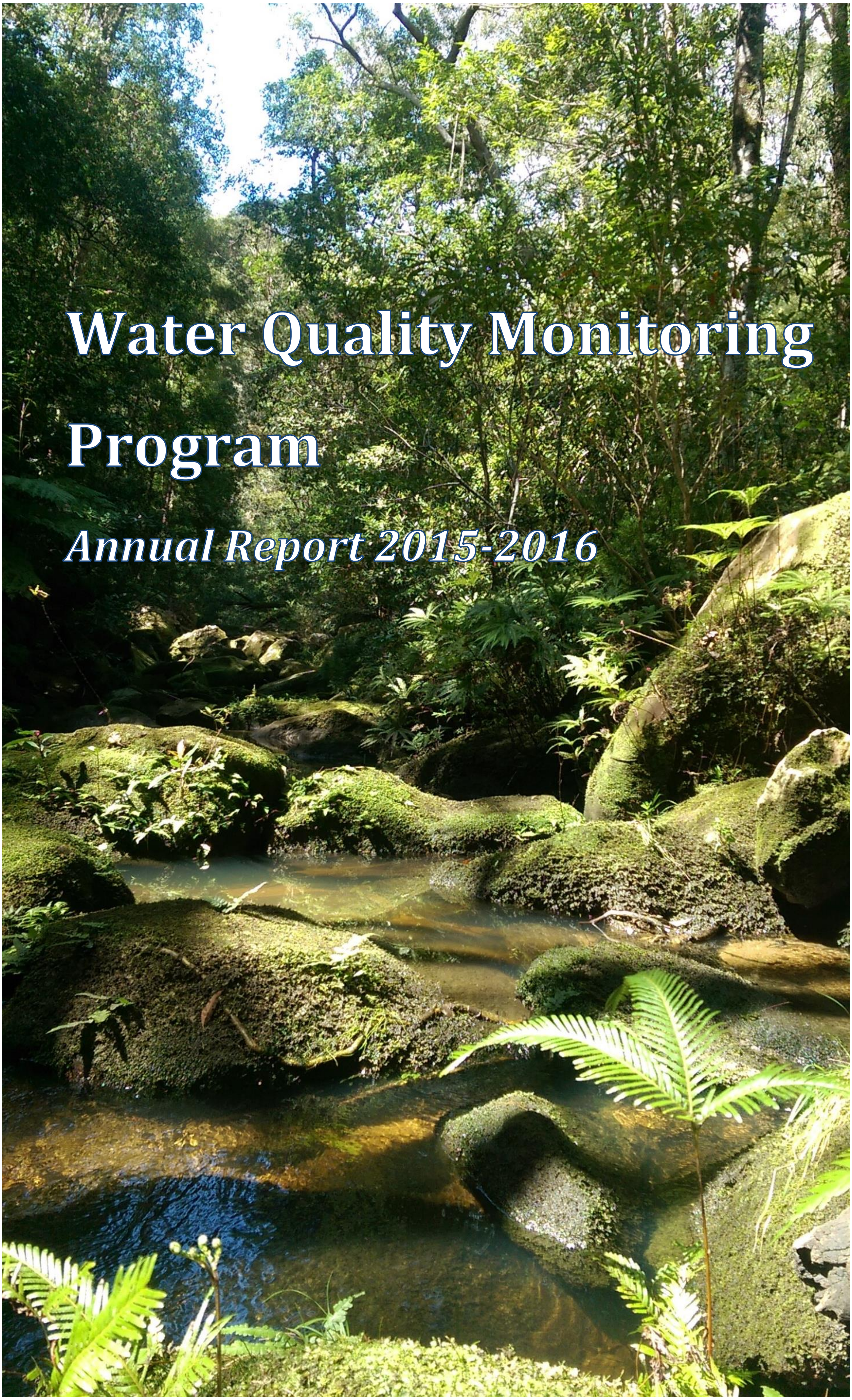
Water Quality Monitoring Program

Annual Report 2015-2016



Acknowledgements

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Executive Summary

Water quality refers to the physical, chemical and biological parameters of water. These elements are measured to assess the condition of aquatic systems.

Hornsby Shire Council established the water quality monitoring program in 1994 to (i) collect information to improve catchment knowledge, (ii) gain an understanding of the condition of local waterways, (iii) assess the impact of land use on waterway condition, (iv) monitor how waterway conditions change through time, and (v) inform natural resource management decisions to improve waterway condition. This data is available to the community and interested authorities upon request and is presented within Annual Reports and on Council's website *www.hornsby.nsw.gov.au/water*.

Within the Hornsby Shire there are four major water catchments: Berowra Creek, Cowan Creek, the Hawkesbury River and Lane Cove River. The catchments are further categorised into industrial activity, urban areas and rural areas. Wastewater treatment plants and landfill remediation sites are monitored to assess the effectiveness of treatment processes on sewage and leachate discharge respectively.

During the 2015-16 reporting period water quality was routinely monitored at 48 sites across the Shire in both freshwater and estuarine locations. Water was sampled at all sites for turbidity, temperature, dissolved oxygen, electrical conductivity, pH, suspended solids, nutrients (nitrogen and phosphorus), faecal coliforms. In addition at the estuarine sites, the biotic indicators of chlorophyll *a* and phytoplankton were sampled. Data collected from each site was then used to assign health grades to each site, where each parameter was assessed relative to regional environmental health values (REHVs) and ANZECC trigger values, which when exceeded indicate environmental disturbance.

There were a total of 82 sampling days which included six 'wet weather' sampling days in this reporting period. Further, there were 41 instances of overflow or partially treated sewage releases throughout the reporting period.

Analysis of data collected in the 2015-16 monitoring period found:

- Land use in the catchment to be a major factor influencing the water quality of local creeks, and the Hawkesbury River.
- Health grades for reference sites were consistent, with many being assigned grades of *A*.
  - Overall physical-chemical health grades and microbial health grades are all *A* and *A+*, with the exception of one *B*.
  - The receiving waters of primarily undisturbed catchments, that is, reference sites, in Hornsby Shire are generally characterised by low pH, EC, faecal coliforms, SS and nutrients, and high DO values.
  - Overall health grades of reference sites have remained relatively stable through the last three reporting periods
- Industrial and urban activity had the greatest negative impact on water quality.
  - Physical-chemical health grades of industrial sites have remained relatively stable through the last three reporting periods.
  - The overall trend in results from urban sites indicates a decline in water quality with time. Additionally, microbial health at all sites except Joe Crafts Creek have degraded through time.
- Health grades for rural sites were variable, ranging from grades of *F* to *A*.
  - The overall physical-chemical and microbial health grades for rural creeks and streams are highly variable, shifting between good and poor grades through time.
- Health grades for Wastewater Treatment Plant (WTP) sites were relatively variable, ranging from grades of *F* to *A*,
  - Microbial health grades improved downstream of both West Hornsby WTP and Hornsby Heights WTP compared to upstream sites.
  - WTP effluent may be contributing to increase concentrations of nitrogen downstream of discharge points.
- The overall water quality data from sites located within the estuary indicated a healthy system.

- Health grades for estuarine sites were variable, ranging from good overall health grades near the mouth of the estuary, to poor health with distance upstream.
- In February 2016 at Gunya Point (site 150) *Pseudo-nitzschia delicatissima* was present in concentrations that exceeded trigger values, prompting tissue sampling and testing for shellfish in the region. Around 25% of the phytoplankton species present were potentially harmful to humans.

- Comparisons of data from this reporting period to the two previous reporting periods (2013-14 and 2014-15) indicated:
  - a decline in water quality in industrial and urban sites, particularly in terms of microbial health, and
  - Stable water quality at rural and estuarine sites.
- Landfill remediation treatment processes are successful in improving water quality of leachate.

1.0 Background: Introduction

1.1 What is water quality?

Organisms depend upon access to clean water for survival. *Water quality* is a term used to describe the chemical, physical and biological characteristics of water. Many environmental factors can influence these parameters including geomorphology of the catchment, riparian and vegetative cover, and local climate (Frissell, Liss et al. 1986; Snelder and Biggs 2002), thus it is important to consider local variables when determining the health of a specific river, estuary or catchment.

1.2 Why monitor it?

Stressors resulting from human activities are known to negatively affect the health of surrounding aquatic ecosystems (Allan 2004). The continuity and flow of creeks, rivers and estuaries mean that the negative impacts from human activities, such as discharge of polluted storm water into waterways or release of effluent from wastewater treatment plants, may persist downstream from the discharge point. It is important to monitor the water quality of waterways to gain an understanding of how human pressures may have impacted systems relative to un-impacted systems within the catchment. It is also important to understand the overall health of the waterways to ensure any preventable damage to waterways are managed, and the local rivers are healthy to support endemic wildlife.

1.3 How do we use the information gained from the monitoring program?

Every ecosystem functions within a niche defined by the limits of the natural variability of water quality parameters. These include *physical chemical* parameters such as turbidity, temperature, and nutrients (nitrogen and phosphorus), and *biological indicators* such as phytoplankton and macroinvertebrates. Physical-chemical parameters and phytoplankton are indicative of the short-term health of the system, whereas macroinvertebrates are used as indicators of long-term ecosystem health. These parameters can be interpreted to give insight into water quality in the following ways:

- ***Turbidity***
  - Turbidity can affect the light penetration through water, with high values of turbidity smothering aquatic plants and physically obstructing access to sunlight (Kirk 1985; Henley, Patterson et al. 2000).
  - High turbidity can harm organisms such as fish by damaging their gills (Sutherland and Meyer 2007).
- ***Temperature***
  - Cold blooded organisms including invertebrates (e.g. macroinvertebrates, or water bugs) and fish depend on the ambient water temperature to control and maintain their body temperature.
  - Natural thermal regimes of rivers and creeks are important for successful growth, development and reproduction of these organisms (Lehmkuhl 1972; Clarkson and Childs 2000; Todd, Ryan et al. 2005).
- ***Nutrients***
  - Nutrients are key drivers of ecosystem functioning and health.
  - Nitrogen and phosphorus are essential for the process of photosynthesis carried out by plants (Nicholls and Dillon 1978).
  - Plant growth can be restricted by a lack of nutrient availability or become problematic through overgrowth as a result of excess nutrients in the system.

- ***Phytoplankton***

- Phytoplankton are small, microscopic, free floating aquatic plants.
- The rapid reproduction of phytoplankton, often referred to as a *bloom*, can occur when excess concentrations of essential nutrients (e.g. nitrate, phosphate, and silicate) are available as a result of natural processes (e.g. oceanic upwelling or rainfall run off) or human activities (e.g. fertiliser use or effluent discharge (Reynolds and Walsby 1975; ANZECC & ARMCANZ 2000).
- Some phytoplankton species can produce and release harmful toxins into the water, compelling the need to identify the community structure (i.e. species present) within the bloom to guide management and use of the affected waterways (Suthers and Rissik 2009).
- Blooms can cause harmless water discolouration and be non-toxin-producing, but can be harmful to marine organisms by damaging the gills of fish, and smothering aquatic plants.
- Further, they may produce toxins that can lead to fish kills, the death of wildlife, and have adverse health effects in humans (Suthers and Rissik 2009).
    - Some species of phytoplankton produce toxins which can bio-accumulate in the tissue of filter feeders such as mussels. This can then lead to the toxins reaching concentrations in the organism's tissue that may be harmful to humans if consumed (NSW Food Authority 2015).

- ***Macroinvertebrates***

- Deterioration of water quality can negatively affect the survival of sensitive species of macroinvertebrates, altering the community structure (number of species present).
- The water quality of a water body influence the presence or absence of certain macroinvertebrates, meaning they can be used as indicators of ecosystem health (Growns, Chessman et al. 1995; Chessman 2003).

1.4 Factors affecting water quality

- ***Land use***

Investigating human influences on water quality can be simplified by categorising the catchment into land uses. Rural areas are often not connected to piped sewerage networks and rely on septic tanks to process waste. In some well-established communities, the tanks are old and often leak, filtering through the ground into nearby creeks. This can influence the nutrient and bacterial concentrations present within affected water bodies. Further, in rural areas practicing agriculture heavy use of fertilisers can result in increased nutrient concentrations in nearby waterbodies as a result of groundwater seepage or surface run off (Berka, Schreier et al. 2001).

Catchment development including urban and industrial areas often leads to an increased percentage of surface area covered by impervious materials, such as roofs, roads and pavements. Additionally, there is often development of complex stormwater systems designed to capture run off from these impervious surfaces and redirect to local creeks and rivers (Arnold and Gibbons 1996). As a result, the flow volume in these creeks are often more variable and extreme than what they would be naturally, with increased flow rates during large storm events, an increase in variability of base flow rate, and less slow rain water infiltration through soft ground (Arnold and Gibbons 1996).

- ***Rainfall***

Rainfall run off can increase the turbidity and suspended solids in receiving waters. Turbulent flows caused by heavy rainfall can erode and suspend top soil and river bank sediment into the water body. It can also increase the likelihood of overflows from sewage systems into local waterways in developed areas.

In urban catchments high rainfall events generate the most significant contaminant loads. Around 70-90% of contaminants are exported by storm events of 1 year average recurrence interval and smaller (Wong 2006). The impact of rainfall on water quality at a site is related to the quantity of and temporal proximity from the rainfall event.

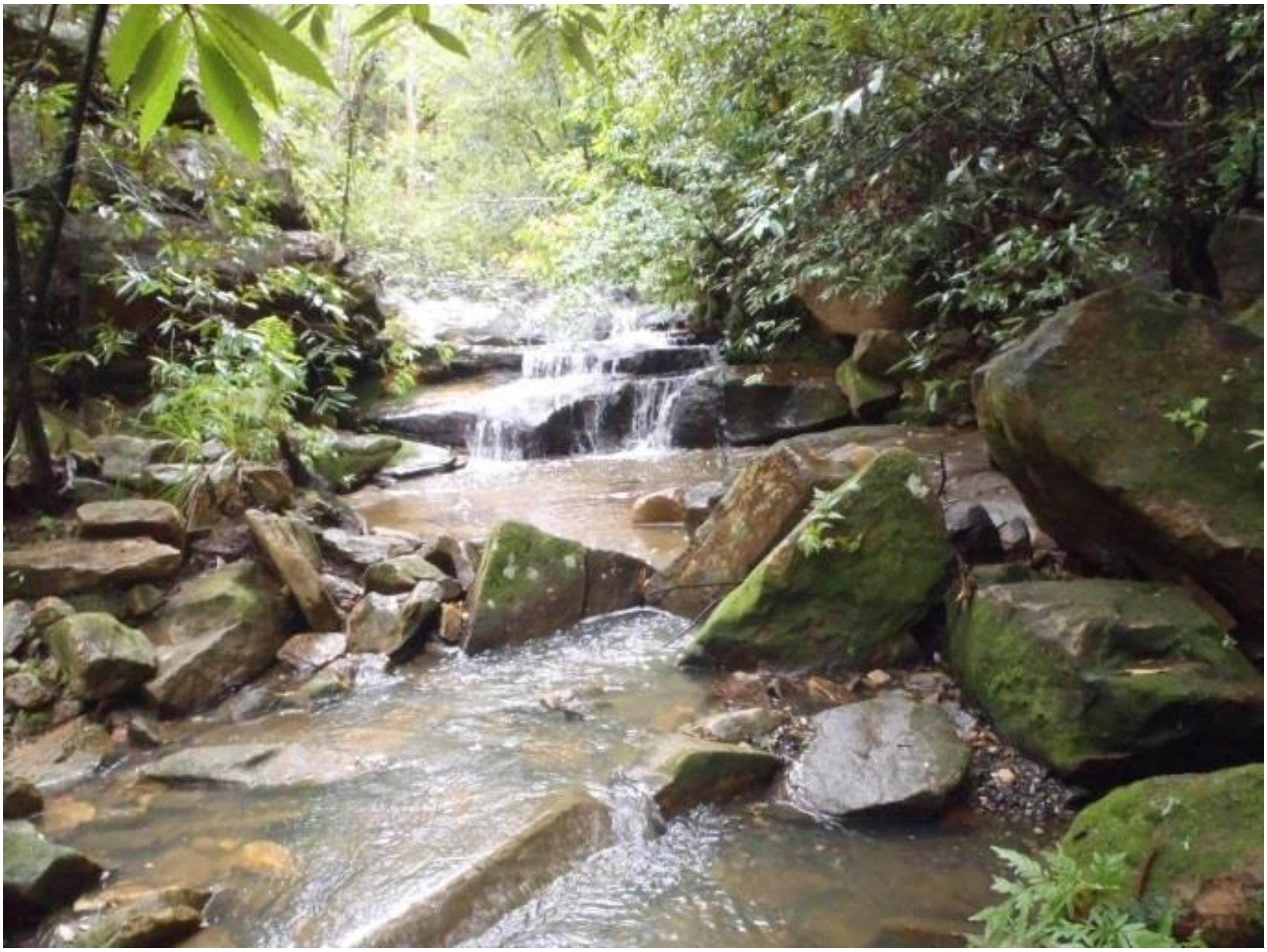

Figure 1.1: *Laughtondale Creek after rain (Site 54).*

2.0 Background: Hornsby Shire and Catchments

2.1 Hornsby Shire Region

The Hornsby Shire is approximately 25 kilometres north-west of Sydney covering an area of 510 square kilometres. Nearly two-thirds of Hornsby Shire is National Park and bushland. The Shire includes land from Eastwood in the south to Wisemans Ferry in the north and Brooklyn to the east (HSC 2013).

The traditional owners of the Shire are the Aboriginal people of the Darug and Guringai language groups. European settlement in the Shire dates from 1794 when the first land grants were made along the Hawkesbury River, with land primarily used for farming (HSC 2013).

Hornsby Shire's main urban and rural developments are located on the plateau areas in the southern half of the Shire. Approximately 10% of the Shire is zoned and used for urban development, 15% for rural purposes, 5% for open space and 70% is Environmental Protection or National Park (Figure 2.1).

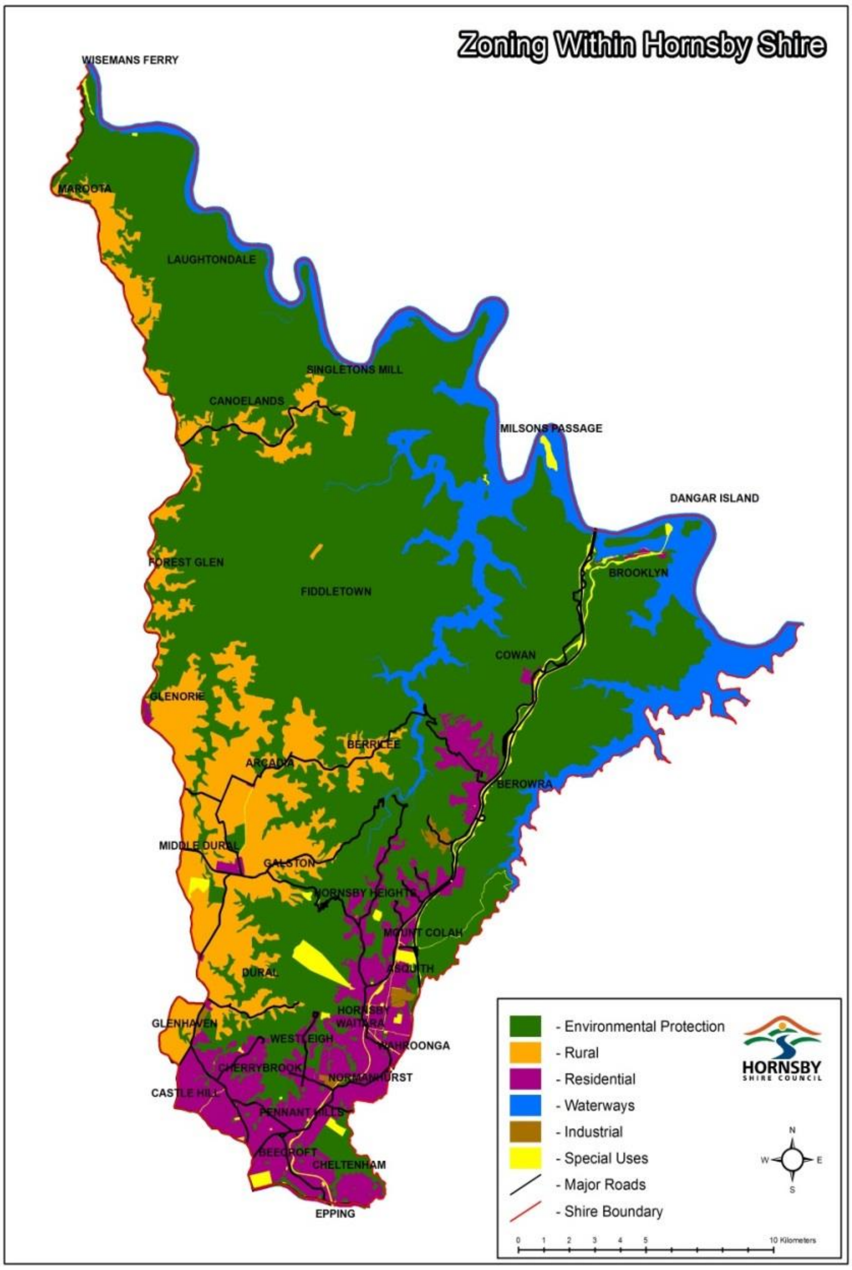

Figure 2.1: *Map of Hornsby Shire Council zoning*

2.2 Major Water Catchments

The major water catchments within Hornsby Shire include Berowra Creek, Cowan Creek, the Hawkesbury River and Lane Cove River (Figure 2.2). The lower Hawkesbury River (estuary) connects with the ocean at Broken Bay and is the receiving water for Berowra Creek and Cowan Creek catchments. Water from the Lane Cove River catchment is received in Sydney Harbour.

2.2.1 Berowra Creek

The Berowra Creek catchment is bounded on the south by Castle Hill Road, to the west by Old Northern Road, to the north by Canoelands Ridge and to the east by the Pacific Highway. The entire Berowra Creek Catchment is within the Hornsby Shire Local Government Area.

The catchment contains significant bushland areas, including Marramarra National Park, Muogamarra Nature Reserve and Berowra Valley National Park. Land uses in this catchment include bushland, rural, developed and developing urban, light industrial and commercial. The main negative impacts on water quality in Berowra Creek arise from the discharge of tertiary treated sewage from the West Hornsby and Hornsby Heights Wastewater Treatment Plants (WTPs) into Waitara and Calna Creeks, and from stormwater run off from the developed urban and commercial areas located in the south-eastern parts of the Shire.

Run off from the rural and rural-residential areas in the southern end of the Shire enters Berowra Creek, Tunks, Still and Calabash Creeks. Along the south-western edge, run off from similar areas flow to Colah and Fiddletown Creeks then to Marramarra Creek which runs to lower Berowra Creek, close to the confluence with the Hawkesbury River.

2.2.2 Cowan Creek

Within the Cowan Creek catchment there are four Local Government Areas. The western boundary of Cowan Creek catchment, defined by the Pacific Highway, lies within Hornsby Shire. Cockle Creek and Cowan Creek form part of the Shire boundary. Land uses in the southern part of this area include extensive light industrial areas, large commercial shopping centres and developed urban areas. Ku-ring-gai Chase National Park also covers a large part of the catchment.

2.2.3 Lane Cove River

Seven Local Government authorities have jurisdiction over the Lane Cove River catchment. Only the upper reaches of the Lane Cove River catchment are within Hornsby Shire; Devlins Creek, upper Lane Cover River and Terrys Creek. This catchment is dominated by developed urban land uses and some commercial areas as well as bushland areas including the upper parts of Lane Cove National Park. This is Hornsby Shire's only catchment area that flows to Sydney Harbour.

2.2.4 Hawkesbury River

The Hawkesbury River catchment within Hornsby Shire is divided into two areas which include the Wiseman's Ferry and Maroota region as well as the Brooklyn region. Run off from these regions flows directly to the Hawkesbury River. Land uses in these areas include small farming ventures, market gardening, residential development, marinas, boat ramps, aquaculture and fishing industries (commercial and recreational). A WTP that services Brooklyn, Dangar Island, Mooney Mooney and Cheero Point discharges tertiary treated effluent beneath Peats Ferry Bridge on the Old Pacific Highway, into an area of strong tidal current.

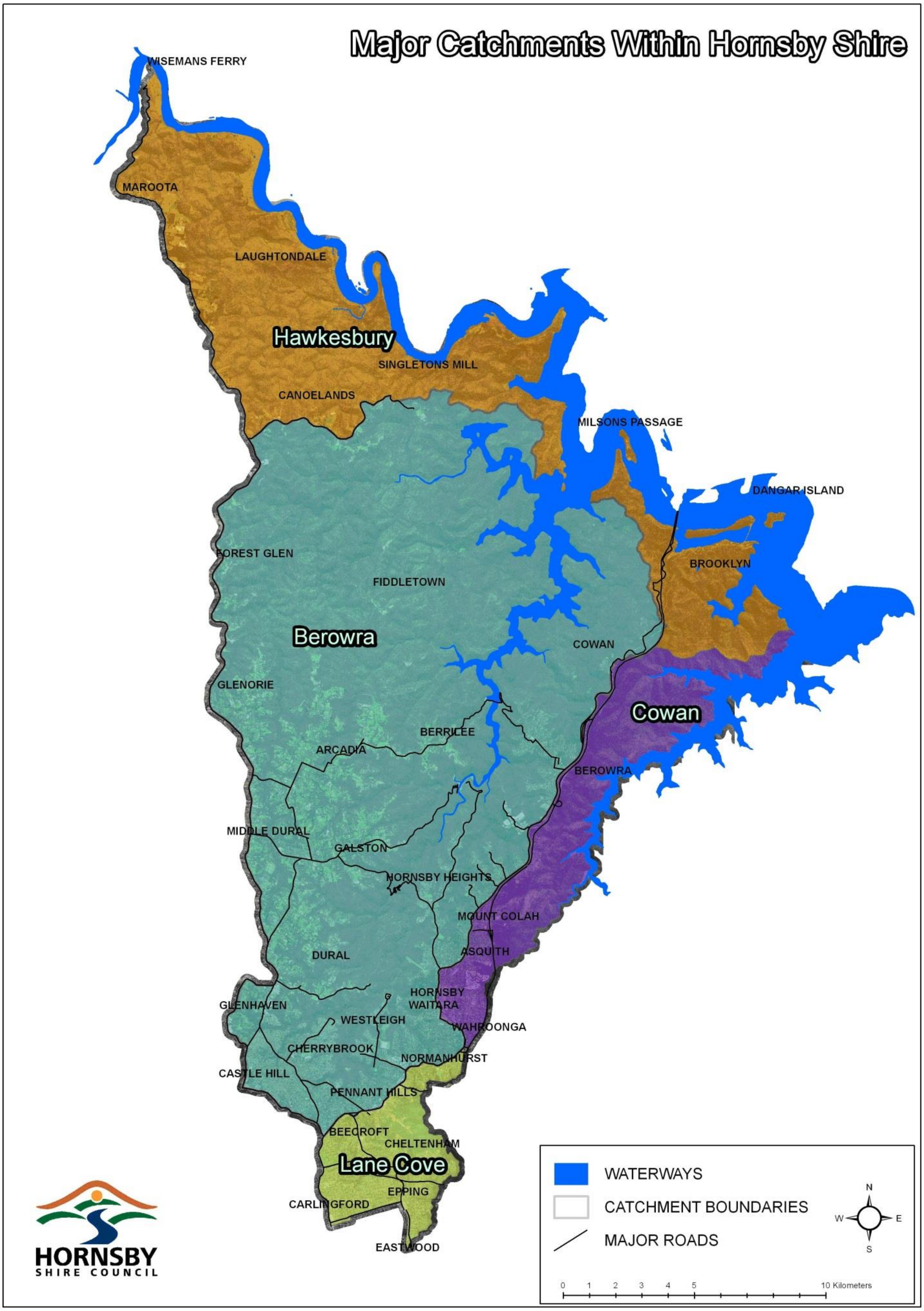

***Figure 2.2**: Major catchments in Hornsby Shire*

3.0 Background: Water Quality Monitoring Program

3.1 Water Quality Management

3.1.1 National Level

The National Water Quality Management Strategy (NWQMS) outlines a national approach to improving water quality in Australian and New Zealand waterways. It was originally endorsed by two Ministerial Councils; the former Agriculture and Resources Management Council of Australia and New Zealand (ARMCANZ) and the former Australian and New Zealand Environment and Conservation Council (ANZECC). Since 1992 the NWQMS has been developed by the Australian and New Zealand Governments in cooperation with state and territory governments. Ongoing development is currently overseen by the Standing Council on Environment and Water (SCEW) and the National Health and Medical Research Council (NHMRC). The NWQMS aims to protect the nation's water resources by improving water quality while supporting businesses, industry, environment and communities that depend on water for their continued development (ANZECC & ARMCANZ 1994).

Australia has a national framework for assessing water quality which is explained in the ANZECC Guidelines (ANZECC & ARMCANZ 2000). These guidelines outline framework to assess water quality in terms of whether the water is suitable for a range of environmental and community values. The Water Quality Objectives identify environmental values for NSW waters and the ANZECC Guidelines provide the technical guidance to assess the water quality needed to protect those values (DECCW 2010).

3.1.2 Regional Level

NSW has a set of Water Quality Objectives that are the environmental values and long-term goals for NSW surface waters (DAWR 2016). They describe:

- Community values and uses for our rivers, creeks, estuaries and lakes (i.e. healthy aquatic life, water suitable for recreational activities like swimming and boating, and drinking water).
- A range of water quality indicators to assess whether the current condition of our waterways supports those values and uses.

NSW water quality objectives have been established for fresh, estuarine and marine waters. These objectives are consistent with the national framework for assessing water quality set out in the ANZECC Guidelines (ANZECC & ARMCANZ 2000; DAWR 2016).

3.1.3 Local Level

The local environment within the Hornsby Shire has substantial and continual pressure to accommodate a rapidly growing population. Over a period of 10 years from 2013, it is forecast over 4270 new private dwellings will be built, and over 2380 new jobs created (HSC 2013). The importance of understanding the condition of our local environment is critical as a healthy environment supports our health and wellbeing and thus our quality of life (HSC 2012). Water quality is one of the prime indicators of the condition of our local environment. The collection and interpretation of water quality through time is essential to understand both the impact of climate variability and development on the Shire’s natural environment (HSC 2012).

Hornsby Council has a number of programs to protect and enhance the local waterways. These include:

- Catchment Remediation Rate Program.
- Hawkesbury Estuary Program.
- Sustainable Total Water Cycle Management.
- Water Quality Monitoring Program.

This report will detail the results of Council's Water Quality Monitoring Program for the 2015-2016 period.

3.2 History of the Program

Hornsby Shire Councils water quality monitoring program began soon after the Statement of Joint Intent (SoJI) was signed in 1994. This was an agreement between the NSW Department of Planning, Environmental Protection Authority, Hawkesbury-Nepean Catchment Management Trust, Hornsby Shire Council and the Water Board. The agreement was established in response to environmental issues which included the regular occurrence of algal blooms in the estuarine section of Berowra Creek, increasing pressures of urban development and sewage discharge, tighter pollution regulations coming into force, the publication of Australian environmental water quality guidelines (ANZECC & ARMCANZ 2000), and the recognition of the detrimental impacts of catchment activities on water quality.

A review of the water quality monitoring program was undertaken in 2015-16, resulting in some recommended changes to the program.

3.3 Program Objectives

Objectives of the Water Quality Monitoring Program include:

- *Trends through time*: undertake long term monitoring of water catchments within Hornsby Shire to assess trends in water quality from both point and diffuse pollution sources.
- *Environmental condition assessment:* compare the observed water quality data at all sites with undisturbed catchments through the employment of Regional Environmental Health Values (REHVs).
- *Improve catchment knowledge:* use water quality data to calibrate and support catchment/pollutant modelling and assist with environmental education programs.

4.0 Methods: Site Description

Representative sampling sites have been selected across the Shire to meet the objectives of the water quality monitoring program. A site is a geographic location where a hand held probe can be used to measure the physical conditions of a water body and a sample of water can be collected for analysis of the water body's chemical, microbial and biological characteristics.

During 2015-16 water quality was routinely monitored at 48 sites (Figure 4.2) across the Shire to assess:

- The effect of land use types (urban, industrial, rural, bushland) on the long term ecosystem health in estuarine and freshwater sites.
- Human activities directly influencing water quality (e.g. release of effluent from WTPs into local creeks).
- Effectiveness of disused landfill leachate collection and treatment.

4.1 Aquatic Ecosystem Health

Freshwater sites monitored for long term aquatic ecosystem health were selected with consideration given to the reliability of stream flow throughout the year, site accessibility and the ability to monitor stormwater flows. These sites are representative of different catchment land uses within the Shire; natural reference condition, urban, rural and industrial (Table 4.1, Appendix A)

4.1.1 Reference Sites

Reference sites represent the highest water quality against which water quality in disturbed waterways can be compared. Data from reference sites show natural variation of water parameters in creeks with minimal human impact, thus providing reference data. These creeks with primarily undisturbed catchments reflect the water quality that may have existed before the land in Hornsby Shire was developed.

Ideally reference sites should have similar geography, geology, soils and vegetation to the creeks to which they are being compared. However, development within the Shire historically began in areas with good quality soils suitable for farming and on ridge tops with shale derived soils. Subsequent urban development concentrated around the ridge top areas. As a result there is now a paucity of un-impacted creeks draining such types of soils and geology.

Council monitors eight reference sites (36, 37, 54, 114, 123, 147, 149 and 164) that are within National Parks and Nature Reserves. Two of these sites (36 and 37) were used in the development of Council's Regional Environmental Health Values (REHVs) (Section 6)

4.1.2 Industrial, Rural and Urban Sites

The major industrial areas in Hornsby Shire are located around Sefton Rd Thornleigh, Leighton Place Hornsby and Beaumont Road Mount Kuring-Gai. These industrial areas are respectively within the catchments of Larool Creek (10), Hornsby Creek (12) and Sams Creek (13) (Table 4.1).

Rural areas are classified as those areas with a majority of their catchment being zoned rural or with townships which primarily rely on onsite sewage management systems to dispose of their effluent. Current rural sites are generally located in the north and western parts of the Shire (2, 42, 49, 62, 63, 64 and 80, Table 4.1). The townships of Galston, Glenorie and Cowan have recently had sewer infrastructure installed by Sydney Water and it is expected that the impacts from onsite systems in these areas will lessen into the future as more properties become connected. To date, 235 new properties in Glenorie and 395 new properties in Galston Village have been connected (Sydney Water Corporation 2016).

Urban catchments consist of residential and light commercial areas throughout the Shire. They are characterised by reticulated water and sewerage systems, a large percentage of impervious surfaces (e.g. roads, driveways and roofs) and complex stormwater collection infrastructure which often discharges directly into local streams. Current urban sites include 4, 5, 6, 8, 39 and 181 (Table 4.1).

4.1.3 Estuarine Sites

Monitoring of water quality at estuarine sites in the Hawkesbury River is undertaken to assess the environmental health of the estuary (Table 4.1). It is the receiving water body for the majority of the Shire as well as upstream catchments outside of the Hornsby Shire Local Government Area. Estuarine sites are located across the salinity gradient of the estuary from high salinity sea water (25-35 ppt) near the mouth of the Hawkesbury River to brackish (10-25 ppt) and mostly fresh water (<10 ppt) with distance upstream of the estuary and in tributaries. In addition to catchment inputs flowing down the river, water quality in estuarine sites relies significantly on the amount of tidal flushing a site receives from the ocean, predominantly related to proximity to the mouth of the estuary.

Brooklyn Baths (site 55), Crosslands Reserve (site 100) and Bradleys Beach, Dangar Island (site 108) are popular swimming locations. In addition to environmental health, water quality data from these sites provides information regarding public health and the suitability of the sites for recreational activities. Long term monitoring data has been used to develop an online application providing daily updates on the suitability of swimming at different locations in the Hawkesbury estuary, which can be viewed at www.hornsby.nsw.gov.au/waterquality.

Council also manages a number of water quality monitoring buoys (Figure 4.1) remotely deployed to monitor temperature, chlorophyll *a*, salinity and turbidity levels within the estuary. Chlorophyll *a* is used as an indicator for algal growth where persistently elevated values (~30 µg/L) may be indicative of a problematic micro-algal bloom, requiring a response from Council. Further details of this monitoring program are available at *www.hornsby.nsw.gov.au/waterquality*.

Figure 4.1: *Remote water quality monitoring buoy at Gunya Point on the Hawkesbury River. The buoy houses a probe that measures several water quality parameters.*

4.1.4 Wastewater Treatment Plant Sites

Reticulated sewerage systems comprise of pipes, pumping stations, overflow points and treatment plants designed to transport, treat and dispose of sewage. Property owners are responsible for the maintenance of sewerage systems on private land, from private property to the connection point with the sewer main, while Sydney Water Corporation (SWC) maintains the remaining infrastructure and treatment plants.

Within Hornsby Shire there are three wastewater treatment plants operated by SWC; Hornsby Heights, West Hornsby and Brooklyn. The two larger plants, Hornsby Heights and West Hornsby provide tertiary treatment to sewage collected in the more densely settled urban suburbs and industrial areas located in the southern half of the Shire. Treated effluent from these plants is discharged to Calna Creek and Waitara Creek respectively, both of which are tributaries to Berowra Creek. The smaller plant operating at Brooklyn discharges treated effluent directly into the Hawkesbury River under Old Peats Ferry Road bridge.

The treatment plants operate under an Environmental Protection Licence issued by the NSW Environment Protection Authority. SWC is required to operate and maintain the sewer pipe collection system and the treatment plants to certain standards. The Licences specify monitoring requirements and pollution reduction programs. Monitoring data, plant operation and licencing information is publically available on the SWC website, *www.sydneywater.com.au*.

Despite having these licence conditions and controls in place it is not uncommon for untreated or partially treated sewage to enter local creeks in sewered areas. There are a number of ways this can happen:

- During wet weather, stormwater may infiltrate sewer pipes from illegal connections or fractured pipes, greatly increasing flows in the sewer pipe network. This can cause an overload of the system's capacity resulting in the treatment plant releasing only partially treated sewage, or releasing overflows from designated discharge points adjacent to sewer mains or pumping stations throughout the network. For example, within the catchment of West Hornsby WTP, there are approximately 30 overflow points designed to relieve pressure through sewerage releases into creeks.
- Overflows of sewage can occur at relief points as a result of blockage in a pipe (e.g. by tree roots). Blockages reduce the pipes flow capacity, leading to a build-up of sewerage in the network. The pressure is relieved at designated overflow points.

Due to the significant impact of sewage management processes on creeks, Council monitors a number of water quality sites to assess the combined impacts of urban stormwater run off and treated and untreated effluent on aquatic ecosystem health. Current wastewater treatment plant sites are 1, 23, 43, 45 and 52 (Table 4.1).

Hornsby Heights WTP discharges approximately 6.7 mega litres of tertiary treated effluent per day to Calna Creek in Walls Gully(Sydney Water Corporation 2016). Calna Creek enters Berowra Creek in the tidal reach about 1 kilometre downstream of Crosslands Reserve. The treatment plant discharge point into Calna Creek is about four kilometres upstream of its confluence with Berowra Creek.

West Hornsby WTP discharges approximately 11.9 mega litres per day of tertiary treated effluent to Waitara Creek (Sydney Water Corporation 2016). The discharge point is about 700 metres upstream of the confluence of Waitara Creek with Berowra Creek, and approximately 12 kilometres upstream of the tidal reach of the Berowra Creek estuary at Crosslands Reserve.

Brooklyn WTP discharges approximately 0.4 mega litres per day of tertiary treated effluent to the Hawkesbury River beneath the Peats Ferry Road bridge (Sydney Water Corporation 2016). This WTP was commissioned in 2007 to service Brooklyn, Mooney Mooney, Dangar Island and Cheero Point residences. It is a closed system which does not incorporate the use of overflow points or partial treatment bypasses to deal with an increase in loads, thus minimising the impacts on local creeks

4.1.5 Landfill Remediation

Council manages three (3) disused landfill sites at Arcadia, Mount Colah (Foxglove Oval) and Wisemans Ferry. These sites are all decommissioned and have been remediated. Leachate from Arcadia landfill is captured and treated (Sites 18, 94). Leachate from Wisemans Ferry is captured) and retained (Site 112. Leachate from Foxglove Oval, Mount Colah is captured, treated and reused for irrigating the sport field (Sites 77, 95, 96, 132).

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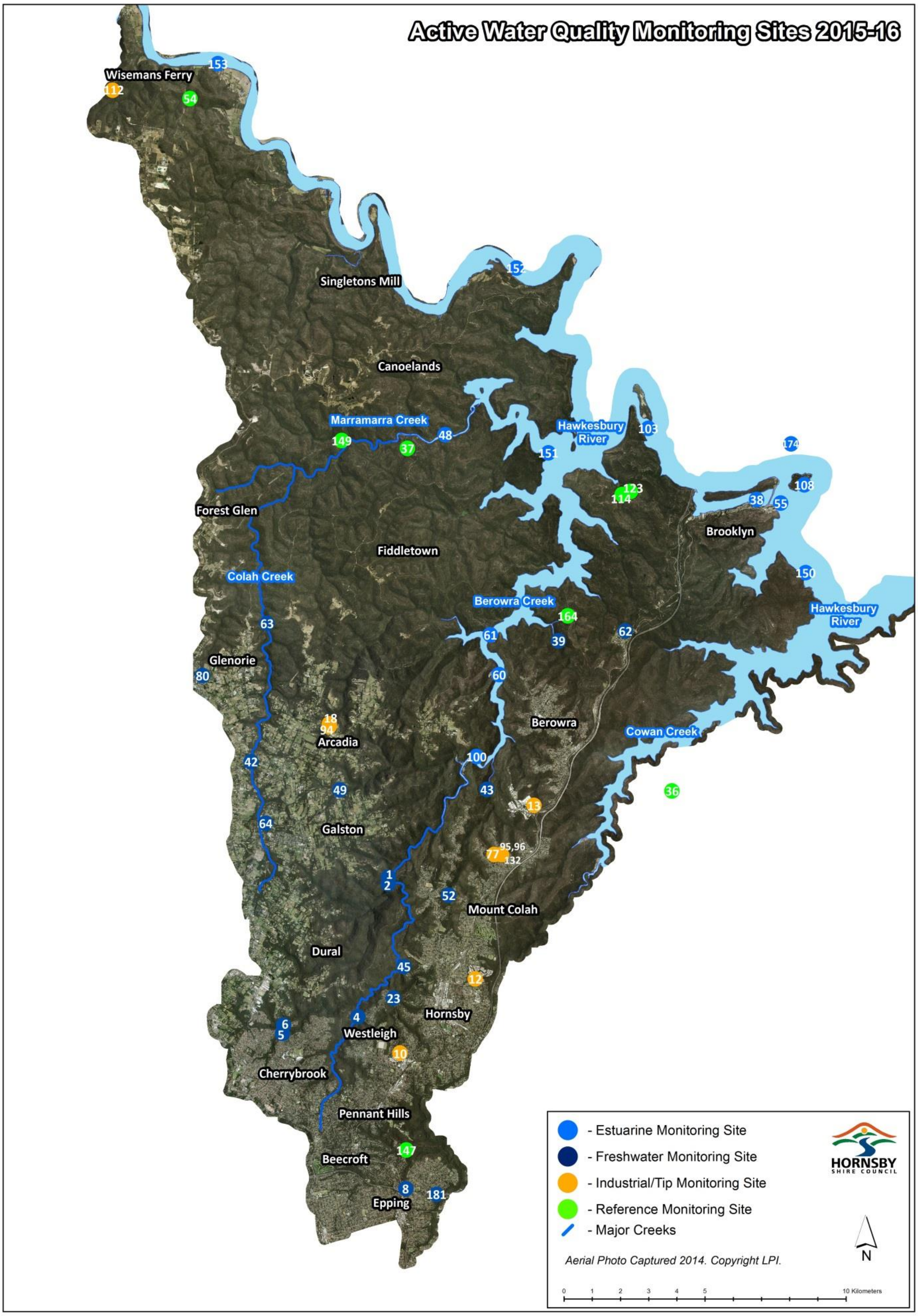

Figure 4.2: *Water quality monitoring sites for 2015-2016*

***Table 4.1:** Freshwater and estuarine sites monitored for aquatic ecosystem health during 2015-16*

Site	Land use	Creek	Location
174	Estuarine	Mullet Creek	Mouth of Mullet Creek
38	Estuarine	Sandbrook Inlet	Brooklyn, Hawkesbury River
48	Estuarine	Marramarra Creek	Marramarra National Park
55	Estuarine	Hawkesbury River	Brooklyn Baths
60	Estuarine	Berowra Creek	Berowra Ferry Crossing
61	Estuarine	Berowra Creek	Calabash Point
100	Estuarine	Berowra Creek	Crosslands Reserve Hornsby Heights
103	Estuarine	Hawkesbury River	Milsons Passage
108	Estuarine	Hawkesbury River	Bradleys Beach, Dangar Island
150	Estuarine	Hawkesbury River	Gunyah Point
151	Estuarine	Hawkesbury River	Mouth Marramarra Ck
152	Estuarine	Hawkesbury River	Courangra point
153	Estuarine	Hawkesbury River	Laughtondale
10	Industrial	Larool Creek	Larool Cres Thornleigh
12	Industrial	Hornsby Creek	Leighton Place Hornsby
13	Industrial	Sams Creek	Hamley Rd Mt Kuring-Gai
36	Reference	Murray Anderson Creek	Ku-ring-gai Chase National Park
37	Reference	Smugglers Creek	Marramarra National Park
54	Reference	Laughtondale Creek	Laughtondale Gully Rd Marramarra National Park
114	Reference	Muogamarra Creek	Muogamarra Nature Reserve
123	Reference	Peats Crater Creek	Muogamarra Nature Reserve
147	Reference	Unnamed Creek, tributary Byles Creek	Day Rd Cheltenham
149	Reference	Unnamed Creek, Marramarra National Park	Duckpond Ridge Firetrail Marramarra National Park
164	Reference	Djarra Crossing	Muogamarra Nature Reserve
2	Rural	Tunks Creek	Galston Gorge
42	Rural	Colah Creek	Wylds Rd Glenorie
49	Rural	Still Creek	Mansfield Rd Arcadia
62	Rural	Kimmeriking Creek	Alberta Ave Cowan
63	Rural	Colah Creek	Ben Bullen Firetrail Glenorie
64	Rural	Unnamed, tributary of Colah Creek	Sallaway Rd Galston
80	Rural	Glenorie Creek	Tekapo Ave Glenorie
4	Urban	Berowra Creek	Benowie Walking Trail Westleigh
5	Urban	Pyes Creek	Kristine Pl Cherrybrook
6	Urban	Georges Creek	Fallon Rd Cherrybrook
8	Urban	Devlins Creek	Sutherland Rd Cheltenham
39	Urban	Joe Crafts Creek	Tributary of Berowra Creek
181	Urban	Unnamed, tributary of Terrys Creek	Somerset St North Epping
23	Wastewater Treatment Plant	Waitara Creek	Upstream West Hornsby WTP
1	Wastewater Treatment Plant	Berowra Creek	Downstream West Hornsby WTP
52	Wastewater Treatment Plant	Calna Creek	Upstream Hornsby Heights WTP
43	Wastewater Treatment Plant	Calna Creek	Downstream Hornsby Heights WTP
45	Wastewater Treatment Plant	Berowra Creek	Downstream West Hornsby WTP
18	Landfill Remediation	-	Arcadia
94	Landfill Remediation	-	Arcadia
112	Landfill Remediation	-	Wisemens Ferry
77	Landfill Remediation	Gleeson Creek	Foxglove Oval, Mt Colah – Receiving Stream
95	Landfill Remediation	-	Foxglove Oval, Mt Colah – Untreated Leachate
96	Landfill Remediation	-	Foxglove Oval, Mt Colah – Partially Treated Leachate
132	Landfill Remediation	-	Foxglove Oval, Mt Colah – Treated Leachate

5.0 Methods: Sampling and Testing

5.1 Routine Monitoring

The water quality monitoring program involves systematic sampling to a predetermined (usually monthly) schedule over the year. Sampling is carried out during daylight hours (8am to 3pm) on weekdays, through all seasons and in both wet and dry periods. Industrial sites, which have historically been the most impacted, are monitored fortnightly.

5.1.1 Field measurements

Physical-chemical water quality parameters are measured in-situ using a multi-sensor water quality probe (Yeokal™ 615 Sonde). These include:

- Dissolved Oxygen (DO% sat and DO mg/L)
- Electrical Conductivity (EC mS/cm and EC µS/cm)
- pH
- Salinity (ppt)
- Temperature (°C)
- Turbidity (NTU)

At each water testing site observations are recorded on weather conditions, rainfall, tide status, the occurrence of nuisance organisms, oily films, frothing and odours, stream flow, water clarity, water colour and any other notable site details. These observations and portable probe measurements are recorded in the field on a mobile electronic device and downloaded each afternoon into Council's database.

5.1.2 Laboratory Analysis

Freshwater and landfill remediation water samples are collected and sent for laboratory analysis of:

- Bacteria :
  - Faecal coliforms (CFU/100 mL)
- Nutrients:
  - Total nitrogen (TN, mg/L)
  - Oxidised nitrogen (NOx-N, mg/L)
  - Ammonia nitrogen (NH_3-N, mg/L)
  - Total phosphorus (TP, mg/L)
- Suspended solids (mg/L)

In addition, all freshwater sites are sampled quarterly and analysed for (data in Appendix E):

- Alkalinity (Bicarbonate mg CaCO3/L)
- Major cations and anions
- Trace metals

Estuarine water samples are collected and sent for laboratory analysis of:

- Chlorophyll *a* (µg/L)
- Bacteria :
  - Faecal coliforms (CFU/100 mL)
- Nutrients:
  - Total nitrogen (TN, mg/L)
  - Oxidised nitrogen (NOx-N, mg/L)
  - Ammonia nitrogen (NH_3-N, mg/L)
  - Total phosphorus (TP, mg/L)
  - Soluble Reactive Phosphorus (mg/L)
- Suspended Solids (mg/L)

At freshwater sites the sampling depth is 5 -10 cm below the water surface, and approximately 50 cm below the surface at estuarine sites. Immediately after collection all the water bottles are placed in an esky with ice bricks. During the 2015-16 sampling period, chemical and microbial analyses were carried out by Sydney Water Monitoring Services in accordance with the parameters, detection limits and testing methods described in Table 5.1

Table 5.1: *Laboratory parameters, reporting limits and test methods*

Analyte	Detection Limit	Method reference	Bottle	Preservative
General				
Suspended solids	<2 mg/L	APHA 2540-D	1 L HDPE	No preservative
Bicarbonate/ alkalinity	5 mg $CaCO_3$/L	APHA 2320-B	500 ml PET	No preservative
Nutrients				
Oxidised nitrogen	<0.01 mg/L	APHA 4500-NO3 I FIA	200 ml PET	No preservative
Ammonia nitrogen	<0.01 mg/L	APHA 4500-NH3 H FIA		
Total nitrogen	<0.05 mg/L	APHA 4500-P J FIA		
Total phosphorus	<0.002 mg/L	APHA 4500-P J / NO3 FIA		
Soluble reactive phosphorus	<0.002 mg/L	APHA 4500-P		
Micro-biological				
Faecal coliforms	<1 CFU/100 ml	AS 4276-7	250 ml PET	Thiosulphate
Chlorophyll *a*	<1 µg/L	APHA 10200-H	1.25 L PET	No preservative
Metals (freshwater only)				
Trace metals	Various	Various methods	250 ml PET	No preservative
Cations & Anions	Various	Various methods	200 ml PET	No preservative

5.1.3 Phytoplankton collection for identification

Phytoplankton (>5 µm) samples are obtained from surface waters at estuarine sites using a 1 m long plastic bailer tube (5.1a), and transferred to a 500 mL PET bottle containing Lugol's iodine solution for preservation. Additionally, a concentrated phytoplankton sample is collected using a 30 micron mesh net. The net is towed behind the boat for approximately 5 minutes at slow speed. The contents of the net are washed into a 200mL PET bottle containing Lugol's solution (Figure 5.1b). These samples are stored in a cool dark location then sealed in a plastic bag, wrapped in bubble wrap and sent by overnight express post to Microalgal Services laboratory in Victoria for algal identification and enumeration.

Figure 5.1: Sample collection using a bailer tube (a) and phytoplankton net (b)

5.2 Quality Assurance/ Quality Control

5.2.1 Multi-Probe Calibration

To ensure accurate in-situ measurements, the Yeokal™ probe sensors are calibrated the morning of each sampling run using commercially available standard solutions and check tests (Table 5.2). Calibration is checked again in the afternoon following each sampling run. Correction factors are applied to probe data if sensor calibration drifted by more than accepted daily variation (Table 5.2).

At each sample site the date, time, site details, visual observations and probe readings are recorded for future reference.

5.2.2 Sample Handling

The contract laboratory supplies new bottles for sampling prepared with preservatives where required. The date and unique sample identification number is printed on waterproof adhesive labels prior to sampling (Figure 5.3). After the water samples are taken the sample bottles are immediately placed in eskies with ice and freezer blocks. After returning from the field the bottles are repacked on ice, a 'Chain of Custody' form is completed and attached to the esky. The samples are then couriered to the laboratory by 5pm the same day.

5.2.3 Duplicate and Field Blank Samples

A duplicate field sample is taken at one site each month. This effectively provides two samples (*A* and *B*) of the same water which are labelled differently. The results from the laboratory analysis provide an indication of combined variability of water quality at a site and variability of the laboratory testing procedures.

Further, a field blank is prepared each month and sent to the laboratory for analysis. Field blanks are sample bottles filled with deionised (DI) water before the sampling run. They are labelled and handled as other field samples, for example stored in a chilled esky. The blank samples are then sent to the laboratory with the other water samples for analysis of all parameters. They provide a check for potential contamination from either the sample bottles or transportation and handling. Field blanks can also provide a check of a laboratories handling, analysis and detection limits.

5.2.3 Laboratory Procedures

The contract laboratory has a comprehensive quality control program which is a requirement to retain national accreditation (NATA certification). With each daily batch of samples for each test parameter the laboratory includes extra Quality Assurance/Quality Control (QA/QC) samples including replicate tests, lab blanks, spiked samples and lab check samples, which must all pass in-house QC standards before results are released. Final reports provided to Council include QA/QC test results.

Figure 5.3: *Sampling equipment used to measure water quality parameters. Sample are collected in bottles labelled with unique sample ID numbers.*

Table 5.2: *Calibration values and checks, and acceptable daily variation.*

Probe Tests	Low Value Calibration		High Value Calibration		Check solution	Daily Calibration check	Accepted Daily Variation (±)
	Frequency	**Calibration Range**	**Frequency**	**Calibration Range**		*Before and after site visits*	
Temperature	Quarterly	3 – 7 °C	Quarterly	40 to 45 °C		One point check against standardised thermometer in water bath	0.2 °C
EC	Daily	0 µS/cm *(DI water)*	Daily	1413 µS/cm *(commercial solution)*	Sydney Tap water (approximately 200µS/cm)	Low and high point calibration check	15 µS/cm
Salinity	Daily	0 ppt *(DI water)*	Daily	35 ppt *(commercial solution)*		Low and high point calibration check	0.01 / 0.5 ppt
DO	Monthly	0 % sat *(zero DO sensor insert)*	Daily	100 % sat *(air bubbled in tank of tap water)*		Low and high point calibration check	5 %
pH	Daily	pH 7 *(commercial solution)*	Daily	pH 10 *(commercial solution)*	Daily pH 4 and pH 7 dilute x10 (commercial solution)	Low and high point calibration check	0.1 pH units. *Correct pH for temperature variation*

6.0 Methods: Water Quality Guidelines

"A water quality guideline is a numerical concentration limit or narrative statement recommended to support and maintain a designated water use. Guidelines are used as a general tool for assessing water quality and are the key to determining water quality objectives that protect and support the designated environmental values of our water resources, and against which performance can be measured.

Guidelines are derived with the intention of providing some confidence that there will be no significant impact on the environmental values if they are achieved. Exceedance of the guidelines indicates that there is potential for an impact to occur, but does not provide any certainty that an impact will/has occurred."

ANZECC 2000

6.1 Aquatic Ecosystem Protection

6.1.1 Australian Water Quality Guidelines

The National Guidelines (ANZECC & ARMCANZ 2000) suggest that trigger values for selected water quality indicators should be developed based on long term local or regional monitoring data of reference sites. Reference sites represent the highest quality of water against which the water quality at sites in less pristine locations can be compared.

Faecal coliform trigger values provided in the national Guidelines for Managing Risk in Recreational Waters(NHMRC 2008) have been applied within the water quality program. Trigger values for suspended solids and turbidity are not specifically defined in the Guidelines (ANZECC & ARMCANZ 2000), therefore Council uses the NSW State Authority recommendations listed in the guidelines.

6.1.2 Regional Environmental Health Values

Freshwater

Measurements of physical, chemical and biological indicators at suitable reference sites provide benchmarks for assessing water quality of waterways in local regions. REHVs for freshwater sites were derived from water quality data collected at two local reference sites (036, 037) between 2002 and 2010 (HSC 2012). These are used for data analysis and reporting on aquatic ecosystem health.

Estuarine Water

Due to the nature of development in Hornsby Shire the water quality monitoring program does not include an estuarine reference site. All estuarine areas in or near Hornsby Shire (Hawkesbury River, Berowra and Cowan Creeks) are impacted by developed areas. Therefore, it was not possible to collect long term estuarine reference data. In the absence of reference estuarine data for REHV development, ANZECC (2000) and NHMRC (2008) trigger values have been used (Table 6.1).

***Table 6.1:** Trigger values for physical-chemical, microbial and biotic parameters for freshwater and estuarine waterways. Concentrations of parameters detected in breach of trigger values indicate the degradation of water quality.*

Parameter	Units	Freshwater Trigger Values (REHVs)	Estuarine Trigger Values (REHVs)
Turbidity	NTU	8	10
Suspended Solids	mg/L	7	6
Total Phosphorus	mg/L	0.01	0.03
Total Nitrogen	mg/L	0.32	0.3
Oxidised Nitrogen	mg/L	0.05	0.015
Ammonia Nitrogen	mg/L	0.02	0.015
pH (Lower)	unit	4.8	7
pH (Upper)	unit	7	8.5
Electrical Conductivity	mS/cm	0.32	
Dissolved Oxygen (Lower)	% sat	75	80
Dissolved Oxygen (Upper)	% sat	118	110
Chlorophyll *a*	µg/L		4
Faecal Coliforms (Median)	CFU/100 mL	150	150
Faecal Coliforms (80th Percentile)	CFU/100 mL	600	600

6.2 Estuarine Phytoplankton: Potentially Harmful Algal Blooms

The NSW Food Authority sets out recommended Phytoplankton Action Levels (PALs) based on the concentrations of specific algal species that affect shellfish aquaculture (Appendix B). Whenever monitoring indicates these species are present in concentrations greater than the trigger values, the Regional Algal Coordinating Committee (RACC) is notified. This may result in the closure of the estuary to fishing (by the Department of Primary Industries – Fishing and Aquaculture), or closure of shellfish harvesting (by the NSW Food Authority) and the placement of public warning notices by Council (Figure 6.1).

***Figure 6.1:** Sign warning the public of a potentially harmful algal bloom in a swimming area erected by Council*

7.0 Methods: Data Analysis

7.1 Rainfall

The sampling schedule for the program is inclusive of all seasons, and dry and wet periods as they occur throughout the sampling period. A *wet weather* sampling event is defined as one in which there has been over 10 mm of rainfall observed within the 24 hours prior to the sampling event.

Daily and cumulative rainfall for 2015 – 2016 reporting period was calculated by averaging the rainfall data from 12 gauging sites within the Shire, obtained from the Bureau of Meteorology (BoM) (Appendix C). The two variables were then plotted with lines on a scatter plot. Data on wet and dry weather partial treatment bypass events was provided by Sydney Water and plotted on the scatterplot as single points. All sampling events as well as sampling events in wet conditions, as defined above were also included in the plot as single points.

7.2 Physical-Chemical and Microbial Analysis

Boxplots were used as a tool to compare observed values of each parameter recorded at different sites throughout the Shire against values recorded at reference sites in the form of REHVs. Results were graded according to the frequency of REHV exceedance (7.3). Poor grades result from consistent REHV exceedance, and are indicative of an unhealthy and stressed system.

7.3 Waterway Health Grading

In 2012 Council developed a waterway health grading system to report on the health of creeks and estuaries in the Shire (HSC 2012). This involves determining an indicator health grade, site health grade and subsequent summary health grade for each water quality monitoring site.

To determine a summary Waterway Health Grade three categories of indicators are used;

- physical-chemical stressors
- microbial indicators
- aquatic biota indicators
  - freshwater sites: macroinvertebrate community structure
  - estuarine sites: chlorophyll *a*

For freshwater sites, this report presents indicator and site health grades using physical-chemical stressors and microbial indicators only as aquatic biota data was not collected during this reporting period.

For estuarine sites this report presents indicator and site health grades for all categories and an overall Waterway Health Grade for each site.

7.3.1 Indicator Health Grade

Physical-Chemical Indicators

Indicator health grades for physical-chemical parameters were determined by using box and whisker plots; median, 80th and 20th percentile and maximum and minimum data. Water quality data was compared to their respective REHVs for each parameter for fresh or estuarine water (Figure 7.1).

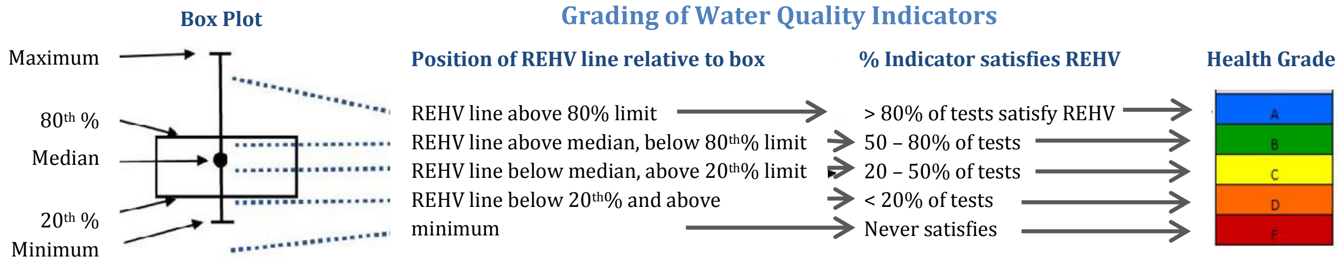

Figure 7.1: *Method for indicator health grading using boxplots. The REHV is plotted with the boxplot, allowing the assessment of each site against the trigger values*

Table 7.1: *Thresholds for faecal coliforms to calculate microbial health grades for each site*

Median (CFU/100mL)	80th Percentile (CFU/100mL)	Grading
≤ 150	≤ 150	A +
≤ 150	≤ 600	A
≤ 150	> 600 and ≤ 1000	B
> 150	≤ 600	B
≤ 150	> 1000	C
> 150 and ≤ 600	> 600 and ≤ 1000	C
> 150 and ≤ 600	> 1000	D
> 600	≤ 1000	D
> 600	> 1000	F

7.3.2 Freshwater & Estuarine: Site Health Grade

Site Health Grades are calculated by combining indicator grades as follows (Figure 7.2):

1. Each individual indicator grade is given an indicator score
2. Scores for all physical-chemical parameters are then averaged
3. The average score is compared to average score categories
4. Assign corresponding site health grades

The site health grades range from *A to F* (Table 7.3): *Grade A* is the top score, indicating clean water and a healthy ecosystem, *Grades B, C and D* indicate increasingly degraded water bodies, *Grade F* represents a fail and is indicative of a severely degraded system.

Physical-Chemical Site Grade

Site Grades for physical and chemical parameters were calculated by combining indicator grades for turbidity, dissolved oxygen, pH, suspended solids, ammonia, oxidised nitrogen, total nitrogen and total phosphorus for each site.

Microbial Site Grade

Microbial Site Grades were determined using box and whisker plots based on the median and 80th percentile. These data were compared against the REHVs to determine health grades according to categories in Table 7.1. There is only one microbial indicator for estuarine sites, as such the microbial Site Health Grade is calculated as per the physical-chemical indicator health grades (Figure 7.1).

Bioindicator Site Grades (Estuarine Only)

Health grades for aquatic biota in estuarine water is based on chlorophyll *a* results and determined using box and whisker plots, as per the physical-chemical indicator health grades (Figure 7.1). No aquatic bio-indicators were sampled for freshwater sites this reporting period.

7.3.3 Estuarine: Waterway Health Grades

Aquatic biota grades were calculated from Chlorophyll *a* concentration data. Site Health Grades for biota, physical-chemical parameters and microbial parameters were combined as in Table. 7.2 to calculate the overall Waterway Health Grade for each site.

Table 7.2: *Individual indicator grades for each site are scored and averaged to determine the overall physical-chemical site grade*

Step 1 Indicator Grade	Step 2 Indicator Score	Step 3 Average Indicator Score	Step 4 Site Grade
A	9	> 8	A
B	7	> 6 – 8	B
C	5	> 4 – 6	C
D	3	> 2 – 4	D
F	1	0 – 2	F

Table 7.3: *Grading system and interpretation used to categorise water quality physical-chemical stressors*

Health Grade	Percentage of occurrences whereby phys-chem indicators satisfy REHVs	Health Description	Cleanliness Description	Probable impact on native aquatic biota
A	Over 80%	Excellent	Clean	Healthy
B	50 – 80%	Good	Slightly degraded	Mild impairment
C	20 – 50%	Poor	Moderately degraded	Moderate impairment
D	Less than 20%	Very poor	Seriously degraded	Serious impairment
F	Never satisfies REHVs	Fail	Severely degraded	Severe impairment

7.4 Phytoplankton Community Structure

7.4.1 Classes

Concentrations of phytoplankton classes present at each site were graphed using column plots. The 5 most dominant classes of each month were overlayed, and counts for all other classes were combined and presented in the group *Other*.

7.4.2 Harmful vs Non-Harmful

Potentially harmful species were identified and enumerated in water samples taken at 7 sites (60, 61, 150, 151, 152, 153 and 174) and plotted on a column graph overlayed with cell counts of non-harmful species. Asterisks above the months correspond with the occurrence of potentially harmful algal blooms during sampling events

8.0 Results & Discussion

8.1 Influence of Rainfall on Water Quality

During this reporting period there were a total of 82 sampling days (Figure 8.1, red dots) which included six 'wet weather' sampling days (Figure 8.1, green dots). Stream flows are influenced by the amount of impervious surface area within a catchment. Small rain events within catchments containing a high percentage of impervious area (e.g. industrial and urban areas) generate high volumes of run off whilst vegetated catchments with a small percentage of impervious area generate run off only after extended periods of rainfall.

The total annual rainfall in Hornsby Shire in 2015/16 was approximately 1145 mm, around 225 mm less rainfall than the previous reporting period of 2014/15. There were also fewer sampling days classified as 'wet weather'; 6 in 2015/16 compared to 8 in 2014/15. There were two considerable storm events in 2016, occurring in January and June. A number of smaller events were spread throughout the 12 months with most rainfall occurring during the summer months, August and September 2015, and October 2016

Rainfall events can cause bypass events at either West Hornsby or Hornsby Heights WTPs, resulting in the release of partially treated sewage into local creeks (Figure 8.1, orange circles). There were 41 instances of overflow or partially treated sewage releases throughout the reporting period.

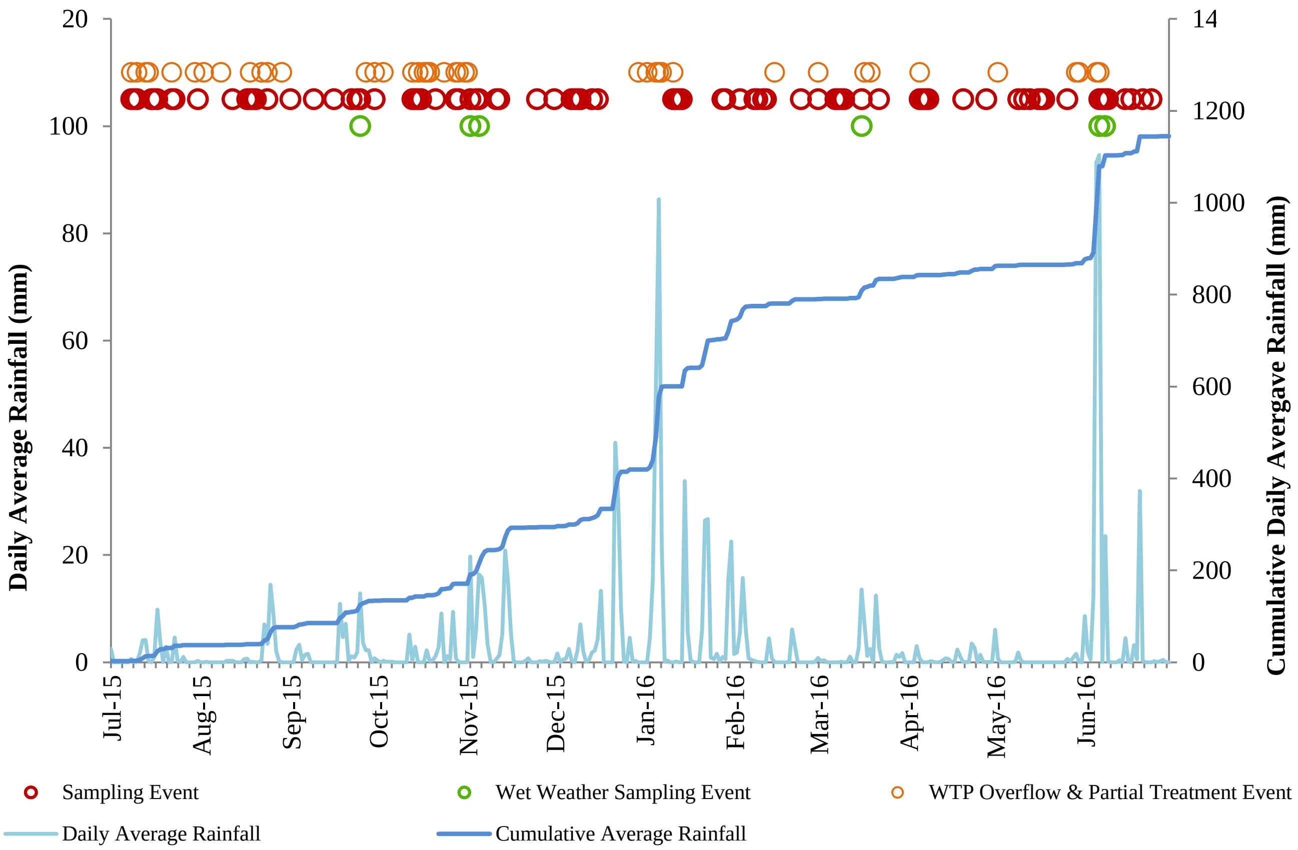

Figure 8.1: *Daily average rainfall (mm, light blue) of 12 gauging stations located in Hornsby Shire and cumulative daily average rainfall (mm, dark blue) are shown. Sampling events are indicated by red circles, wet weather sampling events by green circles and WTP overflow and partial treatment events in orange circles.*

8.2 QA/QC

8.2.1 Blank samples

Twelve blank suites of samples (n = 92) were prepared, carried in the field and sent for analysis during this reporting period. For selected parameters, the results were less than detection limits for 96% of blank samples analysed (Table 8.1). Observed concentrations that are equal to or greater than detection limits (Table 8.1, orange squares) may be indicative of sample contamination during the sampling and handling process, or through laboratory practices.

8.2.2 Duplicate Samples

Twelve duplicate sample suites were collected and sent for analysis during this reporting period. At the site of duplicate sampling, two suites of samples were collected; sample suite *A* and sample suite *B*. High r^2 values all parameters indicate a strong linear relationship between the results for samples A and B. This indicates that there has been no contamination of duplicates whilst sampling (Table 8.1).

Table 8.1: *Laboratory results for field blanks. All results should return observed concentrations less than the detection limit (light blue). Concentrations detected are highlighted in orange. Asterisks indicate no samples taken for that parameter.*

Suspended Solids (mg/L)	Ammonia Nitrogen (mg/L)	Oxides of Nitrogen (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	Chlorophyll *a* (µg/L)	Faecal Coliforms (CFU/100ml)
2	0.01	0.01	0.05	0.002	0.2	1
<2	<0.01	<0.01	<0.05	<0.002	<0.2	<1
<2	<0.01	<0.01	<0.05	0.002	*	<1
<2	<0.01	<0.01	<0.05	<0.002	*	<1
<2	<0.01	0.01	<0.05	<0.002	*	<1
<2	<0.01	<0.01	<0.05	<0.002	<0.2	<1
<2	<0.01	<0.01	<0.05	<0.002	*	<1
<2	<0.01	<0.01	<0.05	<0.002	<0.2	<1
<2	<0.01	<0.01	<0.05	<0.002	<0.2	<1
<2	<0.01	<0.01	<0.05	<0.002	<0.2	<1
<2	<0.01	<0.01	<0.05	0.002	<0.2	<1
<2	<0.01	<0.01	<0.05	<0.002	<0.2	<1
<2	<0.01	<0.01	<0.05	0.002	<0.2	<1

Table 8.2: *r^2 values from Pearson correlation for parameters measured with duplicate samples. r^2 values range from 0-1, where the greater the value, the more strongly the duplicate samples taken for each parameter are correlated through the reporting period*

	Suspended Solids	Ammonia Nitrogen	Oxidised Nitrogen	Total Nitrogen	Total Phosphorus	Chlorophyll *a*	Faecal Coliforms
r^2	.9911	.9933	.9991	.9997	.9716	0.9211	.9881

8.3 Reference Sites

8.3.1 Grades for reporting period 2015-16

Health grades for reference sites were consistent, with many being assigned grades of *A* (Table 8.3). Overall physical-chemical health grades and microbial health grades are all *A* and *A+*, with the exception of one *B*.

Site 36 – Murray Anderson Creek

- Data for all parameters were within the REHV ranges, with each being assigned grade *A*
- Overall physical-chemical health grade of *A*
- Microbial health grade of *A*

Site 37 – Smugglers Creek

- Data for all parameters were within the REHV ranges, with each being assigned grade *A*
- Overall physical-chemical health grade of *A*
- Microbial health grade of *A+*

Site 54 – Laughtondale Creek

- TP concentrations exceeded the REHV, indicating nutrient enrichment was occurring during 20-50% of the sampling events, resulting in a grade of *B*
- Data for all parameters except TP were within the REHV ranges, with each being assigned grade *A*
- Overall physical-chemical health grade of *A*
- Microbial health grade of *A+*

Site 114 - Muogamarra Creek

- DO and pH values were less than their respective lower REHVs during <20% of sampling events, resulting in a grade of *B* each
- Data for all parameters except DO and pH were within the REHV ranges, with each being assigned grade *A*
- Overall physical-chemical health grade of *A*
- Microbial health grade of *A+*

Site 123 – Peats Crater Creek

- TP concentrations were observed to exceed the REHV during all sampling events and was assigned a grade of *F*, which was also assigned in the previous reporting period
- pH values were greater than the upper REHV threshold during 50-80% of sampling events, indicating the system was more alkaline than expected, and was assigned a grade of *C*
- Turbidity and EC values were greater than their respective REHVs during 20-50% of sampling events, resulting in a grade of *B* each
- Data for DO, SS, ammonia, oxidised nitrogen and TN were within the REHV limits during all sampling events, with each being assigned grade *A*
- Overall physical-chemical health grade of B
- Microbial health grade of A

Site 147 – Unnamed creek, Cheltenham

- Data for all parameters were within the REHV ranges, with each being assigned grade *A*
- Overall physical-chemical health grade of *A*
- Microbial health grade of *A*

Site 149 – Duckpond Ridge Creek

- pH values were observed to be less than the lower REHV, and EC exceeded the REHV during 50-80% of sampling events, resulting in a grade of C each
- In the previous reporting period, pH was assigned a grade of *F*, and EC a grade of *C*
- Data for all parameters except pH and EC were within the REHV ranges, with each being assigned grade *A*
- Overall physical-chemical health grade of *A*
- Microbial health grade of *A+*

Site 164 – Djarra Crossing

- pH values were less than the lower REHV threshold during 50-80% of sampling events, indicating the creek was more acidic than expected, and was assigned a grade of *C*
- Data for all parameters except pH were within the REHV ranges, with each being assigned grade *A*
- Overall physical-chemical health grade of *A*
- Microbial health grade of *A*

Data from the reference sites demonstrate natural variation of water parameters in creeks with minimal human impact, and have catchments predominantly inclusive of native bushland. These creeks reflect the water quality that may have existed before Hornsby Shire was developed, thus providing control, or reference data to compare other streams to.

The receiving waters of primarily undisturbed catchments in Hornsby Shire are generally characterised by low pH, EC, faecal coliforms, SS and nutrients, and high DO values. The pH values at reference sites are more acidic (i.e. lower pH) than the pH range found in other sites in Hornsby Shire. These lower pH levels are not unusual for unbuffered waters in wholly sandstone catchments (Thomas, Dambrine et al. 1999). pH values of creeks in many developed sandstone catchment areas are considerably higher (more alkaline) than the natural background, which may be attributed to the widespread use of alkaline concretes and detergents.

Site 23 within Peats Crater, Muogamarra Nature Reserve, shows some major differences when compared with other reference sites; pH, turbidity, total phosphorus, total nitrogen and oxidised-nitrogen results are consistently higher relative to other reference sites. These observed values reflect the known igneous geology influence of the catchment. Further, phosphorus release from sediments into the water column is a function of pH, where a high or low pH value can correspond with increased phosphorus concentrations in the water column (Seitzinger 1991; Kim, Choi et al. 2003). Peats Crater Creek had the highest pH of all sites. The maximum was 7.65, compared to the overall reference mean of 5.55 and median of 5.44 for pH. Further investigation is necessary into this relationship and the potential cause of high TP at this site.

Figure 8.3: *Reference creek:* Murray Anderson Creek (Site 36)

***Table 8.3:** Physical-chemical grades for reference sites calculated for each parameter sampled throughout the reporting period. Parameters include turbidity, dissolved oxygen (DO), pH, electrical conductivity (EC), suspended solids (SS), ammonia (NH3-N), oxidised nitrogen (NOx-N), total nitrogen (TN), and total phosphorus (TP). Overall physical chemical grades and microbial grades for each site are also included for each site (bold borders).*

Sites		Physical-Chemical Grades									Site Grades	
Number	Waterway	Turb	DO	pH	EC	SS	NH_3-N	NOx-N	TN	TP	Phys-Chem	Microbial
36	Murray-Anderson Ck	A	A	A	A	A	A	A	A	A	A	A
37	Smugglers Ck	A	A	A	A	A	A	A	A	A	A	A+
54	Laughtondale Ck	A	A	A	A	A	A	A	A	B	A	A+
114	Muogamarra Ck	A	B	B	A	A	A	A	A	A	A	A+
123	Peats Crater Ck	B	A	C	B	A	A	A	A	F	B	A
147	Unnamed Ck, Cheltenham	A	A	A	A	A	A	A	A	A	A	A
149	Duckpond Ridge Ck	A	A	C	C	A	A	A	A	A	A	A+
164	Djarra Crossing	A	A	C	A	A	A	A	A	A	A	A

8.3.2 Health Grades Through Time

Overall health grades of reference sites have remained relatively stable through the last three reporting periods (Table 8.4). Physical-chemical grades display consistent grades of *A* for all sites except Peats Crater Creek (123) which has had a consistent grade of B, and except for Duckpond Ridge Creek (149) which has shown an improvement in the last reporting year, changing from a *B* grade to an *A*.

Similarly, microbial grades are relatively consistent throughout the last 3 reporting periods, with some variation between A and A+ at Djarra Crossing (164), Unnamed creek at Cheltenham (147), Peats Crater Creek (123), Laughtondale Creek (54) and Murray Anderson Creek (36). Smugglers Creek (37), Muogamarra Creek (114) and Duckpond Ridge Creek (149) have been consistently A+.

***Table 8.4:** Comparisons of overall site physical-chemical (phys-chem) and microbial health grades through three reporting periods; 2013-14, 2014-15, and 2015-16 for reference sites*

Sites		Phys-Chem			Microbial		
Number	**Waterway**	**2015-16**	**2014-15**	**2013-14**	**2015-16**	**2014-15**	**2013-14**
36	Murray-Anderson Ck	A	A	A	A	A+	A+
37	Smugglers Ck	A	A	A	A+	A+	A+
54	Laughtondale Ck	A	A	A	A+	A	A+
114	Muogamarra Ck	A	A	A	A+	A+	A+
123	Peats Crater Ck	B	B	B	A	A	A+
147	Unnamed Ck, Cheltenham	A	A	A	A	A	A+
149	Duckpond Ridge Ck	A	B	B	A+	A+	A+
164	Djarra Crossing	A	A	A	A	A	A+

8.4 Industrial Sites

8.4.1 Grades for reporting period 2015-16

Health grades for industrial sites were variable, ranging from grades of *F* to *A* (Table 8.5).

Site 10 – Larool Creek

- Ammonia, oxidised nitrogen, pH, TN and TP were all observed to be greater than the REHVs for respective parameters during all sample events, indicating persistent nutrient enrichment in the creek and resulting in grade for *F* each parameter
- EC exceeded the REHV during more than 80% of sampling events, resulting in grade *D*
- DO was observed to be less than the lower REHV threshold during 50-80% of sampling events, resulting in grade *C*
- Turbidity was greater than the REHV during 50-80% of sampling events, assigned grade *C*
- Suspended solids exceeded the REHV during 20-50% of all sample events in the reporting period, resulting in a grade of *B*
- Overall physical-chemical health grade of *D*
- Microbial health grade of *F*

Site 12 – Hornsby Creek

- Grade *F* was assigned to pH, oxidised nitrogen, TN and TP as they all exceeded their respective REHVs during all sample events, indicating persistent nutrient enrichment in the creek and more acidity than expected
- Both EC and ammonia exceeded their respective REHVs during 50-80% of sampling events, resulting in grade *C* each
- SS and turbidity both exceeded their respective REHVs during 20-50% of sampling events, and were each assigned grade *B*
- DO was consistently within the REHV range of 75 to 115% (Table 6.1) and was assigned a grade of *A*
- Overall physical-chemical health grade of *C*
- Microbial health grade of *F*

Site 13 – Sams Creek

- Grade *F* was assigned to pH and TP as they both exceeded their respective REHVs during all sampling events
- Oxidised nitrogen and TN both exceeded their respective REHVs during 80-100% of sampling events, and were each assigned a grade of *D*
- DO was less than the lower REHV during 50-80% of sampling events, resulting in a grade of *C*
- Turbidity, EC and ammonia each exceeded their respective REHVs during 20-50% of sampling events, resulting in a grade of *B* each
- Overall physical-chemical health grade of *C*
- Microbial health grade of *C*

Health grades for sites 10, 12 and 13 indicate substantial degradation of the creeks, most likely due to the industrial activity and urbanised areas within their catchments. Larool Creek (10) was the most degraded of the three sites. The overall physical-chemical grades for turbidity and suspended solids were impacted by a single event where a pulse of unnaturally high suspended sediment was detected. Respective readings were 370 NTU and 83 mg/L during the event. Hornsby Creek (12), though slightly better than Larool Creek, was highly degraded. Sams Creek (13) was the least degraded of the three industrial sites, with overall physical-chemical and microbial grades of *C*. Results for this site indicated better water quality in comparison to the other two sites, particularly for parameters of turbidity, EC, suspended solids and ammonia.

Receiving waters of industrial catchments in Hornsby Shire are generally characterised by high concentrations of nutrients (TP, TN, NOx-N, NH_3-N) and elevated levels of pH and faecal coliforms. pH values greater than reference values (REHVs) may reflect widespread use of alkaline products (e.g. concrete and surfactants) within developed areas. Elevated nutrient levels in industrial catchments may be due to discharge of human waste, industrial and household chemicals, industrial processes and stormwater inputs. Common sources of faecal contaminants in developed catchments are sewer overflows and animal faeces, and infrastructure is directly connected to the drainage system (Wong 2006).

Table 8.5: *Physical-chemical grades for industrial sites calculated for each parameter sampled throughout the reporting period. Parameters include turbidity), dissolved oxygen (DO), pH, electrical conductivity (EC), suspended solids (SS), ammonia (NH3-N), oxidised nitrogen (NOx-N), total nitrogen (TN), and total phosphorus (TP). Overall physical chemical grades and microbial grades for each site are also included for each site (bold borders).*

Sites		Physical-Chemical Grades									Site Grades	
Number	Waterway	Turbidity	DO	pH	EC	SS	NH3-N	NOx-N	TN	TP	**Phys-Chem**	**Microbial**
10	Larool Ck	C	C	F	D	B	F	F	F	F	**D**	**F**
12	Hornsby Ck	B	A	F	C	B	C	F	F	F	**C**	**F**
13	Sams Ck	B	C	F	B	A	B	D	D	F	**C**	**C**

8.4.2 Health Grades Through Time

Physical-chemical health grades of industrial sites have remained relatively stable through the last three reporting periods (Table 8.6). Physical-chemical grades have been poor throughout all three reporting periods, remaining at a grade of *C* for Hornsby Creek (12) and Sams Creek (13), and fluctuating between grades *C* and *D* at Larool Creek (10).

Alternatively, microbial grades indicate the three sites are becoming increasingly degraded with time, where Larool Creek dropped from a grade *D* in 2013-14 and 2014-15 to *F* in 2015-16, Hornsby Creek has consistently been found to have a poor microbial health grade of F, and Sams Creek has drastically degraded from grade *A* in 2016-14 to D in 2014-15, with slight improvement to grade *C* in 2015-16

Table 8.6: *Comparisons of overall site physical-chemical (phys-chem) and microbial health grades through three reporting periods; 2013-14, 2014-15, and 2015-16 for industrial sites*

Sites		Phys-Chem			Microbial		
Number	**Waterway**	**2015-16**	**2014-15**	**2013-14**	**2015-16**	**2014-15**	**2013-14**
10	Larool Ck	**D**	**C**	**D**	**F**	**D**	**D**
12	Hornsby Ck	**C**	**C**	**C**	**F**	**F**	**F**
13	Sams Ck	**C**	**C**	**C**	**C**	**D**	**A**

8.5 Urban Sites

8.5.1 Grades for reporting period 2015-16

Health grades for urban sites were variable, ranging from grades of *F* to *A* (Table 8.7).

Site 4 – Berowra Creek, Westleigh

- pH and oxidised nitrogen did not comply with their respective REHVs during all sampling events, resulting in a grade of *F* for each parameter
- TP exceeded the REHVs during 80-100% of sampling events, resulting in a grade of *D*
- TN exceeded the REHVs during 50-80% of sampling events and was assigned a grade of *C*
- EC and turbidity both exceeded their respective REHVs during 20-50% of sampling events, resulting in a grade of *B* each
- DO was within the REHV range during all sampling events, whilst SS and ammonia where compliant with their respective REHVs during 80-100% of sampling events, resulting in a grade *A* each
- Overall physical-chemical health grade of *C*
- Microbial health grade of *C*

Site 5 – Pyes Creek

- Grade *F* was assigned to pH, oxidised nitrogen, TN and TP as they were all observed to be greater than their respective REHVs during all sample events, indicating persistent nutrient enrichment in the creek and more alkaline water than expected
- Ammonia exceeded the REHV during 80-100% of sampling events, resulting in a grade of *D*
- EC exceeded the REHV during 50-80% of sampling events, resulting in a grade of *C*
- Turbidity and SS were assigned a grade B as they exceeded their respective REHVs during 20-50% of sample events
- DO was compliant with the REHV for 80-100% of sampling events, being assigned grade A
- Overall physical-chemical health grade of *D*
- Microbial health grade of *F*

Site 6 – Georges Creek

- pH was more alkaline than the upper REHV, resulting in a grade *F* due to non-compliance in 100% of sampling events
- TN and TP both exceeded their respective REHVs during 80-100% of sampling events, indicating nutrient enrichment in the creek and resulting in a grade of *D*
- Oxidised nitrogen and EC exceeded their respective REHVs during 50-80% of sampling events, resulting in a grade of *C*
- DO, turbidity and SS each exceeded their respective REHVs during 0-20% of sampling events, and were each assigned a grade of *A*
- Overall physical-chemical health grade of *C*
- Microbial health grade of *C*

Site 8 – Devlins Creek

- pH was consistently more alkaline than the upper REHV threshold, and oxidised nitrogen and TP consistently exceeding their respective REHVs in 100% of sampling events, resulting in a grade *F* each
- TN and ammonia both exceeded their respective REHVs during 80-100% of sampling events, resulting in a grade of *D* each
- EC exceeded the REHV during 50-80% of sampling events, resulting in a grade of *C*
- DO, turbidity and SS each exceeded their respective REHVs during 20-50% of sampling events, and were each assigned a grade of *B*
- Overall physical-chemical health grade of *D*

- Microbial health grade of *C*

Site 39 – Joe Crafts Creek

- pH exceeded the upper REHV during 80-100% of sampling events resulting in a grade of *D*
- Oxidised nitrogen exceeded the REHV during 50-80% of sampling events, resulting in a grade of *C*
- TP and ammonia exceeded their respective REHVs during 20-50% of sampling events and were each assigned grade *B*
- EC and SS were each compliant with their respective REHVs during 100% of sampling events, while Turbidity, DO and TN were compliant during 80-100% of sampling events, resulting in each parameter being assigned a grade of *A*
- Overall physical-chemical health grade of *B*
- Microbial health grade of *A+*

Site 181 – Unnamed Creek, Epping

- Grade *F* was assigned to pH and oxidised nitrogen as they were observed to be greater than their respective REHVs during all sample events
- TP and TN exceeded their respective REHVs during 80-100% of sampling events, resulting in a grade of *D* and indicating nutrient enrichment of the creek
- EC exceeded the REHV during 50-80% of sampling events, resulting in a grade of *C*
- Turbidity and ammonia were each assigned a grade of B as they exceeded their respective REHVs during 20-50% of sample events
- DO and SS were both compliant with their respective REHVs for 80-100% of sampling events, and were each assigned grade A
- Overall physical-chemical health grade of *C*
- Microbial health grade of *C*

Receiving waters of urban catchments in Hornsby Shire are generally characterised by elevated electrical conductivity and pH values and high concentrations of nutrients (TP, TN, oxidised nitrogen). pH values above natural (reference) levels may reflect widespread use of alkaline products (e.g. concrete and surfactants) within developed urban areas. Elevated concentrations of bacteria in urban areas may be attributed to faecal contamination entering streams via stormwater runoff and/or sewage overflows during wet weather events.

High nutrient concentrations resulted in poor grades across all sites with urban catchments. These increased concentrations may be due to the overuse of garden fertilisers and manures, eroding soils, road runoff and sewage overflows.

Relatively good water quality was observed at Joe Crafts Creek (39) in comparison to other creeks with urban areas in their catchment. This is likely a result of the location of the site where the headwaters are located in the urban areas near Berowra, however a substantial proportion of the river runs through healthy native bushland prior to the sampling point. The creek also has tributary contribution from other creeks that also run through bushland. Vegetation filters nutrients and pollutants, reducing the detectable impact of urbanised areas on the creek (Lowrance, Todd et al. 1984). Tributary inflows can influence the water quality of receiving streams (O'Farrell, Lombardo et al. 2002), thus flow contribution from healthy creeks can dilute polluted waters.

Table 8.7: *Physical-chemical grades for urban sites calculated for each parameter sampled throughout the reporting period. Parameters include turbidity), dissolved oxygen (DO), pH, electrical conductivity (EC), suspended solids (SS), ammonia (NH3-N), oxidised nitrogen (NOx-N), total nitrogen (TN), and total phosphorus (TP). Overall physical chemical grades and microbial grades for each site are also included for each site (bold borders).*

Sites		Physical-Chemical Grades									Site Grades	
Number	Waterway	Turbidity	DO	pH	EC	SS	NH3-N	NOx-N	TN	TP	Phys-Chem	Microbial
4	Berowra Ck, Westleigh	B	A	F	B	A	A	F	C	D	**C**	**C**
5	Pyes Ck	B	A	F	C	B	D	F	F	F	**D**	F
6	Georges Ck	A	A	F	C	A	A	C	D	D	**C**	**C**
8	Devlins Ck	B	B	F	C	B	D	F	D	F	**D**	**D**
39	Joe Crafts Ck	A	A	D	A	A	B	C	A	B	**B**	**A+**
181	Unnamed Ck, Epping	B	A	F	C	A	B	F	D	D	**C**	**C**

8.5.2 Health Grades Through Time

The overall trend in results that is evident is a decline in water quality with time (Table 8.8). Physical-chemical results are stable over the three years of comparison, where sites located at Berowra Creek (4), Georges Creek (6), Devlins Creek (8) and an unnamed creek in Cheltenham (181) have all been given overall grades of *C*. Joe Crafts Creek has been consistently assigned the grade of *B*. At Pyes Creek, water quality appears to have degraded from *C* grade in 2013-15 and 2014-15 to grade *D* in 2015-16, as well as in terms of microbial health.

Microbial health at all sites except Joe Crafts Creek have degraded through time. Joes Craft Creek has fluctuated between good microbial health grades of *A* and *A+*. Berowra Creek, Pyes Creek and Georges Creek were all graded *A* in 2013-14, with Berowra and Georges Creeks dropping to *C* in 2015-16, and Pyes Creek declining to *F*. Devlins Creek was rated as a *B* in 2013-14 and fell to grade *D* in 2014-15 and 2015-2016, while the unnamed creek in Epping has fluctuated between *D* and *C*.

Table 8.8: *Comparisons of overall site physical-chemical (phys-chem) and microbial health grades through three reporting periods; 2013-14, 2014-15, and 2015-16 for urban sites*

Sites		Phys-Chem			Microbial		
Number	**Waterway**	**2015-16**	**2014-15**	**2013-14**	**2015-16**	**2014-15**	**2013-14**
4	Berowra Ck, Westleigh	**C**	**C**	**C**	**C**	**C**	**A**
5	Pyes Ck	**D**	**C**	**C**	**F**	**D**	**A**
6	Georges Ck	**C**	**C**	**C**	**C**	**B**	**A**
8	Devlins Ck	**C**	**C**	**C**	**D**	**D**	**B**
39	Joe Crafts Ck	**B**	**B**	**B**	**A+**	**A**	**A+**
181	Unnamed Ck, Epping	**C**	**C**	**C**	**C**	**D**	**C**

8.6 Rural Sites

8.6.1 Grades for reporting period 2015-16

Health grades for rural sites were relatively variable, ranging from grades of *F* to *A* (Table 8.9).

Site 2 – Tunks Creek

- pH exceeded the upper REHV during more than 80% of sampling events, resulting in grade *D*
- Oxidised nitrogen was observed to exceed the REHV during 50-80% of sampling events, resulting in grade *C*
- TP and EC were both greater than their respective REHVs during 20-50% of all sample events in the reporting period, resulting in a grade of *B*
- Turbidity and TN were compliant with their respective REHVs during 80-100% of sampling events, while DO and ammonia and were compliant during 100% of sampling events, resulting in each being assigned a grade *A*
- Overall physical-chemical health grade of *B*
- Microbial health grade of *A+*

Site 42 – Colah Creek, Glenorie

- TN and TP exceeded their respective REHVs and pH the upper REHV during more than 80% of sampling events, resulting in each being assigned a grade of *D*
- Oxidised nitrogen and EC both exceeded the REHV during 50-80% of sampling events, resulting in grade *C*
- Turbidity values were greater than the REHV during 20-50% of all sample events in the reporting period, resulting in a grade of *B*
- DO was compliant with the REHV during 80-100% of sampling events, while SS and ammonia were compliant during 100% of sampling events, resulting in each being assigned a grade *A*
- Overall physical-chemical health grade of *C*
- Microbial health grade of *A*

Site 63 – Colah Creek, Ben Bullen Road

- TP exceeded the REHV during all sample events, resulting in grade *F*
- EC exceeded the REHV during more than 80% of sampling events, resulting in grade *D*
- Oxidised nitrogen and pH exceeded their respective REHVs during 50-80% of sampling events, resulting in grade *C*
- DO and TN exceeded their respective REHVs during 20-50% of all sample events in the reporting period, resulting in a grade of *B* each
- Turbidity was compliant with the REHV during 80-100% of sampling events, while SS and ammonia were compliant during 100% of sampling events, resulting in each being assigned a grade *A*
- Overall physical-chemical health grade of *B*
- Microbial health grade of *A+*

Site 49 – Still Creek

- Oxidised nitrogen exceeded the REHV during all sample events, resulting in grade *F*
- pH exceeded the REHV during more than 80% of sampling events, resulting in grade *D*
- EC and TN exceeded their respective REHVs during 50-80% of sampling events, resulting in grade *C*
- TP exceeded the REHV during 20-50% of all sample events in the reporting period, resulting in a grade of *B*
- Turbidity was compliant with the REHV during 80-100% of sampling events, while DO, SS and ammonia were compliant during 100% of sampling events, resulting in each being assigned a grade *A*

- Overall physical-chemical health grade of *B*
- Microbial health grade of *A+*

Site 62 – Kimmerikong Creek, Cowan

- TP, TN, oxidised nitrogen and pH all exceeded their respective REHVs during >80% of sampling events, resulting in each being assigned grade *D*
- EC exceeded the REHV during 50-80% of sampling events, resulting in grade *C*
- Turbidity and SS were compliant with their respective REHVs during 80-100% of sampling events, while DO and ammonia were compliant during 100% of sampling events, resulting in each being assigned a grade *A*
- Overall physical-chemical health grade of *D*
- Microbial health grade of *D*

Site 64 – Unnamed Creek, Galston Village

- TP exceeded the REHV during all sample events, resulting in grade *F*
- TN, oxidised nitrogen and EC all exceeded their respective REHVs during more than 80% of sampling events, resulting in grade *D* each
- pH exceeded the upper REHV threshold during 50-80% of sampling events, resulting in grade *C*
- DO and turbidity exceeded their respective REHVs during 20-50% of all sample events in the reporting period, resulting in a grade of *B* each
- SS and ammonia were compliant during 100% of sampling events, resulting in each being assigned a grade *A*
- Overall physical-chemical health grade of *C*
- Microbial health grade of *C*

Site 80 – Glenorie Creek

- pH, oxidised nitrogen, TN and TP all exceeded their relative REHVs during all sample events, resulting in grade *F* each
- Turbidity and EC both exceeded their respective REHVs during 50-80% of sampling events, resulting in grade *C* each
- SS and ammonia exceeded their respective REHVs during 20-50% of all sample events in the reporting period, resulting in a grade of *B* each
- DO was compliant during 100% of sampling events, resulting in being assigned a grade *A*
- Overall physical-chemical health grade of *C*
- Microbial health grade of D

Receiving waters downstream of rural catchments in Hornsby Shire are generally characterised by elevated electrical conductivity, faecal coliforms and nutrient concentrations (TP, TN, NH3-N, NOx-N). Elevated concentrations of nutrients and bacteria are likely due to the use of on-site wastewater management systems (OSWMS) in areas not yet connected to sewer. Council routinely inspects the OSWMSs in rural areas, however the shallow, sandstone geology is not well suited to absorption trenches or aerated wastewater treatment systems (AWTS). As such, significant seepage of untreated effluent can occur. Fertilisers, domestic use of detergents, incorrect disposal of grey water and illegal septic tank discharges could also contribute to the high nutrient loads. Site Tunks Creek (2) and Colah Creek at Ben Bullen Road (63) both maintain relatively good water quality despite the rural areas located within their catchments. This is likely to be attributed to the location of the sampling point on each creek relative to native and healthy bushland. The bushland and riparian vegetation filter nutrients and pollutants from surface run off (Lowrance, Todd et al. 1984). Further, significant contributions to streams from tributaries influence the water quality of the receiving stream (O'Farrell, Lombardo et al. 2002), as such, tributary inflow of good water quality may result in an improvement of water quality in the receiving stream.

Table 8.9: *Physical-chemical grades for rural sites calculated for each parameter sampled throughout the reporting period. Parameters include turbidity), dissolved oxygen (DO), pH, electrical conductivity (EC), suspended solids (SS), ammonia (NH3-N), oxidised nitrogen (NOx-N), total nitrogen (TN), and total phosphorus (TP). Overall physical chemical grades and microbial grades for each site are also included for each site (bold borders).*

Sites		Physical-Chemical Grades									Site Grades	
Number	Waterway	Turbidity	DO	pH	EC	SS	NH3-N	NOx-N	TN	TP	**Phys-Chem**	**Microbial**
2	Tunks Ck	A	A	D	B	A	A	C	A	B	**B**	**A+**
42	Colah Ck, Glenorie (U/S)	B	A	D	C	A	A	C	D	D	**C**	**A**
63	Colah Ck, Ben Bullen Rd (D/S)	A	B	C	D	A	A	C	B	F	**B**	**A+**
49	Still Ck	A	A	D	C	A	A	F	C	B	**B**	**A+**
62	Kimmerikong Ck, Cowan	A	A	D	C	A	A	D	D	D	**C**	**D**
64	Unnamed Ck, Galston Village	B	B	C	D	A	A	D	D	F	**C**	**C**
80	Glenorie Ck	C	A	F	C	B	B	F	F	F	**C**	**F**

8.6.2 Health Grades Through Time

The overall physical-chemical and microbial health grades for rural creeks and streams are highly variable, shifting between good and poor grades through time. The physical-chemical health grade at Tunks Creek (2) dropped from grade *A* in 2013-14 to *B* in 2014-15 and remained consistent in 2015-16, while Still Creek (49) dropped from *B* in 2013-14 to *C* in 2014-15, then improved back to *B* in 2015-16. Colah Creek at Glenorie (42) and the unnamed creek at Galston Village (64) and Cowan (62) were consistently grade *C* through the last three reporting periods and Colah Creek at Ben Bullen Road (63) has been consistently graded *B* in this time. Glenorie Creek (80) displayed improvement from *D* in 2013-14 to *C* in 2014-15 and 2015-16.

Microbial health has been vastly variable between sites and over time, ranging from *A+* to *F*. Tunks and Colah Creeks (Ben Bullen Road) have both exhibited stable microbial health of *A+* over the three reporting periods, except for *A* in 2013-14 at Colah Creek. Colah Creek (Glenorie) fluctuated substantially from *A* in 2013-14 to *C* in 2014-15 and back to *A* in 2015-16. Similarly, Still Creek dropped from *A+* to *B* and improved back to *A+* consecutively in the reporting periods. The two unnamed creeks at Cowan and Galston Village, and Glenorie Creek all showed signs of degradation in terms of microbial health. The creek at Cowan declined from *A* to *C* then to *D*, the creek at Galston Village from *B* to *C* and *C* again, and Glenorie Creek from *F* to *D* and back to *F* in consecutive reporting periods from 2013-14.

***Table 8.10:** Comparisons of overall site physical-chemical (phys-chem) and microbial health grades through three reporting periods; 2013-14, 2014-15, and 2015-16 for rural sites*

Sites		Phys-Chem			Microbial		
Number	Waterway	2015-16	2014-15	2013-14	2015-16	2014-15	2013-14
2	Tunks Ck	B	B	A	A+	A+	A+
42	Colah Ck, Glenorie	C	C	C	A	C	A
63	Colah Ck, Ben Bullen Rd	B	B	B	A+	A+	A
49	Still Ck	B	C	B	A+	B	A+
62	Kimmerikong Ck, Cowan	C	C	C	D	C	A
64	Unnamed Ck, Galston Village	C	C	C	C	C	B
80	Glenorie Ck	C	C	D	F	D	F

8.7 Wastewater Treatment Plants

8.7.1 Grades for reporting period 2015-16

Health grades for WTP sites were relatively variable, ranging from grades of *F* to *A* (Table 8.11).

West Hornsby Wastewater Treatment Plant (WHWTP)

Site 23 – Waitara Creek (upstream WHWTP)

- Oxidised nitrogen, TN and TP all exceeded their relative REHVs during all sample events, resulting in grade *F* each
- Ammonia, pH, DO and EC exceeded their respective REHVs during 50-80% of sampling events, resulting in grade *C* each
- Turbidity exceeded the REHV during 20-50% of all sample events in the reporting period, resulting in a grade of *B*
- SS was compliant during 80-100% of sampling events, resulting in being assigned a grade *A*
- Overall physical-chemical health grade of *C*
- Microbial health grade of *D*

Site 45 Berowra Creek (~1 km downstream WHWTP)

- TP, TN, oxidised nitrogen and pH all exceeded their respective REHVs during all sample events, resulting in grade *F*
- EC exceeded the REHV during > 80% of sampling events, resulting in grade *D*
- Ammonia exceeded the REHV during 20-50% of all sample events in the reporting period, resulting in a grade of *B*
- Turbidity and SS were compliant with their respective REHVs during 80-100% of sampling events, while DO was compliant during 100% of sampling events, resulting in each being assigned a grade *A*
- Overall physical-chemical health grade of *C*
- Microbial health of *A*

Site 1 – Berowra Creek (~5.7 km downstream WHWTP)

- TP, TN, oxidised nitrogen and pH all exceeded their respective REHVs during all sample events, resulting in grade *F*
- EC exceeded the REHV during > 80% of sampling events, resulting in grade *D*
- Ammonia exceeded the REHV during 20-50% of all sample events in the reporting period, resulting in a grade of *B*
- Turbidity and SS were compliant with their respective REHVs during 80-100% of sampling events, while DO was compliant during 100% of

sampling events, resulting in each being assigned a grade *A*

- Overall physical-chemical health grade of *C*
- Microbial health grade of *A+*

Hornsby Heights Wastewater Treatment Plant (HHWTP)

Site 52 – Calna Creek (upstream HHWTP)

- pH, and TP exceeded their respective REHVs during > 80% of sampling events, resulting in grade *D* each
- Turbidity, DO, SS, ammonia, oxidised nitrogen and TN each exceeded their respective REHVs during 20-50% of all sample events in the reporting period, resulting in a grade of *B* each
- EC was compliant during 80-100% of sampling events, resulting in being assigned a grade *A*
- Overall physical-chemical health grade of *B*
- Microbial health grade of *A*

Site 43 – Calna Creek (~4.5 km downstream HHWTP)

- TP exceeded the REHV during all sample events, resulting in grade *F*
- pH, oxidised nitrogen and TN exceeded their respective REHVs during > 80% of sampling events, resulting in grade *D* each
- EC exceeded the REHV during 50-80% of sampling events, resulting in grade *C*
- Turbidity and DO were compliant during 100% of all sampling events, while SS, and ammonia were compliant during 80-100% of sampling events, resulting in each being assigned grade *A*
- Overall physical-chemical health grade of *C*
- Microbial health grade of *A*

Three sites are located longitudinally along a waterway to assess the impact of effluent from the WHWTP on the water quality of receiving waters; upstream of the plant at Calna Creek, and downstream at Calna Creek, and further downstream at Berowra Creek.

Water quality results at the site upstream of WHWTP on Waitara Creek indicated oxidised nitrogen, TN and TP exceeded the REHVs, rendering any negative changes as a result of WTP effluent difficult to detect. The concentrations detectable of these nutrients do not improve downstream, with a grade of *F* assigned to all sites both upstream and downstream of the plant. Health in terms of Grades for EC and pH declined when comparing grades from upstream to downstream of the WHWTP. Alternatively, there was improvement in concentrations downstream of turbidity, DO and ammonia.

Physical-chemical data from Calna Creek upstream of the HHWTP indicated relatively good water quality, with grades of *A*'s and *B*'s for 7 of 9 parameters. Only two parameters were assigned a grade of D. Water quality at the site located downstream of HHWTP on Calna Creek declined when assessing TP, TN, oxidised nitrogen and EC. This resulted in a decline in the overall physical-chemical site grade from *B* upstream, to *C* downstream.

The microbial health grades improved downstream of both WHWTP and HHWTP as a result of the disinfection stage of the water treatment processes at the plants.

Table 8.11: *Physical-chemical grades for WTP sites calculated for each parameter sampled throughout the reporting period. Parameters include turbidity), dissolved oxygen (DO), pH, electrical conductivity (EC), suspended solids (SS), ammonia (NH3-N), oxidised nitrogen (NOx-N), total nitrogen (TN), and total phosphorus (TP). Overall physical chemical grades and microbial grades for each site are also included for each site (bold borders). Double lines indicate upstream (above the line) and downstream (below the line) sites relative to the respective WTP. Triple lines indicate different WTPs.*

Sites			Physical-Chemical Grades									Site Grade	
WTP	Number	Waterway	Turbidity	DO	pH	EC	SS	NH3-N	NOx-N	TN	TP	Phys-Chem	Microbial
WHWTP	23	Waitara Ck, Upstream	B	C	C	C	A	C	F	F	F	C	D
	45	Berowra Ck, ~1km Downstream	A	A	F	D	A	B	F	F	F	C	A
	1	Berowra Ck, ~5.7km Downstream	A	A	F	D	A	B	F	F	F	C	A+
HHWTP	52	Calna Ck, Upstream	B	B	D	A	B	B	B	B	D	B	A
	43	Calna Ck~4.5 km Downstream	A	A	D	C	A	A	D	D	F	C	A

8.7.2 Health Grades Through Time

Physical-chemical health grades have all be stable over the last three reporting periods, with sites located on Waitara Creek (23) and Berowra Creek (45 and 1) and Calna Creek downstream of HHWTP (43) all maintaining the grade of *C*. Calna Creek upstream of HHWTP (52) has consistently been assigned a grade of *B*.

Microbial health declined from 2013-14 to 2014-15 and improved in 2015-16 at all sites but one. Waitara Creek declined from *C* to *D*, and recovered back to *C*, Berowra Creek (45) declined from *B* to *C*, and recovered back to *A*, and Berowra Creek (1) declined from *A+* to *C*, and improved to *A+* consecutively. Calna Creek (52) declined from *A+* to *D*, and recovered to D consecutively through the reporting periods, while Calna Creek (43) remain at *A+* from 2013-14 to 2014-15, and declined to *A* in 2015-16 reporting periods.

The declines in microbial health can be seen in sites located both upstream and downstream of the WTPs, which suggests that these fluctuations in health are not attributed to effluent from the plants themselves, but rather the greater catchment and perhaps other factors including climate and rainfall.

Table 8.12: *Comparisons of overall site physical-chemical (phys-chem) and microbial health grades through three reporting periods; 2013-14, 2014-15, and 2015-16 for WTP sites*

Sites			Phys-Chem			Microbial		
	Number	**Waterway**	**2015-16**	**2014-15**	**2013-14**	**2015-16**	**2014-15**	**2013-14**
WHWTP	23	Waitara Ck, Upstream	C	C	C	C	D	C
	45	Berowra Ck, ~1km Downstream	C	C	C	A	C	B
	1	Berowra Ck, ~5.7km Downstream	C	C	C	A+	C	A+
HHWTP	52	Calna Ck, Upstream	B	B	B	A	D	A+
	43	Calna Ck~4.5 km Downstream	C	C	C	A	A+	A+

8.8 Estuarine Sites

8.8.1 Grades for reporting period 2015-16

Health grades for estuarine sites were variable, ranging from good overall health grades near the mouth of the estuary, to poor health with distance upstream (Table 8.13).

Site 150 – Hawkesbury River, Gunya Point

- SS and oxidised nitrogen each exceeded their respective REHVs during 50-80% of sampling events, resulting in grade *C*
- Ammonia and TN exceeded their respective REHVs during 20-50% of all sample events in the reporting period, resulting in a grade of *B* each
- Turbidity and DO were compliant during 80-100% of sampling events, while pH and TP were compliant during 100% of sampling events, resulting in each being assigned a grade *A*
- Overall physical-chemical health grade of *B*
- Microbial health grade of *A+*
- Chlorophyll *a* grade of *A*
- Overall waterway health grade of *A*

Site 55 – Hawkesbury River, Brooklyn Baths

- SS exceeded the REHV during all sample events, resulting in grade *F*
- Oxidised nitrogen and turbidity exceeded REHVs during 50-80% of sampling events, resulting in grade *C*
- Ammonia and TN exceeded their respective REHVs during 20-50% of all sample events in the reporting period, resulting in a grade of *B* each
- DO and TP were compliant with their respective REHVs during 80-100% of sampling events, while pH was compliant during 100% of sampling events, resulting in each being assigned a grade *A*
- Overall physical-chemical health grade of *B*
- Microbial health grade of *A+*
- Chlorophyll *a* grade of *A*
- Overall waterway health grade of *A*

Site 174 –Mullet Creek

- SS and oxidised nitrogen exceeded their respective REHVs during more than 80% of sampling events, resulting in grade *D*
- Turbidity exceeded the REHV during 50-80% of sampling events, resulting in grade *C*
- Ammonia and TN exceeded their respective REHVs during 20-50% of all sample events in the reporting period, resulting in a grade of *B* each
- DO and TP were compliant with their respective REHVs during 80-100% of sampling events, while TP was compliant during 100% of sampling events, resulting in each being assigned a grade *A*
- Overall physical-chemical health grade of *B*
- Microbial health grade of *A+*
- Chlorophyll *a* grade of *B*
- Overall waterway health grade of *B*

Site 108 – Hawkesbury River, Dangar Island (Bradley's Beach)

- SS exceeded the REHV during more than 80% of sampling events, resulting in grade *D*
- Oxidised nitrogen and turbidity exceeded their respective REHVs during 50-80% of sampling events, resulting in grade *C*
- Ammonia exceeded the REHV during 20-50% of all sample events in the reporting period, resulting in a grade of *B*
- TN was compliant with the REHV during 80-100% of sampling events, while DO, pH and TP were compliant during 100% of sampling events, resulting in each being assigned a grade *A*
- Overall physical-chemical health grade of *B*
- Microbial health grade of *A+*
- Chlorophyll *a* grade of *B*
- Overall waterway health grade of *A*

Site 38 – Hawkesbury River, Sandbrook Inlet

- SS exceeded the REHV during more than 80% of sampling events, resulting in grade *D*
- TN and turbidity exceeded their respective REHVs during 50-80% of sampling events, resulting in grade *C*
- Oxidised nitrogen exceeded the REHV during 20-50% of all sample events in the reporting period, resulting in a grade of *B*
- DO and ammonia were compliant with their respective REHVs during 80-100% of sampling events, while pH and TP were compliant during 100% of sampling events, resulting in each being assigned a grade *A*
- Overall physical-chemical health grade of *B*
- Microbial health grade of *A+*
- Chlorophyll *a* grade of *C*
- Overall waterway health grade of *B*

Site 103 – Hawkesbury River, Milsons passage

- SS exceeded the REHV during all sample events, resulting in grade *F*
- Oxidised nitrogen turbidity, ammonia and TN exceeded their respective REHVs during 50-80% of sampling events, resulting in a grade of *C* each
- TP was compliant with the REHV during 80-100% of sampling events, while DO and pH were compliant during 100% of sampling events, resulting in each being assigned a grade *A*
- Overall physical-chemical health grade of *C*
- Microbial health grade of *A+*
- Chlorophyll *a* grade of *B*
- Overall waterway health grade of *B*

Site 151 – Hawkesbury River, Bar Island

- SS and oxidised nitrogen exceeded their respective REHVs during more than 80% of sampling events, resulting in grade *D*
- TN exceeded the REHV during 50-80% of sampling events, resulting in grade *C*
- DO, turbidity and ammonia exceeded their respective REHVs during 20-50% of all sample events in the reporting period, resulting in a grade of *B* each
- TP was compliant with the REHV during 80-100% of sampling events, while pH was compliant during 100% of sampling events, resulting in each being assigned a grade *A*
- Overall physical-chemical health grade of *B*
- Microbial health grade of *A+*
- Chlorophyll *a* grade of *B*
- Overall waterway health grade of *B*

Site 48 – Marramarra Creek

- SS, ammonia and TN exceeded their respective REHVs during more than 80% of sampling events, resulting in a grade of *D* each
- Oxidised nitrogen and DO exceeded their respective REHVs during 50-80% of sampling events, resulting in grade *C*
- Turbidity exceeded the REHV during 20-50% of all sample events in the reporting period, resulting in a grade of *B*
- pH and TP were compliant with their respective REHVs during 80-100% of sampling events, resulting in each being assigned a grade *A*
- Overall physical-chemical health grade of *C*
- Microbial health grade of *A+*
- Chlorophyll *a* grade of *C*
- Overall waterway health grade of *B*

Site 61 – Berowra Creek, Calabash Bay

- TN exceeded the REHV during all sample events, resulting in grade *F*
- Oxidised nitrogen and TP exceeded their respective REHVs during 50-80% of sampling events, resulting in grade *C*
- DO, SS and ammonia exceeded their respective REHVs during 20-50% of all sample events in the reporting period, resulting in a grade of *B* each

- Turbidity was compliant with the REHV during 80-100% of sampling events, while pH was compliant during 100% of sampling events, resulting in each being assigned a grade *A*
- Overall physical-chemical health grade of *B*
- Microbial health grade of *A+*
- Chlorophyll *a* grade of *D*
- Overall waterway health grade of B

Site 60 – Berowra Waters

- TN exceeded the REHV during all sample events, resulting in grade *F*
- Oxidised nitrogen, DO and ammonia exceeded their respective REHVs during 50-80% of sampling events, resulting in grade *C*
- TP and SS exceeded their respective REHVs during 20-50% of all sample events in the reporting period, resulting in a grade of *B* each
- pH was compliant with the REHV during 80-100% of sampling events, while turbidity was compliant during 100% of sampling events, resulting in each being assigned a grade *A*
- Overall physical-chemical health grade of *C*
- Microbial health grade of *A+*
- Chlorophyll *a* grade of *C*
- Overall waterway health grade of *B*

Site 100 – Berowra Creek, Crosslands Reserve

- TN, oxidised nitrogen and ammonia exceeded their respective REHVs during all sample events, resulting in grade *F*
- TP and DO exceeded their respective REHVs during 50-80% of sampling events, resulting in grade *C*
- SS exceeded the REHV during 20-50% of all sample events in the reporting period, resulting in a grade of *B*
- pH was compliant with the REHV during 80-100% of sampling events, while turbidity was compliant during 100% of sampling events, resulting in each being assigned a grade *A*
- Overall physical-chemical health grade of *C*
- Microbial health grade of *A+*
- Chlorophyll *a* grade of *A*
- Overall waterway health grade of *B*

Site 152 – Hawkesbury River, Courangra Point

- Oxidised nitrogen exceeded the REHV during all sample events, resulting in grade *F*
- TN exceeded the REHV during more than 80% of sampling events, resulting in grade *D*
- SS and ammonia exceeded their respective REHVs during 50-80% of sampling events, resulting in grade *C*
- Turbidity, DO and TP exceeded their respective REHVs during 20-50% of all sample events in the reporting period, resulting in a grade of *B* each
- pH was compliant with the REHV during 100% of sampling events, resulting in each being assigned a grade *A*
- Overall physical-chemical health grade of *C*
- Microbial health grade of *A+*
- Chlorophyll *a* grade of *A*
- Overall waterway health grade of *B*

Site153 – Hawkesbury River, Laughtondale

- SS and TN exceeded their respective REHVs during all sample events, resulting in grade *F*
- Oxidised nitrogen and turbidity exceeded their respective REHVs during more than 80% of sampling events, resulting in grade *D*
- TP, ammonia and DO exceeded their respective REHVs during 20-50% of all sample events resulting in a grade of *B* each
- Turbidity was compliant with the REHV during 80-100% of sampling events, resulting in grade *A*
- Overall physical-chemical health grade of *C*
- Microbial health grade of *A+*
- Chlorophyll *a* grade of *D*

- Overall waterway health grade of C

Overall, the health grades at all estuarine sites are relatively good, with three *A*'s, nine *B*'s and one *C*. Water quality declined with distance upstream of each arm of the tributary creeks, i.e. Berowra and Marramarra Creeks, as well as with distance upstream the Hawkesbury River. This is likely a result of the influence of tributary input from polluted rivers in the upstream stretches, and better water quality at sites with greater exposure to tidal movements downstream (Roy, Williams et al. 2001).

Table 8.13: *Physical-chemical grades for estuarine sites calculated for each parameter sampled throughout the reporting period. Parameters include turbidity), dissolved oxygen (DO), pH, electrical conductivity (EC), suspended solids (SS), ammonia (NH3-N), oxidised nitrogen (NOx-N), total nitrogen (TN), and total phosphorus (TP). Overall physical chemical grades and microbial grade, and overall waterway health grades (WHG) for each site are also included for each site (bold borders). Sites are listed in order of relative distance from the mouth of the estuary, first along the Berowra Creek arm, then upstream the Hawkesbury River.*

Sites		Physical-Chemical Grades								Site Grades			WHG
Number	Waterway	Turbidity	DO	pH	SS	NH_3-N	NOx-N	TN	TP	**Phys-Chem**	**Microbial**	**Chl *a***	**Overall**
150	Hawkesbury River, Gunya Point	A	A	A	C	B	C	B	A	**B**	**A+**	**A**	**A**
55	Hawkesbury River, Brooklyn Baths	C	A	A	F	B	C	B	A	**B**	**A+**	**A**	**A**
174	Hawkesbury River, Mullet Ck	C	A	A	D	B	D	B	A	**B**	**A+**	**B**	**B**
108	Hawkesbury River, Dangar Island (Bradley's Beach)	C	A	A	D	B	C	A	A	**B**	**A+**	**A**	**A**
38	Hawkesbury River, Sandbrook Inlet	C	A	A	D	A	B	C	A	**B**	**A+**	**C**	**B**
103	Hawkesbury River, Milsons Passage	C	A	A	F	C	C	C	A	**C**	**A+**	**B**	**B**
151	Hawkesbury River, Bar Island	B	B	A	D	B	D	C	A	**B**	**A+**	**B**	**B**
48	Marramarra Ck	B	C	A	D	D	C	D	A	**C**	**A+**	**C**	**B**
61	Berowra Creek, near Calabash Bay	A	B	A	B	B	C	F	C	**B**	**A+**	**D**	**B**
60	Berowra Waters	A	C	A	B	C	C	F	B	**C**	**A+**	**C**	**B**
100	Berowra Ck, Crosslands Reserve	A	C	A	B	F	F	F	C	**C**	**A+**	**A**	**B**
152	Hawkesbury River, Courangra Point	B	B	A	C	C	F	D	B	**C**	**A+**	**B**	**B**
153	Hawkesbury River, Laughtondale	D	B	A	F	B	D	F	B	**C**	**A+**	**D**	**C**

8.8.2 Health Grades Through Time

Most sites have remained stable over the last three reporting periods, with 9 out of 13 sites holding the same health grade. Sites at Gunya Point (150), Brooklyn Baths (55) and Dangar Island (108) all maintained a grade of *A*, and sites at Mullet Creek (174), Sandbrook Inlet (38), Calabash bay (61), Berowra Waters (60), Crosslands Reserve (100) and Courangra Point (152) all remained a grade *B***.**

Health grades improved at Bar Island (151), increasing from a grade *C* in 2013-14 to *B* in 2014-15 and 2015-16, whereas the waterway health has been fluctuating at Marramarra Creek (48) from *B to C and back to B,* and inversely at Laughtondale (153) from *C to B and back to C* consecutively throughout the last three reporting periods.

***Table 8.14:** Comparisons of waterway health grades through three reporting periods; 2013-14, 2014-15, and 2015-16 for estuarine sites*

Sites		Waterway Health Grade		
Number	Waterway	2015-16	2014-15	2013-14
150	Hawkesbury River, Gunya Point	A	A	A
55	Hawkesbury River, Brooklyn baths	A	A	A
174	Mullet Ck	B	B	B
108	Hawkesbury River, Dangar Island (Bradley's Beach)	A	A	A
38	Hawkesbury River, Sandbrook Inlet	B	B	B
103	Hawkesbury River, Milsons Passage	B	A	A
151	Hawkesbury River, Bar Island	B	B	C
48	Marramarra Ck	B	C	B
61	Berowra Creek, near Calabash Bay	B	B	B
60	Berowra Waters	B	B	B
100	Berowra Ck, Crosslands Reserve	B	B	B
152	Hawkesbury River, Courangra Point	B	B	B
153	Hawkesbury River, Laughtondale	C	B	C

8.8.3 Phytoplankton

Classes

Overall, cell counts showed a trend of increasing in the warmer months relative to the cooler months, particularly in January (Figure 8.4, 8.5, 8.6, 8.7, 8.8, 8.9, 8.10 and 8.11). This was the case for all of the sites except for Crosslands Reserve (site 100). At this site, there were peaks in counts of almost 500,000 cells/L in August and 600,000 cells/L November 2015 (Figure 8.6). Classes at each site were mostly dominated by Cryptophyceae, which was the most abundant overall at all sites except Crosslands reserve (100), for which it was the second most abundant after Prasinophyceae. The top three most abundant classes at sites were Cryptophyceae, Prasinophyceae and Prymnesiophyceae.

Potentially Harmful

Potentially harmful phytoplankton species were present at all sites throughout the year, though usually at relatively low concentrations (Figures 8.4b, 8.5b, 8.6b, 8.7b, 8.8b, 8.9b, 8.10b and 8.11b, Table 8.15). Potential harmful phytoplankton cell concentrations did not exceed trigger values in the reporting period at Crosslands Reserve (100), Bar Island (151), Courangara Point (152), Laughtondale (153) or Mullet Creek (174) (Table 8.15).

In February 2016 at Gunya Point (150) (Figure 8.4b, Table 8.15) the concentration of *Pseudo-nitzschia delicatissima* present exceeded trigger values, prompting tissue sampling and testing for shellfish in the region. Around 25% of the phytoplankton species present were potentially harmful to humans.

Sites located in Berowra Waters (60) and near Calabash Bay (61) both consistently had high cell counts in samples taken throughout summer and autumn (Figures 8.8 and 8.7). At Berowra Waters, *Alexandrium minutum,* and *Gymnodinium catenatum* exceeded trigger values in November and December 2015, respectively. *Dinophysis caudata* was present in concentrations greater than trigger values in March, April and May 2016 (Table 8.15).

Three potentially harmful phytoplankton species were present in high concentrations in December 2015 at Berowra Creek Calabash Bay. *Alexandrium minutum*, *Dinophysis acuminata* and *Gynodium catenatum* were present in concentrations greater than their respective trigger values. *Alexandrium minutum* was detected at high concentrations in November and December 2015, and April 2016, *Dynophysis caudata* in February, March April and May of 2016, *Psuedo-nitzchia multistiata* in April 2016, and *Gynodium impudicua* in March 2016 (Table 8.15). Around 80% of the phytoplankton community consisted of potentially harmful species in May 2016 at this site (Figure 8.7).

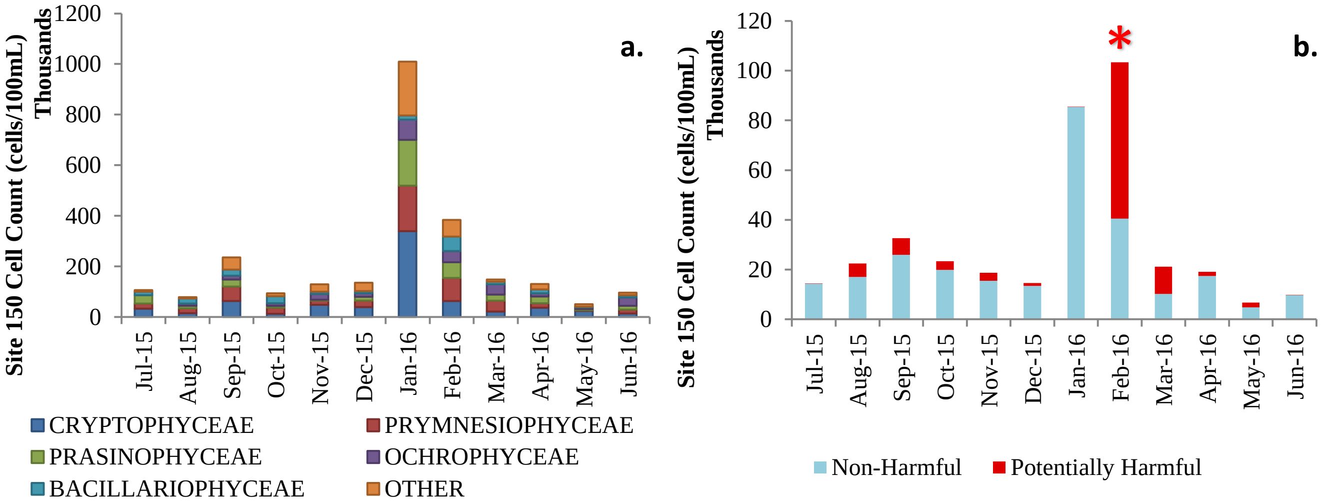

Figure 8.4: *Two plots depicting phytoplankton dynamics at site 150 –Hawkesbury River, Gunya Point. Five dominant classes are presented (a), where the class with the highest proportion is represented by the darkest blue and the lowest cell count of the top five in the second lightest blue colour. All other classes present are represented in* OTHER *in the lightest blue. Potentially harmful phytoplankton species (red) are plotted against non-harmful species (blue) (b). Asterisks indicate the occurrence of a harmful bloom above trigger values set by the NSW Food Authority.*

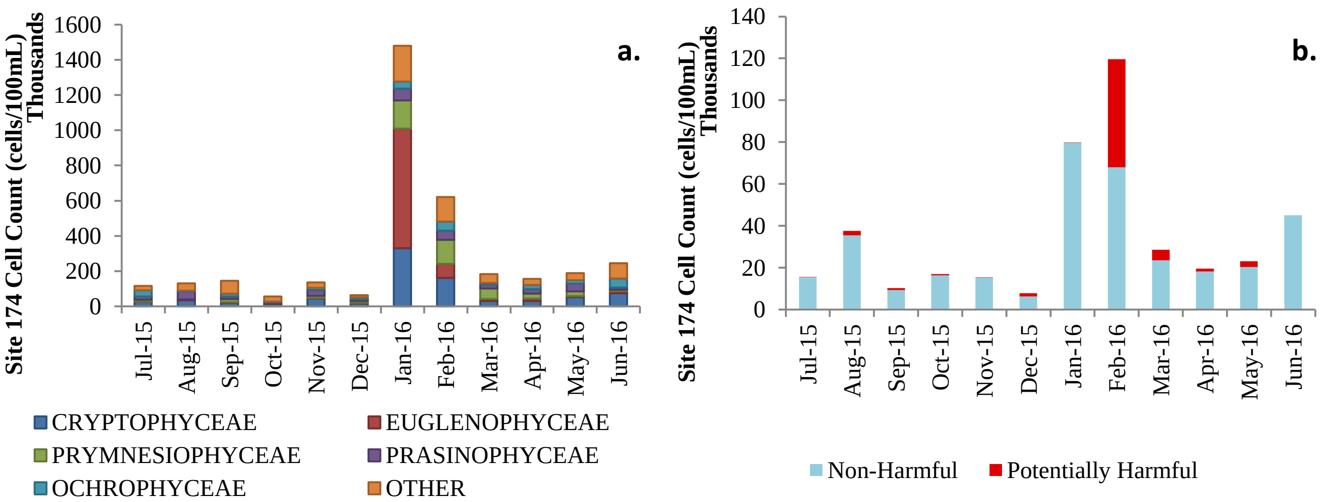

Figure 8.5: *Two plots depicting phytoplankton dynamics at site 174 –Mullet Creek. Five dominant classes are presented (a), where the class with the highest proportion is represented by the darkest blue and the lowest cell count of the top five in the second lightest blue colour. All other classes present are represented in* OTHER *in the lightest blue. Potentially harmful phytoplankton species (red) are plotted against non-harmful species (blue) (b).*

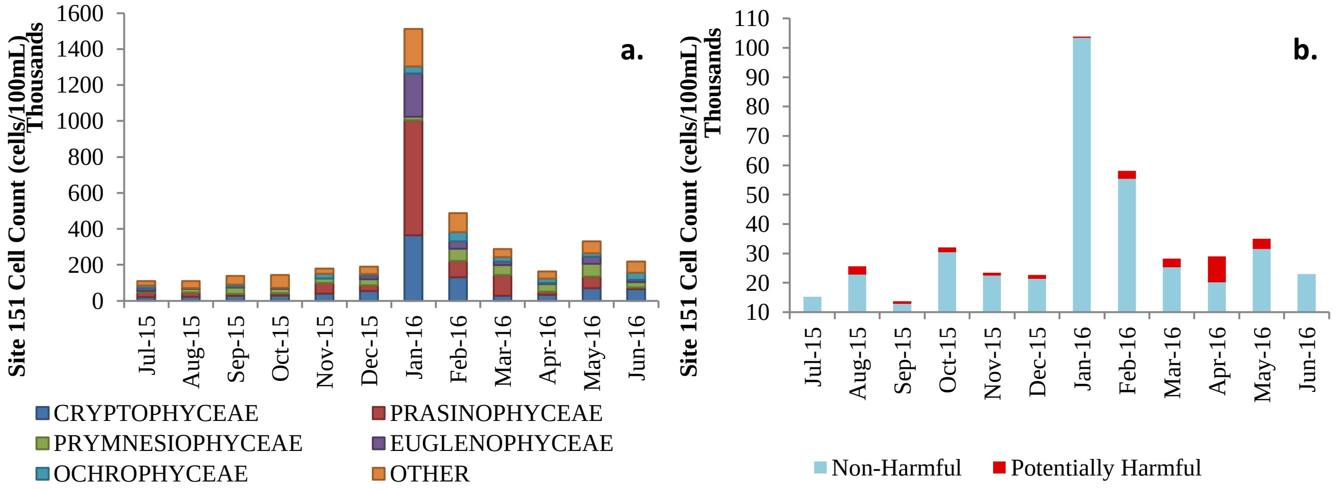

Figure 8.6: Two plots depicting phytoplankton dynamics at site 151 –Hawkesbury River, Bar Island. Five dominant classes are presented (a), where the class with the highest proportion is represented by the darkest blue and the lowest cell count of the top five in the second lightest blue colour. All other classes present are represented in OTHER in the lightest blue. Potentially harmful phytoplankton species (red) are plotted against non-harmful species (blue) (b).

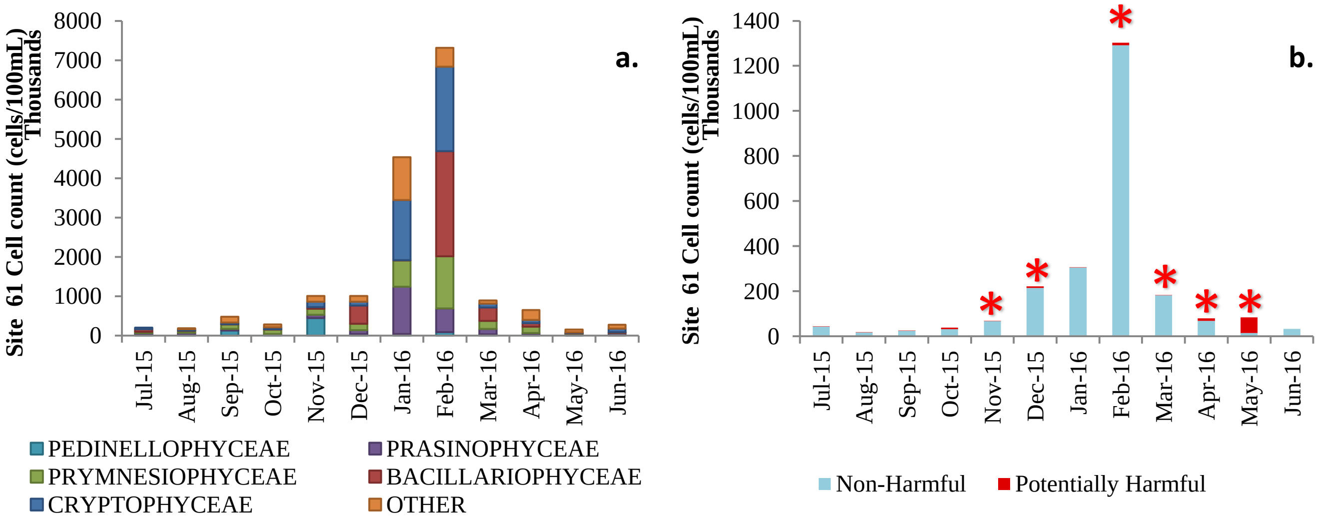

Figure 8.7: Two plots depicting phytoplankton dynamics at site 61 – Berowra Creek, Calabash Bay. Five dominant classes are presented (a), where the class with the highest proportion is represented by the darkest blue and the lowest cell count of the top five in the second lightest blue colour. All other classes present are represented in OTHER in the lightest blue. Potentially harmful phytoplankton species (red) are plotted against non-harmful species (blue) (b). Asterisks indicate the occurrence of a harmful bloom above trigger values set by the NSW Food Authority.

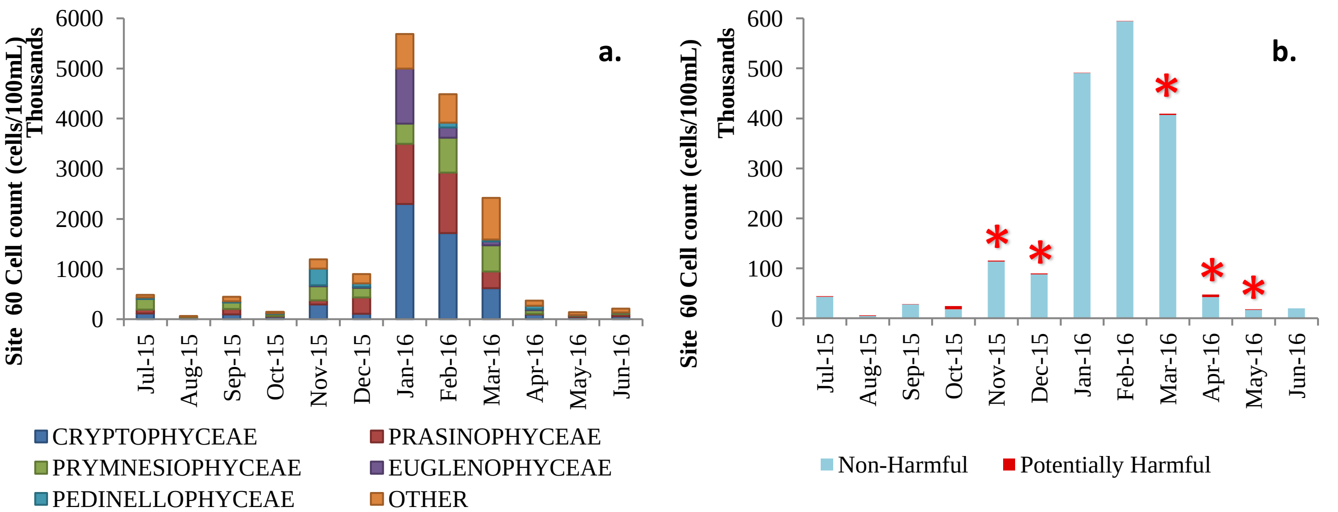

Figure 8.8: Two plots depicting phytoplankton dynamics at site 60 – Berowra Waters. Five dominant classes are presented (a), where the class with the highest proportion is represented by the darkest blue and the lowest cell count of the top five in the second lightest blue colour. All other classes present are represented in OTHER in the lightest blue. Potentially harmful phytoplankton species (red) are plotted against non-harmful species (blue) (b). Asterisks indicate the occurrence of a harmful bloom above trigger values set by the NSW Food Authority.

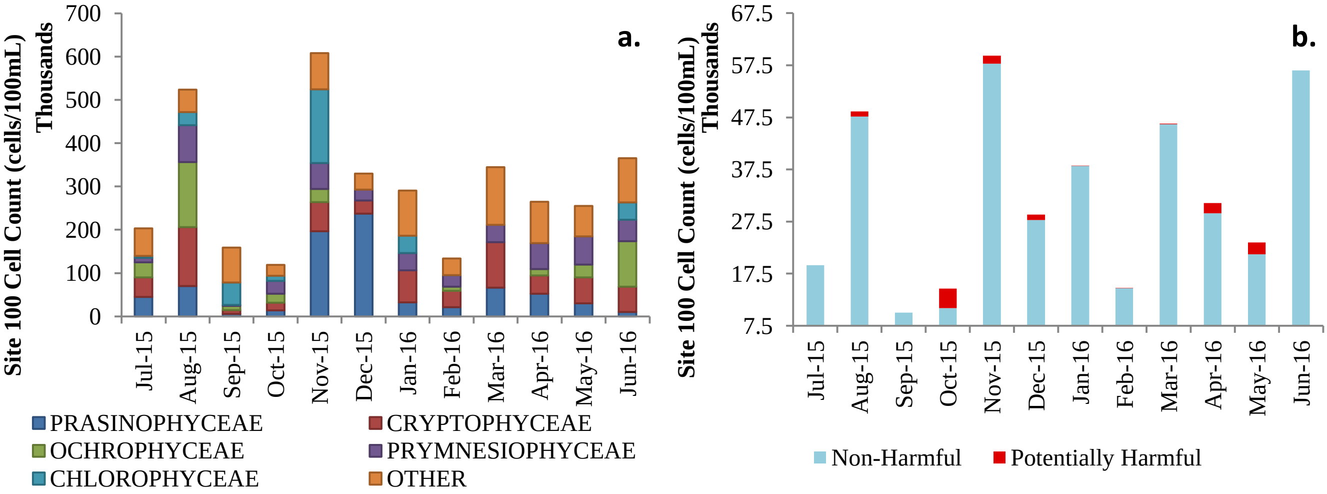

Figure 8.9: *Two plots depicting phytoplankton dynamics at site 100 – Berowra Creek, Crosslands Reserve. Five dominant classes are presented (a), where the class with the highest proportion is represented by the darkest blue and the lowest cell count of the top five in the second lightest blue colour. All other classes present are represented in* OTHER *in the lightest blue. Potentially harmful phytoplankton species (red) are plotted against non-harmful species (blue) (b).*

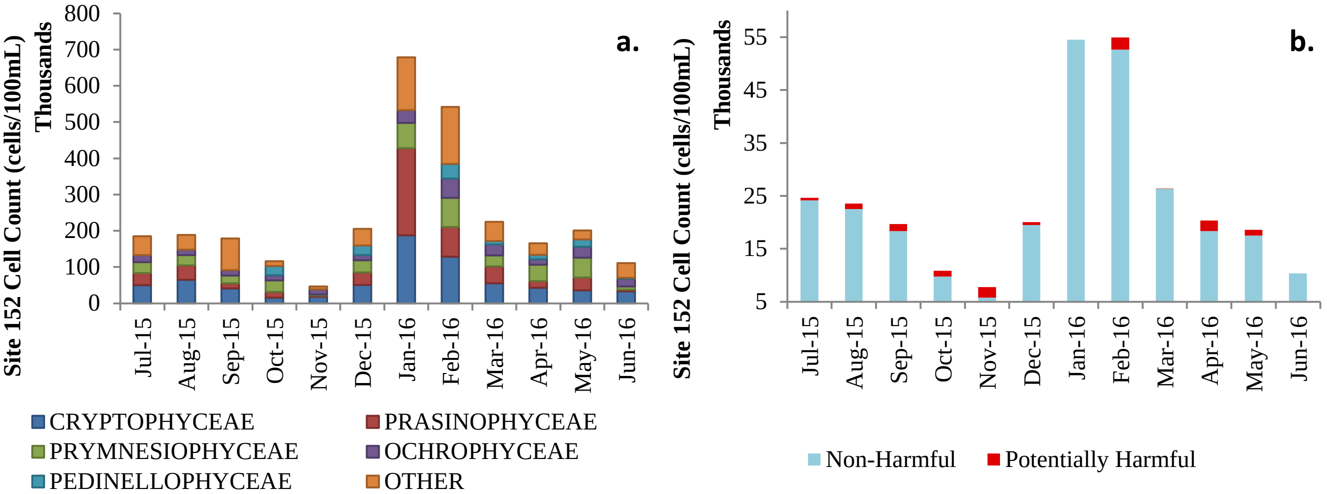

Figure 8.10: *Two plots depicting phytoplankton dynamics at site 152 –Hawkesbury River, Courangra Point. Five dominant classes are presented (a), where the class with the highest proportion is represented by the darkest blue and the lowest cell count of the top five in the second lightest blue colour. All other classes present are represented in* OTHER *in the lightest blue. Potentially harmful phytoplankton species (red) are plotted against non-harmful species (blue) (b).*

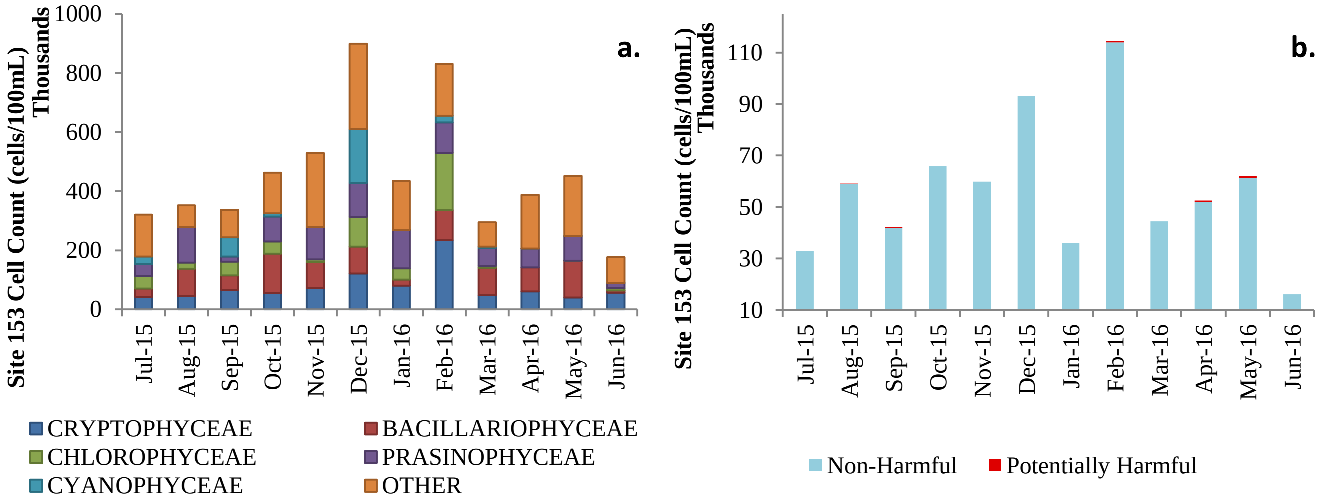

Figure 8.11: *Two plots depicting phytoplankton dynamics at site 153 –Hawkesbury River, Laughtondale. Five dominant classes are presented (a), where the class with the highest proportion is represented by the darkest blue and the lowest cell count of the top five in the second lightest blue colour. All other classes present are represented in* OTHER *in the lightest blue. Potentially harmful phytoplankton species (red) are plotted against non-harmful species (blue) (b).*

Table 8.15: *Occurrence of potentially harmful species of phytoplankton at sites during sampling events. Red squares indicate the presence of potentially harmful species at sites throughout the reporting period, at concentrations greater than the trigger value for tissue sampling of shellfish set by the NSW Food Authority (Category A only). Orange squares indicate at which sites potentially harmful species were present throughout the reporting period. Sites are listed in order of relative distance from the mouth of the estuary, first along the Berowra Creek arm, then upstream the Hawkesbury River.*

Category of Harmfulness Potential	Genus	Species	Trigger Value: tissue sampling (cells/L)	Site numbers							
				150	174	151	061	060	100	152	153
A Amnesic/ Paralytic/ Diarrhetic/ Shellfish Poisoning	***Alexandrium***	*catenella*	200	Orange	Orange	Orange				Orange	
		minutum	200		Orange		Red	Red		Orange	
	Dinophysis	*acuminata*	1000	Orange	Orange		Red	Orange	Orange	Orange	
		caudata	500	Orange	Orange	Orange	Red	Red	Orange	Orange	
	Gymnodinium	*catenatum*	1000			Orange	Red	Red			
		impudicum	1000				Red				
	Phalachroma/Dinophysis	*rotundata*	500	Orange	Orange	Orange	Orange	Orange	Orange	Orange	
	Pseudo-nitzschia	*delicatissima (group)*	500,000	Red	Orange	Orange	Orange	Orange		Orange	
		fraudulenta	50,000	Orange	Orange	Orange	Orange	Orange		Orange	
		fraudulenta/australi	50,000								
		multistriata	50,000	Orange	Orange	Orange	Red	Orange	Orange	Orange	
		pungens/multiseries	50,000	Orange	Orange	Orange	Orange	Orange	Orange	Orange	
		turgidula/dolorosa	50,000	Orange	Orange	Orange	Orange				
B Toxicity Unclear	***Alexandrium***	*pseudogonyaulax*		Orange			Orange	Orange			
	Chattonella	*sp.*					Orange	Orange	Orange		
	Heterosigma	*akashiwo*		Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange
	Pseudochattonella	*sp.*		Orange							
	Pseudo-nitzschia	*americana (group)*		Orange	Orange	Orange					
		subpacifica/heimii		Orange	Orange	Orange					
C Potential Toxin Producer	***Cochlodinium***	*spp.*		Orange	Orange	Orange	Orange	Orange		Orange	Orange
	Dictyocha	*octonaria*		Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange
	Karenia	*mikimotoi*					Orange	Orange			
		sp.		Orange	Orange	Orange	Orange	Orange		Orange	
	Karlodinium	*spp.*		Orange	Orange	Orange	Orange	Orange	Orange	Orange	
	Lepidodinium	*chlorophorum*					Orange				
	Lingulodinium	*polyedrum*				Orange	Orange	Orange	Orange	Orange	
	Mesoporus	*perforatus*				Orange					Orange
	Prorocentrum	*minimum/cordatum*		Orange	Orange	Orange	Orange	Orange	Orange	Orange	Orange
	Pseudochattonella	*spp.*				Orange					
D Toxicity Unlikely	***Alexandrium***	*fraterculus*		Orange	Orange						
		margalefi				Orange	Orange	Orange			Orange
	Prorocentrum	*dentatum*				Orange	Orange	Orange			
		lima var. marina			Orange						

8.9 Landfill Remediation

8.9.2 Arcadia Oval

Each water quality parameter measured decreased in value from the untreated to treated tanks (Table 8.16).

- EC reduced slightly in treated leachate
- Turbidity and suspended solids decreased substantially in the treated leachate from untreated leachate in both sampling events 1 and 2. Turbidity was reduced 8-fold in sampling event 2.
- DO was considerable low in all samples taken. Stagnant leachate is stored in tanks with no access to sunlight and as such no aquatic plant growth or water circulation allows for the input of oxygen into the water body.
- pH increased slightly from untreated to treated water.
- Ammonia and TN both decreased slightly after the treatment process.
- Oxidised nitrogen increased with treatment
- TP decreased slightly in sample event 1, and increased slightly in sample event 2.
- Faecal coliforms were reduced substantially with the treatment process

Table 8.16: *Two sampling events occurred this reporting period at Arcadia Oval (1 and 2). Raw data is supplied in the table for untreated (18) and treated (94) leachate from the disused Arcadia tip. Data is shown for electrical conductivity (EC), turbidity, dissolved oxygen (DO), pH, suspended solids (SS), ammonia (NH3-N), oxidised nitrogen (NOx), total nitrogen (TN), total phosphorus (TP) and faecal coliforms (FC).*

Variable	Unit	Sample Event 1		Sample Event 2	
		18 - Untreated	94 - Treated	18 - Untreated	94 - Treated
EC	mS/cm	1.63	1.54	1.2	1.1
Turbidity	NTU	1.7	0.2	3.5	0.5
DO	% sat	11.4	45.3	3.9	4.9
pH	units	6.96	7.77	6.98	7.62
SS	mg/L	7	1	2	1
NH3-N	mg/L	32.5	26.5	11.8	9.3
NOx-N	mg/L	2.5	3.7	4.1	6.8
TN	mg/L	38.1	32	17.2	16.4
TP	mg/L	0.025	0.021	0.008	0.015
FC	CFU/ 100mL	2	0.5	7	0.5

8.9.1 Foxglove Oval, Mt Colah

Leachate Treatment

The leachate treatment process at Foxglove Oval successfully improves water quality with respect to REHVs (Table 8.17). TP and SS are both compliant with stormwater harvesting and irrigation trigger values throughout the entire treatment process, whereas turbidity and EC decreased to less than the trigger values in the mid-treated leachate (96a, after passing through the bioreactors). Faecal coliforms were also improved from concentrations greater than the trigger value detected at site 95 to less than the trigger value at 96a, remaining compliant in the fully treated irrigation water. In the treated irrigation water (132), all parameters were compliant with their respective trigger values in all samples taken, except faecal coliforms, which was compliant during 80-100% of sampling events.

Environmental Water Quality

Data from the monitoring of water quality parameters at Gleeson Creek (77) indicates poor health of the creek (Table 8.17). Nitrogen in the form of ammonia, oxidised nitrogen and total nitrogen exceeded the trigger values indicating degradation of water quality during all sampling events. DO was persistently low, meeting the lower REHV threshold of 75% saturation during up to 20% of sampling events. EC and turbidity were compliant with REHVs during 0-20% and 50-80% of sampling events, respectively. The elevated faecal coliforms suggest that there may be some contamination within the catchment of the creek.

***Table 8.17**: Summary statistics for sites at Foxglove Oval, Mt Colah. Sites 95, 96a and 132 are assessed against trigger values for stormwater harvesting and irrigation, and site 77 is assessed against trigger values for environmental health of a creek or river. Trigger values for faecal coliforms (FC) are given for median (med) and 80th percentile (80%) values. Summary statistics are presented for total phosphorus (TP), turbidity, faecal coliforms (FC), suspended solids (SS), electrical conductivity (EC), dissolved oxygen (DO) pH, ammonia (NH3), and oxidised nitrogen (NOx). Site 96a had one set of results; as such the data points are presented instead of summary statistics.*

		Variable	Units	N	Value	Mean	Median	Min	Max	20%	80%	Std. Dev.	Trig. value	Comp (%)
Foxglove Oval, Mt Colah	. 95 - Untreated Leachate	TP	mg/L	9		0.028	0.030	0.017	0.045	0.018	0.033	0.009	0.8	100
		Turb	NTU	11		70.38	63.00	13.30	127	40.80	116.12	38.17	10	0
		FC	CFU/100ml	10		18.25	3.50	0.50	120	0.50	21.50	36.98	10	50-80
		SS	mg/L	6		14	13.50	3	32.00	7	15	9.96	50	100
		EC	µS/ cm			2191	2148	2019	2527	2049	2320	169	2000	0
	96a - Mid-Treated Leachate	TP	mg/L	1	0.015								0.8	100
		Turb	NTU	1	5.8								10	100
		FC	CFU/ 100ml	1	2								10	100
		SS	mg/L										50	-
		EC	µS/ cm	1	1901								2000	100
	132 - Treated: Irrigation Water	TP	mg/L	9		0.008	0.004	0.002	0.030	0.002	0.017	0.009	0.8	100
		Turb	NTU	10		0.47	0.20	0	1.40	0.10	1.10	0.53	10	100
		FC	CFU/ 100ml	9		6.00	0.50	0.50	50.00	0.50	0.50	16.50	10	80-100
		SS	mg/L	5		1	1	1	1	1	1	0	50	100
		EC	µS/ cm	10		582	245	230	1963	236	600	700	2000	100
	77 - Receiving Creek, Gleeson Creek	EC	mS/ cm	12		0.78	0.76	0.10	1.41	0.56	1.23	0.39	0.32	0-20
		Turb	NTU	12		5.88	3.70	1.60	19.10	3.00	9.30	4.89	8	50-80
		DO	%sat	12		51.89	50.76	22.40	84.40	28.00	69.20	20.75	75-118	0-20
		pH		12		7.57	7.54	7.35	7.86	7.39	7.75	0.18	4.8-7	0
		SS	mg/L	12		1.92	1.00	1.00	6.00	1.00	3.00	1.62	7	100
		NH3	mg/L	12		12.58	8.82	0.32	33.80	3.70	21.30	11.32	0.02	0
		NOx	mg/L	12		7.77	7.94	2.35	14.50	4.90	10.20	3.87	0.05	0
		TN	mg/L	12		21.94	18.20	3.01	54.80	9.67	36.00	16.08	0.32	0
		TP	mg/L	12		0.025	0.023	0.011	0.060	0.017	0.030	0.013	0.010	0
		FC	CFU/ 100ml	12		2185.3	300	80	20000	120	1500	5656.2	Med 150, 80% 600	0

9.0 Impact of Land use on Water Quality

When comparing physical-chemical and microbial grades for each site, it becomes apparent that different land uses place different pressures on local creeks and streams. The best water quality was found at reference sites. The sites where the poorest water quality was detected were located within catchments of industrial use, followed by urban areas, rural areas, and estuarine sites.

All references sites were assigned A and B grades for physical-chemical health, and A's and A+'s for microbial health, indicating healthy systems with excellent water quality. Contrastingly 100% of sites located in the most stressed systems, creeks with industrial activity within their catchments, were moderately to severely degraded in terms of physical-chemical and microbial health. The sites within urban catchments were slightly improved in comparison to industrial sites, where 83% of urban creeks were moderately to severely degraded for both overall physical-chemical and microbial indicators.

Industrial and urban landscapes are largely altered from natural, vegetated environments. These areas typically have a high percentage of impervious surfaces which results in high volumes rainfall run off directly accessing creeks. Further, there is often very little riparian vegetation of the edge of streams to filter contaminants from the inflowing water. Industrial run off into local creeks has been found to result in the degradation of water quality through increased sedimentation, concentration of ions (EC), flow volume and depth of streams (Nedeau, Merritt et al. 2003). Sedimentation results in an altered stream bed, where cobbled and rocky beds are smothered with sand and silt. This subsequently disrupts the macroinvertebrate and aquatic plant communities, negatively impacting on the ecosystem health and functioning.

The water quality in streams located in catchments of rural activity was moderately to severely degraded in terms of physical-chemical health at 57% of sites, and 43% of sites in terms of microbial health. The overall water quality of these sites surpassed that of creeks affected by urban and industrial activity.

Estuarine sites were found to have the best water quality, with the exception of reference sites. Ninety-two percent of estuarine waterway health grades were good (*A* or *B*), with only one site graded a *C*. Generally, the water quality grades decreased with distance upstream from the mouth of the estuary. Water quality may be related to proximity of the testing site to the mouth of the estuary, upstream sites are more heavily influenced by river inflows and catchment activity, and downstream sites are heavily influenced by tidal flushing (Roy, Williams et al. 2001).

Inflowing water from creeks and streams is likely to influence the water quality in the upstream regions of Berowra Creek and Marramarra Creek. For example, the persistently high concentrations of nutrients detected at Berowra Creek (1) upstream of the tidal limit may be contributing to the high nutrient concentrations detected further downstream in Berowra Creek at Crosslands Reserve (100). Further, the high concentrations of nutrients detected at Berowra Creek at Berowra Waters (61) and Calabash Bay (60) is likely to be influencing the regular algal blooms (Anderson, Glibert et al. 2002).

All freshwater sites were consistently more alkaline (higher pH) than reference sites, likely due to the differing geomorphology reference sites from other freshwater sites monitored in the Water Quality

Program. This should be considered when interpreting results and health grades of freshwater sites.

Overall, consistently poor physical-chemical grades were assigned as a result of data for parameters of EC and nutrients. This highlights the issue of eutrophication and pollution in local waterways, the need to manage catchment land use to control these issues, and the importance of education of residents within the shire about the effects of land management and household effluent on the health of local waterways and ultimately the Hawkesbury River.

10.0 Conclusions

Physical-chemical and biological data collected from waterways in Hornsby Shire indicated that land use in the catchment is a major influence of the water quality in local creeks, and the Hawkesbury River. Industrial and rural activity had the greatest impact on water quality, with rural areas exhibiting an effect to a lesser degree. The overall water quality data from sites located within the estuary indicated a healthy system. At these sites, there were few exceedances of the REHV trigger values for total nitrogen and oxidised nitrogen upstream, typically located further upstream Berowra Creek and the Hawkesbury River from the estuary mouth.

There was a seasonal pattern of phytoplankton abundance made evident by increase in cells counts in warmer, spring and summer months. Toxin-producing species were present at all sites in low concentrations throughout most of the year. Three sites (Berowra water, Berowra Creek near Calabash Bay, and Hawkesbury River at Gunya Point) experienced potentially toxic blooms with cell concentrations greater than NSW Food Authority trigger values prompting tissue sampling and testing for shellfish.

Water quality data from landfill remediation sites indicate that the treatment processes are successful in the treatment of leachate according to stormwater harvesting and irrigation guidelines. Water quality of leachate at Arcadia improved with the treatment process. Gleeson Creek, downstream of Foxglove Oval shows signs of contamination from within its catchment. This could be due to an array of pollution sources and may be investigated.

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12.0 Glossary

Term	Meaning
Water Quality	The chemical, physical and biological characteristics of water
Parameter	A measurable factor of water quality; can be physical (e.g. temperature), chemical (e.g. conductivity) or biological (e.g. presence of macroinvertebrates)
Leachate	Water that has filter through a solid (in this report, landfill contents) and contains dissolved or physical substances from that solid
Turbidity	Measure of light refraction in water, affected by suspended particles
Dissolved Oxygen	The amount of oxygen present in a water body
pH	Measure of acidity or alkalinity of a water body on a scale of 0 (acidic) to 14 (alkaline)
Suspended Solids	Measure of sediment being carried in a water body, usually provided in terms of grams per 100 mL
Electrical Conductivity	Measure of ions (salts) present in a water body
Geomorphology	Characteristics of landform
Riparian Vegetation	Trees, shrubs and bush located in the riparian zone. They are important for river bank stability and to avoid erosion.
Riparian Zone	The interface of land and water, also known as the river bank
Chlorophyll	Pigments present in plants that are used to absorb sunlight for photosynthesis
Phytoplankton	Small, microscopic aquatic plants. Phytoplankton can be unicellular or multicellular and exist as a solitary organism or in colonies.
Catchment	The catchment for a creek or waterbody refers to the area of land that when rain falls, surface water flows into that creek or waterbody
Eutrophication	Surplus nutrients in a waterbody which can lead to rapid and excessive plant growth
Bloom	High density presence of phytoplankton in a waterbody, often resulting from eutrophication and subsequent rapid reproduction
Macroinvertebrate	Also known colloquially as *water bugs*, these are invertebrate fauna that often dwell in the sediment of rivers and lakes
Parameter	A water quality variable or component which is observed and recorded during the reporting period (e.g. temperature, phosphorus etc.).
N	The number of water samples taken or tests conducted at the site during the reporting period for each parameter
Mean	The numerical average of the values for the parameter for the samples taken or tested during the reporting period. The mean value can be biased by extreme values
Median	The middle value of the parameter at a site for all the samples taken or tested during the reporting period. When all the values are sorted into increasing magnitude from lowest to highest (rank order), the median is the middle number if there are uneven number of values, or it is the average of the two central numbers when there is an even number of values
Minimum	The lowest value of the parameter at a site for all the samples taken or tested during the reporting period
Maximum	The highest observed value of a parameter at the during the reporting period
Range	The numerical difference between the minimum and maximum values observed during the reporting period for the parameter
20^{th} Percentile	The statistically calculated value of the parameter above which 80% of all test results occur. Values below the 20^{th} percentile might be considered significantly lower than the average
80^{th} Percentile	The statistically calculated value of the parameter below which 80% of all test results occur Values above the 80^{th} percentile might be considered significantly higher than the average
Standard Deviation	The statistical standard deviation of the values for a parameter for the samples taken or tested during the reporting period. If the standard deviation is high relative to the mean (e.g. turbidity, faecal coliforms) it means the parameter is variable throughout the reporting period. If the standard deviation is low relative to the mean (e.g. pH) it means there is low variability of observed values for the parameter

Appendix A - Detailed site descriptions freshwater and estuarine sites monitored as part of the Water Quality Monitoring Program

Reference Creeks

Site 36 – Murray Anderson Creek.

Site 36 is located in Murray Anderson Creek, with the sampling point just upstream of the tidal influence of Smiths Creek. Murray Anderson Creek is a tributary of Smiths Creek within the Cowan Creek catchment. The catchment for this site is approximately 250 hectares in size, all within Ku-ring-gai Chase National Park. This site has been sampled since 1995.

Site 37 – Smugglers Creek.

The sampling point for this site is located approximately 500 m upstream of the tidal influence of Marramarra Creek. Smugglers Creek is a tributary of Marramarra Creek within the Berowra Creek catchment. The catchment for this creek is approximately 533 hectares in size, all within Marramarra National Park. This site has been sampled since 1995.

Site 54 – Laughtondale Creek.

Site 54 is located in Laughtondale Creek on the northern boundary of Marramarra National Park. The catchment is approximately 312 hectares which has about 10% cleared land under horticulture. There is a gravel road running beside the creek for much of its length which, during wet weather, can lead to sedimentation in the creek of coarse sediment eroded from the road. The creek flows through a narrow gully with a series of shallow pools of sandstone bedrock. The site was sampled from 1996 to 2002, with sampling re-commencing in 2011.

Site 114 – Muogamarra Creek.

The sampling point for this site is located approximately 100m upstream of the saltwater marsh of Peats Bight. Muogamarra Creek flows through within Muogamarra Nature Reserve and the catchment for the creek is approximately 305 hectares of undisturbed bushland valley with sandstone geology. The creek has a stable base flow, but surface water may cease in drought conditions, leaving stagnant pools.

Site 123 – Peats Crater Creek.

This site located in an unnamed creek, referred to as *Peats Crater Creek* in this report, in Muogamarra Nature Reserve where the creek flows through a densely shaded gully. It does not have a permanent base flow, drying out occasionally during drought conditions. It has a relatively small catchment size of approximately 90 hectares and was chosen because of it's predominantly basalt geology. The catchment includes exposure of igneous rock in a diatreme. The central part of the valley (Peats Crater) was cleared for farming in the late 1800's, but since the area was declared a Nature Reserve it has been undergoing natural revegetation.

Site 147 – Unnamed Creek.

Site 147 is located in an unnamed creek adjacent to the Pennant Hills Oval complex, and a tributary to Byles Creek. The catchment consists of bushland catchment and is approximately 33 hectares. The creek periodically dries out. It is in sandstone geology and the sample site has wide shallow pools on bare sandstone bedrock.

Site 149 – Duckpond Ridge Creek.

Site 149 is located in an unnamed creek in Canoelands, referred to as *Duckpond Ridge Creek* in this report. It flows through predominantly undisturbed bushland in sandstone geology within Marramarra National Park. The catchment is approximately 760 hectares and is bound by Duckpond Ridge, the Old Northern Road and Canoelands Ridge. Approximately 10% of the catchment along Old Northern Road and Canoelands Road has been cleared for sand extraction and horticulture. The creek at the sample site is in a deep rocky gully, heavily shaded and with sandstone boulders.

Site 164 – Djarra Crossing.

Site 164 is tributary to Joe Crafts Creek in Muogamarra Nature Reserve. The catchment is approximately 90 hectares in size, and consists of undisturbed bushland in sandstone geology. The creek at the sample site is predominantly bare sandstone bedrock open to midday sunlight. Water flow may cease during drought conditions.

Industrial Sites

Site 10 – Larool Creek, Thornleigh.

The headwaters of Larool Creek originate within the Thornleigh industrial area and flow in a northerly direction until it intersects Waitara Creek west of Hornsby. This site is located approximately 100 m downstream from Sefton Road. The catchment is approximately 38 hectares, of which 34% is zoned residential, 51% is zoned commercial/business/industrial, 13% is open space and 2% is special use. This site has been sampled since October 1994.

Site 12 – Hornsby Creek, Hornsby.

The sampling point for this site is located approximately 30 m upstream of the road bridge at Leighton Place and flows into Ku-ring-gai Chase National Park. The catchment above this site is approximately 305 hectares in size and 60% of the land use is residential comprising high, medium and low density residential zonings. Commercial/Industrial/Business makes up 17%, 20% is zoned for special use (roads, rail, community use) and 2% is open space. This highly urbanised catchment contains large areas of impervious surfaces. This site has been sampled since October 1994.

Site 13 – Sams Creek, Mount Kuring-Gai.

This site is located near the headwaters of Sams Creek within Berowra Valley National Park, at the end of Hamley Road, Mt Kuring-Gai. The catchment above this site is approximately 18 hectares with 86% zoned industrial and 14% zoned open space. The area was connected to sewer in 2008 and premises are being progressively connected. Any new development in the area is required to connect to the sewer. Downstream of this sample site the creek flows in a north westerly direction through Berowra Valley National Park for 3km before it joins Berowra Creek. This site has been sampled since October 1994.

Rural Sites

Site 2 – Tunks Creek, Galston Gorge.

Site 2 is located in Tunks Creek, 100 metres upstream of the confluence with Berowra Creek. The catchment area is approximately 1690 hectares with 65% being zoned rural and approximately 30% consisting of open space and environmental protection zones. Sampling commenced at this site in October 1994.

Site 42 – Colah Creek, Glenorie.

Site 42 is located in Colah Creek, upstream of Wylds Road Bridge, Glenorie. The catchment of this creek is approximately 990 hectares, 83% zoned as rural with the remaining areas being a mix of residential, main roads, commercial and open space. Sampling commenced at this site in October 1994.

Site 49 – Still Creek, Arcadia.

Site 49 is located in the upper reaches of Still Creek with a catchment of approximately 440 hectares, 80% of which is zoned rural and 17% is open space. Sampling commenced at this site in October 1994.

Site 62 – Kimmerikong Creek, Cowan.

This site is located in the headwaters of Kimmerikong Creek and receives run off from the Cowan township. The catchment area is estimated to be approximately 11 hectares. Sampling commenced at this site in July 2002.

Site 63 – Colah Creek, Glenorie.

Site 63 is located in Colah Creek upstream of Marramarra National Park. The creek has a catchment of approximately 2290 hectares. Sampling commenced at this site in July 2002.

Site 64 – Unnamed Creek, Galston.

This site is located on an unnamed creek near Sallaway Road in Galston. The creek has a catchment of approximately 145 hectares, which includes Galston township. It is a tributary to Colah Creek.

Site 80 – Glenorie Creek, Glenorie.

Site 80 is located in Glenorie Creek near the corner of Tekopa Ave and Tecoma Drive Glenorie. Sampling commenced at this site in August 1999 to assess the impact of the Glenorie township and residential area with onsite sewage treatment facilities on the water quality of the creek. The catchment area is approximately 100 hectares, encompassing market gardens and small animal farms.

Urban Sites

Site 4 – Berowra Creek, Westleigh.

The site is located upstream of wastewater treatment plants at Hornsby Heights and West Hornsby, with the sampling point in the Berowra Valley National Park. The estimated catchment area for the creek is 1230 hectares. The creek near the sample location is surrounded by predominantly bushland areas. Monitoring started here in October 1994.

Site 5 – Pyes Creek, Cherrybrook.

Pyes Creek at Cherrybrook has a catchment of approximately 380 hectares, of which 79% is zoned residential. The site is located in a section of creek that has extensive patches of exposed bedrock. Monitoring started here in October 1994.

Site 6 – Georges Creek, Cherrybrook.

Site 6 is located within Georges Creek. The catchment is 440 hectares in size with 56% zoned rural, 20% zoned residential and approximately 24% being zoned open space and environmental protection. The site is located adjacent to a gabion wall constructed to retain a sewage pumping station. Monitoring started here in October 1994.

Site 8 – Devlins Creek, Cheltenham.

This site is located in Devlins Creek, adjacent to Sutherland Road at Cheltenham and is about 200m downstream of the crossing of the M2 Motorway. The catchment influencing the water quality at this site is approximately 823 hectares with about 8% falling in the Parramatta City Council area. Almost 77% of this catchment is zoned residential with the remaining 23% consisting of special uses (9%), commercial/industrial and business (1%) and open space (13%). Monitoring started here in October 1994.

Site 39 – Joe Crafts Creek, Berowra.

This site is located in the freshwater section of Joe Crafts Creek, approximately 100 m above the tidal influence of Berowra Creek. The headwaters are located in an urban area and flows through approximately 4 km through bushland before the sample site. The characteristics of the creek near the sampling site include a rocky substrate with large boulders throughout the creek. The estimated catchment area for the creek is 688 hectares. Sampling commenced at this site in October 1994.

Site 181 – Unnamed Creek.

Site 181 is located in a tributary of Terrys Creek at Epping in the Lane Cover River catchment. Part of the creek is piped under the M2 Motorway. The catchment influencing the water quality at this site is approximately 82 hectares, 87% of which is zoned residential. Monitoring started here in October 1994. During the construction and expansion of the M2 motorway it was necessary to relocate this site approximately 200m downstream of the original location (Site 46A).

Estuarine Sites

Site 38 – Sandbrook Inlet.

This site is located in the navigation channel towards the upstream end of Sandbrook Inlet, Brooklyn. This area is heavily influenced by marine industry and is characterised by shallow foreshores with a navigation channel down the middle of the inlet and swing moorings on either side. The Inlet is bound by marina operations and residential development along the southern shore and Long Island Nature Reserve to the north. Sandbrook Inlet is enclosed from the Hawkesbury River at the eastern end, restricting flushing of the water. The Brooklyn area commenced connection to the Brooklyn STP in 2006/07.

Site 48 – Marramarra Creek.

This site is located within Marramarra National Park in the estuarine reaches of Marramarra Creek, adjacent to the old orange orchard. The creek receives runoff from a large area of undisturbed bushland as well as rural developments at Galston, Glenorie, Fiddletown, Arcadia, Forrest Glen and Canoelands. The site has been monitored since October 1994.

Site 55 – Brooklyn Baths, Hawkesbury River.

Brooklyn Baths is a popular recreational area, with an enclosed, netted area for swimming. It is openly connected to the Hawkesbury River.

Site 60 – Berowra Waters, Berowra Creek.

This site is located in the middle of Berowra Creek at Berowra Waters, downstream of the Berowra Ferry crossing. The site is characterised by the ferry crossing, marina operations, swing moorings and residential development along the foreshore. The site has been monitored since 1997.

Site 61 – Calabash Bay, Berowra Creek.

This site is located in Berowra Creek at Calabash Point. The site has a depth of approximately 15m which is subject to regular stratification. In 2002 a remote water quality monitoring probe was deployed to monitor temperature, salinity and chlorophyll *a*, utilised for algal bloom detection (please see the Hawkesbury Estuary Program Annual Reports for more information). This site has been monitored since 1997.

Site 100 – Berowra Creek.

This site is located at the northern beach of Crosslands Reserve, in the upper reaches of Berowra Creek.

Site 103 – Milsons Passage, Hawkesbury River.

This site is located at the eastern end of Milsons Passage where the water quality is influenced by the river side settlement of Milsons Passage.

Site 108 –. Bradleys Beach, Dangar Island, Hawkesbury River.

This site is located off Bradleys Beach, Dangar Island, Hawkesbury River. The site is primarily marine and highly influenced by tidal movement. This is a popular recreational area.

Sites 150 – 153 Hawkesbury River.

Council has deployed a number of remote water quality monitoring buoys along the salinity gradient of the Hawkesbury River estuary, from the freshwater river section upstream near Wisemans Ferry to the marine waters near Gunyah Point. Water quality data collected at these sites includes temperature, salinity and chlorophyll *a* concentrations and is available at www.hornsby.nsw.gov.au/estuary.

Site 174 – Mullet Creek, Hawkesbury River.

This site is located in the mouth of Mullet Creek on the Hawkesbury River. The site is primarily marine and highly influenced by tidal movement. This location is an oyster growing area.

Wastewater Treatment Plant

Hornsby Heights Wastewater Treatment Plant

Site 52 – Calna Creek.

This site is located in Calna Creek about 300 m above the HHWTP discharge point. The water quality at site 52 allows a comparison to be made with water downstream of the WTP to determine the impact of the plant effluent on water quality. The catchment area influencing the water quality at this site is approximately 280 hectares with 59% zoned residential. Monitoring started here in November 1995.

Site 43 – Calna Creek.

Site 43 is located in the freshwater section of Calna Creek 4km downstream of the HHWTP discharge point, and approximately 1km upstream of the confluence with the estuarine section of Berowra Creek. the catchment for this creeks is approximately 1060 hectares. The section of the creek surrounding the sampling locations is shaded by riparian vegetation and has a substrate consisting of large sandstone boulders. Dry weather flows in Calna Creek are dominated by WTP discharge which typically contains high levels of oxidised nitrogen. Monitoring started here in October 1994.

West Hornsby Wastewater Treatment Plant

Site 23 – Waitara Creek.

Site 23 is located approximately 100 metres upstream of the WHWTP discharge point. The total catchment area for this site is approximately 650 hectares of which 58% is zoned residential, 19% is zoned special uses, 18% is zoned open space and 5% is zoned commercial. Monitoring started here in October 1994.

Site 45 – Fishponds, Berowra Creek.

This site is located in the Berowra Valley Regional Park and is influenced by the catchments of upper Berowra Creek, and receives inflows from Waitara Creek, Pyes and Georges Creeks. The site is located approximately 1 km downstream of the discharge point of WHWTP, which discharges into Waitara Creek. The catchment influencing the water quality at this this site is approximately 3370 hectares of which 12% is zoned rural, 46% is zoned residential, 3% is zoned industrial/commercial/business, 10% is special uses, 9% is open space, 3% is environmental protection and 17% is national parks and reserves. Monitoring started here in October 1994.

Site 1 – Berowra Creek.

Berowra Creek at Galston Gorge is sampled approximately 500 m downstream of the Galston Road bridge, and approximately 5.7 km downstream from the discharge point of WHWTP. The catchment influencing the water quality at this site is approximately 5550 hectares, with 30% zoned rural, 33% residential and 19% national parks and reserves. Other land uses in the catchment include open space, industrial/commercial/business, special uses and environmental protection. Monitoring started here in November 1994.

Landfill Remediation

Arcadia Landfill (Sites 18 and 94).

The Arcadia landfill near Arcadia Park was remediated in 1997/1998 by clay capping. Water management included separation of stormwater seepages. The captured leachate is collected in underground tanks (Site 18) and treated using a trailer-mounted bioreactor (Site 94). Water is tested at two sites to assess the effectiveness of seepage collection and the bioreactor performance.

Foxglove Oval, Mt Colah (Sites 95, 96a, 132, and 77).

Foxglove oval was initially operated as a landfill site which closed in 1980. The landfill site was compacted, capped and converted into an oval in 1985. In the 1990’s Council installed a water quality treatment process to reduce the impacts of the leachate leaving the site. With the leachate being treated to a quality suitable for irrigation, a harvesting system was commissioned and completed in 2010. To assess the effectiveness of the system, samples are collected to analyse untreated leachate (95), mid treated leachate after the water is passed through bioreactors (96a), and the water stored for irrigation of the oval (132). Gleeson Creek (77) is also sampled regularly to assess the impact of leachate run off on the stream.

Appendix B – Phytoplankton Action Levels

The following is an extract from the Marine Biotoxin Management Plan (NSW Food Authority 2015)

The following table summarises the phytoplankton levels (in cells/litre) which are used to trigger sampling of shellfish flesh. The levels relate to discrete or composite samples. These levels are a combination of levels used internationally and in various states in Australia. They should be revised as further monitoring and research is undertaken and supports a change.

Phytoplankton species	Toxin	Trigger flesh sampling# (cells per litre)	Alert level – Close harvest area pending flesh testing results	Issue public health warning (cells per litre)
Alexandrium minutum#	PSP	200	500	5000
Alexandrium ostenfeldii#	PSP	200	500	5000
Alexandrium catenella#	PSP	200	500	5000
Alexandrium tamarense#	PSP	200	500	5000
Alexandrium spp#	PSP (?)			
Gymnodinium catenatum	PSP	1000 mussels 2000 other shellfish	5000	5000
Pseudonitzschia *(P.multiseries & P.australis)**	ASP	50,000	500,000	N/A
Pseudonitzschia delicatissima group (historically non-toxic in Australia)	ASP (?)	500,000		N/A
Karenia cf *brevis*	NSP	1000		5000
Dinophysis acuminata	DSP	1000		N/A
Dinophysis acuta	DSP	500		N/A
Dinophysis caudata	DSP	500		N/A
Dinophysis fortii	DSP	500		N/A
Dinophysis hastate	DSP	500		N/A
Dinophysis mitra	DSP	500		N/A
Dinophysis rotundata	DSP	500		N/A
Dinophysis tripos	DSP	500		N/A
Total *Dinophysis spp.*	DSP	500		N/A
Prorocentrum lima	DSP	500		N/A

Note: For Pseudonitzschia spp. risk remains high for a minimum of two weeks post bloom crash.

The cell levels within each toxin group are cumulative, eg 600 cells/L of both D. acuta and D. fortii would mean a total count of 1200 cells/L, exceeding the critical level to initiate flesh testing.

Alexandrium species may be difficult to identify when numbers are low. If any doubt exists, they should be treated as potentially toxic.

* Species within the Pseudo-nitzchia groups are difficult to identify. The toxic species of most concern in each group are listed for those laboratories that have capacity to identify these algae to species level.

Otherwise all algae within these groups should be considered potentially toxic.

Appendix C – Rainfall Gauging Stations

Number	Location
66211	Wahroonga (Ada Avenue)
66047	Pennant Hills (Yarra Road)
66119	Mount Kuring-Gai
67052	Berowra (Goodwyn Road)
67062	Cherrybrook
67086	Dural
67010	Glenorie
67065	Hornsby (Swimming Pool)
67014	Maroota
66124	Parramatta
61119	Wisemens Ferry
67023	Canoelands

Appendix D – Summary Statistics

Presented is the number of data points (n), mean, median, minimum (min), maximum (max), 20th percentile (20th%), 80th percentile (80th%) and standard deviation (SD) for data collected for parameters at each site.

Reference Sites

Site	Parameter	n	Mean	Median	Min	Max	20th%	80th%	SD
Site 36 - Murray Anderson Creek	Temperature (°C)	12	16.46	17.28	9.29	22.21	12.59	20.30	4.30
	Electrical Conductivity (mS/cm)	12	0.13	0.14	0.05	0.21	0.09	0.17	0.05
	Turbidity (NTU)	12	0.88	0.30	0.00	6.50	0.10	1.00	1.81
	Dissolved oxygen (%sat)	12	98.71	100.50	90.95	104.20	94.01	102.30	4.60
	pH (units)	12	5.46	5.48	4.76	5.96	5.03	5.94	0.42
	Salinity (ppt)	12	0.06	0.07	0.02	0.10	0.03	0.08	0.02
	Suspended Solids (mg/L)	12	1.00	1.00	1.00	1.00	1.00	1.00	0.00
	Ammonium-Nitrogen (mg/L)	12	0.01	0.01	0.01	0.01	0.01	0.01	0.00
	Oxidised Nitrogen (mg/L)	12	0.01	0.01	0.01	0.03	0.01	0.01	0.01
	Total Nitrogen (mg/L)	12	0.09	0.09	0.05	0.17	0.06	0.11	0.04
	Total Phosphorus (mg/L)	12	0.003	0.003	0.002	0.005	0.002	0.004	0.001
	Faecal Coliforms (CFU/100ml)	12	107.79	8.00	0.50	730.00	0.50	190.00	216.57
Site 37 - Smugglers Creek	Temperature (°C)	12	16.38	17.42	8.45	24.44	11.38	19.96	4.91
	Electrical Conductivity (mS/cm)	12	0.18	0.19	0.09	0.28	0.10	0.22	0.06
	Turbidity (NTU)	12	1.50	1.35	0.20	3.30	0.40	2.80	1.12
	Dissolved oxygen (%sat)	12	104.00	104.70	96.57	113.20	99.05	107.40	4.86
	pH (units)	12	5.73	5.56	5.44	6.71	5.47	6.04	0.38
	Salinity (ppt)	12	0.58	0.09	0.05	6.00	0.05	0.12	1.71
	Suspended Solids (mg/L)	12	2.08	1.00	1.00	7.00	1.00	3.00	1.83
	Ammonium-Nitrogen (mg/L)	12	0.01	0.01	0.01	0.02	0.01	0.01	0.00
	Oxidised Nitrogen (mg/L)	12	0.01	0.01	0.01	0.01	0.01	0.01	0.00
	Total Nitrogen (mg/L)	12	0.14	0.12	0.06	0.28	0.06	0.21	0.07
	Total Phosphorus (mg/L)	12	0.005	0.005	0.002	0.011	0.003	0.006	0.003
	Faecal Coliforms (CFU/100ml)	12	41.33	10.00	0.50	290.00	2.00	54.00	81.68

Site	Parameter	n	Mean	Median	Min	Max	20th%	80th%	SD
Site 54 - Laughtondale Creek	Temperature (°C)	12	16.28	16.95	8.24	22.84	11.77	21.83	5.14
	Electrical Conductivity (mS/cm)	12	0.22	0.21	0.06	0.37	0.10	0.31	0.10
	Turbidity (NTU)	12	3.77	2.40	0.00	11.30	0.10	8.00	4.00
	Dissolved oxygen (%sat)	12	101.09	103.30	88.80	107.20	97.20	104.90	5.44
	pH (units)	12	5.44	5.23	4.64	6.44	4.87	6.02	0.60
	Salinity (ppt)	12	0.11	0.11	0.03	0.18	0.07	0.16	0.05
	Suspended Solids (mg/L)	12	2.33	2.00	1.00	6.00	1.00	3.00	1.61
	Ammonium-Nitrogen (mg/L)	12	0.01	0.01	0.01	0.01	0.01	0.01	0.00
	Oxidised Nitrogen (mg/L)	12	0.01	0.01	0.01	0.01	0.01	0.01	0.00
	Total Nitrogen (mg/L)	12	0.12	0.10	0.03	0.27	0.06	0.18	0.07
	Total Phosphorus (mg/L)	12	0.008	0.007	0.004	0.018	0.005	0.010	0.004
	Faecal Coliforms (CFU/100ml)	12	49.54	12.50	0.50	290.00	1.00	65.00	85.02
Site 114 - Muogamarra Creek	Temperature (°C)	9	15.90	16.92	10.13	20.97	10.42	20.11	4.08
	Electrical Conductivity (mS/cm)	9	0.14	0.15	0.04	0.23	0.05	0.20	0.06
	Turbidity (NTU)	9	2.07	1.10	0.20	7.50	0.40	4.80	2.45
	Dissolved oxygen (%sat)	9	93.21	94.60	65.90	109.40	83.90	100.95	12.31
	pH (units)	9	5.01	4.93	4.72	5.75	4.77	5.28	0.32
	Salinity (ppt)	9	0.14	0.08	0.02	0.70	0.03	0.11	0.21
	Suspended Solids (mg/L)	8	1.13	1.00	1.00	2.00	1.00	1.00	0.35
	Ammonium-Nitrogen (mg/L)	8	0.01	0.01	0.01	0.01	0.01	0.01	0.00
	Oxidised Nitrogen (mg/L)	8	0.01	0.01	0.01	0.01	0.01	0.01	0.00
	Total Nitrogen (mg/L)	8	0.10	0.09	0.06	0.19	0.07	0.11	0.04
	Total Phosphorus (mg/L)	8	0.003	0.003	0.001	0.005	0.002	0.004	0.001
	Faecal Coliforms (CFU/100ml)	8	26.69	9.00	0.50	100.00	2.00	52.00	34.85

Site 123 - Peats Crater Creek	n	Mean	Median	Min	Max	20th%	80th%	SD
Temperature (°C)	10	16.00	17.69	9.19	21.70	11.06	19.82	4.52
Electrical Conductivity (mS/cm)	10	0.27	0.32	0.15	0.35	0.19	0.34	0.08
Turbidity (NTU)	10	6.92	4.90	1.60	16.80	3.20	12.55	5.30
Dissolved oxygen (%sat)	10	94.17	93.90	81.20	105.33	90.75	98.05	6.24
pH (units)	10	7.24	7.27	6.92	7.65	6.98	7.41	0.23
Salinity (ppt)	10	0.13	0.16	0.07	0.17	0.10	0.17	0.04
Suspended Solids (mg/L)	10	1.70	1.00	1.00	3.00	1.00	3.00	0.95
Ammonium-Nitrogen (mg/L)	10	0.01	0.01	0.01	0.01	0.01	0.01	0.00
Oxidised Nitrogen (mg/L)	10	0.01	0.01	0.01	0.02	0.01	0.02	0.00
Total Nitrogen (mg/L)	10	0.20	0.20	0.10	0.34	0.14	0.24	0.07
Total Phosphorus (mg/L)	10	0.038	0.036	0.023	0.054	0.028	0.049	0.011
Faecal Coliforms (CFU/100ml)	10	321.40	67.00	6.00	2100.00	7.50	365.00	642.18

Site 147 - Unnamed Creek, Cheltenham	n	Mean	Median	Min	Max	20th%	80th%	SD
Temperature (°C)	7	15.57	16.82	9.51	22.10	9.57	19.76	4.91
Electrical Conductivity (mS/cm)	7	0.17	0.18	0.09	0.22	0.15	0.21	0.04
Turbidity (NTU)	7	2.03	0.70	0.10	6.00	0.60	4.20	2.24
Dissolved oxygen (%sat)	7	93.61	93.80	81.70	102.80	87.30	100.60	7.48
pH (units)	7	5.88	5.82	5.58	6.47	5.58	5.99	0.30
Salinity (ppt)	7	0.09	0.09	0.05	0.11	0.07	0.10	0.02
Suspended Solids (mg/L)	7	1.71	1.00	1.00	6.00	1.00	1.00	1.89
Ammonium-Nitrogen (mg/L)	7	0.01	0.01	0.01	0.01	0.01	0.01	0.00
Oxidised Nitrogen (mg/L)	7	0.01	0.01	0.01	0.01	0.01	0.01	0.00
Total Nitrogen (mg/L)	7	0.15	0.14	0.09	0.28	0.09	0.18	0.07
Total Phosphorus (mg/L)	7	0.003	0.003	0.002	0.006	0.002	0.004	0.001
Faecal Coliforms (CFU/100ml)	7	501.71	74.00	2.00	3000.00	2.00	220.00	1104.94

Site 149 - Unnamed Creek, Marramarra NP	n	Mean	Median	Min	Max	20th%	80th%	SD
Temperature (°C)	11	14.42	15.41	7.50	20.63	18.57	10.17	4.83
Electrical Conductivity (mS/cm)	11	0.29	0.32	0.14	0.39	0.36	0.20	0.09
Turbidity (NTU)	11	2.15	1.70	0.00	9.60	2.10	0.90	2.56
Dissolved oxygen (%sat)	11	91.42	91.90	76.90	102.70	98.20	84.80	8.68
pH (units)	11	4.77	4.72	4.56	5.12	4.92	4.61	0.18
Salinity (ppt)	11	0.14	0.16	0.07	0.20	0.18	0.10	0.04
Suspended Solids (mg/L)	11	2.00	1.00	1.00	6.00	3.00	1.00	1.55
Ammonium-Nitrogen (mg/L)	11	0.01	0.01	0.01	0.02	0.01	0.01	0.00
Oxidised Nitrogen (mg/L)	11	0.01	0.01	0.01	0.01	0.01	0.01	0.00
Total Nitrogen (mg/L)	11	0.09	0.09	0.06	0.17	0.11	0.06	0.03
Total Phosphorus (mg/L)	11	0.004	0.004	0.003	0.005	0.004	0.003	0.001
Faecal Coliforms (CFU/100ml)	11	14.95	5.00	0.50	59.00	34.00	2.00	20.83

Site 164 - Unnamed Creek, Djarra Crossing	n	Mean	Median	Min	Max	20th%	80th%	SD
Temperature (°C)	9	18.93	21.63	10.40	25.20	11.36	25.16	5.90
Electrical Conductivity (mS/cm)	9	0.11	0.09	0.04	0.21	0.05	0.20	0.06
Turbidity (NTU)	9	2.20	1.10	0.30	7.50	0.50	5.30	2.49
Dissolved oxygen (%sat)	9	97.94	97.40	94.20	104.00	95.30	103.00	3.39
pH (units)	9	4.94	5.00	4.54	5.19	4.74	5.17	0.23
Salinity (ppt)	9	0.05	0.04	0.02	0.10	0.03	0.10	0.03
Suspended Solids (mg/L)	8	1.88	1.00	1.00	4.00	1.00	3.00	1.25
Ammonium-Nitrogen (mg/L)	8	0.01	0.01	0.01	0.01	0.01	0.01	0.00
Oxidised Nitrogen (mg/L)	8	0.01	0.01	0.01	0.01	0.01	0.01	0.00
Total Nitrogen (mg/L)	8	0.11	0.10	0.08	0.16	0.09	0.13	0.03
Total Phosphorus (mg/L)	8	0.004	0.004	0.001	0.005	0.002	0.005	0.002
Faecal Coliforms (CFU/100ml)	8	79.25	14.50	0.50	320.00	0.50	250.00	128.67

Industrial Sites

Site	Parameter	n	Mean	Median	Min	Max	20th%	80th%	SD
Site 10 - Larool Creek	Temperature (°C)	24	15.89	16.10	7.94	21.80	10.77	19.82	4.24
	Electrical Conductivity (mS/cm)	24	0.68	0.72	0.07	1.15	0.50	0.93	0.26
	Turbidity (NTU)	24	35.27	10.70	5.50	370.00	6.90	52.80	74.76
	Dissolved oxygen (%sat)	24	66.50	69.30	34.70	99.10	46.30	79.10	18.34
	pH (units)	24	7.84	7.68	7.50	9.96	7.59	7.76	0.60
	Salinity (ppt)	24	0.34	0.37	0.03	0.58	0.25	0.47	0.13
	Suspended Solids (mg/L)	24	13.00	5.00	1.00	83.00	2.00	22.00	18.50
	Ammonium-Nitrogen (mg/L)	24	1.43	0.58	0.10	9.09	0.14	2.30	2.00
	Oxidised Nitrogen (mg/L)	24	1.75	1.68	0.17	3.35	1.14	2.75	0.79
	Total Nitrogen (mg/L)	24	8.34	3.25	0.64	93.40	2.04	7.62	18.54
	Total Phosphorus (mg/L)	24	1.014	0.039	0.015	23.000	0.028	0.082	4.683
	Faecal Coliforms (CFU/100ml)	24	3348.33	1350.00	190.00	10000.00	540.00	7700.00	3377.75
	CBOD5 (mg/L)	19	3.53	1.00	1.00	24.00	1.00	6.00	5.75
Site 12 -Hornsby Creek	Temperature (°C)	25	16.07	16.38	9.39	22.10	12.63	19.85	3.92
	Electrical Conductivity (mS/cm)	25	0.37	0.39	0.04	0.57	0.29	0.45	0.11
	Turbidity (NTU)	25	17.25	4.70	1.60	86.30	3.15	23.75	24.44
	Dissolved oxygen (%sat)	25	96.75	97.00	83.70	104.20	93.81	100.40	4.29
	pH (units)	25	7.81	7.81	7.07	8.02	7.72	7.96	0.19
	Salinity (ppt)	25	0.18	0.19	0.02	0.29	0.14	0.23	0.06
	Suspended Solids (mg/L)	25	7.36	3.00	1.00	37.00	1.00	9.00	10.87
	Ammonium-Nitrogen (mg/L)	25	0.14	0.05	0.02	1.65	0.03	0.12	0.32
	Oxidised Nitrogen (mg/L)	25	0.72	0.70	0.10	1.99	0.40	0.92	0.37
	Total Nitrogen (mg/L)	25	2.12	1.08	0.41	19.20	0.86	1.48	3.76
	Total Phosphorus (mg/L)	25	0.077	0.050	0.031	0.525	0.040	0.083	0.097
	Faecal Coliforms (CFU/100ml)	25	13988.00	710.00	130.00	270000.00	535.00	4100.00	53664.51
	CBOD5 (mg/L)	19	1.89	1.00	1.00	15.00	1.00	1.00	3.21

Site	Parameter	n	Mean	Median	Min	Max	20th%	80th%	SD
Site 13 -Sams Creek	Temperature (°C)	24	16.61	16.06	9.38	22.57	12.52	20.77	4.35
	Electrical Conductivity (mS/cm)	24	0.28	0.28	0.05	0.46	0.21	0.37	0.09
	Turbidity (NTU)	24	6.72	3.25	0.80	39.60	1.30	13.00	8.57
	Dissolved oxygen (%sat)	24	69.89	70.55	40.70	94.60	60.60	81.00	13.11
	pH (units)	24	7.41	7.34	7.13	8.51	7.23	7.54	0.28
	Salinity (ppt)	24	0.14	0.14	0.03	0.23	0.10	0.18	0.05
	Suspended Solids (mg/L)	24	2.79	1.50	1.00	13.00	1.00	3.00	3.19
	Ammonium-Nitrogen (mg/L)	24	0.08	0.04	0.01	0.94	0.02	0.06	0.19
	Oxidised Nitrogen (mg/L)	24	0.26	0.18	0.02	1.22	0.12	0.36	0.25
	Total Nitrogen (mg/L)	24	0.58	0.48	0.22	2.23	0.37	0.69	0.40
	Total Phosphorus (mg/L)	24	0.029	0.025	0.014	0.067	0.019	0.042	0.013
	Faecal Coliforms (CFU/100ml)	24	440.54	225.00	2.00	2200.00	31.00	900.00	578.19
	CBOD5 (mg/L)	20	1.45	1.00	1.00	5.00	1.00	1.50	1.10

Urban Sites

Site	Parameter	n	Mean	Median	Min	Max	20th%	80th%	SD
Site 4 - Berowra Creek	Temperature (°C)	12	15.36	16.23	7.87	20.61	11.61	19.03	4.32
	Electrical Conductivity (mS/cm)	12	0.27	0.29	0.10	0.43	0.12	0.35	0.12
	Turbidity (NTU)	12	7.69	2.85	0.40	31.90	1.30	15.40	9.82
	Dissolved oxygen (%sat)	12	91.37	89.80	80.80	102.60	84.10	99.60	7.47
	pH (units)	12	7.46	7.46	7.06	7.67	7.38	7.62	0.17
	Salinity (ppt)	12	0.13	0.14	0.05	0.21	0.06	0.17	0.06
	Suspended Solids (mg/L)	12	3.33	1.00	1.00	15.00	1.00	6.00	4.36
	Ammonium-Nitrogen (mg/L)	12	0.01	0.01	0.01	0.02	0.01	0.01	0.01
	Oxidised Nitrogen (mg/L)	12	0.23	0.15	0.07	1.24	0.09	0.22	0.32
	Total Nitrogen (mg/L)	12	0.47	0.39	0.24	1.56	0.30	0.46	0.35
	Total Phosphorus (mg/L)	12	0.031	0.025	0.008	0.067	0.019	0.043	0.018
	Faecal Coliforms (CFU/100ml)	12	1504.42	70.00	14.00	10000.00	25.00	2600.00	2899.38

		n	Mean	Median	Min	Max	20th%	80th%	SD
Site 5 - Pyes Creek	Temperature (°C)	12	16.51	18.09	8.94	22.15	12.59	19.79	4.23
	Electrical Conductivity (mS/cm)	12	0.85	0.74	0.15	2.10	0.21	1.31	0.65
	Turbidity (NTU)	12	8.48	4.55	1.10	32.60	2.00	10.30	10.87
	Dissolved oxygen (%sat)	12	83.15	80.35	70.30	99.90	76.20	93.47	9.32
	pH (units)	12	7.47	7.47	7.07	7.90	7.37	7.60	0.20
	Salinity (ppt)	12	0.44	0.39	0.08	1.09	0.10	0.67	0.34
	Suspended Solids (mg/L)	13	3.62	1.00	1.00	12.00	1.00	8.00	4.23
	Ammonium-Nitrogen (mg/L)	13	0.07	0.02	0.01	0.26	0.02	0.08	0.09
	Oxidised Nitrogen (mg/L)	13	0.55	0.28	0.18	2.50	0.19	0.74	0.64
	Total Nitrogen (mg/L)	13	0.87	0.68	0.39	2.78	0.46	1.01	0.65
	Total Phosphorus (mg/L)	13	0.051	0.046	0.027	0.083	0.034	0.063	0.018
	Faecal Coliforms (CFU/100ml)	13	3609.08	660.00	59.00	32000.00	280.00	3100.00	8635.11
Site 6 - Georges Creek	Temperature (°C)	12	16.21	17.49	8.70	22.28	12.23	19.95	4.54
	Electrical Conductivity (mS/cm)	12	0.32	0.34	0.10	0.43	0.28	0.41	0.10
	Turbidity (NTU)	12	12.37	3.75	0.50	90.80	1.50	7.70	25.47
	Dissolved oxygen (%sat)	12	88.13	90.20	56.60	101.50	83.90	99.20	13.09
	pH (units)	12	7.52	7.52	7.24	7.77	7.26	7.73	0.21
	Salinity (ppt)	12	0.16	0.16	0.05	0.22	0.14	0.20	0.05
	Suspended Solids (mg/L)	11	4.36	1.00	1.00	28.00	1.00	4.00	7.97
	Ammonium-Nitrogen (mg/L)	11	0.01	0.01	0.01	0.04	0.01	0.01	0.01
	Oxidised Nitrogen (mg/L)	11	0.16	0.07	0.01	0.75	0.04	0.15	0.21
	Total Nitrogen (mg/L)	11	0.50	0.38	0.30	1.41	0.34	0.47	0.32
	Total Phosphorus (mg/L)	11	0.034	0.024	0.009	0.099	0.014	0.044	0.028
	Faecal Coliforms (CFU/100ml)	11	733.00	240.00	9.00	3800.00	46.00	880.00	1178.43

		n	Mean	Median	Min	Max	20th%	80th%	SD
Site 8 - Devlins Creek	Temperature (°C)	12	17.60	18.71	9.62	23.58	13.36	21.63	4.54
	Electrical Conductivity (mS/cm)	12	0.75	0.88	0.10	1.80	0.30	1.08	0.50
	Turbidity (NTU)	12	20.23	6.15	2.70	114.00	2.80	34.10	31.83
	Dissolved oxygen (%sat)	12	83.56	87.60	28.50	103.40	74.60	97.16	19.88
	pH (units)	12	7.63	7.61	7.12	8.20	7.52	7.76	0.27
	Salinity (ppt)	12	0.38	0.44	0.05	0.92	0.15	0.55	0.25
	Suspended Solids (mg/L)	14	8.57	4.00	1.00	67.00	1.00	8.00	17.14
	Ammonium-Nitrogen (mg/L)	14	0.06	0.03	0.01	0.22	0.03	0.08	0.05
	Oxidised Nitrogen (mg/L)	14	0.32	0.19	0.08	1.85	0.12	0.32	0.45
	Total Nitrogen (mg/L)	14	0.71	0.60	0.30	2.35	0.48	0.73	0.50
	Total Phosphorus (mg/L)	14	0.051	0.056	0.028	0.070	0.037	0.061	0.012
	Faecal Coliforms (CFU/100ml)	14	1699.86	330.00	21.00	10000.00	52.00	3500.00	2749.77
Site 39 - Joe Crafts Creek	Temperature (°C)	12	16.02	17.10	8.30	21.52	12.39	20.09	4.42
	Electrical Conductivity (mS/cm)	12	0.20	0.19	0.12	0.28	0.16	0.25	0.05
	Turbidity (NTU)	12	2.60	1.60	0.00	10.00	0.80	3.60	2.85
	Dissolved oxygen (%sat)	12	91.78	92.50	70.86	104.00	83.00	103.40	9.81
	pH (units)	12	7.23	7.22	6.96	7.68	7.06	7.36	0.21
	Salinity (ppt)	12	0.16	0.11	0.06	0.80	0.08	0.13	0.20
	Suspended Solids (mg/L)	12	1.25	1.00	1.00	3.00	1.00	1.00	0.62
	Ammonium-Nitrogen (mg/L)	12	0.01	0.01	0.01	0.03	0.01	0.01	0.01
	Oxidised Nitrogen (mg/L)	12	0.06	0.05	0.02	0.25	0.04	0.06	0.06
	Total Nitrogen (mg/L)	12	0.25	0.22	0.14	0.58	0.18	0.29	0.12
	Total Phosphorus (mg/L)	12	0.008	0.007	0.003	0.014	0.006	0.013	0.003
	Faecal Coliforms (CFU/100ml)	12	161.92	11.50	1.00	1600.00	6.00	40.00	456.18

Site 181 - Unnamed Creek, North Epping	n	Mean	Median	Min	Max	20th%	80th%	SD
Temperature (°C)	11	16.76	18.50	9.90	22.18	20.37	13.35	4.27
Electrical Conductivity (mS/cm)	11	0.38	0.41	0.10	0.58	0.54	0.20	0.17
Turbidity (NTU)	11	4.58	2.10	0.80	18.60	7.80	1.30	5.39
Dissolved oxygen (%sat)	11	80.43	77.80	62.90	99.70	90.10	75.60	11.34
pH (units)	11	7.40	7.42	7.14	7.60	7.51	7.32	0.13
Salinity (ppt)	11	0.19	0.20	0.07	0.29	0.27	0.10	0.08
Suspended Solids (mg/L)	11	2.18	1.00	1.00	5.00	4.00	1.00	1.54
Ammonium-Nitrogen (mg/L)	11	0.03	0.01	0.01	0.17	0.02	0.01	0.05
Oxidised Nitrogen (mg/L)	11	0.26	0.21	0.16	0.69	0.28	0.17	0.15
Total Nitrogen (mg/L)	11	0.51	0.45	0.27	1.39	0.50	0.37	0.30
Total Phosphorus (mg/L)	11	0.028	0.021	0.009	0.089	0.036	0.017	0.022
Faecal Coliforms (CFU/100ml)	11	1622.27	69.00	20.00	10000.00	2500.00	34.00	3168.56

Rural Sites

Site 2 - Tunks Creek	n	Mean	Median	Min	Max	20th%	80th%	SD
Temperature (°C)	12	15.48	16.52	7.96	20.52	12.18	20.00	4.44
Electrical Conductivity (mS/cm)	12	0.27	0.28	0.12	0.36	0.21	0.33	0.07
Turbidity (NTU)	12	2.25	1.35	0.50	9.30	0.70	3.40	2.45
Dissolved oxygen (%sat)	12	92.24	91.80	83.70	101.10	86.30	99.80	6.42
pH (units)	12	7.13	7.15	6.82	7.41	7.01	7.27	0.18
Salinity (ppt)	12	0.14	0.14	0.06	0.21	0.10	0.16	0.04
Suspended Solids (mg/L)	12	1.08	1.00	1.00	2.00	1.00	1.00	0.29
Ammonium-Nitrogen (mg/L)	12	0.01	0.01	0.01	0.01	0.01	0.01	0.00
Oxidised Nitrogen (mg/L)	12	0.07	0.04	0.01	0.31	0.02	0.08	0.08
Total Nitrogen (mg/L)	12	0.28	0.26	0.14	0.68	0.21	0.31	0.14
Total Phosphorus (mg/L)	12	0.009	0.008	0.005	0.022	0.006	0.011	0.005
Faecal Coliforms (CFU/100ml)	12	43.38	5.00	0.50	330.00	2.00	29.00	96.25

Site 42 - Colah Creek	n	Mean	Median	Min	Max	20th%	80th%	SD
Temperature (°C)	12	16.50	18.20	8.54	21.60	12.85	21.24	4.41
Electrical Conductivity (mS/cm)	12	0.34	0.33	0.24	0.44	0.31	0.38	0.06
Turbidity (NTU)	12	6.38	4.80	1.20	20.60	1.90	9.70	6.13
Dissolved oxygen (%sat)	12	82.50	81.25	66.50	104.40	75.40	90.90	10.76
pH (units)	12	7.10	7.11	6.81	7.36	7.03	7.18	0.14
Salinity (ppt)	12	0.17	0.16	0.12	0.22	0.15	0.19	0.03
Suspended Solids (mg/L)	12	2.17	1.50	1.00	5.00	1.00	3.00	1.40
Ammonium-Nitrogen (mg/L)	12	0.02	0.02	0.01	0.03	0.01	0.02	0.01
Oxidised Nitrogen (mg/L)	12	0.18	0.07	0.01	1.06	0.02	0.21	0.30
Total Nitrogen (mg/L)	12	0.55	0.45	0.21	1.55	0.34	0.70	0.36
Total Phosphorus (mg/L)	12	0.031	0.024	0.007	0.077	0.019	0.047	0.019
Faecal Coliforms (CFU/100ml)	12	356.17	102.00	13.00	2300.00	51.00	320.00	649.26

Site 49 - Still Creek	n	Mean	Median	Min	Max	20th%	80th%	SD
Temperature (°C)	12	15.93	17.34	7.72	21.51	11.98	20.29	4.88
Electrical Conductivity (mS/cm)	12	0.49	0.52	0.19	0.77	0.31	0.62	0.17
Turbidity (NTU)	12	5.15	2.20	0.20	26.00	1.10	7.30	7.09
Dissolved oxygen (%sat)	12	92.66	94.95	83.50	98.10	89.10	97.40	5.34
pH (units)	12	7.16	7.18	6.95	7.41	7.11	7.22	0.12
Salinity (ppt)	12	0.24	0.26	0.09	0.39	0.15	0.31	0.09
Suspended Solids (mg/L)	12	1.50	1.00	1.00	6.00	1.00	1.00	1.45
Ammonium-Nitrogen (mg/L)	12	0.01	0.01	0.01	0.04	0.01	0.02	0.01
Oxidised Nitrogen (mg/L)	12	0.17	0.09	0.06	1.09	0.06	0.15	0.29
Total Nitrogen (mg/L)	12	0.50	0.36	0.14	1.65	0.31	0.62	0.39
Total Phosphorus (mg/L)	12	0.023	0.012	0.004	0.104	0.007	0.029	0.028
Faecal Coliforms (CFU/100ml)	12	139.92	43.50	6.00	780.00	18.00	140.00	231.31

Site	Parameter	n	Mean	Median	Min	Max	20th%	80th%	SD
Site 62 - Unnamed Creek	Temperature (°C)	10	17.21	18.82	11.48	21.25	12.78	20.43	3.82
	Electrical Conductivity (mS/cm)	10	0.33	0.32	0.11	0.62	0.25	0.42	0.14
	Turbidity (NTU)	10	5.47	4.10	0.50	17.60	2.20	7.45	4.80
	Dissolved oxygen (%sat)	10	92.05	94.05	81.30	101.10	84.45	97.31	6.78
	pH (units)	10	7.42	7.38	6.86	8.19	7.14	7.59	0.36
	Salinity (ppt)	10	0.17	0.16	0.06	0.31	0.13	0.21	0.07
	Suspended Solids (mg/L)	10	1.90	1.00	1.00	8.00	1.00	2.00	2.23
	Ammonium-Nitrogen (mg/L)	10	0.03	0.03	0.01	0.05	0.01	0.03	0.01
	Oxidised Nitrogen (mg/L)	10	0.20	0.12	0.02	0.89	0.04	0.24	0.26
	Total Nitrogen (mg/L)	10	0.51	0.46	0.27	1.15	0.37	0.57	0.24
	Total Phosphorus (mg/L)	10	0.026	0.023	0.007	0.055	0.017	0.037	0.014
	Faecal Coliforms (CFU/100ml)	10	1729.90	184.00	4.00	9000.00	49.00	3575.00	3215.25
Site 63 - Colah Creek, Ben Bullen Road Creek	Temperature (°C)	11	14.64	15.96	7.34	19.92	10.27	19.06	4.49
	Electrical Conductivity (mS/cm)	11	0.40	0.42	0.25	0.52	0.39	0.45	0.08
	Turbidity (NTU)	11	3.75	3.00	2.50	7.50	2.70	4.40	1.54
	Dissolved oxygen (%sat)	11	80.50	76.50	61.60	100.30	66.30	94.90	13.75
	pH (units)	11	7.17	7.21	6.90	7.43	6.99	7.34	0.19
	Salinity (ppt)	11	0.20	0.21	0.12	0.26	0.19	0.22	0.04
	Suspended Solids (mg/L)	11	1.36	1.00	1.00	3.00	1.00	2.00	0.67
	Ammonium-Nitrogen (mg/L)	11	0.01	0.01	0.01	0.02	0.01	0.02	0.01
	Oxidised Nitrogen (mg/L)	11	0.07	0.04	0.01	0.20	0.02	0.12	0.07
	Total Nitrogen (mg/L)	11	0.38	0.34	0.18	0.59	0.31	0.47	0.12
	Total Phosphorus (mg/L)	11	0.018	0.016	0.010	0.031	0.012	0.024	0.007
	Faecal Coliforms (CFU/100ml)	11	42.64	41.00	15.00	70.00	29.00	52.00	17.23

Site	Parameter	n	Mean	Median	Min	Max	20th%	80th%	SD
Site 64 - Unnamed Creek, Galston	Temperature (°C)	12	16.94	17.63	9.76	21.91	13.40	21.33	4.17
	Electrical Conductivity (mS/cm)	12	0.39	0.39	0.24	0.53	0.33	0.48	0.08
	Turbidity (NTU)	12	6.58	6.70	2.10	12.00	2.40	10.20	3.79
	Dissolved oxygen (%sat)	12	81.64	90.20	40.80	121.00	60.80	96.80	23.04
	pH (units)	12	7.20	7.20	6.83	8.03	6.93	7.34	0.32
	Salinity (ppt)	12	0.20	0.20	0.12	0.27	0.16	0.24	0.04
	Suspended Solids (mg/L)	12	1.75	1.00	1.00	5.00	1.00	2.00	1.36
	Ammonium-Nitrogen (mg/L)	12	0.06	0.05	0.01	0.12	0.03	0.10	0.04
	Oxidised Nitrogen (mg/L)	12	0.52	0.27	0.01	1.85	0.06	1.11	0.64
	Total Nitrogen (mg/L)	12	0.91	0.65	0.26	2.32	0.42	1.56	0.68
	Total Phosphorus (mg/L)	12	0.083	0.078	0.042	0.143	0.066	0.108	0.028
	Faecal Coliforms (CFU/100ml)	12	532.92	485.00	39.00	1100.00	240.00	890.00	371.79
Site 80 - Glenorie Creek	Temperature (°C)	10	16.64	17.00	8.88	22.45	12.62	21.08	4.50
	Electrical Conductivity (mS/cm)	10	0.38	0.37	0.11	0.56	0.29	0.54	0.14
	Turbidity (NTU)	10	16.23	8.50	2.40	53.20	5.00	31.45	16.79
	Dissolved oxygen (%sat)	10	92.61	94.65	80.80	100.30	85.40	97.55	6.64
	pH (units)	10	7.38	7.36	7.17	7.70	7.30	7.45	0.14
	Salinity (ppt)	10	0.19	0.19	0.05	0.28	0.14	0.27	0.07
	Suspended Solids (mg/L)	10	6.90	3.00	1.00	32.00	1.00	11.50	9.77
	Ammonium-Nitrogen (mg/L)	10	0.29	0.19	0.09	0.78	0.11	0.54	0.25
	Oxidised Nitrogen (mg/L)	10	0.90	0.50	0.22	3.80	0.44	0.98	1.05
	Total Nitrogen (mg/L)	10	1.72	1.25	0.96	5.01	1.08	2.05	1.27
	Total Phosphorus (mg/L)	10	0.169	0.128	0.037	0.410	0.076	0.291	0.130
	Faecal Coliforms (CFU/100ml)	10	3492.80	1505.00	92.00	14000.00	248.00	6850.00	4738.17

Estuarine Sites

Site	Parameter	n	Mean	Median	Min	Max	20th%	80th%	SD
Site 150 - Gunya Point	Temperature (°C)	14	20.34	21.56	14.76	25.86	23.09	16.60	3.68
	Electrical Conductivity (mS/cm)	13	7056.92	6899.00	6266.00	8000.00	7749.80	6434.80	654.65
	Turbidity (NTU)	14	5.95	5.55	1.00	11.70	8.84	3.18	3.27
	Dissolved oxygen (%sat)	14	92.45	93.28	76.30	99.90	98.08	89.20	6.36
	pH (units)	14	7.99	7.99	7.81	8.15	8.07	7.95	0.09
	Salinity (ppt)	14	31.29	33.04	21.24	34.69	33.80	29.98	4.12
	Suspended Solids (mg/L)	15	7.87	6.00	1.00	19.00	11.40	3.00	5.36
	Ammonium-Nitrogen (mg/L)	15	0.02	0.01	0.01	0.07	0.02	0.01	0.02
	Oxidised Nitrogen (mg/L)	15	0.05	0.02	0.01	0.28	0.07	0.01	0.07
	Total Nitrogen (mg/L)	15	0.28	0.23	0.17	0.61	0.36	0.20	0.12
	Total Phosphorus (mg/L)	15	0.019	0.018	0.012	0.026	0.021	0.016	0.003
	Soluble Reactive Phosphorus (mg/L)	14	0.006	0.006	0.003	0.009	0.007	0.005	0.002
	Chlorophyll *a* (µg/L)	16	2.69	2.45	1.10	6.40	3.10	1.60	1.47
	Faecal Coliforms (CFU/100ml)	15	2.40	0.50	0.50	9.00	5.00	0.50	2.95
Site 55 - Brooklyn Baths	Temperature (°C)	12	20.78	21.91	14.08	25.26	16.31	23.90	3.73
	Electrical Conductivity (mS/cm)	12	47.58	50.32	35.42	51.32	47.49	50.92	5.68
	Turbidity (NTU)	12	10.98	10.10	4.90	17.20	9.60	12.70	3.42
	Dissolved oxygen (%sat)	12	96.35	96.02	85.30	111.50	87.65	103.30	8.01
	pH (units)	12	8.07	8.05	7.85	8.40	7.92	8.16	0.16
	Salinity (ppt)	12	31.02	33.01	22.34	33.70	30.89	33.41	4.07
	Suspended Solids (mg/L)	14	12.29	11.50	6.00	24.00	7.00	17.00	5.31
	Ammonium-Nitrogen (mg/L)	14	0.02	0.01	0.01	0.03	0.01	0.02	0.01
	Oxidised Nitrogen (mg/L)	14	0.03	0.02	0.01	0.09	0.01	0.05	0.02
	Total Nitrogen (mg/L)	14	0.27	0.25	0.20	0.45	0.21	0.30	0.07
	Total Phosphorus (mg/L)	14	0.019	0.019	0.012	0.036	0.014	0.022	0.006
	Soluble Reactive Phosphorus (mg/L)	13	0.006	0.005	0.002	0.010	0.004	0.007	0.002
	Chlorophyll *a* (µg/L)	14	2.28	2.05	1.40	5.20	1.50	2.90	1.00
	Faecal Coliforms (CFU/100ml)	14	25.04	3.50	0.50	250.00	0.50	25.00	65.39

Site	Parameter	n	Mean	Median	Min	Max	20th%	80th%	SD
Site 108 - Bradleys Beach, Dangar Island	Temperature (°C)	12	19.95	20.90	14.61	24.35	22.19	16.31	3.29
	Electrical Conductivity (mS/cm)	12	48.05	50.54	35.91	51.68	51.18	47.34	5.57
	Turbidity (NTU)	12	8.22	6.00	2.10	19.90	13.72	3.02	6.08
	Dissolved oxygen (%sat)	12	91.44	92.11	83.63	101.50	94.98	87.21	5.38
	pH (units)	12	8.04	8.07	7.82	8.19	8.14	7.97	0.11
	Salinity (ppt)	12	31.35	33.19	22.74	33.96	33.60	30.80	3.99
	Suspended Solids (mg/L)	12	10.83	9.50	5.00	23.00	14.80	7.00	5.47
	Ammonium-Nitrogen (mg/L)	12	0.02	0.01	0.01	0.04	0.02	0.01	0.01
	Oxidised Nitrogen (mg/L)	12	0.03	0.02	0.01	0.08	0.04	0.01	0.02
	Total Nitrogen (mg/L)	12	0.27	0.26	0.20	0.41	0.27	0.23	0.06
	Total Phosphorus (mg/L)	12	0.018	0.019	0.012	0.025	0.021	0.014	0.004
	Soluble Reactive Phosphorus (mg/L)	11	0.005	0.006	0.001	0.011	0.007	0.003	0.003
	Chlorophyll *a* (µg/L)	12	2.46	2.30	1.20	4.80	2.90	1.78	0.93
	Faecal Coliforms (CFU/100ml)	12	34.21	0.50	0.50	390.00	1.80	0.50	112.10
Site 174 - Mullet Creek	Temperature (°C)	13	20.29	22.02	13.65	26.59	15.04	24.21	4.58
	Electrical Conductivity (mS/cm)	12	44.81	46.54	28.82	50.38	43.80	48.78	5.97
	Turbidity (NTU)	13	11.12	11.30	3.20	20.90	4.80	16.70	5.89
	Dissolved oxygen (%sat)	13	88.14	90.48	77.10	99.80	80.30	92.20	6.35
	pH (units)	13	7.92	7.94	7.74	8.08	7.82	8.05	0.11
	Salinity (ppt)	13	28.34	29.82	17.80	33.00	24.00	31.86	4.63
	Suspended Solids (mg/L)	15	9.87	8.00	4.00	20.00	6.50	13.50	4.32
	Ammonium-Nitrogen (mg/L)	15	0.02	0.01	0.01	0.05	0.01	0.03	0.01
	Oxidised Nitrogen (mg/L)	15	0.06	0.04	0.01	0.26	0.02	0.10	0.07
	Total Nitrogen (mg/L)	15	0.34	0.28	0.23	0.59	0.24	0.48	0.12
	Total Phosphorus (mg/L)	15	0.020	0.019	0.013	0.030	0.017	0.025	0.004
	Soluble Reactive Phosphorus (mg/L)	14	0.006	0.006	0.002	0.007	0.005	0.007	0.001
	Chlorophyll *a* (µg/L)	15	3.27	2.90	1.60	7.30	2.00	4.15	1.49
	Faecal Coliforms (CFU/100ml)	15	3.13	1.00	0.50	18.00	0.50	5.00	4.95

Site 38 - Sandbrook Inlet	n	Mean	Median	Min	Max	20th%	80th%	SD
Temperature (°C)	11	20.90	22.01	12.12	28.68	15.97	24.35	5.14
Electrical Conductivity (mS/cm)	12	40.21	43.58	23.59	47.85	35.74	45.10	7.77
Turbidity (NTU)	12	11.68	11.65	5.10	18.20	8.10	14.90	4.06
Dissolved oxygen (%sat)	12	93.89	94.00	76.70	113.00	84.10	99.00	10.35
pH (units)	12	7.89	7.87	7.60	8.24	7.71	8.14	0.21
Salinity (ppt)	12	25.65	28.08	13.34	31.14	22.51	29.20	5.59
Suspended Solids (mg/L)	12	11.25	11.00	5.00	16.00	9.00	15.00	3.47
Ammonium-Nitrogen (mg/L)	12	0.01	0.01	0.01	0.03	0.01	0.01	0.01
Oxidised Nitrogen (mg/L)	12	0.03	0.01	0.01	0.10	0.01	0.04	0.03
Total Nitrogen (mg/L)	12	0.33	0.31	0.20	0.54	0.25	0.41	0.09
Total Phosphorus (mg/L)	12	0.018	0.019	0.008	0.026	0.015	0.023	0.005
Soluble Reactive Phosphorus (mg/L)	11	0.003	0.002	0.001	0.008	0.001	0.005	0.002
Chlorophyll *a* (µg/L)	12	5.51	4.70	2.40	10.50	3.50	6.90	2.65
Faecal Coliforms (CFU/100ml)	12	27.58	5.00	0.50	240.00	1.00	26.00	67.59

Site 103 - Milsons Passage	n	Mean	Median	Min	Max	20th%	80th%	SD
Temperature (°C)	12	20.62	21.75	13.34	26.41	23.96	16.61	4.22
Electrical Conductivity (mS/cm)	12	41.32	44.88	16.10	48.47	46.37	40.72	9.22
Turbidity (NTU)	12	16.45	13.20	3.60	35.00	23.12	7.82	10.04
Dissolved oxygen (%sat)	12	90.12	89.30	83.60	104.00	93.26	85.42	5.94
pH (units)	12	7.94	7.98	7.56	8.18	8.13	7.79	0.20
Salinity (ppt)	12	26.55	29.01	9.32	31.66	30.05	26.12	6.39
Suspended Solids (mg/L)	13	22.00	17.00	6.00	44.00	32.40	11.20	12.56
Ammonium-Nitrogen (mg/L)	13	0.02	0.02	0.01	0.06	0.02	0.01	0.01
Oxidised Nitrogen (mg/L)	13	0.04	0.04	0.01	0.08	0.07	0.01	0.03
Total Nitrogen (mg/L)	13	0.32	0.30	0.23	0.47	0.37	0.26	0.08
Total Phosphorus (mg/L)	13	0.023	0.022	0.012	0.040	0.027	0.017	0.007
Soluble Reactive Phosphorus (mg/L)	12	0.006	0.005	0.002	0.009	0.008	0.005	0.002
Chlorophyll *a* (µg/L)	13	3.06	2.70	1.40	5.80	4.06	1.74	1.36
Faecal Coliforms (CFU/100ml)	13	24.38	2.00	0.50	280.00	5.00	1.00	76.89

Site 48 - Marramarra Creek	n	Mean	Median	Min	Max	20th%	80th%	SD
Temperature (°C)	12	19.45	20.99	10.66	26.26	12.81	24.73	5.44
Electrical Conductivity (mS/cm)	12	28.49	29.39	4.00	42.36	20.61	39.66	12.30
Turbidity (NTU)	12	9.51	8.30	2.40	22.00	2.70	16.40	6.59
Dissolved oxygen (%sat)	12	71.93	68.05	54.80	93.80	56.48	90.20	14.82
pH (units)	12	7.19	7.21	6.74	7.50	7.11	7.40	0.23
Salinity (ppt)	12	17.78	18.17	2.13	27.18	12.37	25.29	8.09
Suspended Solids (mg/L)	12	11.25	11.50	1.00	20.00	6.00	17.00	5.80
Ammonium-Nitrogen (mg/L)	12	0.04	0.04	0.01	0.08	0.02	0.05	0.02
Oxidised Nitrogen (mg/L)	12	0.04	0.03	0.01	0.12	0.01	0.07	0.03
Total Nitrogen (mg/L)	12	0.40	0.41	0.24	0.60	0.31	0.47	0.10
Total Phosphorus (mg/L)	12	0.019	0.020	0.006	0.035	0.009	0.028	0.009
Soluble Reactive Phosphorus (mg/L)	9	0.004	0.004	0.001	0.008	0.002	0.007	0.002
Chlorophyll *a* (µg/L)	12	2.89	2.60	0.60	6.10	1.10	4.50	1.78
Faecal Coliforms (CFU/100ml)	12	16.42	16.00	3.00	29.00	12.00	24.00	8.18

Site 61 - Calabash Point	n	Mean	Median	Min	Max	20th%	80th%	SD
Temperature (°C)	25	21.00	22.32	12.41	28.34	25.88	15.03	5.22
Electrical Conductivity (mS/cm)	24	33.09	35.69	8.01	43.91	38.35	28.85	8.92
Turbidity (NTU)	25	3.92	1.90	0.30	41.00	2.90	1.14	8.05
Dissolved oxygen (%sat)	25	94.83	95.24	63.70	115.20	106.12	86.54	12.93
pH (units)	25	7.71	7.78	7.07	8.05	7.94	7.58	0.27
Salinity (ppt)	25	19.47	21.88	2.85	28.30	24.26	15.95	7.22
Suspended Solids (mg/L)	29	4.62	5.00	1.00	18.00	6.40	2.00	3.44
Ammonium-Nitrogen (mg/L)	29	0.02	0.01	0.01	0.14	0.02	0.01	0.03
Oxidised Nitrogen (mg/L)	29	0.10	0.06	0.01	0.41	0.19	0.01	0.12
Total Nitrogen (mg/L)	29	0.53	0.44	0.34	0.98	0.66	0.39	0.18
Total Phosphorus (mg/L)	29	0.031	0.031	0.009	0.075	0.043	0.015	0.015
Soluble Reactive Phosphorus (mg/L)	28	0.006	0.003	0.001	0.022	0.012	0.001	0.006
Chlorophyll *a* (µg/L)	29	13.54	9.80	1.10	43.10	19.16	4.56	11.44
Faecal Coliforms (CFU/100ml)	29	214.31	4.00	0.50	5900.00	14.60	2.00	1093.68

Site 60 - Berowra Waters

	n	Mean	Median	Min	Max	20th%	80th%	SD
Temperature (°C)	12	21.11	22.53	12.99	28.04	25.56	15.80	5.04
Electrical Conductivity (mS/cm)	12	29.52	34.67	6.20	42.01	37.32	23.50	11.76
Turbidity (NTU)	12	4.78	1.20	0.30	38.10	2.98	0.82	10.63
Dissolved oxygen (%sat)	12	81.31	79.76	59.00	109.80	89.87	72.90	13.89
pH (units)	12	7.53	7.60	7.00	7.98	7.81	7.29	0.33
Salinity (ppt)	12	18.61	21.81	3.04	26.89	23.63	14.64	7.71
Suspended Solids (mg/L)	12	5.08	4.00	1.00	14.00	6.80	2.00	3.94
Ammonium-Nitrogen (mg/L)	12	0.03	0.02	0.01	0.10	0.05	0.01	0.03
Oxidised Nitrogen (mg/L)	12	0.14	0.09	0.01	0.50	0.23	0.01	0.17
Total Nitrogen (mg/L)	12	0.53	0.43	0.32	1.20	0.65	0.35	0.27
Total Phosphorus (mg/L)	12	0.034	0.025	0.010	0.096	0.042	0.013	0.028
Soluble Reactive Phosphorus (mg/L)	12	0.008	0.009	0.001	0.026	0.010	0.001	0.007
Chlorophyll *a* (µg/L)	12	9.54	6.80	1.10	23.00	18.70	1.96	7.89
Faecal Coliforms (CFU/100ml)	12	482.38	10.50	0.50	5600.00	28.40	5.20	1611.77

Site 100 - Crosslands Reserve

	n	Mean	Median	Min	Max	20th%	80th%	SD
Temperature (°C)	12	19.63	21.22	10.63	27.33	13.66	24.29	5.66
Electrical Conductivity (mS/cm)	12	20.73	24.04	1.18	33.52	8.68	30.67	11.12
Turbidity (NTU)	12	2.89	1.65	0.30	9.80	0.80	5.00	2.84
Dissolved oxygen (%sat)	12	71.91	73.50	45.33	98.00	50.50	89.50	18.00
pH (units)	12	7.33	7.36	6.93	7.70	7.15	7.47	0.21
Salinity (ppt)	12	12.57	14.55	0.60	20.98	4.38	19.02	7.06
Suspended Solids (mg/L)	13	3.46	3.00	1.00	8.00	1.00	6.00	2.37
Ammonium-Nitrogen (mg/L)	13	0.07	0.05	0.02	0.18	0.02	0.11	0.06
Oxidised Nitrogen (mg/L)	13	0.56	0.40	0.07	2.20	0.15	0.76	0.57
Total Nitrogen (mg/L)	13	0.99	0.74	0.42	2.62	0.54	1.43	0.61
Total Phosphorus (mg/L)	13	0.038	0.039	0.013	0.070	0.025	0.050	0.018
Soluble Reactive Phosphorus (mg/L)	7	0.018	0.021	0.006	0.030	0.006	0.021	0.009
Chlorophyll *a* (µg/L)	13	1.98	1.60	0.90	3.40	1.20	3.00	0.90
Faecal Coliforms (CFU/100ml)	13	71.38	31.00	7.00	300.00	10.00	89.00	99.54

Site 152 - Courangra Point

	n	Mean	Median	Min	Max	20th%	80th%	SD
Temperature (°C)	13	20.81	22.90	13.27	27.60	15.55	25.55	5.06
Electrical Conductivity (mS/cm)	12	31.90	32.32	16.00	39.62	28.28	38.66	6.60
Turbidity (NTU)	13	12.73	9.80	3.20	39.10	5.30	17.00	10.05
Dissolved oxygen (%sat)	13	84.44	86.20	64.30	100.70	75.20	91.50	10.12
pH (units)	13	7.63	7.62	7.09	8.02	7.34	7.88	0.27
Salinity (ppt)	13	18.16	19.27	7.26	25.19	14.56	22.48	5.39
Suspended Solids (mg/L)	15	11.80	9.00	3.00	42.00	5.00	13.50	9.88
Ammonium-Nitrogen (mg/L)	15	0.03	0.02	0.01	0.14	0.01	0.06	0.04
Oxidised Nitrogen (mg/L)	15	0.15	0.13	0.04	0.55	0.06	0.19	0.13
Total Nitrogen (mg/L)	15	0.48	0.44	0.27	1.03	0.35	0.60	0.19
Total Phosphorus (mg/L)	15	0.024	0.020	0.015	0.045	0.017	0.031	0.010
Soluble Reactive Phosphorus (mg/L)	14	0.007	0.007	0.003	0.014	0.006	0.008	0.002
Chlorophyll *a* (µg/L)	15	3.13	2.80	1.10	5.90	2.40	4.00	1.22
Faecal Coliforms (CFU/100ml)	15	12.70	4.00	0.50	61.00	1.25	25.00	19.67

Site 153 - Laughtondale

	n	Mean	Median	Min	Max	20th%	80th%	SD
Temperature (°C)	13	21.04	23.27	12.88	28.50	14.79	26.60	5.65
Electrical Conductivity (mS/cm)	12	10.43	10.56	0.17	21.98	5.39	13.82	6.27
Turbidity (NTU)	13	26.63	18.60	9.20	125.10	10.80	30.50	30.93
Dissolved oxygen (%sat)	13	90.56	92.70	65.00	115.10	70.70	103.40	15.46
pH (units)	13	7.45	7.48	6.74	8.06	7.05	7.69	0.38
Salinity (ppt)	13	5.50	5.84	0.08	13.20	1.81	7.94	3.99
Suspended Solids (mg/L)	15	15.60	13.00	7.00	38.00	10.50	19.50	8.42
Ammonium-Nitrogen (mg/L)	15	0.02	0.01	0.01	0.11	0.01	0.02	0.03
Oxidised Nitrogen (mg/L)	15	0.20	0.18	0.01	0.66	0.06	0.27	0.16
Total Nitrogen (mg/L)	15	0.61	0.59	0.33	1.21	0.37	0.75	0.23
Total Phosphorus (mg/L)	15	0.038	0.028	0.015	0.122	0.021	0.050	0.028
Soluble Reactive Phosphorus (mg/L)	14	0.006	0.003	0.001	0.033	0.002	0.006	0.009
Chlorophyll *a* (µg/L)	15	12.51	12.90	1.20	30.90	5.20	17.85	8.77
Faecal Coliforms (CFU/100ml)	15	28.10	7.00	0.50	270.00	3.00	27.50	68.09

Appendix E – Summary Statistics; *Other analytes*

Site Number	Sample Event	Bicarbonate Alkalinity (mg/CaCO3/L)	Chloride (mg/L)	Sulphate as SO_4^{2-} (mg/L)	Fluoride (mg/L)	Sodium (mg/L)	Potassium (mg/L)	Magnesium (mg/L)	Calcium (mg/L)	Aluminium (µg/L)	Arsenic (µg/L)	Cadmium (µg/L)	Chromium (µg/L)	Copper (µg/L)	Lead (µg/L)	Manganese (µg/L)	Molybdenum (µg/L)	Nickel (µg/L)	Selenium (µg/L)	Silver (µg/L)	Uranium (µg/L)	Zinc (µg/L)	Boron (µg/L)	Iron (µg/L)	Mercury (µg/L)
Reference Sites																									
36	1	2.5	48	5.5	0.025	25.6	0.81	3.99	1.03	128	0.5	0.5	0.5	0.5	0.5	59	0.5	2	1.5	1.5	0.5	8	15	100	0.005
	2	2.2	50	4.9	0.025	22.4	1.31	3.13	0.8	173	0.5	0.5	0.5	0.5	0.5	70	0.5	2	1.5	0.5	0.5	9	18	306	0.005
37	1	2.4	69	5.7	0.025	34	0.95	5.89	1.37	84	0.5	0.5	0.5	0.5	0.5	55	0.5	2	1.5	1.5	0.5	14	13	99	0.005
	2	2.8	63	3.9	0.025	32	1.67	5.27	1.38	203	0.5	0.5	3	0.5	0.5	153	0.5	2	1.5	0.5	0.5	8	14	1520	0.005
54	1	1	71	5.8	0.07	30	1.72	5.4	1.71	688	0.5	0.5	0.5	2	0.5	125	0.5	4	1.5	0.5	0.5	28	14	226	0.005
	2	1	110	7.5	0.06	48.6	2.26	8.51	2.47	1210	0.5	0.5	0.5	3	1	414	0.5	9	1.5	0.5	0.5	44	19	146	0.005
114	1	1	45	4.4	0.025	21.1	0.87	3.29	0.38	191	0.5	0.5	4	0.5	0.5	90	0.5	2	1.5	0.5	0.5	7	18	166	0.005
	2	1	54	3.5	0.025	24.5	1.16	3.3	0.64	154	0.5	0.5	0.5	0.5	0.5	103	0.5	0.5	1.5	0.5	0.5	7	19	405	0.005
123	1	45.4	56	4.2	0.09	29.8	1.86	7.87	7.63	361	0.5	0.5	1	0.5	0.5	56	0.5	3	1.5	0.5	0.5	2.5	21	828	0.005
	2	68.8	62	3.2	0.11	36.4	1.98	8.87	11.3	114	0.5	0.5	0.5	0.5	0.5	39	0.5	2	1.5	0.5	0.5	2.5	25	1040	0.005
147	1	2.9	81	7.4	0.06	34.2	0.98	7.6	3.68	201	0.5	0.5	0.5	0.5	0.5	17	0.5	1	1.5	0.5	0.5	11	12	34	0.005
149	1	1	92	7.8	0.05	40.3	1.46	7.14	1.72	428	0.5	0.5	0.5	0.5	0.5	304	0.5	5	1.5	0.5	0.5	22	14	581	0.005
	2	1	94	5.8	0.05	45.9	1.96	7.24	1.85	280	0.5	0.5	0.5	0.5	0.5	313	0.5	4	1.5	0.5	0.5	14	18	810	0.005
164	1	1	40	4.2	0.025	17.8	0.92	3.32	0.31	367	0.5	0.5	3	0.5	0.5	22	0.5	0.5	1.5	0.5	0.5	5	14	559	0.005
	2	1	43	4.2	0.025	21.8	1.06	3.76	0.38	267	0.5	0.5	0.5	0.5	0.5	20	0.5	0.5	1.5	0.5	0.5	2.5	15	1130	0.005
Industrial Sites																									
10	1	118	130	40	0.29	76.8	4.67	13	41.5	64	0.5	0.5	0.5	4	0.5	99	2	2	1.5	0.5	0.5	39	43	1200	0.005
	2	154	170	41	0.39	100	8	16.8	52	38	0.5	0.5	0.5	4	0.5	48	2	2	1.5	0.5	0.5	17	74	818	0.005
12	1	68.2	66	28	0.36	44.6	4.02	6.46	25.6	119	0.5	0.5	3	5	0.5	15	3	1	1.5	0.5	0.5	31	38	521	0.005
	2	70.8	98	32	0.54	43.9	5.44	8.01	39.1	284	0.5	0.5	3	7	0.5	25	2	2	1.5	0.5	0.5	24	40	612	0.005
	3	66.6	81	29	0.54	55.1	5.08	8.84	34.7	880	0.5	0.5	7	4	2	20	2	2	1.5	0.5	0.5	26	43	1100	0.005
13	1	32.8	17	8.1	0.06	10	1.82	2.41	11.6	1950	0.5	0.5	2	8	3	21	2	1	1.5	0.5	0.5	88	23	1300	0.005
	2	70	42	17	0.28	22.8	3.47	5.4	24.1	72	0.5	0.5	0.5	4	0.5	17	2	0.5	1.5	0.5	0.5	41	42	562	0.005

Site Number	Sample Event	Bicarbonate Alkalinity (mg/CaCO3/L)	Chloride (mg/L)	Sulphate as SO_4^{2-} (mg/L)	Fluoride (mg/L)	Sodium (mg/L)	Potassium (mg/L)	Magnesium (mg/L)	Calcium (mg/L)	Aluminium (µg/L)	Arsenic (µg/L)	Cadmium (µg/L)	Chromium (µg/L)	Copper (µg/L)	Lead (µg/L)	Manganese (µg/L)	Molybdenum (µg/L)	Nickel (µg/L)	Selenium (µg/L)	Silver (µg/L)	Uranium (µg/L)	Zinc (µg/L)	Boron (µg/L)	Iron (µg/L)	Mercury (µg/L)
Urban Sites																									
4	1	41.1	40	9	0.16	23.1	1.94	3.99	11.9	107	0.5	0.5	0.5	3	0.5	12	0.5	0.5	1.5	0.5	0.5	9	23	615	0.005
	2	59.7	72	11	0.32	38.8	2.78	7.44	21.4	21	0.5	0.5	0.5	0.5	0.5	16	0.5	0.5	1.5	0.5	0.5	2.5	25	670	0.005
5	1	72.5	130	120	0.27	112	8.64	6.79	33	157	0.5	0.5	4	3	0.5	46	6	1	1.5	0.5	0.5	7	23	838	0.005
	2	145	420	250	0.37	376	15.3	14.7	33.2	130	0.5	0.5	1	0.5	0.5	29	5	0.5	1.5	0.5	0.5	2.5	25	904	0.005
6	1	53	72	16	0.1	39.8	3.3	6.54	18.3	61	0.5	0.5	0.5	1	0.5	11	0.5	0.5	1.5	0.5	0.5	2.5	23	605	0.005
	2	76.4	90	7.2	0.11	50.9	4.5	8.43	23.4	28	0.5	0.5	0.5	0.5	0.5	27	0.5	0.5	1.5	0.5	0.5	2.5	31	716	0.005
8	1	54.8	86	21	0.17	51.8	3.69	6.24	19.6	96	0.5	0.5	0.5	5	0.5	63	1	1	1.5	0.5	0.5	17	25	954	0.005
	2	62.4	82	20	0.16	51.4	3.71	6.29	19.5	97	0.5	0.5	0.5	4	0.5	48	1	0.5	1.5	0.5	0.5	14	28	956	0.005
	3	146	440	48	0.35	287	11	27.1	29.4	35	0.5	0.5	0.5	0.5	0.5	43	3	1	1.5	0.5	0.5	9	31	583	0.005
39	1	28.3	50	16	0.06	28.6	1.52	5.24	11.3	31	0.5	0.5	0.5	0.5	0.5	8	0.5	0.5	1.5	1.5	0.5	2.5	25	206	0.005
	2	34	60	15	0.06	31.1	2.17	5.12	12.3	30	0.5	0.5	0.5	0.5	0.5	10	0.5	0.5	1.5	0.5	0.5	2.5	29	333	0.005
181	1	31.2	39	13	0.71	20.9	1.94	4.57	13	100	0.5	0.5	0.5	1	0.5	7	0.5	0.5	1.5	0.5	0.5	10	15	350	0.005
	2	84.6	110	33	0.11	66.5	4.7	8.26	36.9	92	0.5	0.5	0.5	2	0.5	82	1	1	1.5	0.5	0.5	12	34	419	0.005
Rural Sites																									
2	1	20.8	79	14	0.05	38.7	2.83	7.29	8.32	63	0.5	0.5	0.5	0.5	0.5	8	0.5	0.5	1.5	0.5	0.5	2.5	22	196	0.005
	2	30.6	74	12	0.07	40	3.6	7.33	8.99	64	0.5	0.5	0.5	0.5	0.5	19	0.5	0.5	1.5	0.5	0.5	2.5	16	465	0.005
42	1	42.1	78	21	0.1	38.6	4.21	7.52	13.4	185	0.5	0.5	0.5	1	0.5	88	0.5	1	1.5	0.5	0.5	6	33	1430	0.005
	2	49.7	86	18	0.13	49	4.92	9.18	16.6	59	0.5	0.5	0.5	1	0.5	51	0.5	0.5	1.5	0.5	0.5	2.5	41	728	0.005
49	1	33.6	120	17	0.08	54.2	4.79	10.4	11.4	251	0.5	0.5	2	1	0.5	63	0.5	2	1.5	0.5	0.5	6	34	1200	0.005
	2	32.3	170	12	0.08	79.7	4.72	13.9	13.1	73	0.5	0.5	0.5	0.5	0.5	44	0.5	0.5	1.5	0.5	0.5	2.5	32	565	0.005
62	1	29.7	37	7.6	0.025	21	2.03	2.71	8.18	579	0.5	0.5	0.5	3	1	12	0.5	0.5	1.5	0.5	0.5	13	22	871	0.005
	2	102	74	2	0.05	47.1	4.28	8.19	21.1	33	0.5	0.5	3	0.5	0.5	84	0.5	8	1.5	0.5	0.5	5	56	436	0.005
63	1	31.7	110	21	0.09	48.4	4.34	9.65	12.5	93	0.5	0.5	1	0.5	0.5	24	0.5	0.5	1.5	0.5	0.5	2.5	28	681	0.005
	2	46.5	98	16	0.11	51.2	5.78	10.9	15.3	79	0.5	0.5	0.5	0.5	0.5	60	0.5	0.5	1.5	0.5	0.5	2.5	29	1520	0.005
64	1	66	96	28	0.1	54.8	3.94	8.41	21.1	80	0.5	0.5	0.5	2	0.5	33	0.5	1	1.5	0.5	0.5	9	36	1380	0.005
	2	65.6	120	9.9	0.1	70	4.02	8.84	20.9	32	0.5	0.5	0.5	1	0.5	31	0.5	0.5	1.5	0.5	0.5	2.5	44	971	0.005
80	1	71.2	75	33	0.1	42.5	8.05	10.8	19	30	0.5	0.5	2	1	0.5	63	0.5	0.5	1.5	0.5	0.5	6	35	1950	0.005
	2	96.5	100	22	0.1	64.3	9.04	14.3	24.5	27	0.5	0.5	8	0.5	0.5	84	0.5	6	1.5	0.5	0.5	2.5	38	1130	0.005

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Landfill Remediation Sites																									
45	1	77.5	84	70	0.62	66.1	10.9	6.56	36.1	93	0.5	0.5	0.5	10	0.5	12	1	2	1.5	0.5	0.5	11	34	152	0.005
	2	125	100	68	0.74	85	13.8	9.96	50.4	67	0.5	0.5	0.5	5	0.5	9	1	2	1.5	0.5	0.5	9	54	80	0.005
95	1	567	220	8.9	0.025	125	60	25.2	84.1	27	0.5	0.5	0.5	2	0.5	226	0.5	6	1.5	0.5	0.5	7	302	2010	0.005
132	1	41.3	35	9.1	1	19.4	3.29	4.67	18	19	0.5	0.5	0.5	106	0.5	2	0.5	0.5	1.5	0.5	0.5	2.5	23	10	0.005
77	2	167	120	22	0.025	66.9	19.1	12.9	43	29	0.5	0.5	0.5	2	0.5	15	0.5	2	1.5	0.5	0.5	9	147	493	0.005
	1	177	120	22	0.06	64	21	11.8	43	96	0.5	0.5	0.5	10	4	10	0.5	3	1.5	0.5	0.5	40	160	1490	0.005
Wastewater Treatment Plant Sites																									
23	1	45.4	34	9.3	0.15	20	2.03	3.95	12.3	111	0.5	0.5	0.5	4	0.5	58	0.5	0.5	1.5	0.5	0.5	9	23	931	0.005
	2	78.9	93	15	0.22	51.6	3.55	9.64	27.3	46	0.5	0.5	0.5	1	0.5	92	0.5	0.5	1.5	0.5	0.5	2.5	33	847	0.005
43	1	30.7	29	14	0.24	20	3.71	2.28	8.29	529	0.5	0.5	0.5	2	1	15	0.5	1	1.5	0.5	0.5	7	20	659	0.005
	2	125	95	57	0.7	77.4	16	6	35.8	60	0.5	0.5	0.5	2	0.5	5	0.5	2	1.5	0.5	0.5	5	51	87	0.005
1	1	72	82	58	0.48	57.4	9.45	6.82	30.7	72	0.5	0.5	0.5	6	0.5	11	2	2	1.5	0.5	0.5	15	39	187	0.005
	2	101	94	75	0.61	76.4	13.6	11.8	44.6	41	0.5	0.5	0.5	4	0.5	12	2	2	1.5	0.5	0.5	6	44	132	0.005
52	1	45.4	46	11	0.08	25.1	1.45	5.47	12.9	30	0.5	0.5	0.5	0.5	0.5	28	0.5	0.5	1.5	0.5	0.5	7	27	1380	0.005
	2	59.6	62	4.8	0.1	32.3	2.13	6.04	15.4	49	0.5	0.5	0.5	0.5	0.5	89	0.5	1	1.5	0.5	0.5	6	39	1730	0.005
45	1	77.5	84	70	0.62	66.1	10.9	6.56	36.1	93	0.5	0.5	0.5	10	0.5	12	1	2	1.5	0.5	0.5	11	34	152	0.005
	2	125	100	68	0.74	85	13.8	9.96	50.4	67	0.5	0.5	0.5	5	0.5	9	1	2	1.5	0.5	0.5	9	54	80	0.005