 out of 16) collected from this site were counted for algae as the chlorophyll-*a* concentrations exceeded the algal counting threshold of 7.0 µg/L. The maximum chlorophyll-*a* concentration was 30.9 µg/L, recorded on 9 January 2020 when toxigenic blue-green algae were present in moderate counts (*Aphanizomenonaceae* 1,347 cells/mL, *Dolichospermum* 455 cells/mL and *Microcystis* 1,749 cells/mL). Toxigenic blue-green algae were also identified from this site on three other samples (10 November 2019: *Dolichospermum* 1,190 cells/mL; 30 January 2020: *Phormidium* 770 cells/mL and *Dolichospermum* 770 cells/mL and 23 April 2020: *Microcystis* 1,081 cells/ML). These counts of potentially toxic alga *Microcystis spp.* are higher than the NHRMC (2008) green alert (500 cells/mL) but within the Amber alert (5,000 cells/mL).

In the 2019-20 period, the median ammonia nitrogen, oxidised nitrogen, total nitrogen, total phosphorus and chlorophyll-*a* concentrations exceeded the respective ANZECC (2000) guideline at Wilberforce (N35).

There were no other significant trends and/or exceptions (median values higher than the guideline limits) for any other water quality or algae analyte in 2019-20.




N35: Hawkesbury River at Wilberforce
ANZECC 2000
Oxidised nitrogen (mg/L)
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=4.2964; Pr>F=0.0397)
Financial year


N35: Hawkesbury River at Wilberforce
HRC 1998
ANZECC 2000
Total nitrogen (mg/L)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
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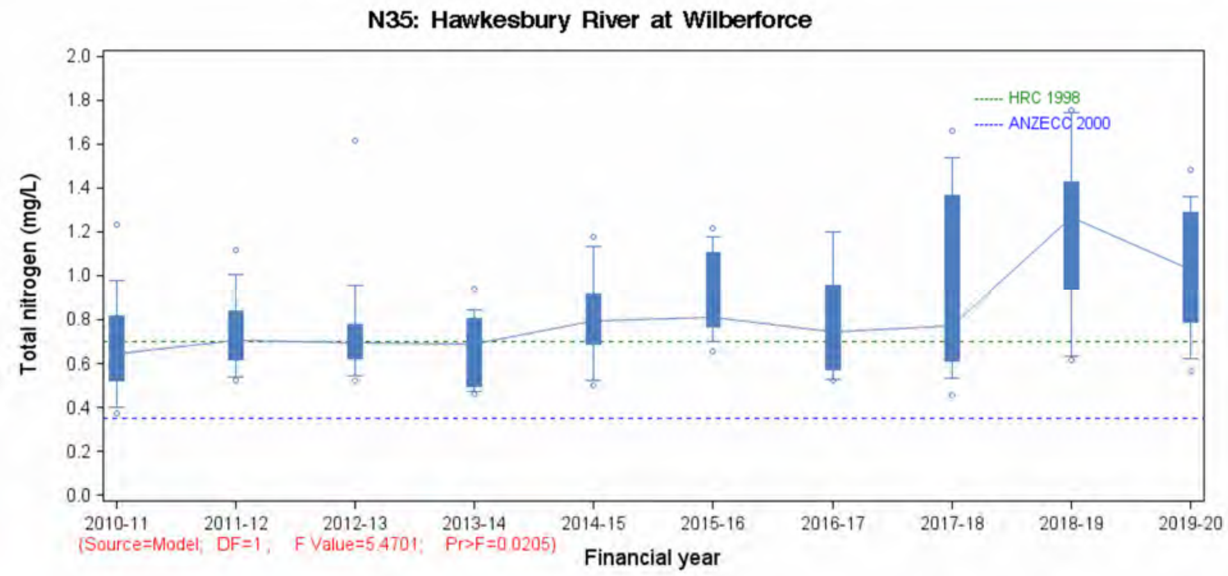
Financial year


N35: Hawkesbury River at Wilberforce
HRC 1998
ANZECC 2000
Total nitrogen (mg/L)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
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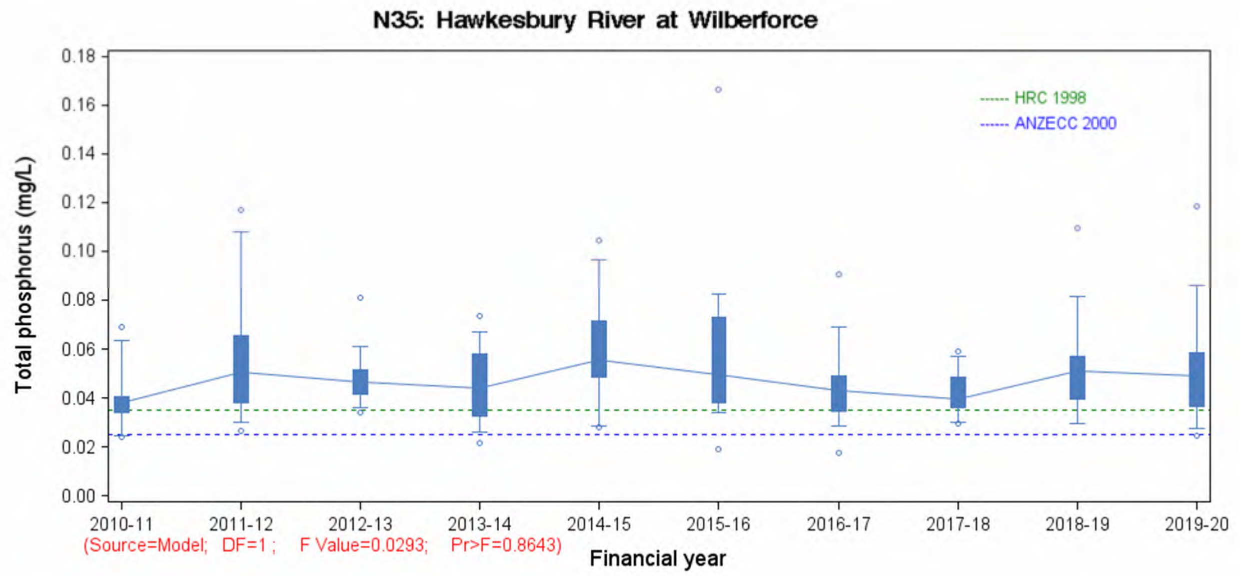
Financial year


N35: Hawkesbury River at Wilberforce
Total phosphorus (mg/L)
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
HRC 1998
ANZECC 2000
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
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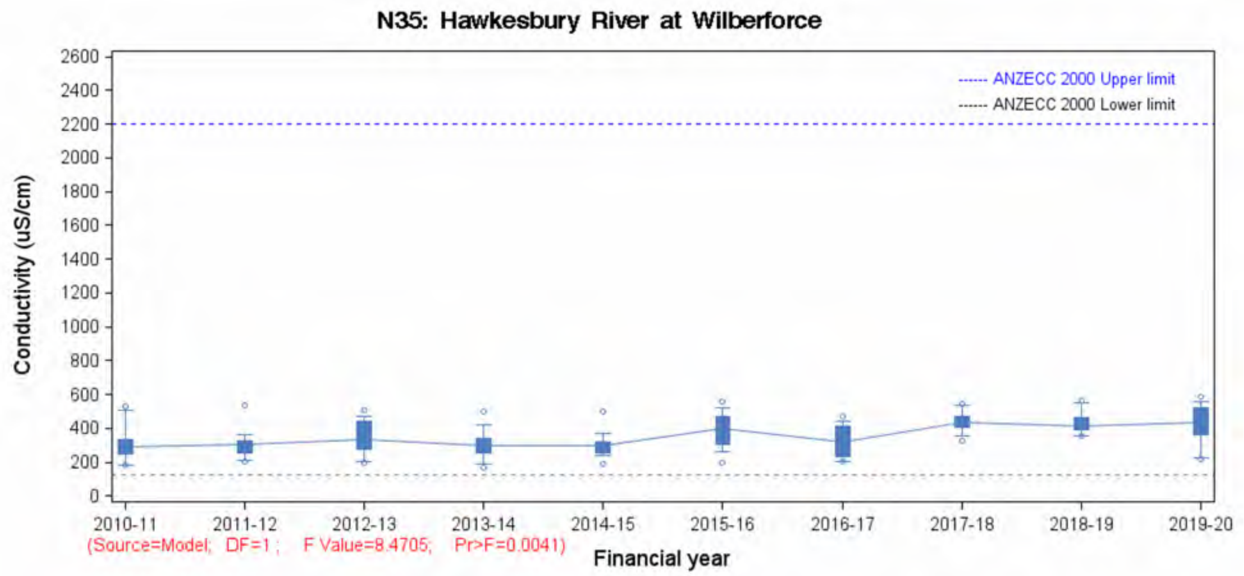
Financial year


N35: Hawkesbury River at Wilberforce
Conductivity (uS/cm)
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
ANZECC 2000 Upper limit
ANZECC 2000 Lower limit
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=8.4705; Pr>F=0.0041)
Financial year

NC11A: Lower Cattai Creek at Cattai Ridge Road

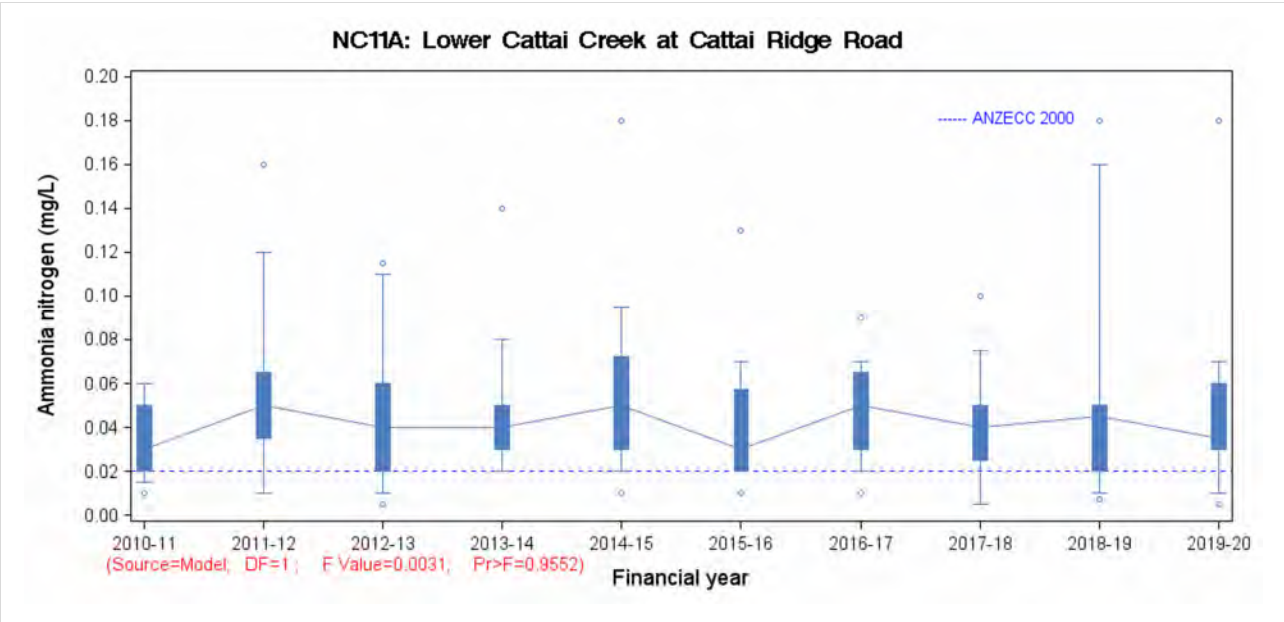
Lower Cattai Creek at Cattai Ridge Road (NC11A) is a major tributary of the Hawkesbury River draining one of the fastest growing urban catchments of Sydney. The upper Cattai Creek catchment land use influences are new urban development and light industrial activities. Further down the catchment, land uses are for rural and agricultural purposes. Two of Sydney Water WWTPs (Castle Hill and Rouse Hill) operate in the Cattai Creek catchment. The Rouse Hill WWTP discharges to a constructed wetland and then to Seconds Ponds Creek, a tributary of Cattai Creek. Castle Hill WWTP discharges directly to 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.

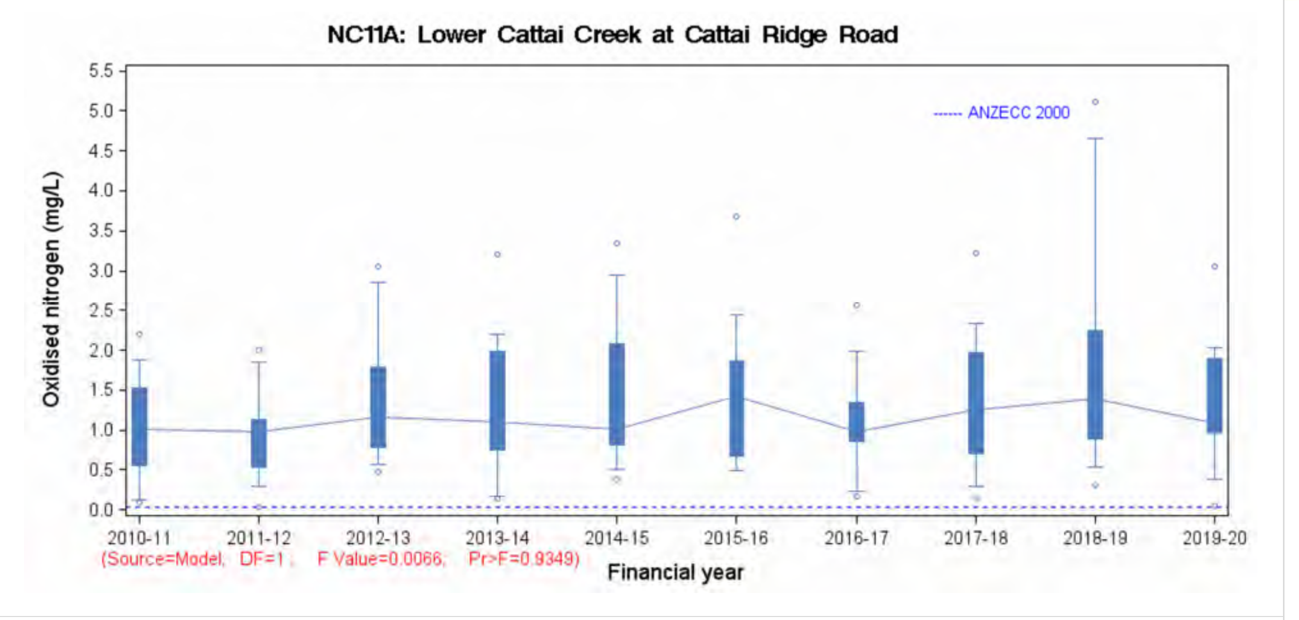
Statistical analysis confirmed that, the 2019-20 nutrients, chlorophyll-*a* and algae conditions of lower Cattai Creek (NC11A) were steady compared to the previous nine years. Six of the 17 samples exceeded the chlorophyll-*a* concentration of 7 µg/L in 2019-20, which triggered algal analysis. Chlorophyll-*a* concentrations reached as high as 30.0 µg/L in January 2020, indicating the presence of algal blooms. Toxigenic blue green alga *Microcystis* was present in two samples (8 November 2019 and 9 January 2020) in low counts (688 and 920 cells/mL) and within the NHMRC (2008) Amber alert. Two other toxigenic blue-green algal species were also identified: *Aphanizomenonaceae* 245 cells/mL (9 January 2020) and *Phormidium* 4,561 cells/mL (*28* November 2019).

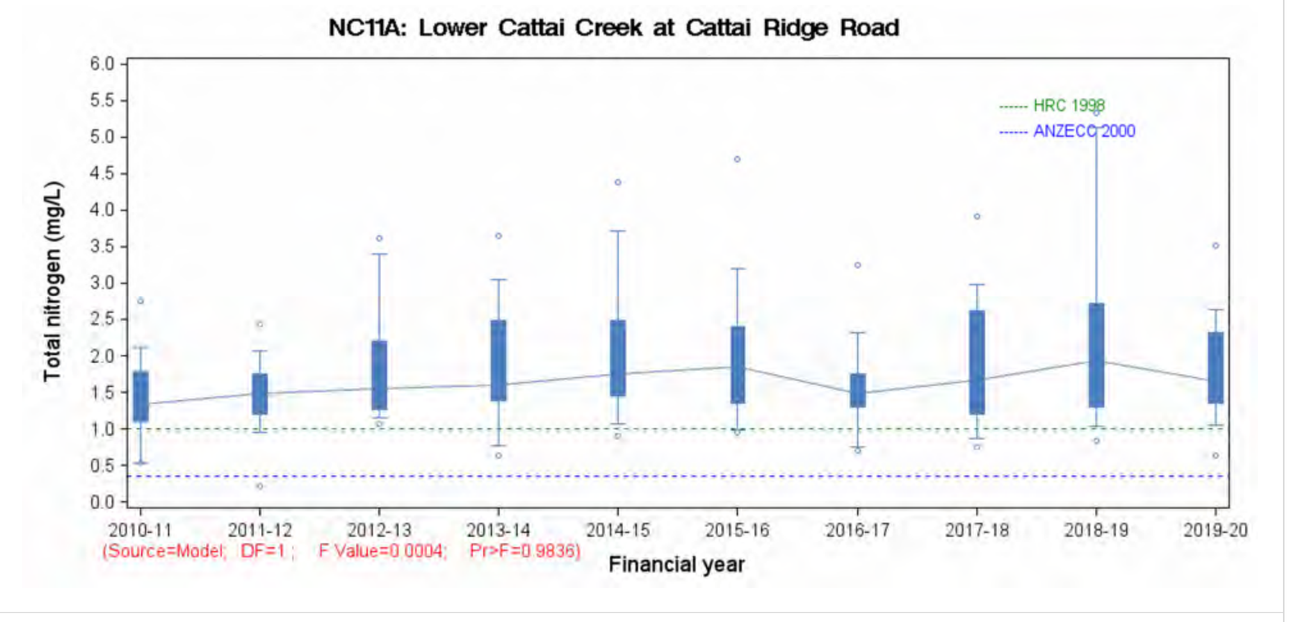
Among the physico-chemical analytes, both dissolved oxygen concentrations and percent saturations were significantly higher, or improved, at Cattai Creek in 2019-20 compared to the previous nine years.

In the 2019-20 period, the median ammonia nitrogen, oxidised nitrogen, total nitrogen, total phosphorus and chlorophyll-*a* concentrations exceeded the respective ANZECC (2000) guideline in Cattai Creek (NC11A). The median dissolved oxygen saturation was less than the lower guideline limit (ANZECC 2000).

There were no other significant trends and/or exceptions (median values higher than the guideline limits) for any other water quality or algae analyte in 2019-20.




NC11A: Lower Cattai Creek at Cattai Ridge Road
Oxidised nitrogen (mg/L)
ANZECC 2000
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=0.0066; Pr>F=0.9349)
Financial year


NC11A: Lower Cattai Creek at Cattai Ridge Road
Total nitrogen (mg/L)
HRC 1998
ANZECC 2000
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
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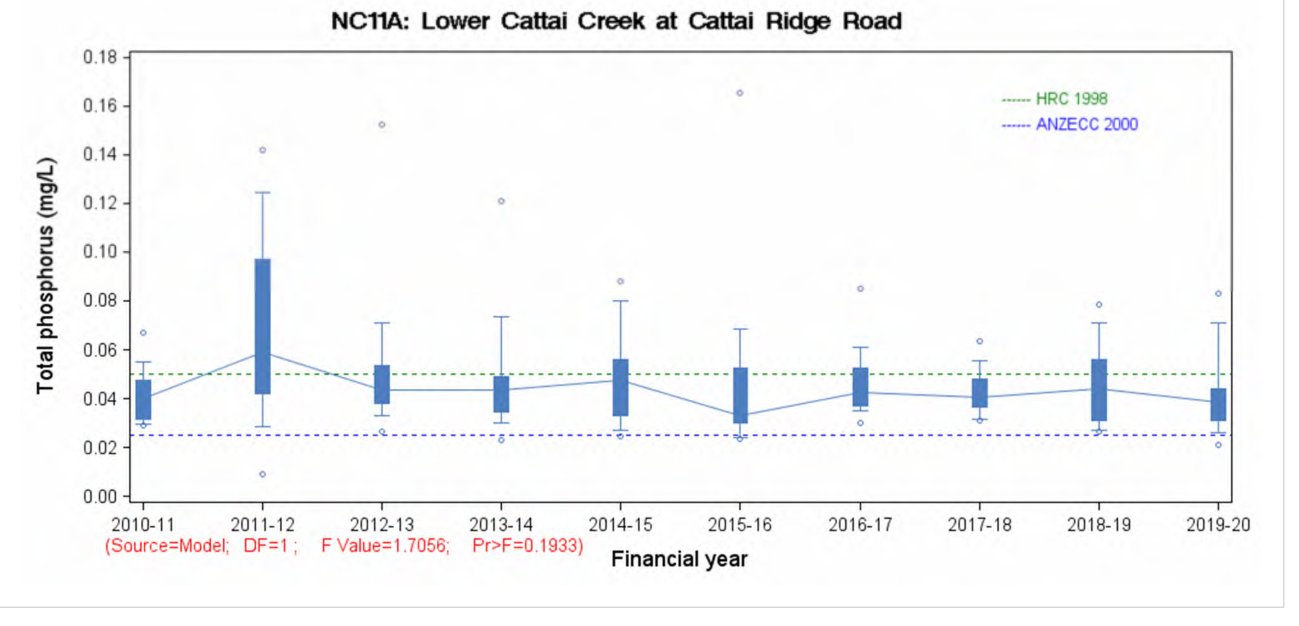
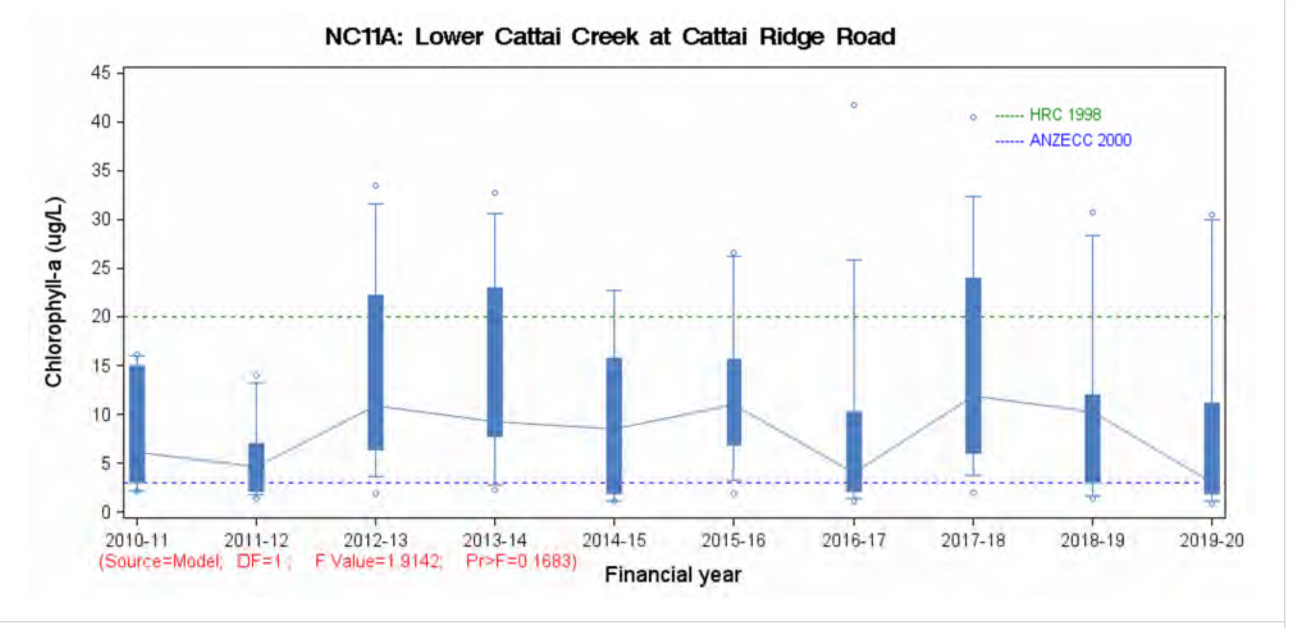
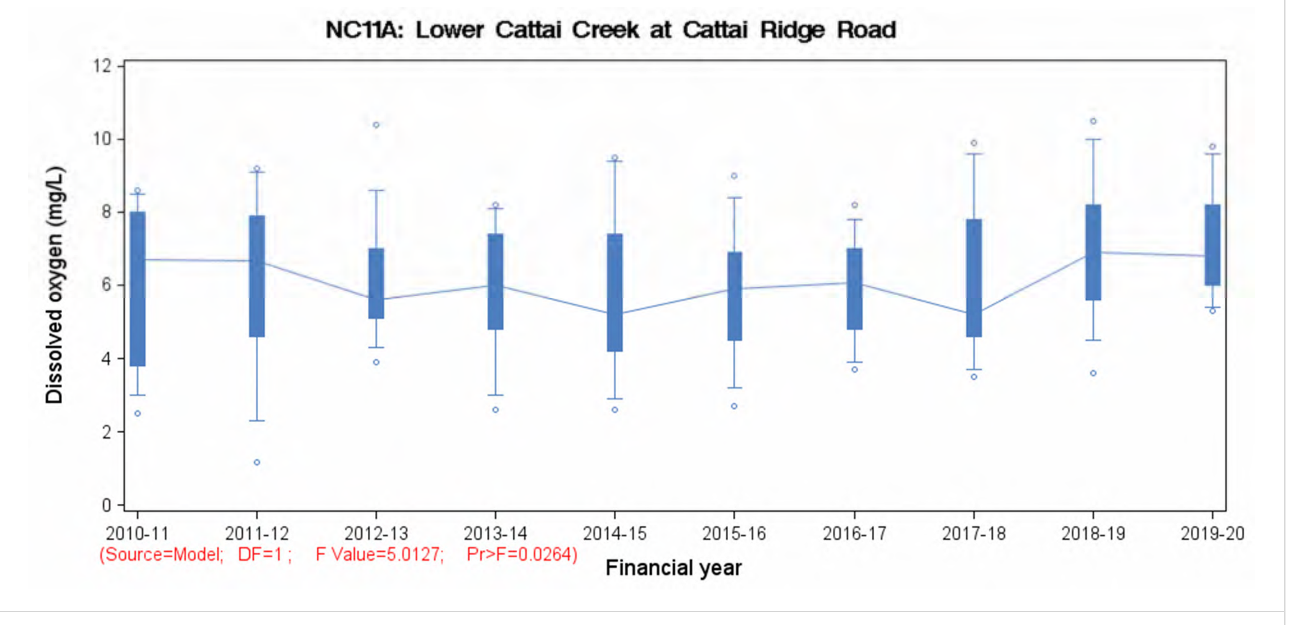
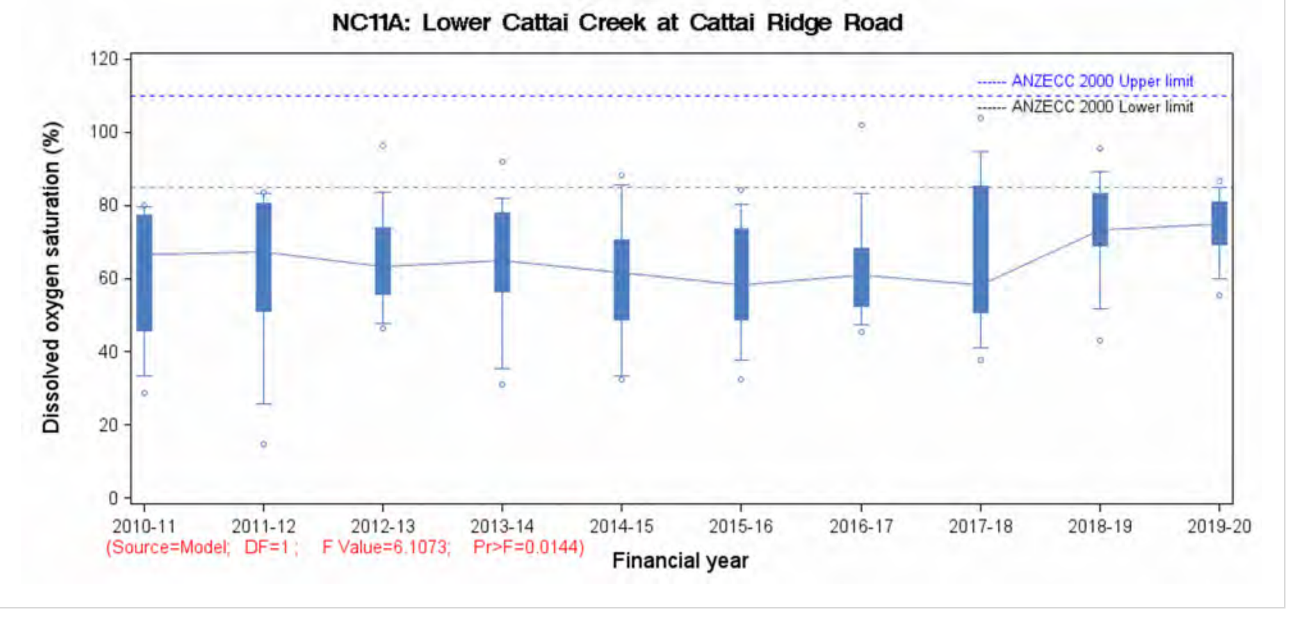
Financial year


NC11A: Lower Cattai Creek at Cattai Ridge Road
Total phosphorus (mg/L)
HRC 1998
ANZECC 2000
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=1.7056; Pr>F=0.1933)
Financial year


NC11A: Lower Cattai Creek at Cattai Ridge Road
HRC 1998
ANZECC 2000
Chlorophyll-a (ug/L)
Financial year
(Source=Model; DF=1 ; F Value=1.9142; Pr>F=0.1683)


NC11A: Lower Cattai Creek at Cattai Ridge Road
Dissolved oxygen (mg/L)
Financial year
(Source=Model; DF=1 ; F Value=5.0127; Pr>F=0.0264)


NC11A: Lower Cattai Creek at Cattai Ridge Road
ANZECC 2000 Upper limit
ANZECC 2000 Lower limit
Dissolved oxygen saturation (%)
Financial year
(Source=Model; DF=1 ; F Value=6.1073; Pr>F=0.0144)

N3001: Hawkesbury River off Cattai SRA

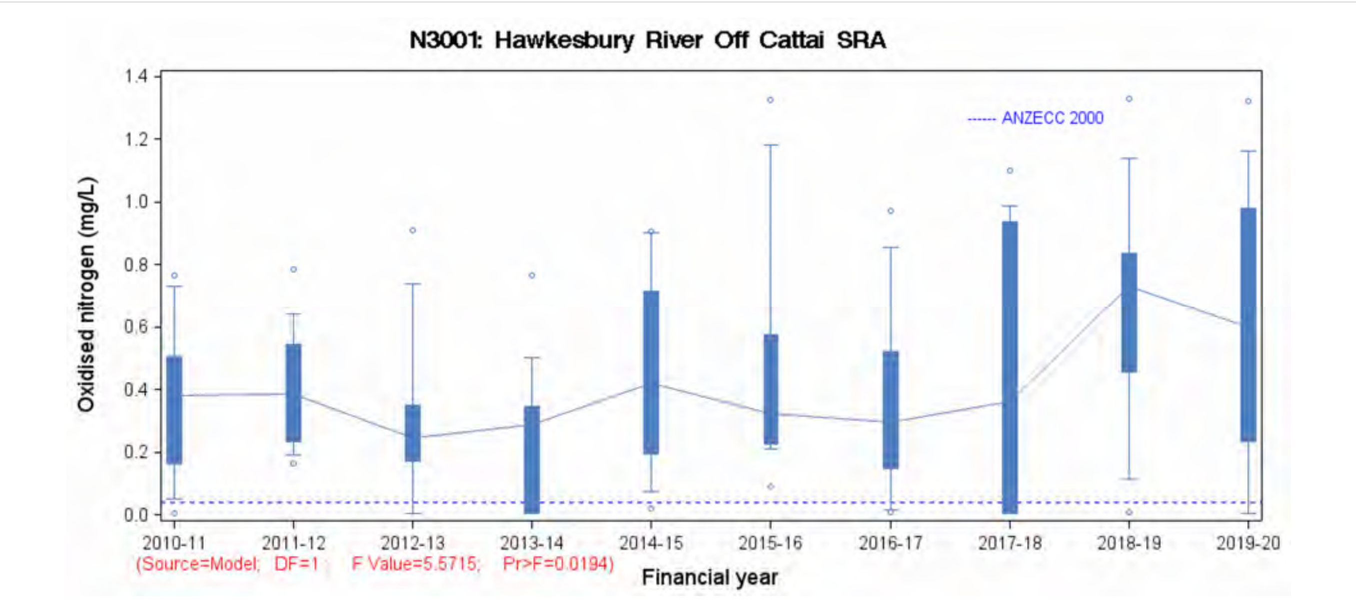
The Hawkesbury River off Cattai SRA (N3001) is located about 2 km downstream of the confluence with Cattai Creek. The water quality at this site is influenced by flows from both South Creek and Cattai Creek. Historically, this site has exhibited high nutrients, high chlorophyll-*a* and algal blooms.

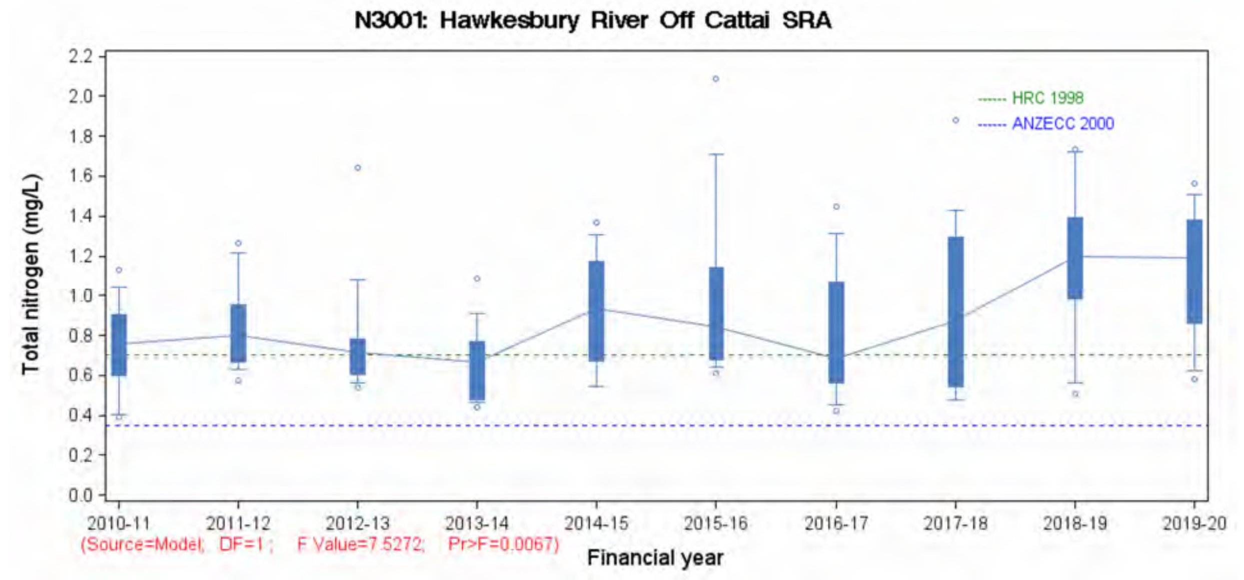
In 2019-20, oxidised nitrogen, total nitrogen and conductivity levels/concentrations were significantly higher at Cattai SRA (N3001) compared to the previous nine years. The trends in all other analytes were steady.

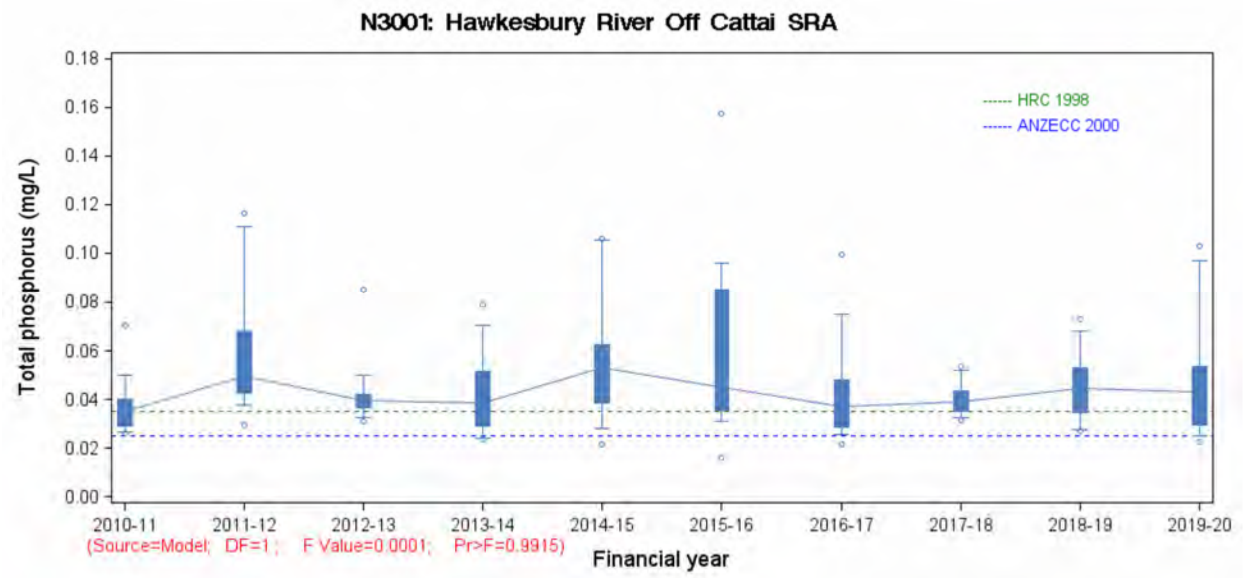
Most of the samples (13 out of 16) collected from this site were counted for algae as the chlorophyll-*a* concentrations exceeded the algal counting threshold of 7.0 μg/. The maximum chlorophyll-*a* concentration was 48.8 μg/L, recorded on 10 November 2019. Toxigenic blue-green algae *Aphanizomenonaceae* and *Microcystis* were found in this sample (210 and 1,834 cells/mL, respectively). Toxigenic blue-green alga *Microcystis* was also present in three other samples (1011, 639 and 553 cells/mL) and all these counts were within the Amber alert. Another toxigenic algal taxa *Dolichospermum* was found in low counts (175 cells/mL) in one sample.

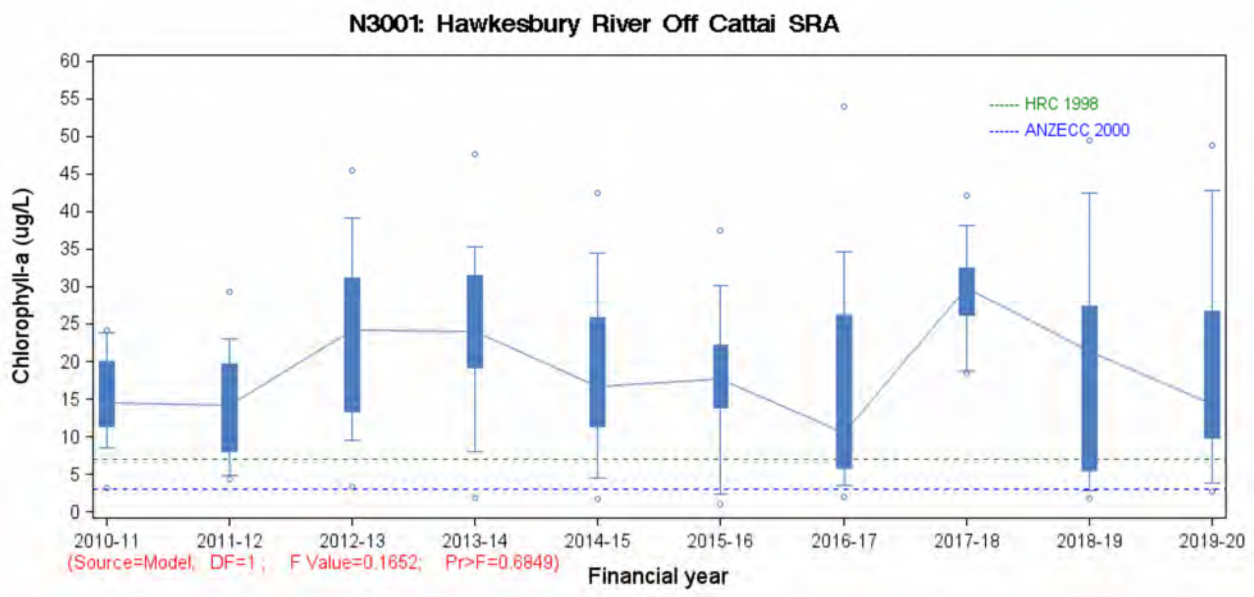
In the 2019-20 period, the median oxidised nitrogen, total nitrogen, total phosphorus and chlorophyll-*a* concentrations were higher than the respective ANZECC (2000) guideline values at Cattai SRA.

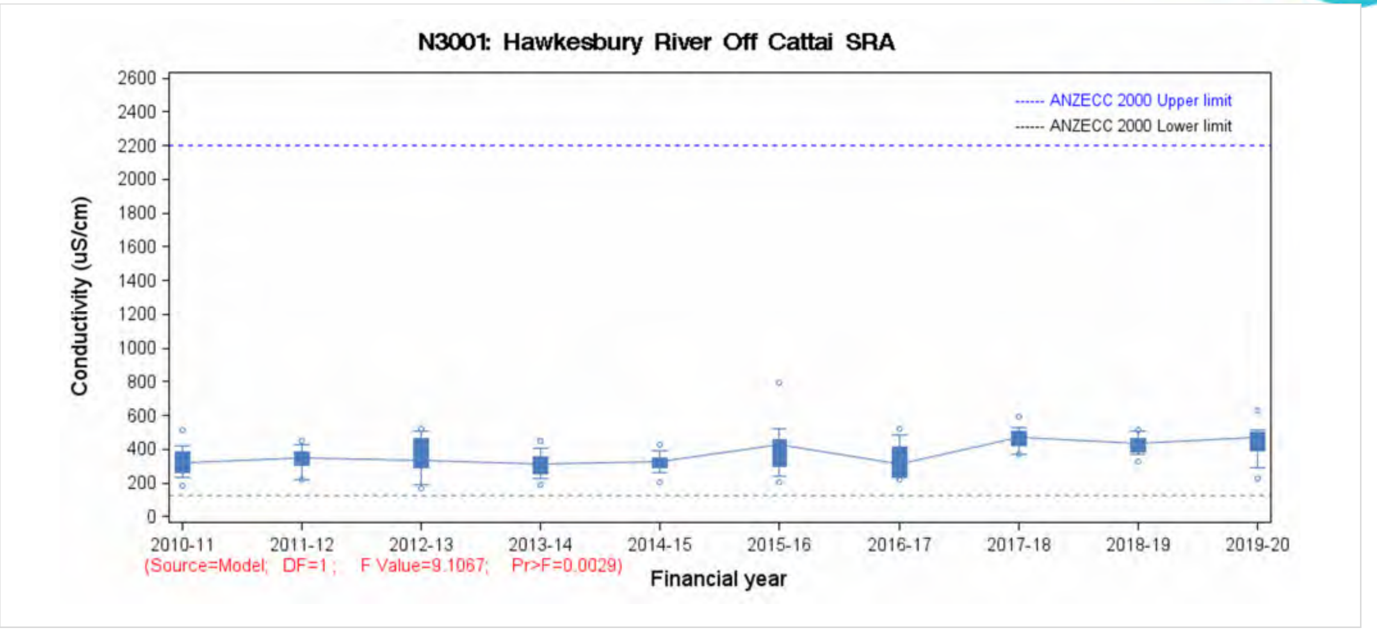
There were no other significant trends and/or exceptions (median values higher than the guideline limits) for any other water quality or algae analyte in 2019-20.




N3001: Hawkesbury River Off Cattai SRA
Total nitrogen (mg/L)
HRC 1998
ANZECC 2000
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=7.5272; Pr>F=0.0067)
Financial year


N3001: Hawkesbury River Off Cattai SRA
Total phosphorus (mg/L)
HRC 1998
ANZECC 2000
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=0.0001; Pr>F=0.9915)
Financial year


N3001: Hawkesbury River Off Cattai SRA
Chlorophyll-a (ug/L)
HRC 1998
ANZECC 2000
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=0.1652; Pr>F=0.6849)
Financial year


N3001: Hawkesbury River Off Cattai SRA
ANZECC 2000 Upper limit
ANZECC 2000 Lower limit
Conductivity (uS/cm)
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=9.1067; Pr>F=0.0029)
Financial year

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 algal blooms, especially blue-green algae.

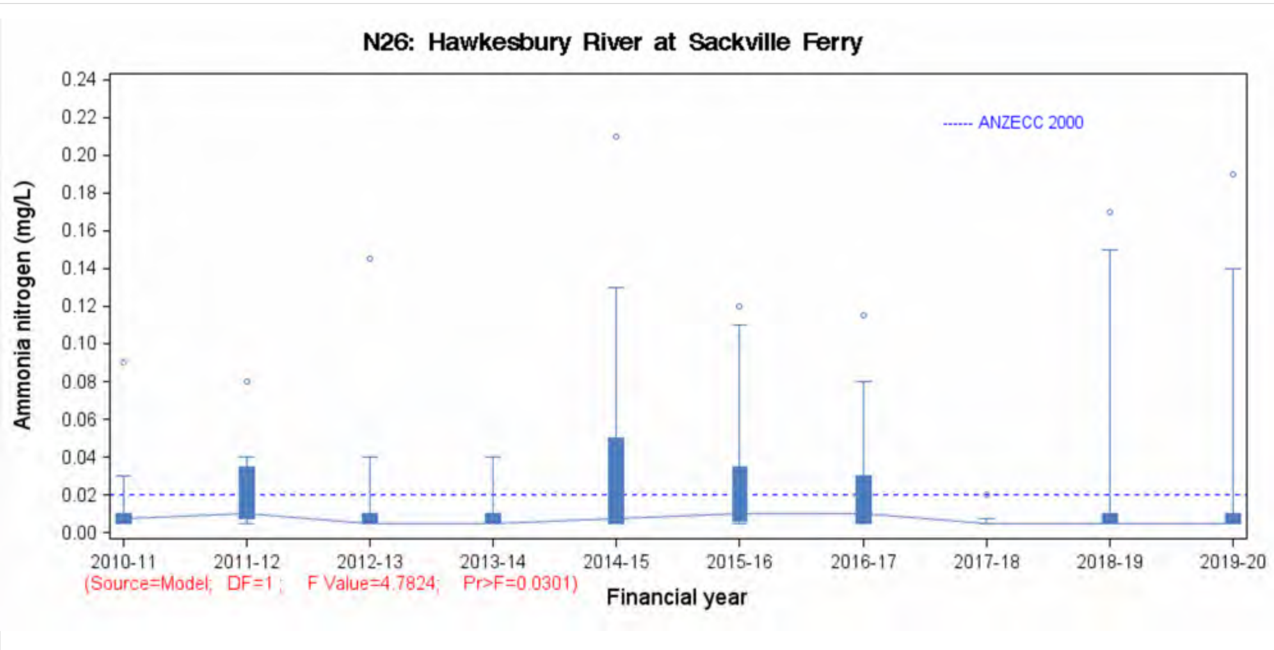
Ammonia nitrogen, oxidised nitrogen, total nitrogen, total algal biovolume and blue-green algal biovolume were significantly higher at Sackville Ferry (N26) in 2019-20 compared to the previous nine years.

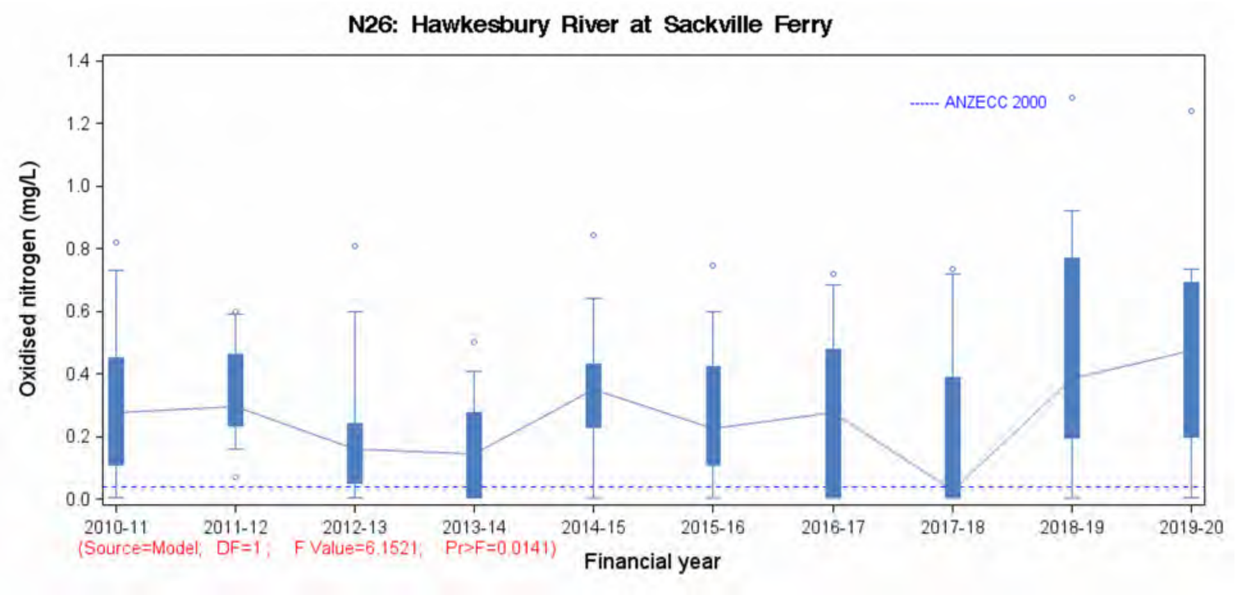
The majority of samples collected from this site were counted for algae (12 out of 16) as the chlorophyll-*a* concentration was consistently higher than 7.0 µg/L, the threshold to count the algal samples. Chlorophyll-*a* concentrations were relatively high at this site reaching more than 40 µg/L on three sampling occasions. Three potentially toxic blue green algal species were identified in the majority of the samples (11 out of 12) in one or multiple occasions. Counts for the toxigenic species *Microcystis* reached higher than the Amber alert once (6,334 cells/mL) and also present in moderate counts in five other samples. Another toxigenic species *Dolichospermum* was found in five of these samples with a maximum count of 11,648 cells/mL. Toxigenic species *Aphanizomenonaceae* was present in low counts in another sample (402 cells/mL).

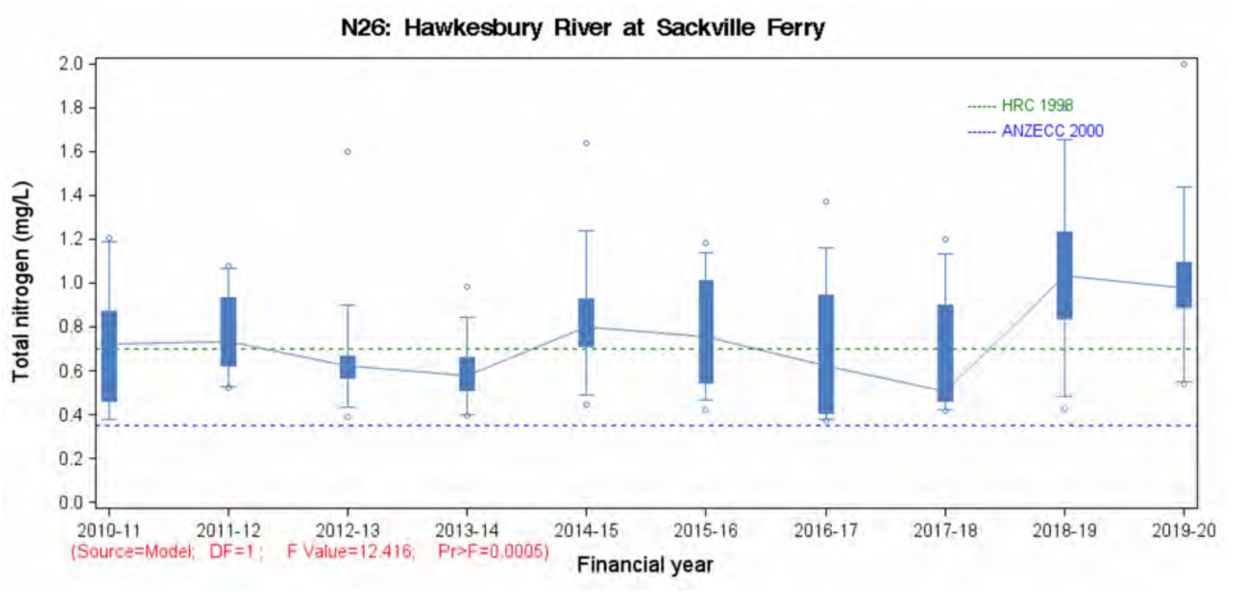
Among the physico-chemical analytes, conductivity and pH values were significantly higher in 2019-20.

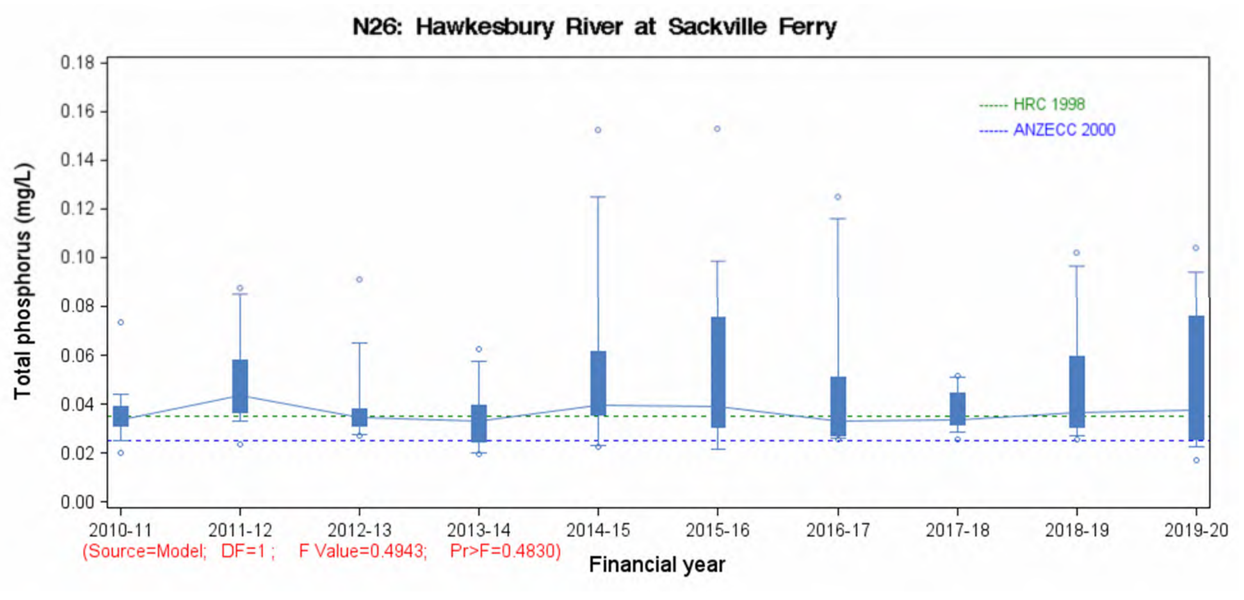
In the 2019-20 period, the median oxidised nitrogen, total nitrogen, total phosphorus and chlorophyll-*a* concentration exceeded the respective ANZECC (2000) guidelines.

There were no other significant trends and/or exceptions (median values higher than the guideline limits) for any other water quality or algae analyte in 2019-20.




N26: Hawkesbury River at Sackville Ferry
Oxidised nitrogen (mg/L)
ANZECC 2000
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=6.1521; Pr>F=0.0141)
Financial year


N26: Hawkesbury River at Sackville Ferry
Total nitrogen (mg/L)
HRC 1998
ANZECC 2000
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=12.416; Pr>F=0.0005)
Financial year


N26: Hawkesbury River at Sackville Ferry
Total phosphorus (mg/L)
HRC 1998
ANZECC 2000
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
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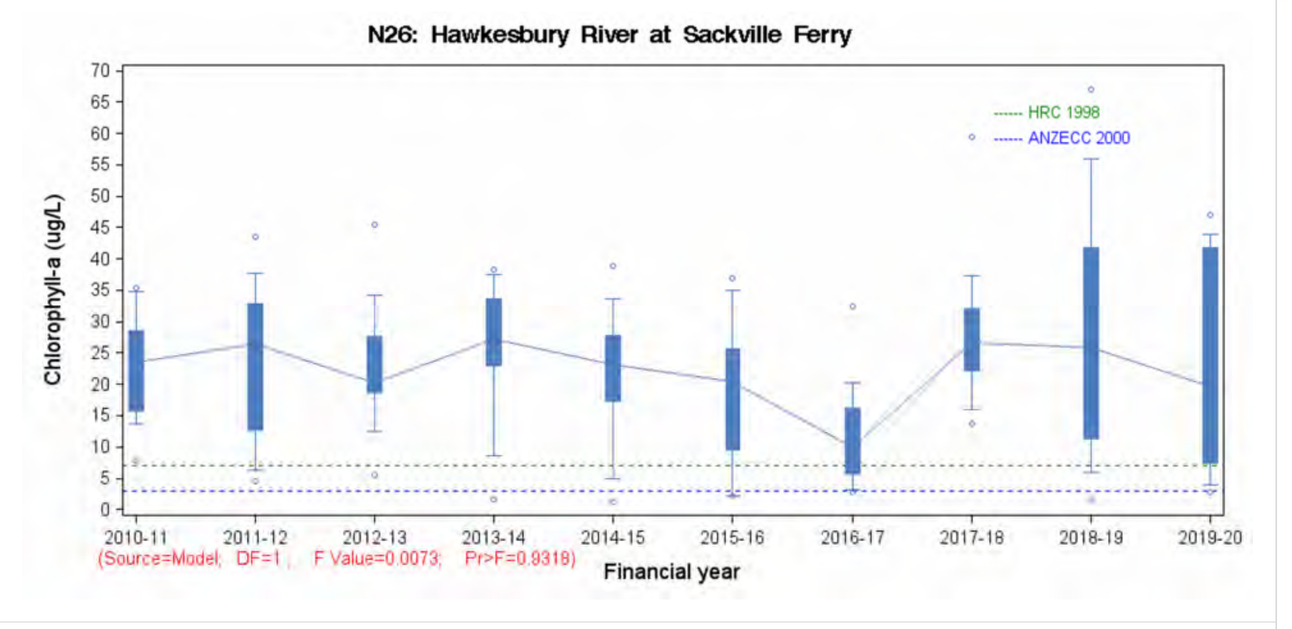
Financial year


N26: Hawkesbury River at Sackville Ferry
HRC 1998
ANZECC 2000
Chlorophyll-a (ug/L)
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
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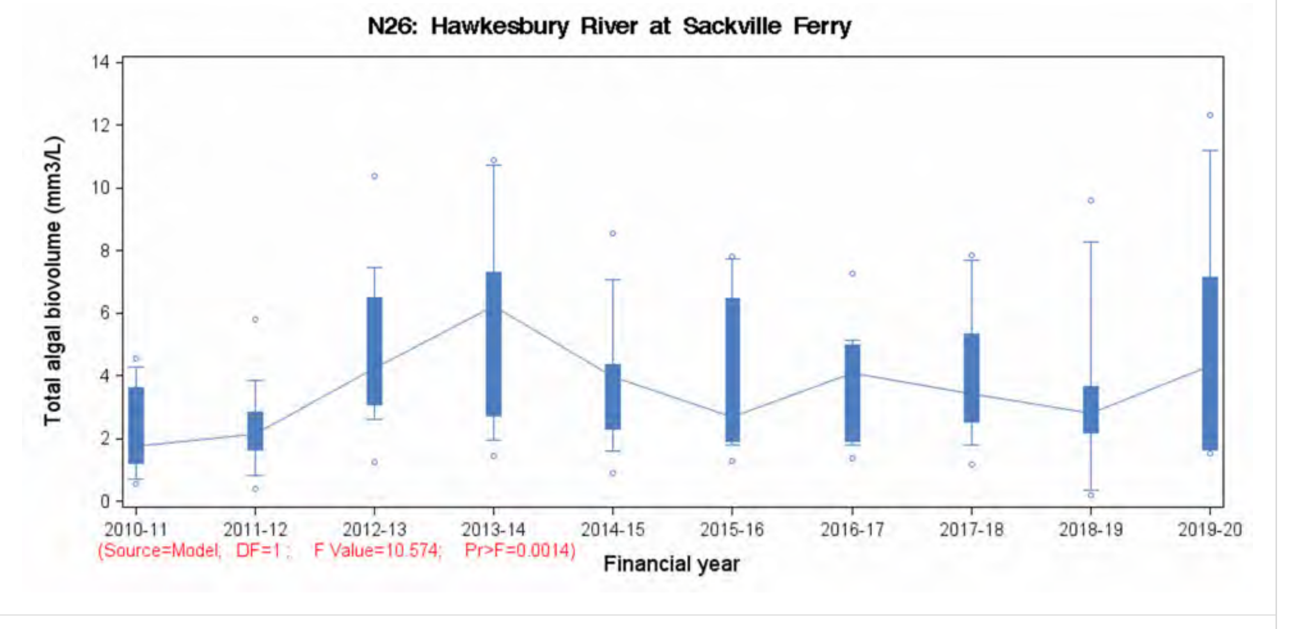
Financial year


N26: Hawkesbury River at Sackville Ferry
Total algal biovolume (mm3/L)
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
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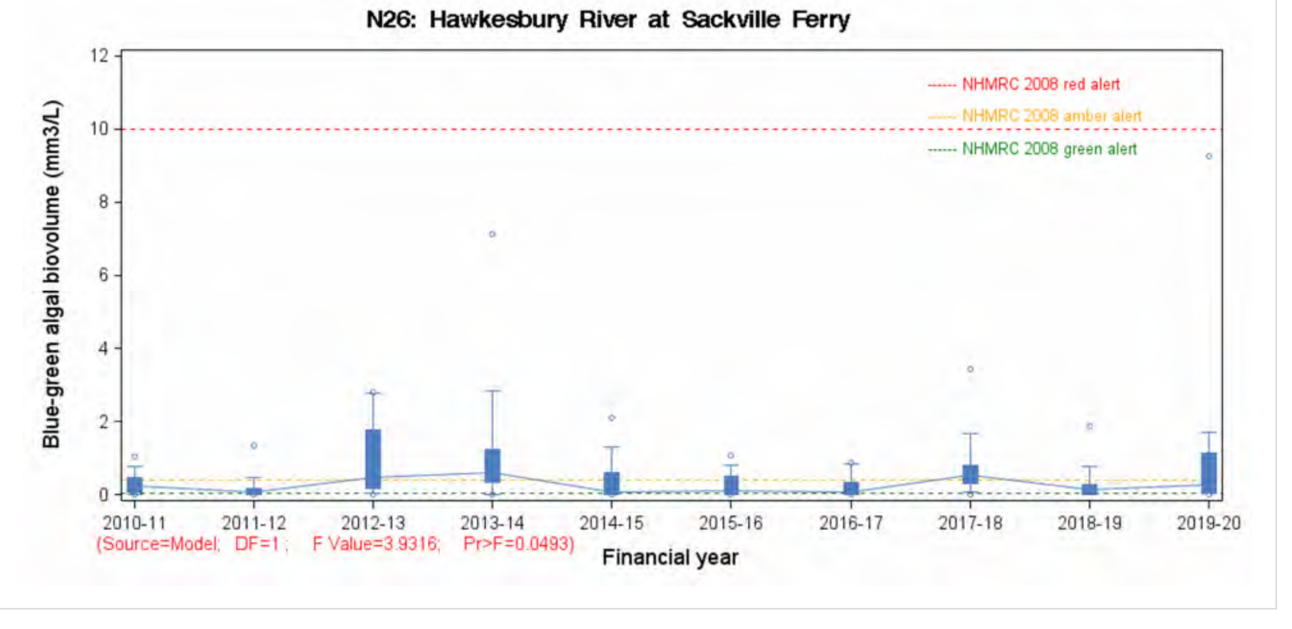
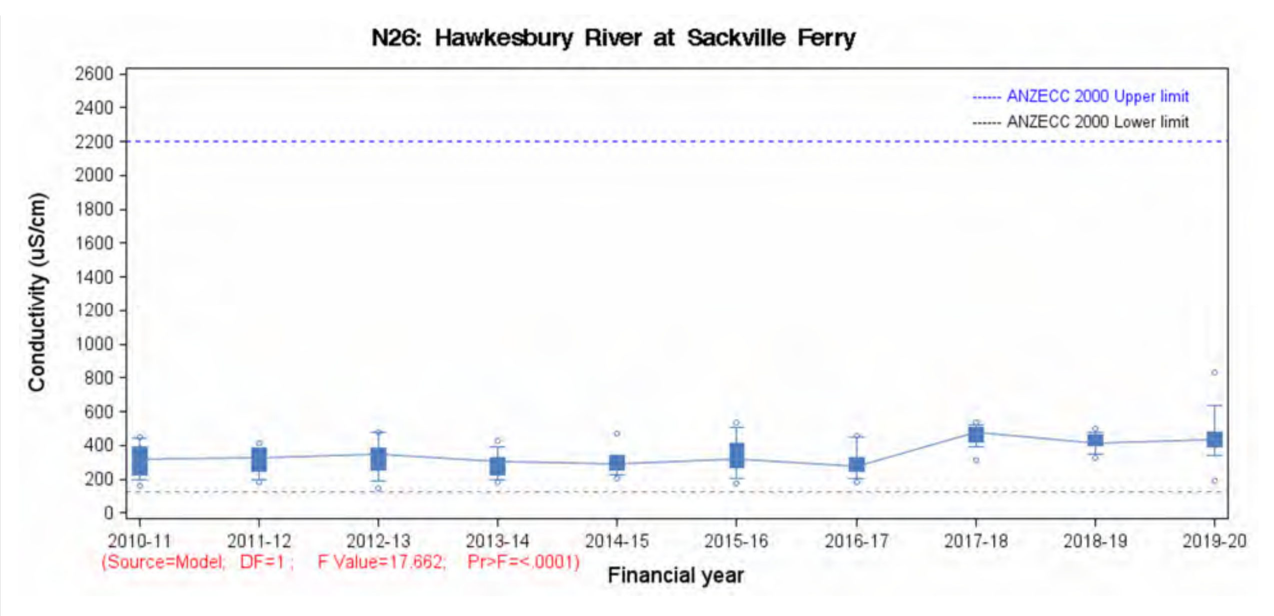
Financial year


N26: Hawkesbury River at Sackville Ferry
NHMRC 2008 red alert
NHMRC 2008 amber alert
NHMRC 2008 green alert
Blue-green algal biovolume (mm3/L)
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=3.9316; Pr>F=0.0493)
Financial year


N26: Hawkesbury River at Sackville Ferry
Conductivity (uS/cm)
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
ANZECC 2000 Upper limit
ANZECC 2000 Lower limit
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
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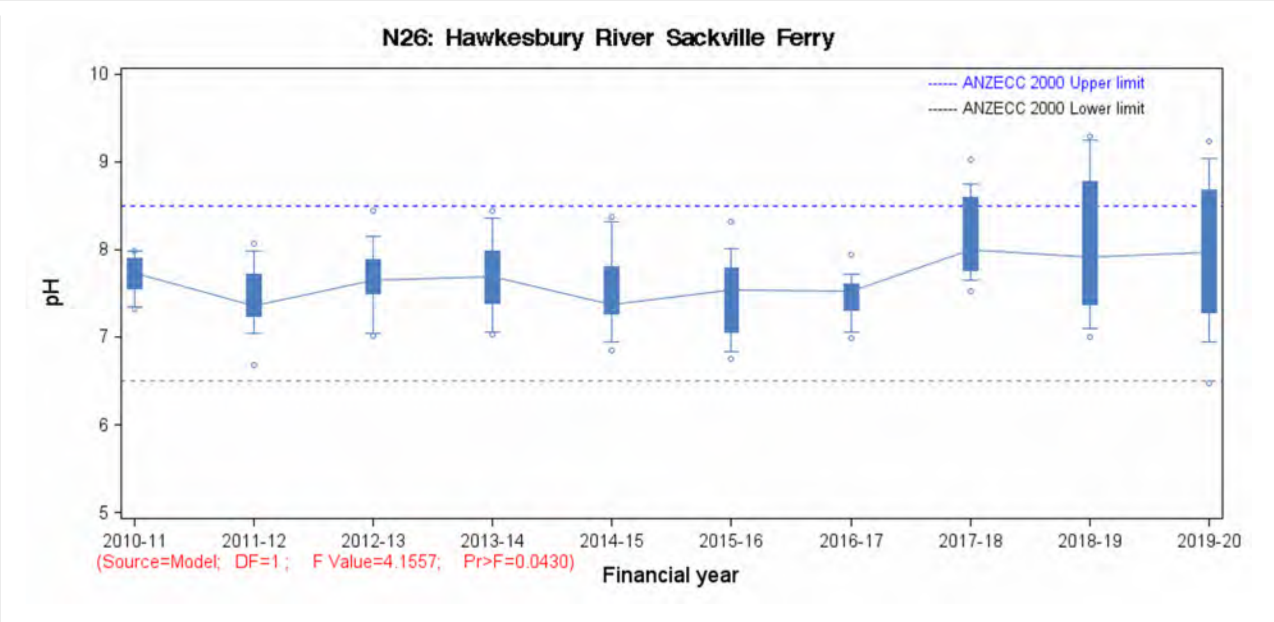
Financial year


N26: Hawkesbury River Sackville Ferry
pH
10
9
8
7
6
5
ANZECC 2000 Upper limit
ANZECC 2000 Lower limit
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=4.1557; Pr>F=0.0430)
Financial year

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.

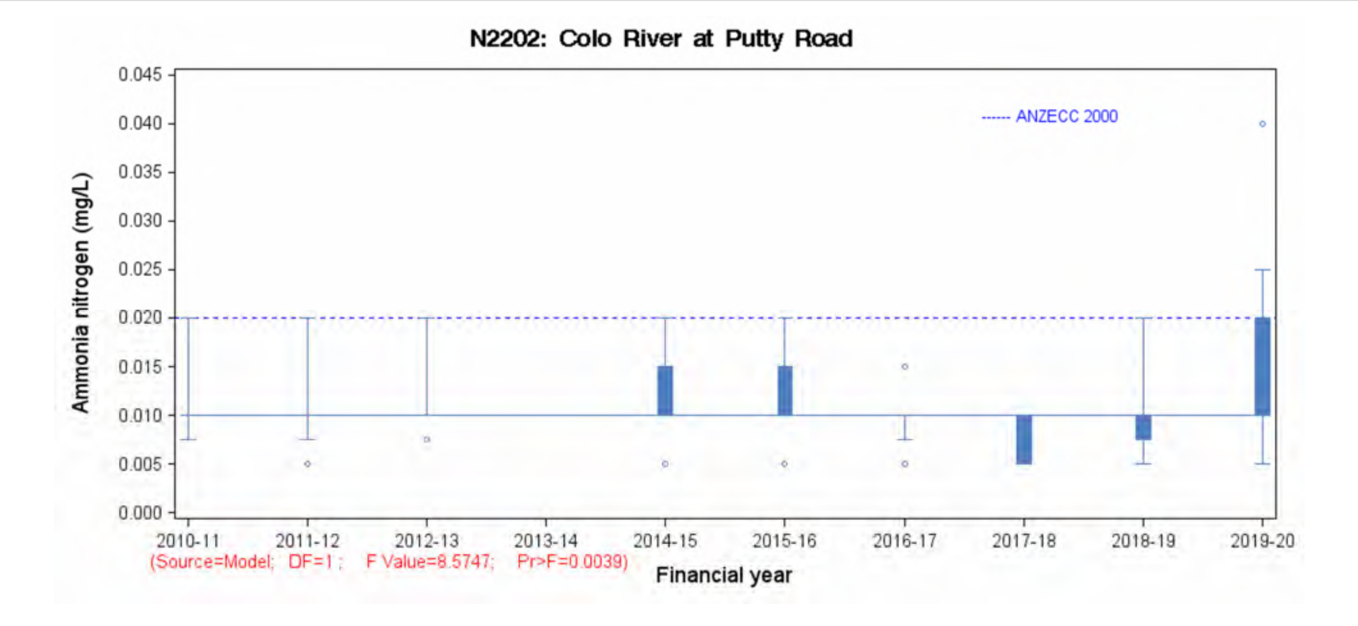
The 2019-20 water quality and algae conditions at the reference site of Colo River (N2202) deteriorated significantly in terms of few key analytes. Ammonia nitrogen, oxidised nitrogen, total nitrogen, chlorophyll-*a* and blue-green algal biovolume increased significantly in the Colo River in comparison to the last nine years.

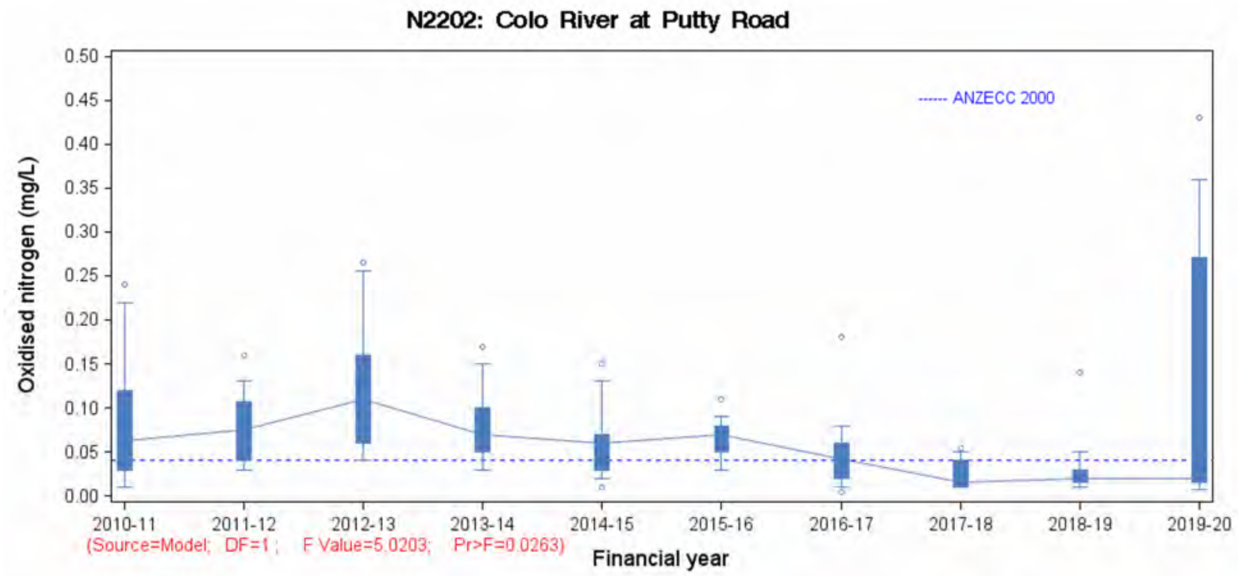
Chlorophyll-*a* concentrations were historically very low at this site but in 2019-20 three of the 17 samples collected were qualified for algal counting (>7 µg/L). Potentially toxic blue-green alga *Microcystis* were present in two of these samples (772 cells/mL and 9,770 cells/mL, higher than the Amber alert).

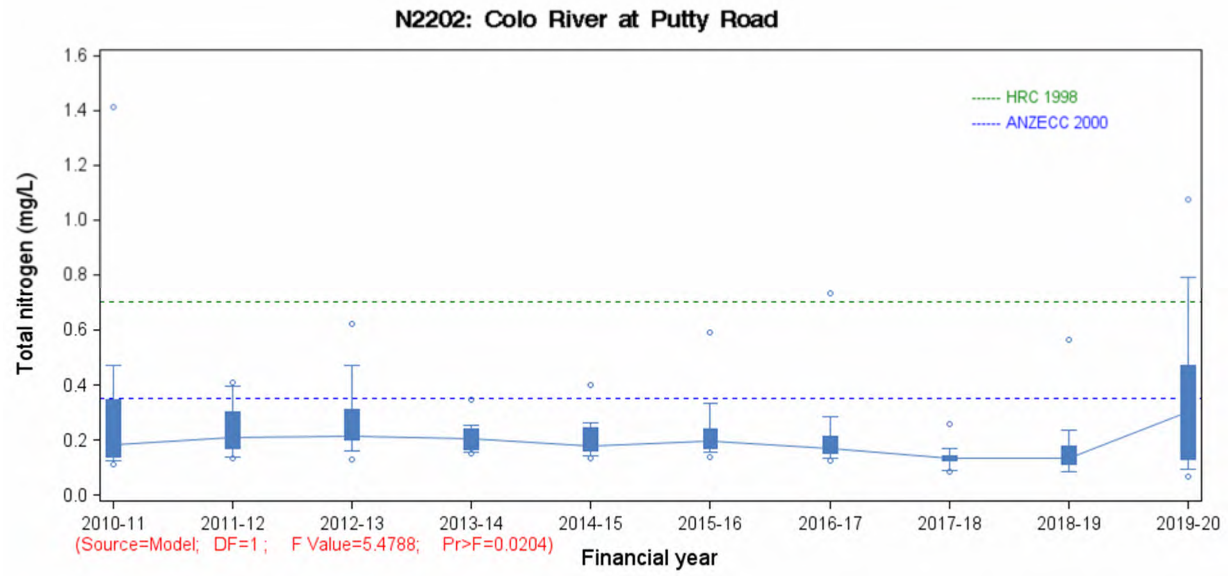
Among the physico-chemical analytes, conductivity was significantly lower in 2019-20. All other water quality analytes were not significantly different in 2019-20.

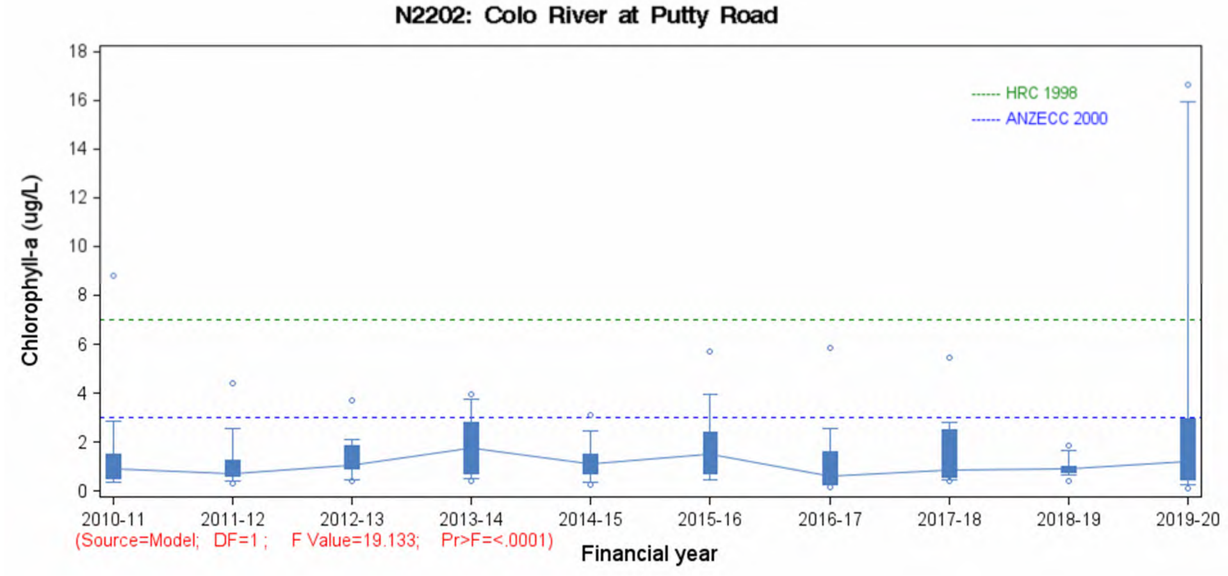
Despite the significantly increasing trend, the median values of all key analytes were within the respective ANZECC (2000) guidelines at this reference site. Only median turbidity was very low and below the ANZECC (2000) lower guideline limit at Colo River.

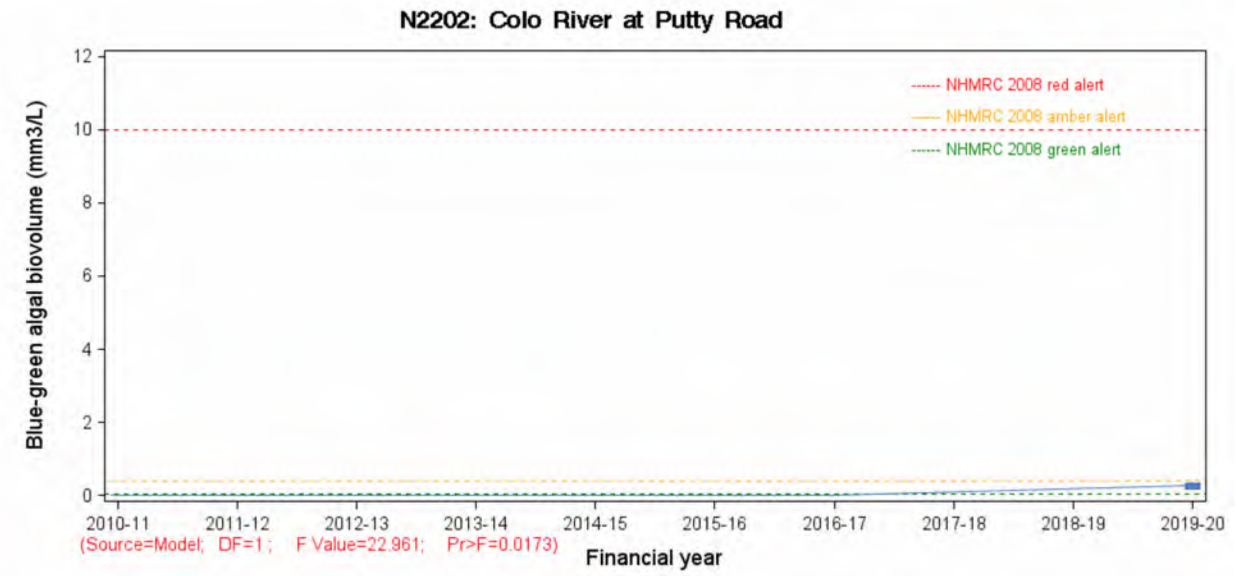
There were no other significant trends and/or exceptions (median values higher than the guideline limits) for any other water quality analyte in 2019-20

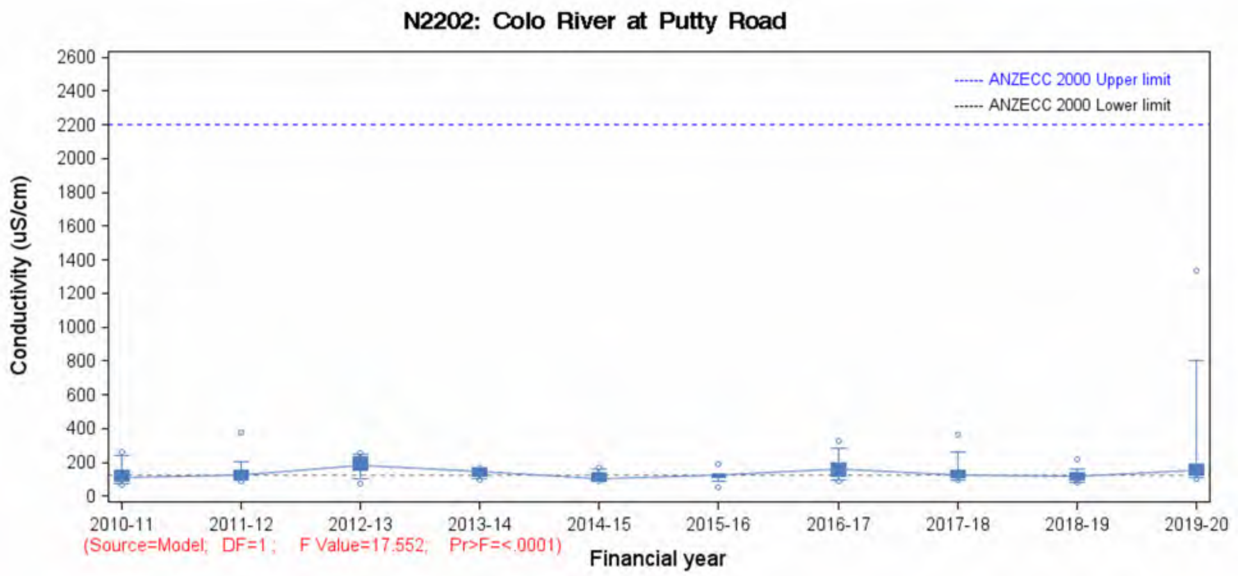



N2202: Colo River at Putty Road
Oxidised nitrogen (mg/L)
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
------ ANZECC 2000
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=5.0203; Pr>F=0.0263)
Financial year


N2202: Colo River at Putty Road
Total nitrogen (mg/L)
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
------ HRC 1998
------ ANZECC 2000
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=5.4788; Pr>F=0.0204)
Financial year


N2202: Colo River at Putty Road
Chlorophyll-a (ug/L)
18
16
14
12
10
8
6
4
2
0
------ HRC 1998
------ ANZECC 2000
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=19.133; Pr>F=<.0001)
Financial year


N2202: Colo River at Putty Road
Blue-green algal biovolume (mm3/L)
------ NHMRC 2008 red alert
------ NHMRC 2008 amber alert
------ NHMRC 2008 green alert
12
10
8
6
4
2
0
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=22.961; Pr>F=0.0173)
Financial year


N2202: Colo River at Putty Road
Conductivity (uS/cm)
------ ANZECC 2000 Upper limit
------ ANZECC 2000 Lower limit
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
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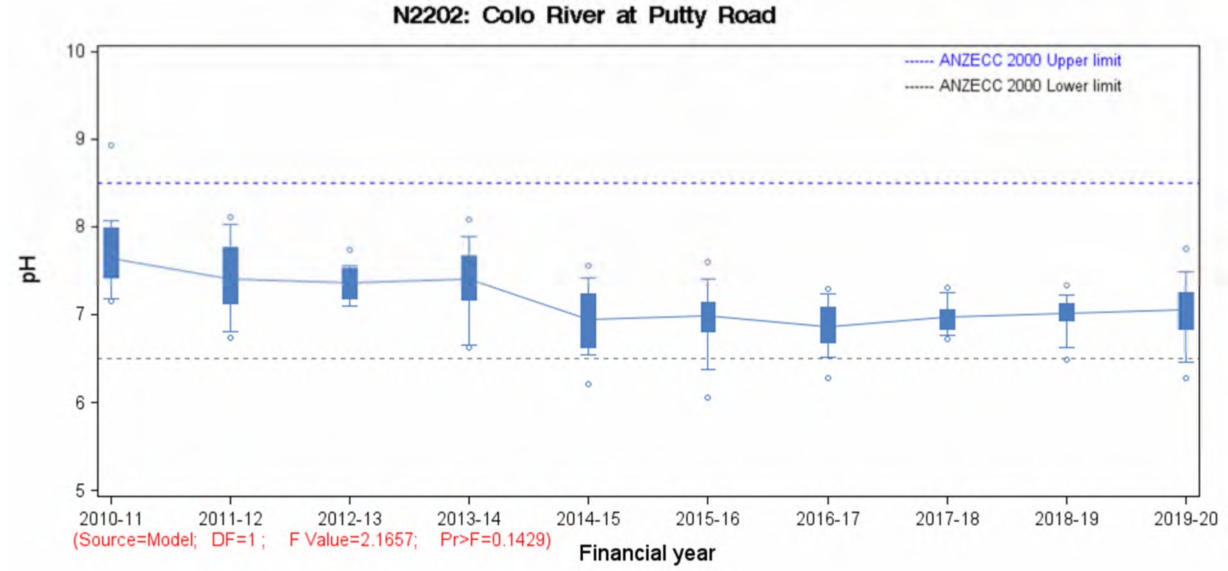
Financial year


N2202: Colo River at Putty Road
pH
------ ANZECC 2000 Upper limit
------ ANZECC 2000 Lower limit
10
9
8
7
6
5
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=2.1657; Pr>F=0.1429)
Financial year

N18: Hawkesbury River at Leets Vale

The Hawkesbury River at Leets Vale (N18), 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 salt levels.

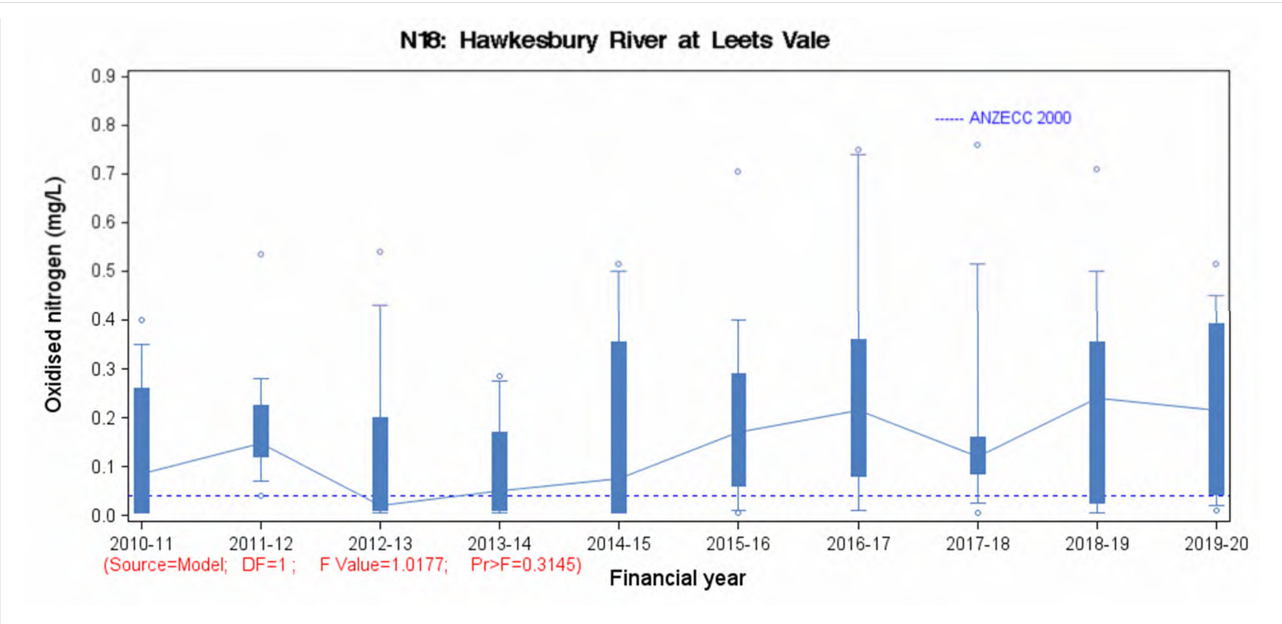
Statistical analysis revealed that the 2019-20 nutrients and algae conditions were steady at Leets Vale (N18) with no significant differences with the previous nine years. Eleven of the 17 samples exceeded a chlorophyll-*a* concentration of 7 µg/L which triggered algal analysis in 2019-20. The algal population was mixed including presence of toxigenic blue-green algae in three of these samples: *Aphanizomenonaceae* 1,102 cells/mL (20 September 2019), *Microcystis 277* cells/mL (17 May 2020) and 7,549 cells/mL (23 June 2020, higher than the Amber alert).

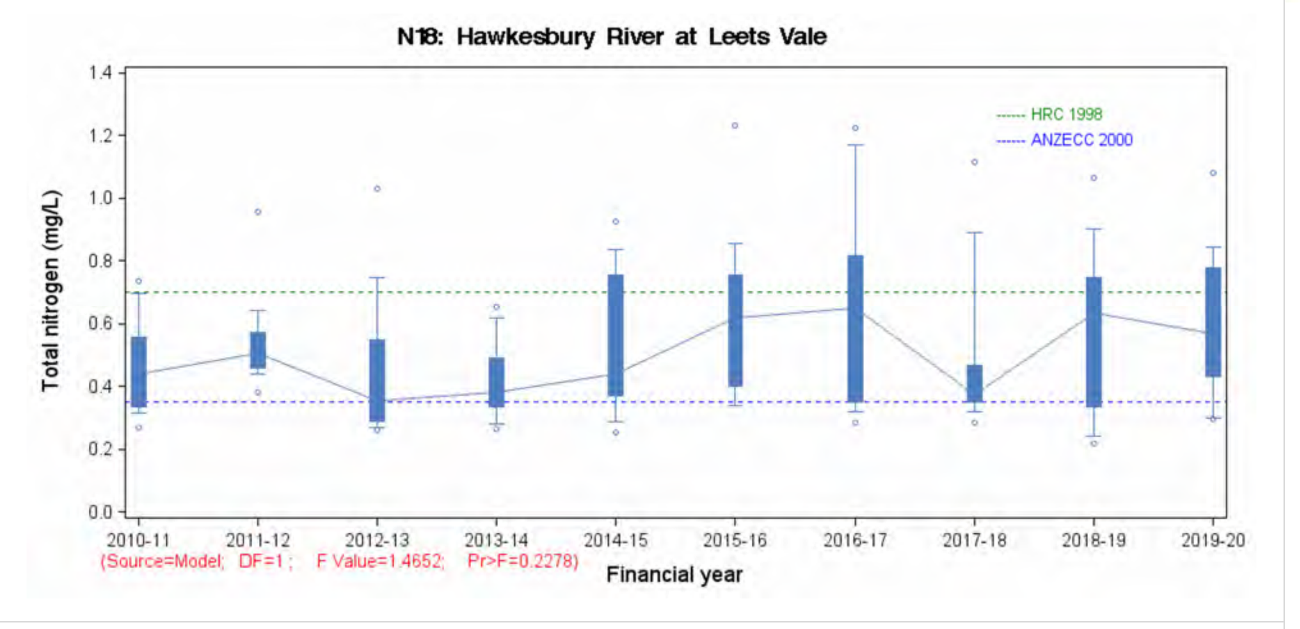
Among physico-chemical analytes conductivity increased significantly in 2019-20 compared to earlier years.

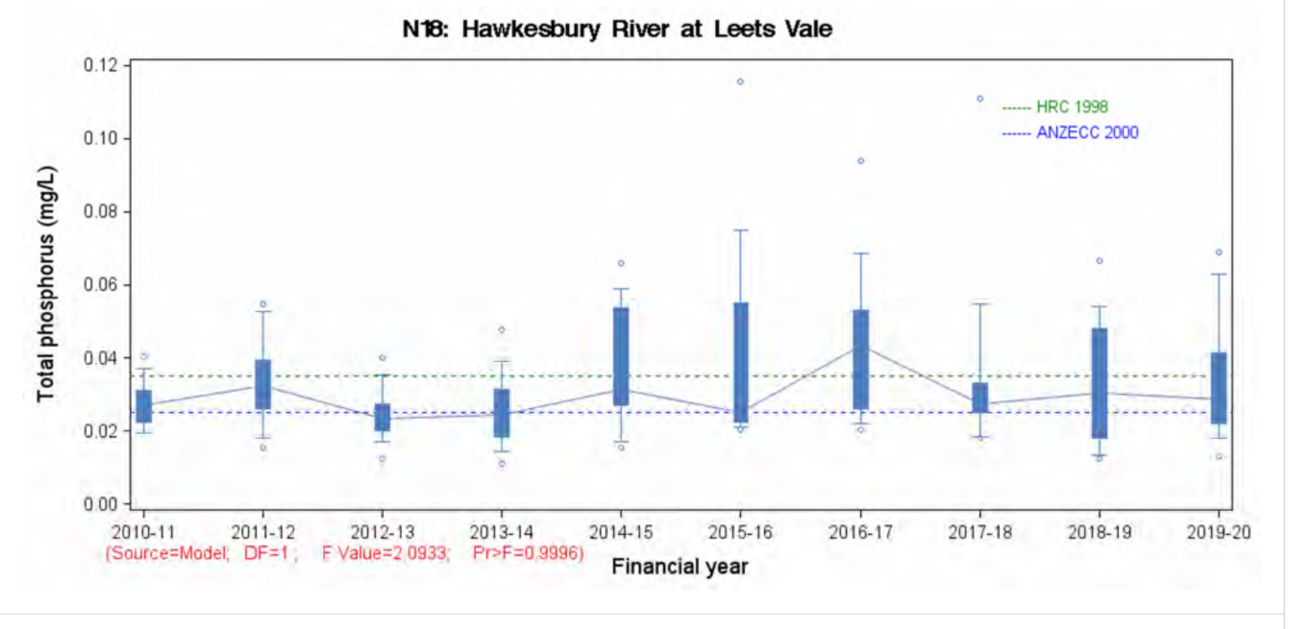
In the 2019-20 period, the median oxidised nitrogen, total nitrogen, total phosphorus and chlorophyll-*a* concentrations exceeded the respective ANZECC (2000) guideline limits.

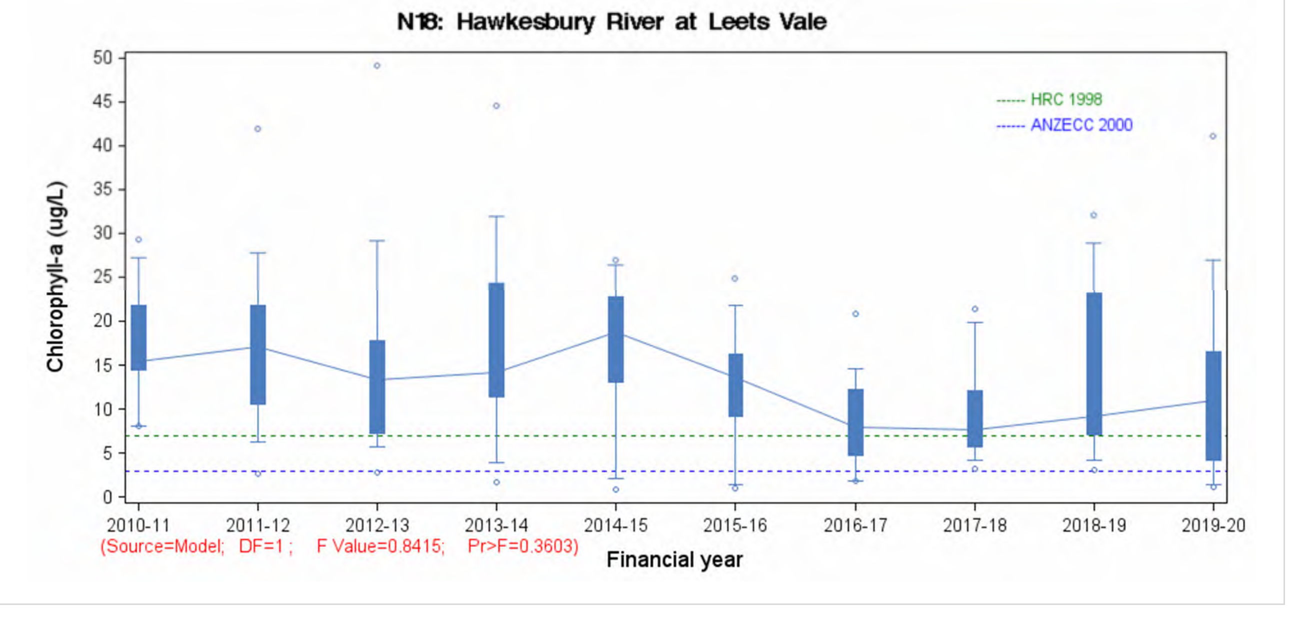
Among physico-chemical analytes the median conductivity was higher than the ANZECC (2000) guideline limit at this estuarine site.

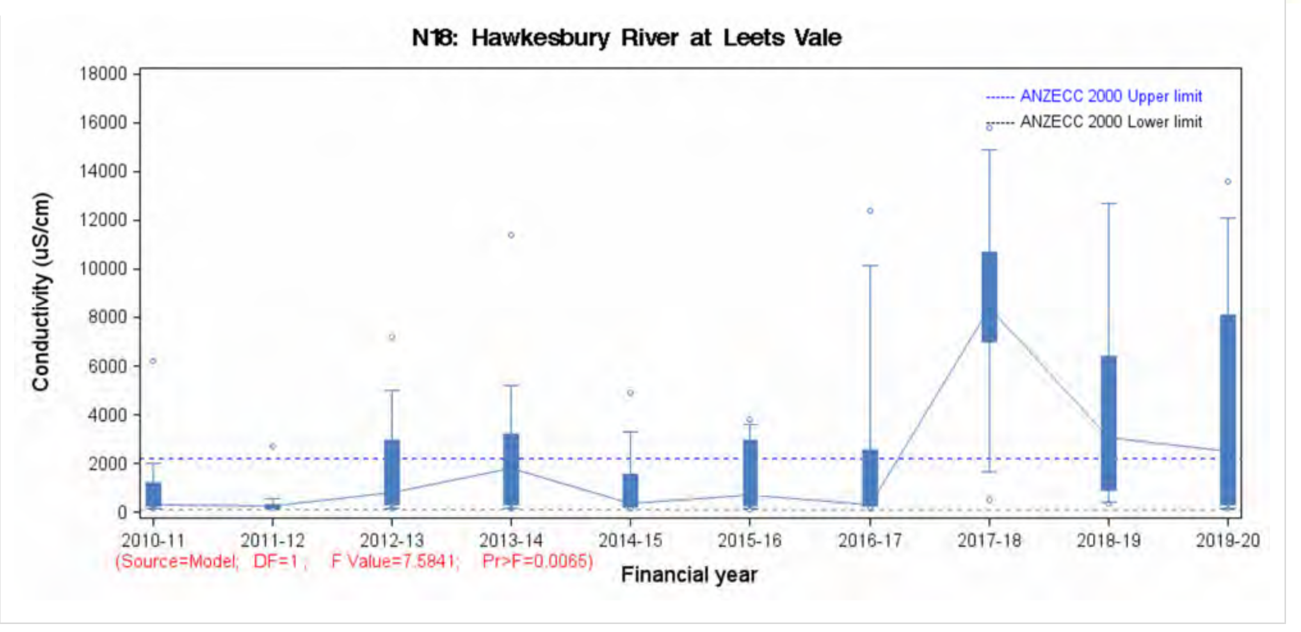
There were no other significant trends and/or exceptions (median values higher than the guideline limits) for any other water quality or algae analyte in 2019-20.




N18: Hawkesbury River at Leets Vale
Total nitrogen (mg/L)
HRC 1998
ANZECC 2000
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=1.4652; Pr>F=0.2278)
Financial year


N18: Hawkesbury River at Leets Vale
Total phosphorus (mg/L)
HRC 1998
ANZECC 2000
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=2.0933; Pr>F=0.9996)
Financial year


N18: Hawkesbury River at Leets Vale
Chlorophyll-a (ug/L)
HRC 1998
ANZECC 2000
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=0.8415; Pr>F=0.3603)
Financial year


N18: Hawkesbury River at Leets Vale
------ ANZECC 2000 Upper limit
------ ANZECC 2000 Lower limit
Conductivity (uS/cm)
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=7.5841; Pr>F=0.0065)
Financial year

NB13: Berowra Creek at Calabash Bay

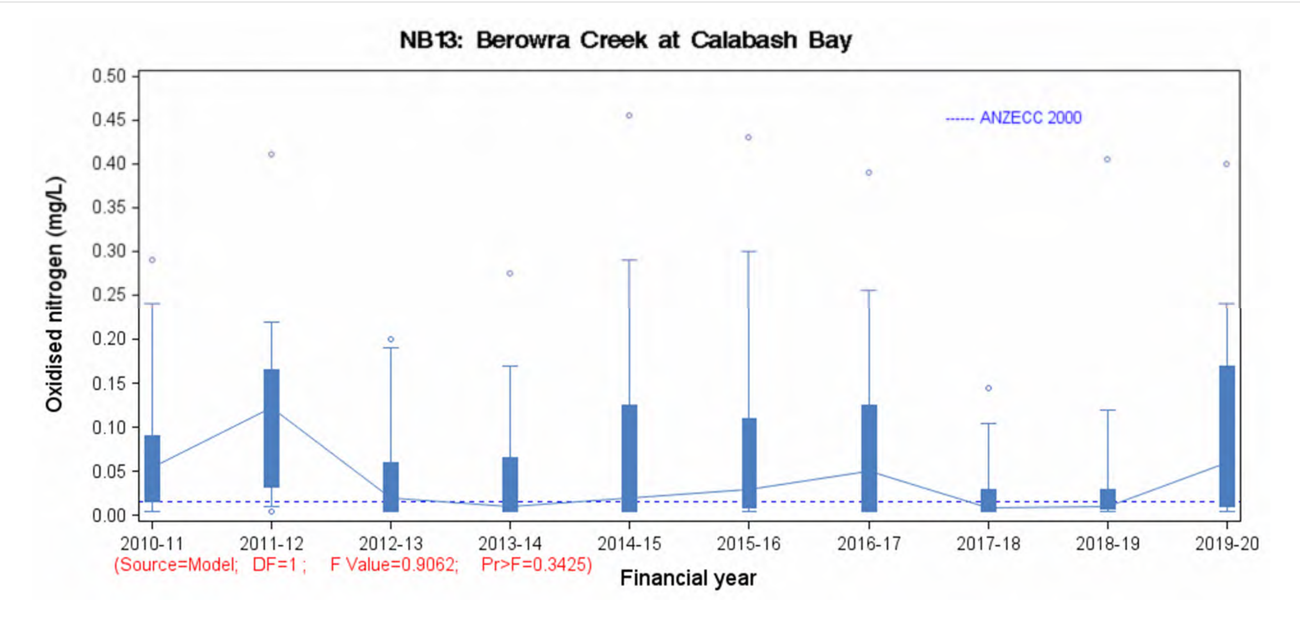
The Berowra Creek site at Calabash Bay (NB13) is located at Cunio Point in the Berowra estuary of the Hawkesbury River. There is strong tidal influence at this site and the water quality is affected by various sources of pollution from the upstream Berowra Creek catchment such as urban runoff, runoff from unsewered areas, agricultural cultivation involving fertiliser use, bushland and two licensed Sydney Water WWTP discharge points. Hornsby Heights WWTP discharges to Calna Creek, a tributary of Berowra Creek, while West Hornsby WWTP discharges to Waitara Creek, also a tributary of Berowra Creek.

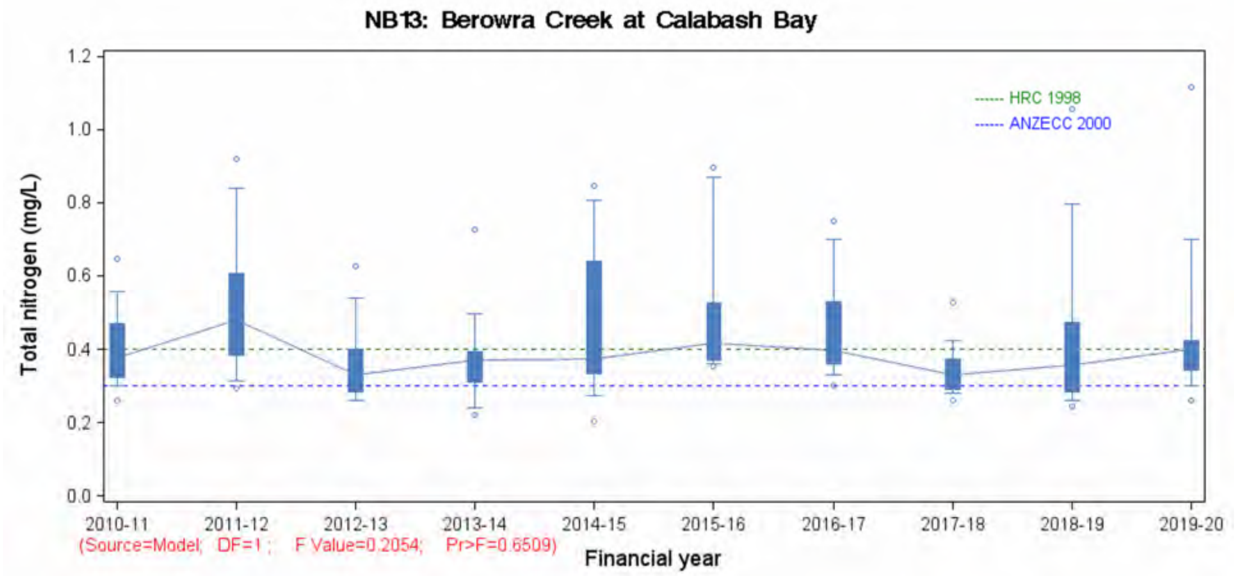
Statistical analysis identified that the 2019-20 water quality and algae conditions were steady at Calabash Bay Berowra Creek (NB13) with no significant differences with previous nine years results. Seven of the 14 samples exceeded a chlorophyll-*a* concentration of 7 µg/L which triggered algal analysis in 2019-20. Algal population was mixed and potentially toxic dinoflagellates were found in small counts in six of these samples (*Heterocapsa*: 35 cells/mL to 351 cells/mL; *Prorocentrum minimum*: 35 cells/mL to 140 cells/mL).

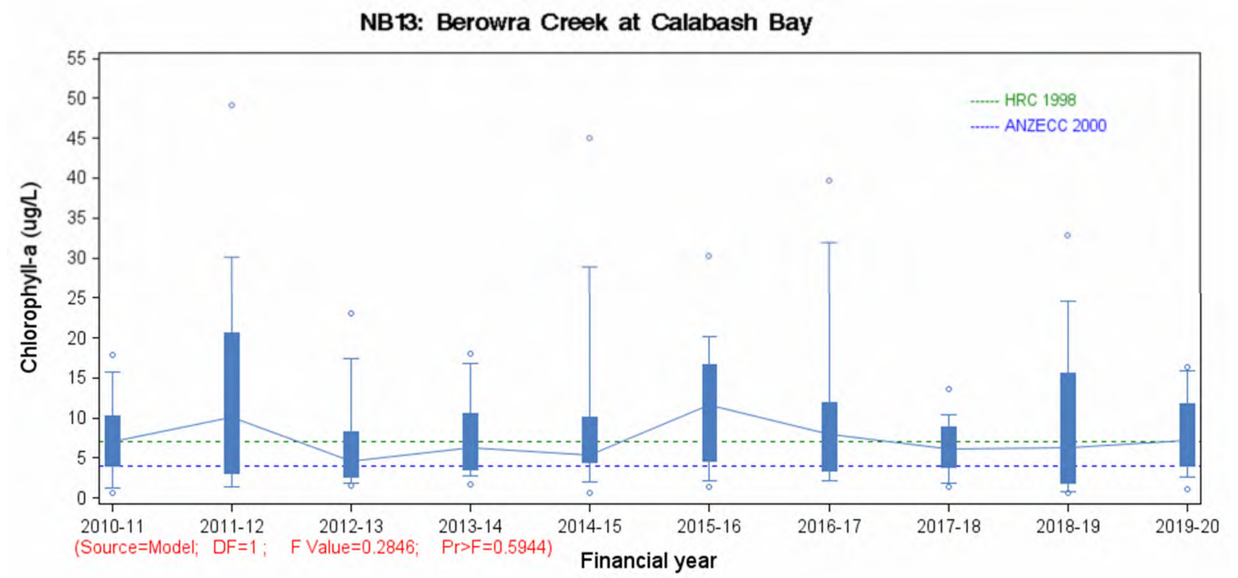
In the 2019-20 period, the median oxidised nitrogen, total nitrogen and chlorophyll-*a* concentrations exceeded the respective ANZECC (2000) guideline limits.

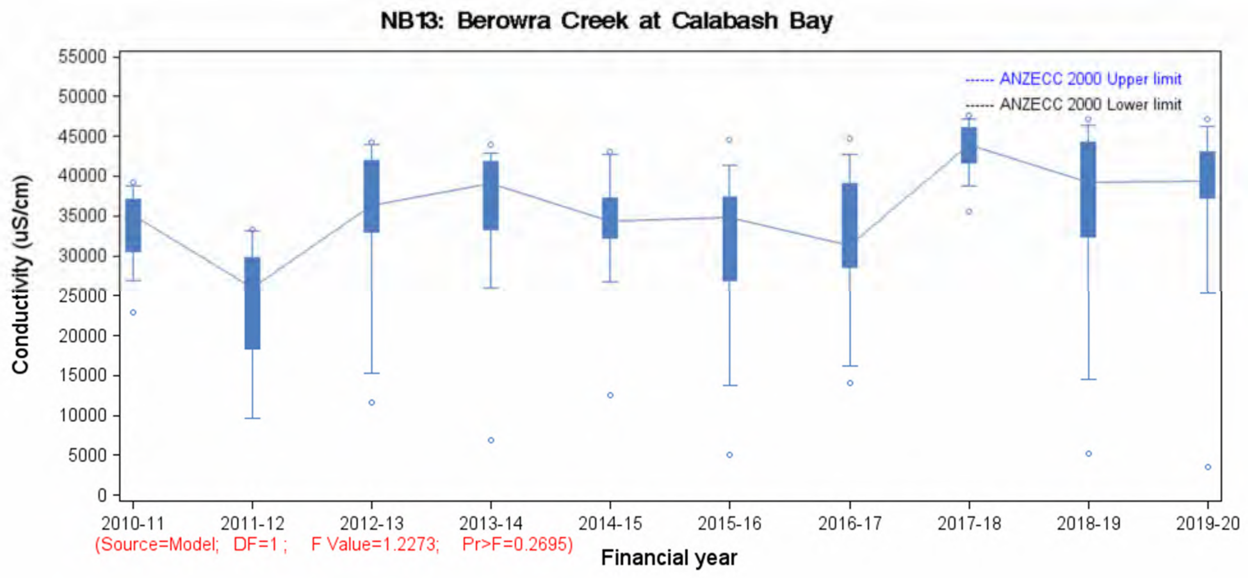
Among physico-chemical analytes the median conductivity was higher than the ANZECC (2000) guideline limit at this estuarine site. Median turbidity was low and below the ANZECC (2000) lower guideline limit at this site.

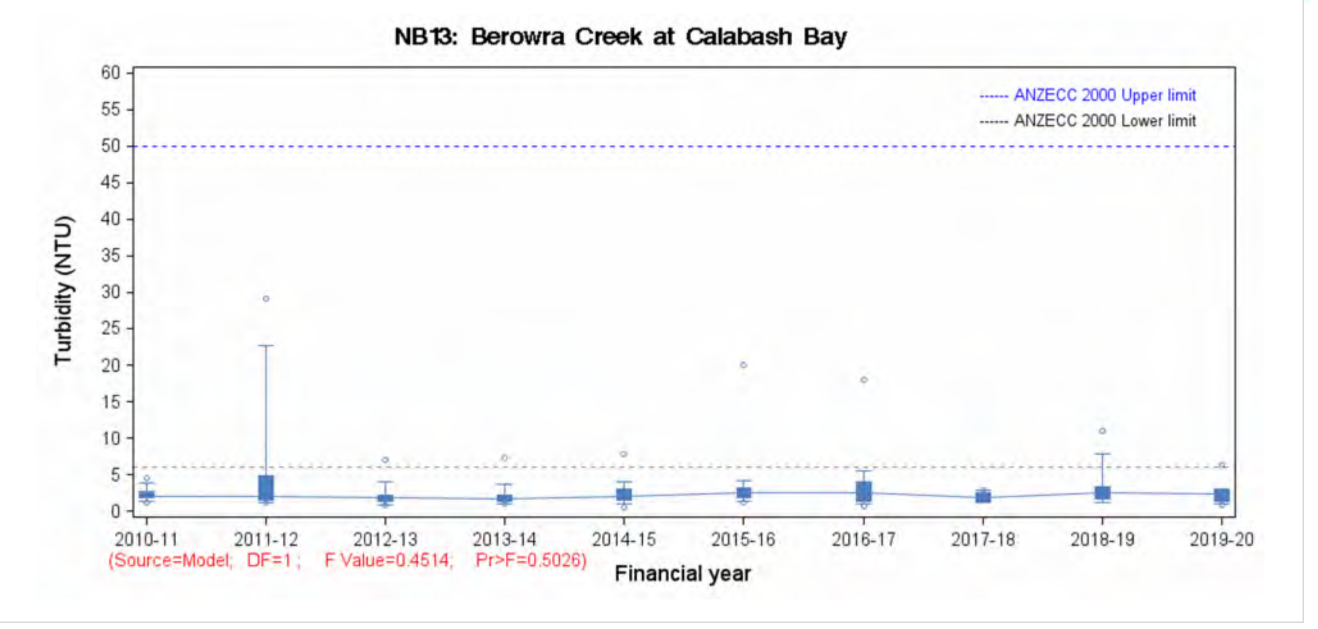
There were no other significant trends and/or exceptions (median values higher than the guideline limits) for any other water quality or algae analyte in 2019-20.




NB13: Berowra Creek at Calabash Bay
Total nitrogen (mg/L)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
------ HRC 1998
------ ANZECC 2000
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=0.2054; Pr>F=0.6509)
Financial year


NB13: Berowra Creek at Calabash Bay
Chlorophyll-a (ug/L)
0
5
10
15
20
25
30
35
40
45
50
55
------ HRC 1998
------ ANZECC 2000
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=0.2846; Pr>F=0.5944)
Financial year


NB13: Berowra Creek at Calabash Bay
Conductivity (uS/cm)
0
5000
10000
15000
20000
25000
30000
35000
40000
45000
50000
55000
------ ANZECC 2000 Upper limit
------ ANZECC 2000 Lower limit
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=1.2273; Pr>F=0.2695)
Financial year


NB13: Berowra Creek at Calabash Bay
ANZECC 2000 Upper limit
ANZECC 2000 Lower limit
Turbidity (NTU)
60
55
50
45
40
35
30
25
20
15
10
5
0
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=0.4514; Pr>F=0.5026)
Financial year

NB11: Berowra Creek off Square Bay

The Berowra Creek site off Square Bay (NB11) is located at Okay Point in the Berowra estuary of the Hawkesbury River. This site is strongly influenced by tidal movement and cycles. The catchment influences at this site are the same as for the nearby Calabash Bay site (NB13), the only difference being this site is further away from wastewater discharges. The influences include urban runoff, runoff from unsewered areas, agricultural cultivation involving fertiliser use, bushland and two licensed Sydney Water WWTP discharge points.

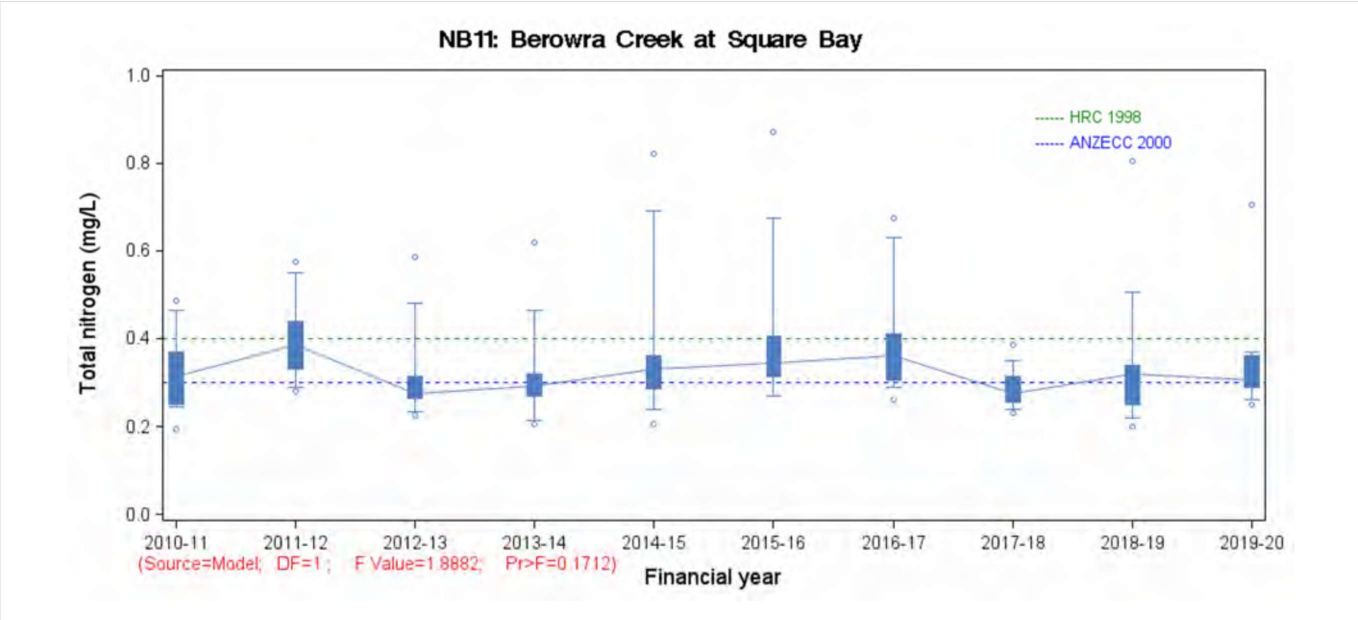
Total phosphorus concentrations at Berowra Creek Off Square Bay (NB11) increased significantly in 2019-20 compared to the previous nine years. Five of the 14 samples exceeded a chlorophyll-*a* concentration of 7 µg/L which triggered algal analysis in 2019-20. Algal population was mixed and potentially toxic dinoflagellates were present in small counts in two of these samples (*Heterocapsa*: 35 cells/mL and 211 cells/mL; *Prorocentrum minimum* 211 cells/mL).

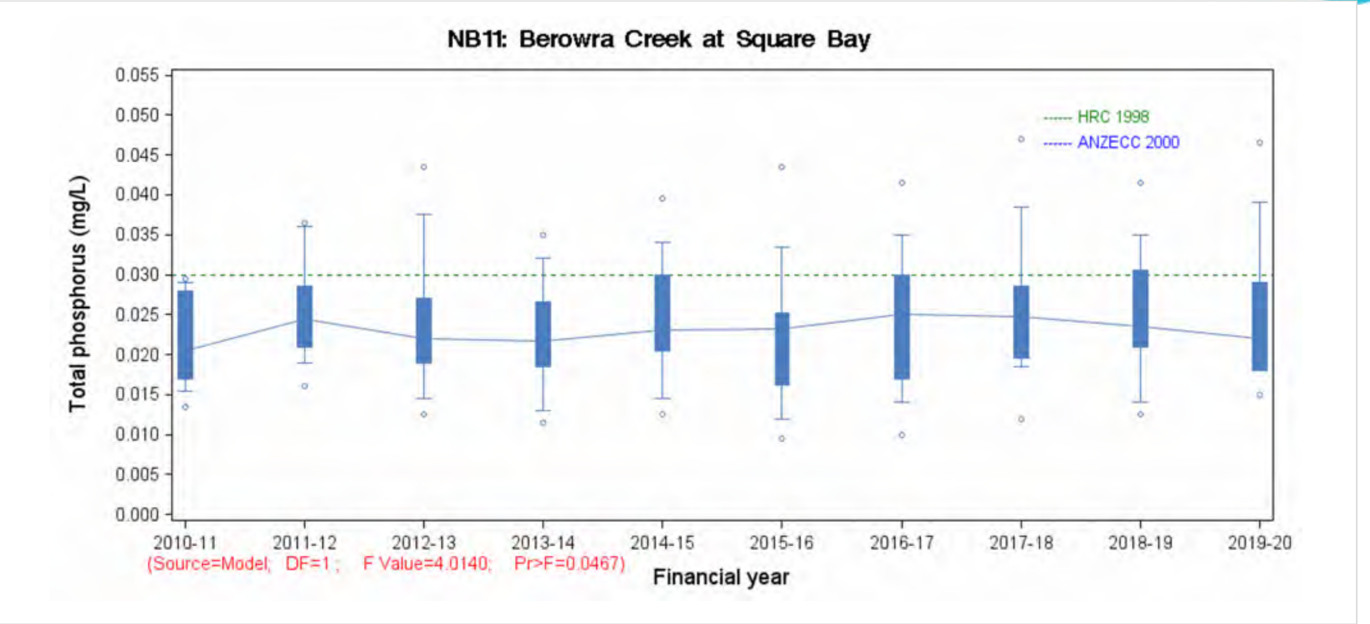
In the 2019-20 period, the median total nitrogen and chlorophyll-*a* concentrations exceeded the respective ANZECC (2000) guideline limits.

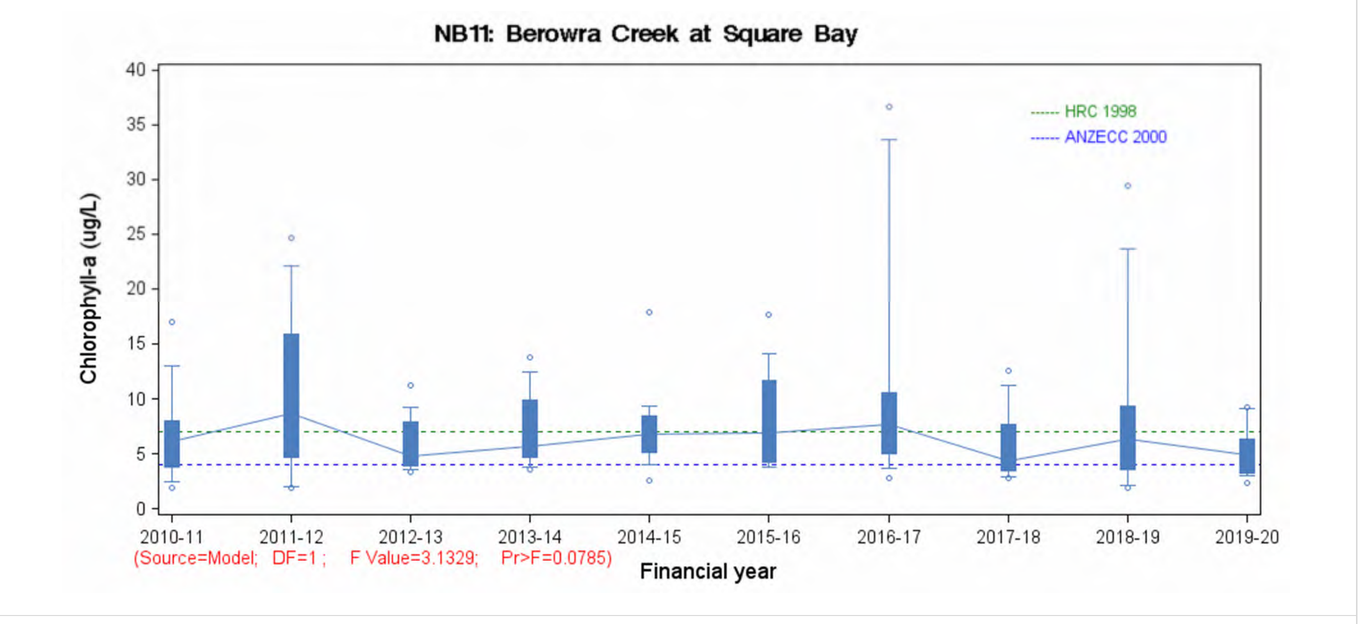
Among physico-chemical analytes dissolved oxygen saturation increased or improved significantly in 2019-20 compared to earlier years.

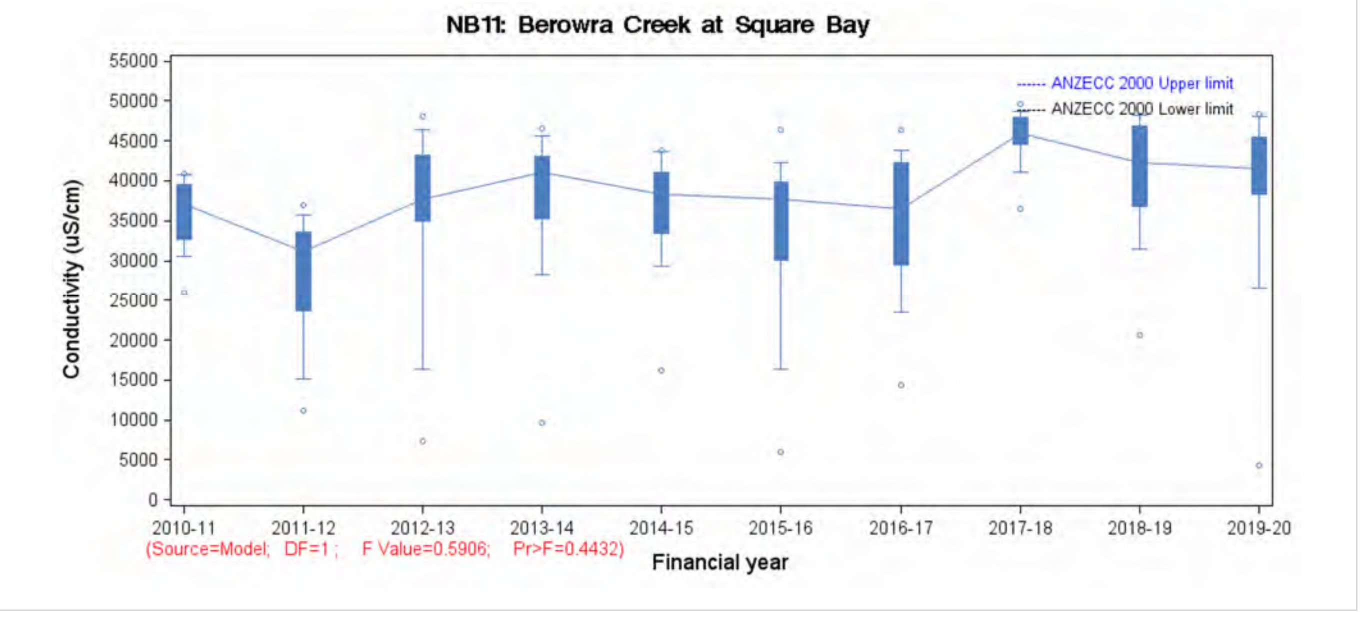
The 2019-20 median conductivity was higher than the ANZECC (2000) freshwater guideline limit, as expected.

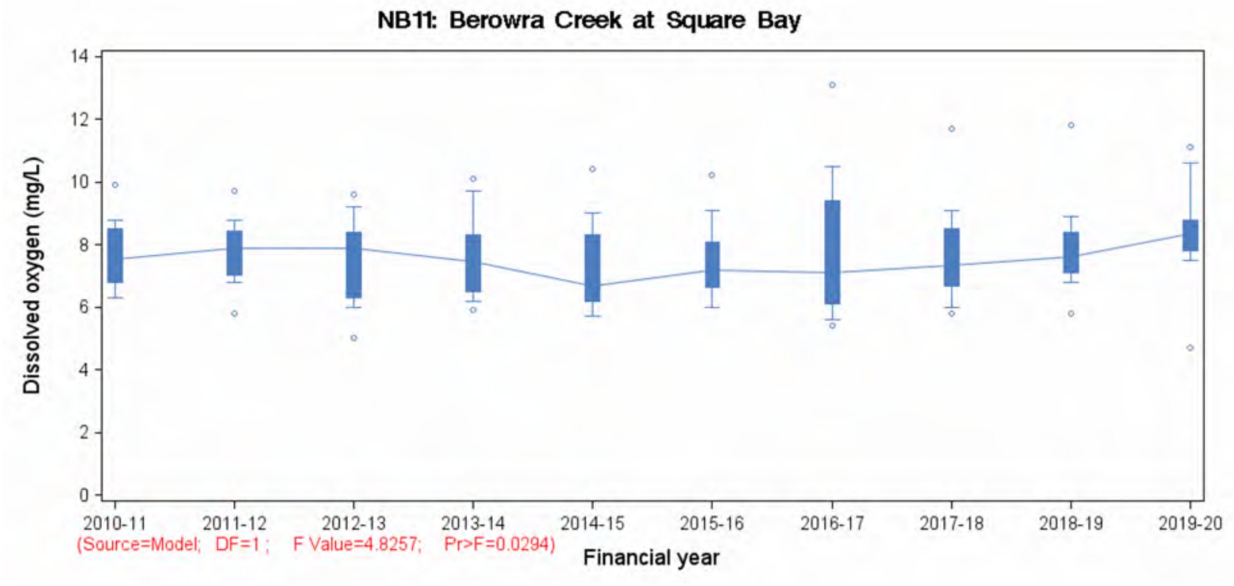
There were no other significant trends and/or exceptions (median values higher than the guideline limits) for any other water quality or algae analyte in 2019-20.




NB11: Berowra Creek at Square Bay
Total phosphorus (mg/L)
HRC 1998
ANZECC 2000
0.055
0.050
0.045
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=4.0140; Pr>F=0.0467)
Financial year


NB11: Berowra Creek at Square Bay
Chlorophyll-a (ug/L)
HRC 1998
ANZECC 2000
40
35
30
25
20
15
10
5
0
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=3.1329; Pr>F=0.0785)
Financial year

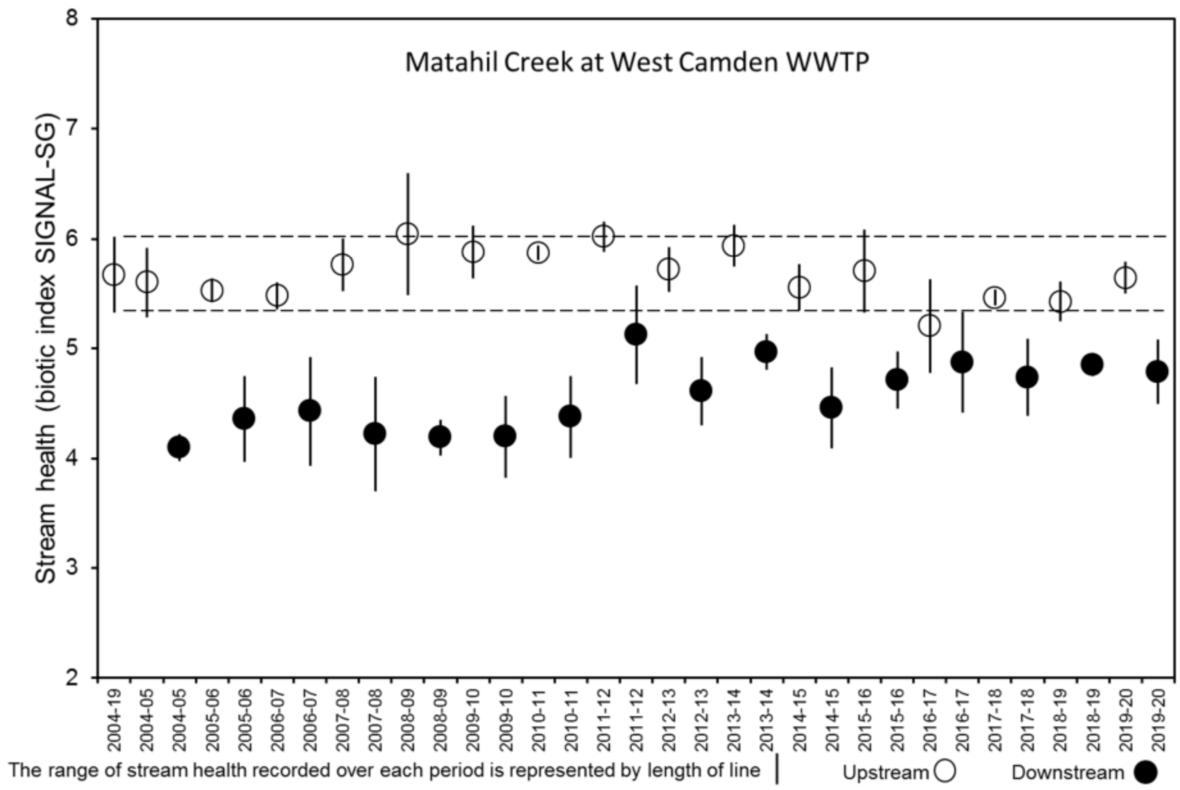

NB11: Berowra Creek at Square Bay
Conductivity (uS/cm)
ANZECC 2000 Upper limit
ANZECC 2000 Lower limit
55000
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=0.5906; Pr>F=0.4432)
Financial year


NB11: Berowra Creek at Square Bay
Dissolved oxygen (mg/L)
14
12
10
8
6
4
2
0
2010-11
2011-12
2012-13
2013-14
2014-15
2015-16
2016-17
2017-18
2018-19
2019-20
(Source=Model; DF=1 ; F Value=4.8257; Pr>F=0.0294)
Financial year

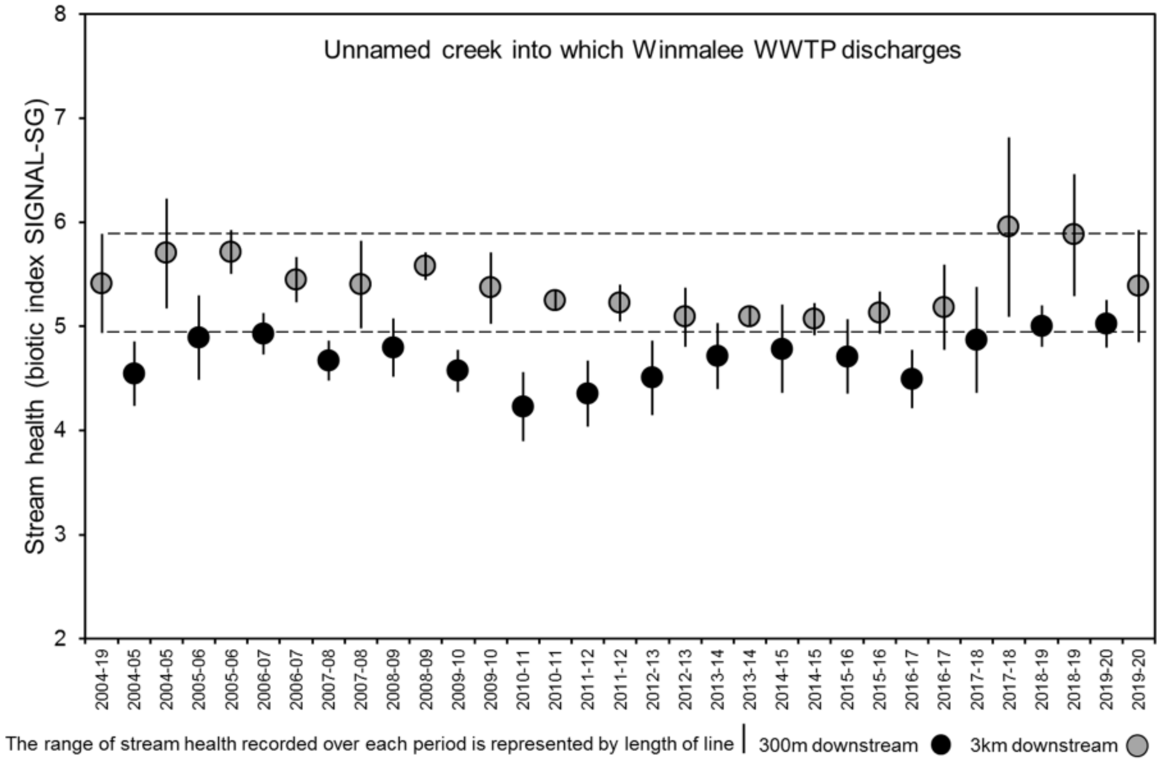
4.6.2 Hawkesbury-Nepean River stream health

The 2019-20 monitoring results show localised ecosystem impacts in creeks downstream of West Camden WWTP, Winmalee WWTP, Hornsby Heights WWTP and West Hornsby WWTP. There was no evidence these impacts had any effect on the Hawkesbury-Nepean River system to which these creeks flow (Volume 2 Appendix N). No other stream health impacts were identified for other inland discharging WWTPs (Volume 2 Appendix N).

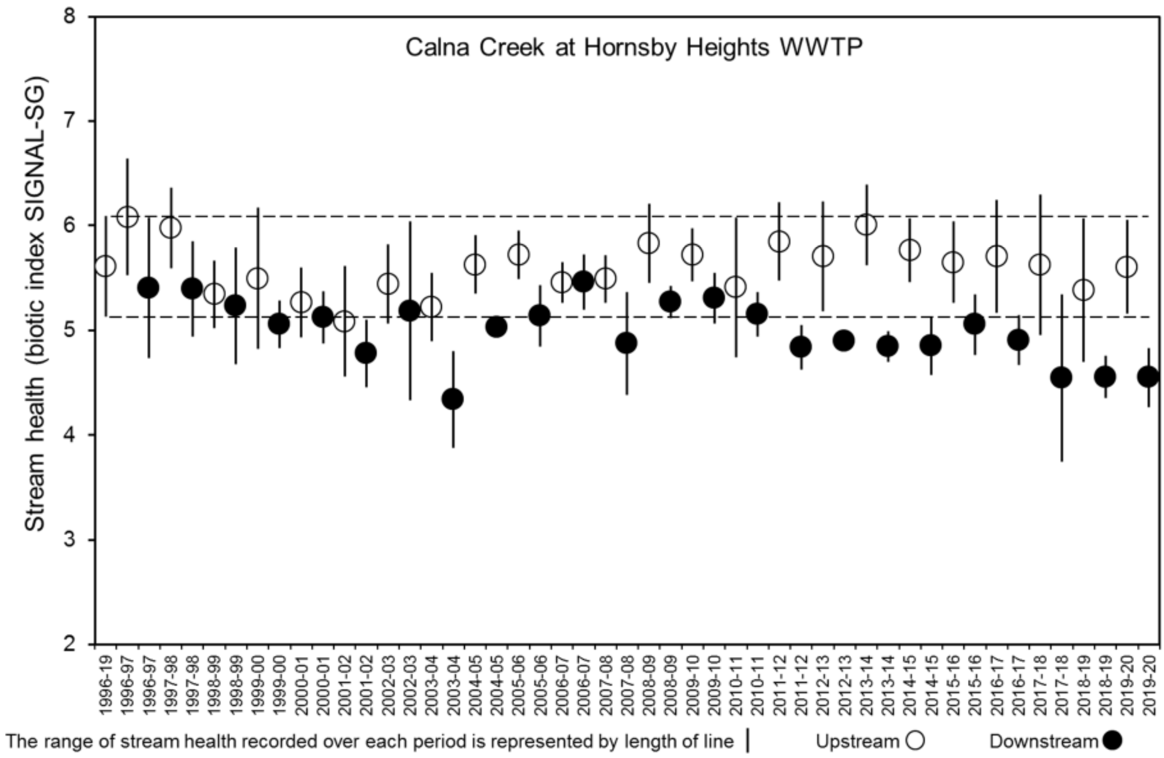
Summary stream health plots for these four WWTPs are below.



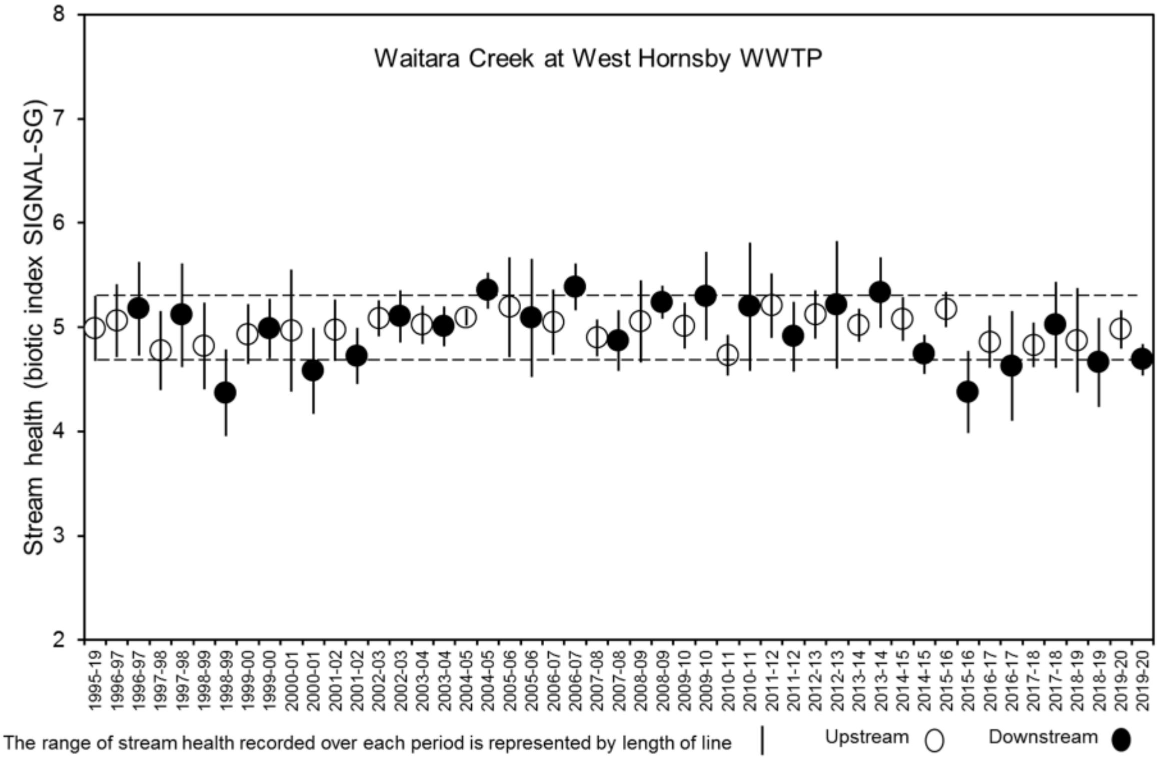
A relatively persistent impact in stream health was also suggested by the SIGNAL-SG scores and multivariate testing of macroinvertebrate data from Matahil Creek which receives treated wastewater from West Camden WWTP, but this impact did not extend to the Nepean River.



A relatively persistent impact in stream health was also suggested by the SIGNAL-SG scores and multivariate testing of macroinvertebrate data from the unnamed creek which receives treated wastewater from Winmalee WWTP, but this impact did not extend to the Nepean River.



The SIGNAL-SG control chart plot from the Calna Creek sites upstream and downstream of Hornsby Heights WWTP suggests an impact has occurred from time to time and has been persistent over the last nine financial years.



SIGNAL-SG and multivariate testing outcomes suggest downstream community structure in Waitara Creek was altered by wastewater discharge from West Hornsby WWTP in the more recent period.

5 Response : Sydney Water initiatives

The aim of this chapter is to present a high-level summary of Sydney Water's 'Response' under the PSR framework. It includes recent and planned actions to minimise the impact of wastewater discharges and overflows on the environment.

With the increasing population pressure, climate change and aging wastewater networks 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
- maintaining low frequencies of wet weather overflows
- reduce the number of dry weather overflow incidents

Sydney Water is committed to face these challenges with special objectives in reducing the environmental impact of its discharges into or onto the air, water or land of substances likely to cause harm to the environment.

The key Sydney Water initiatives, recent and planned, to reduce nutrients and other pollutant loads into the environment include:

1. Upgrade the treatment facilities or WWTPs:
    - Riverstone WWTP – upgrade completed, nutrient load reduction (2019)
    - North Head WWTP – process improvement to reduce oil and grease (ongoing)
    - Winmalee WWTP – planned upgrade, nutrient load reduction (Stage 1 2021)
    - Picton WWTP – planned upgrade and amplification (2021)
    - Quakers Hill WWTP – upgrade in progress, nutrient load reduction (2021)
    - Transfer of flows from Rouse Hill WWTP to Riverstone WWTP – planned (2021)
    - St Marys WWTP – planned upgrade (2021)
    - West Camden WWTP – planned amplification and upgrade (complete 2022)
    - Upper South Creek Advanced Water Recycling Centre – New facility (complete 2026)
2. Production and distribution of more recycled water. The volume of total water recycling was maintained at a historical high 28.2 ML/day in 2019-20
3. Eliminate low quality direct discharges and reduce overflows:
    - Diversion of near shore discharges from Vaucluse and Diamond Bay (expected completion 2023)
    - Reduce dry wastewater overflows from sewer networks by increasing the inspections and surveillance
    - DWLP – Expedite investigations on faecal coliforms threshold exceedances to prevent reoccurrence

- o Wet Weather Overflow Abatement (WWOA) program – extensive environmental monitoring in relation to wet weather overflow event, modelling and interpretation of data to understand and minimise the impact

4. Community education to reduce the undesirable pollutants in wastewater:
   - o Reduce oil and grease in ocean plants influent
   - o Reduce disposal of wet wipes and other non-flushable items into the sewer

5. Review the licence monitoring program (STSIMP) to improve our ability to identify the impact of wastewater discharges and overflows on the environment. This will enable us to better manage the wastewater systems and make appropriate decisions when:
   - o Modifying conditions in our wastewater EPLs
   - o Planning upgrades to existing treatment plants
   - o Planning servicing strategies (including new discharges) for future growth in greater Sydney

6. Environmental Performance Improvement Program (EPIP) – Four key focus areas are:
   a. Digital Innovation – Internet of Things (IoT) devices in sensitive environmental areas to detect wastewater blockages and react before they become an overflow
   b. Incident Management – improve the way environmental incidents are managed with new processes, resources and systems
   c. Incident prevention – Proactively manage assets to deliver an acceptable level of performance
   d. Environment ambition – committed to maintain a high standard of environment care

6 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. *Australian and New Zealand 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.

Banwell, K., 1996. *Structure of intertidal rocky shore assemblages following the removal of sewage.* MSc. Thesis, University of Sydney.

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.

Besley, C.H. and Birch, G.F. (2019a) Deepwater ocean outfalls: A sustainable solution for sewage discharge for mega-coastal cities (Sydney, Australia): A synthesis. *Marine Pollution Bulletin*, 145, pp. 675-677.

Besley, C.H. and Birch, G.F. (2019b) Deepwater ocean outfalls: A sustainable solution for sewage discharge for mega-coastal cities (Sydney, Australia): Influence of deepwater ocean outfalls on shelf sediment chemistry. *Marine Pollution Bulletin*, 145, pp. 707-723.

Besley, C.H. and Birch, G.F. (2019c) Deepwater ocean outfalls: A sustainable solution for sewage discharge for mega-coastal cities (Sydney, Australia): Influence of deepwater ocean outfalls on shelf benthic infauna. *Marine Pollution Bulletin*, 145, pp. 724-738.

Borowitzka, M.A., 1972. Intertidal algal species diversity and the effect of pollution. *Australian Journal of Marine and Freshwater Research* 23:73-84.

Brown, V.B, Davies S.A. and Synott, R.N., 1990. Long term monitoring of the effects of treated sewage effluent on the intertidal macroalgal community near Cape Schanack, Victoria, Australia. *Botanica Marina* 33:85-98.

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.

Camargo J.A., 1993. Macrobenthic surveys as a valuable tool for assessing freshwater quality in the Iberian Peninsula. *Environmental Monitoring and Assessment* 24 (1), 71-90

Campbell, S.J. and Burridge, T.R. 1998. *The effects of sewage discharge on the ecological processes involving marine flora in southern Australian waters*. Urban Water Research Association of 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 swage 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.

Department of Environment and Climate Change (DECC), 2009a. Load Calculation Protocol for use by holders of NSW environment protection licences when calculating assessable pollutant loads. DECC, NSW.

Dickens C.W.S. and Graham P.M., 2002. The South African Scoring System (SASS) version 5 rapid bioassessment method for rivers. *African Journal of Aquatic Science* 27 (1), 1-10.

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.

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.

Hair, J. 2020. Tahmoor mine polluting water in Bargo and Nepean rivers with cocktail of metals. https://www.abc.net.au/news/2020-06-04/tahmoor-mine-polluting-nepean-and-bargo-rivers/12315440?fbclid=IwAR3tMfAi74mroAjaMGfvjvVgxOKN3WZ_dVBLWdITAFMXX4VV3htleThmeK0)

Hannam, P. 2020. Coal miner investigated for pollution spill as it eyes expansion https://www.smh.com.au/environment/sustainability/coal-miner-investigated-for-pollution-spill-as-it-eyes-expansion-20200603-p54yxo.html

Hawkes, H.A., 1997. Origin and development of the Biological Monitoring Working Party Score System*. Water Res.* 32, 964–968.

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.

Kingsford, M and Battershill, C., 1998. *Studying Temperate Marine Environments,* A handbook for ecologists, Canterbury University Press, ISBN 0 908812 54 X, pp 335.

Krogh, M., 2000. *Ocean Outfalls in NSW*. EPA Water Science Section.

Lenat, D.R., 1993. A biotic index for the southeastern United States: derivation and list of tolerance values, with criteria for assigning water-quality ratings. Journal of the North *American Benthological Society* 12 (3), 279-290.

Littler, M.M. and Murray, S.N. 1975. Impact of sewage on the distribution, abundance and community structure of rocky intertidal macro-organisms. *Mar. Biol.* **30**, 277-291

Littler, M.M. and Murray S.N. 1978. Influence of domestic wastes on energetic pathways in rocky intertidal communities. *Journal of Applied Ecology* 15:583-595.

Manning, S., Dixon, J., Birch, G.F. and Besley, C.H. 2019. Deepwater ocean outfalls: a sustainable solution for sewage discharge for mega-coastal cities (Sydney, Australia): Influences on beach water quality. *Marine Pollution Bulletin*, 145, pp. 691-706.

May, V. 1981. Long-term variation in algal intertidal floras. *Australian Journal of Ecology* 6:329-343.

May, V. 1985. Observations on algal floras close to two sewage outlets. *Cunninghamia* 1:385-394.

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.

Murray, S.N. and Littler, M.M., 1978. Patterns of algal succession in a perturbed marine intertidal community *Journal of Phycology* 14:506-512

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

OECD, 1993. Organisation for Economic Co-operation and Development. *Using the Pressure-State-Response model to develop indicators of sustainability.* OECD framework for environmental indicators.

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

Stark J.D., 1998. SQMCI: a biotic index for freshwater macroinvertebrate coded-abundance data. New Zealand *Journal of Marine and Freshwater Research* 32 (1), 55-66.

Stark J.D. and Maxted J.R., 2007. A biotic index for New Zealand's soft-bottomed streams. New Zealand *Journal of Marine and Freshwater Research* 41, 43-61.

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. http://www.sydneywater.com.au/web/groups/publicwebcontent/documents/document/zgrf/mdq1/~edisp/dd_045378.pdf

Sydney Water, 2012. *Sewage Treatment System Impact Monitoring Program Interpretive Report 2010-11*. Sydney Water.

Sydney Water, 2020a. *Sewage Treatment System Licences, Annual System Performance Report Clause R5.5 b) and c), Reticulation System, Dry Weather* Sydney Water, September 2020.

Sydney Water, 2020b. Sewage Treatment System Licence, Annual Sewage Treatment System Performance Report - Wet Weather Overflow, 2019–20, Sydney Water, August 2020.

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.

Turak, E., Waddell, N. and Johnstone, G.,2004. *New South Wales (NSW) Australian Assessment System (AUSRIVAS) Sample Processing Manual.* (Available at https://ausrivas.ewater.org.au/index.php/manuals-a-datasheets?id=55 Accessed on 13/12/2017.

Walsh, C.J., 2004. Protection of in-stream biota from urban impacts: minimise catchment imperviousness or improve drainage design? *Marine and Freshwater Research*, 2004, 55, 317-326.

Walsh, C.J., Fletcher, T.D., and Ladson, A.R., 2005a. Stream restoration in urban catchments through re-designing stormwater systems: looking to the catchment to save the stream. *Journal of the North American Benthological Society*, 24, 690-705.

Walsh, C.J, Roy, A.H., Feminella, J.W., Cottingham, P.D., Groffman, P.M., and Morgan, R.P. 2005b. The urban stream syndrome: current knowledge and the search for a cure. *Journal of the North American Benthological Society*, 24, 706-723.

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.

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, Method 245.7, United States Environmental Protection Agency, Office of Water, Office of Science and Technology Engineering and Analysis Division. Washington DC.

USEPA, 2014. *Method 6020b inductively coupled plasma—mass spectrometry*. Rev. 2, July 2014.

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