City of Ryde Biological and Chemical Monitoring

Macroinvertebrate & Water Quality Report
Spring 2016

Sydney Water Monitoring Services™

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Executive Summary

This report presents the findings of water quality monitoring carried out in spring 2016. The survey area included the Archers, Buffalo, Porters, Shrimptons and Terrys Creek catchments.

Overall water quality showed mixed results among sites and between creeks, which is consistent with historical data. Water hardness varied the most of all water quality variables

High total nitrogen, ammonia and total phosphorus was common across all sites, which has negative flow-on effects on the local ecosystems. This coupled with low dissolved oxygen continues the categorisation of the creeks as highly disturbed.

There were less exceedances of faecal coliforms and metals compared to historical sampling events. This may be explained by relatively dry weather conditions before the sampling event.

Macroinvertebrate results were comparable to previous sampling seasons. Taxa richness remained consistent for Shrimptons and Archers creeks. Buffalo and Terrys creeks showed a decline and Porters Creek slightly increased. There were no EPT taxa recorded at Terrys and Shrimptons creeks.

Survey results suggest that macroinvertebrate community assemblages in all five creeks are consistent with urban systems. SIGNAL2 saw a decline in all creeks except for Archers Creek when compared to spring 2013. SIGNAL-SF and AUSRIVAS OE50 remained consistent with their historical means. AUSRIVAS OE0 SIGNAL showed declines in creek health for Shrimptons and Buffalo compared with increases in health for Terry and Archers creeks.

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2 Glossary

Item	Meaning
Abundance	The total number of individual specimens; in a sample, community, ecosystem etc.
Algae	Comparatively simple chlorophyll-bearing plants, most of which are aquatic and microscopic in size.
Alkalinity	The ability of a solution to neutralise acid (or buffer).
Aquatic ecosystem	Community of aquatic plants and animals together with the physical and chemical environment in which they live.
Ammonia	A colourless gas. In the aquatic environment, it exists in the relatively harmless form ammonium (NH4) and the toxic form ammonia (NH3).
Analyte	The physical and chemical parameters (indicators) to be measured.
Anthropogenic	Impacts on an environment that are produced or caused by humans
ANZECC	ANZECC is a forum for member governments to develop coordinated policies about national and international environment and conservation issues.
AUSRIVAS	AUSRIVAS is a rapid prediction model used to assess the biological health of Australian rivers.
Baseline Data	Is prior collected data that allows comparison to subsequently collected data, enabling comparison to ‘normal’ background levels.
Benthic	Refers to the lowest areas of a water body; the sediment layer; referring to the organisms that live within this area
Catchment	The area that is drained by a river, lake or other water body.
Community	Assemblage of organisms characterised by a distinctive combination of species occupying a common environment and interacting with one another.
Concentration	The quantifiable amount of a chemical divided by the total volume of a mixture.
Conductivity	The measure of salt content in soil or water; it refers to the ability of the substance to transfer an electrical charge.
Detection limit	The smallest concentration or amount of a substance that can be defined by an analytical process for reporting with a specific degree of certainty.
Detritus	Pieces of dead and decomposing plants and organisms (generally in the form of small pieces) found in a water body.
Dissolved Oxygen	The measurement of the concentration of oxygen that is dissolved in a water body.
Diversity (Biological)	The measure of the number and/or degree of available organisms in an environment.

Item	Meaning
Edge habitat	The edge habitat is an area of unbroken water surface that is within 2 m of the bank.
Effluent	A waste product that is discharged to the environment, usually in reference to waste water discharged from sewage treatment plants.
Ethanol	Alcohol used to preserve macroinvertebrates for long-term reference and identification.
Eutrophication	Enrichment of a water body with nutrients that results in increased aquatic plant growth and low oxygen levels.
Faecal Coliforms	Bacteria which inhabit the intestines of humans and other vertebrates and are present in faeces. Used as a primary indicator of sewage pollution in the environment.
Guideline (water quality)	Concentration limit or narrative statement recommended to support and maintain a designated water use.
Habitat	The place where a population lives and its surroundings, both living and non-living.
Indicator	A parameter (chemical, biological or geological) that can be used to provide a measure of the quality of water or the condition of an ecosystem.
Invertebrate	Animal lacking a dorsal column of vertebrae (backbone) or a notochord.
Macroinvertebrate (Aquatic)	Animals without backbones that when mature are greater than 1 millimetre; live in the water column, on the water surface or on the bottom of a waterway.
Macrophyte	Plant species that are adapted to growing in or on permanent water and have a definite life form related to the aquatic environment.
Multivariate Analysis	The statistical analysis of data containing more than one variable.
Nitrogen (Aquatic)	An element that is essential for plant and animal growth, it occurs in three forms Nitrate, Nitrite and ammonium.
Nutrients	Compounds required for growth by plants and other organisms. Major plant nutrients are phosphorus and nitrogen.
Organic Pollution (Aquatic)	Organic compounds in the form of contaminants (pollution) in a water body that in time can be oxidised by microorganisms (biodegrade).
Pathogens	Disease-causing organisms, such as bacteria and viruses.
pH	A measure of the degree of acidity or alkalinity; expressed on a logarithmic scale of 1 to 14 (1 is most acid, 7 neutral and 14 most alkaline).
Phosphorus	Is an element that is essential for plant and animal growth, excess concentrations can lead to eutrophication.
Photosynthesis	The conversion of carbon dioxide to carbohydrates in the presence of chlorophyll using light energy.

Item	Meaning
Physico-Chemical (Aquatic)	The measure and relationship between the physical and chemical identities of a water body.
Reference Site	A sampling site that occurs in a catchment largely void of human related impacts.
Sensitive organism	An organism that's survival is highly susceptible to shifts in environmental conditions.
Sewage	The waste water from homes, offices, shops, factories and other premises discharged to the sewer. Is usually 99% water.
Sewage overflow	A sewage release to prevent sewage flowing back into houses.
SIGNAL	SIGNAL (Stream Invertebrate Grade Number Average Level) is a biotic index using aquatic macroinvertebrates to assess stream health.
Stormwater	Rainwater that runs off the land, frequently carrying various forms of pollution such as litter and detritus, animal droppings and dissolved chemicals. This untreated water is carried in stormwater channels and discharged directly into water bodies.
Stormwater system	The system of pipes, canals and other channels used to carry stormwater to bodies of water, such as rivers or oceans. The system does not usually involve any significant form of treatment.
Taxon	(plural taxa) The definite entity and classification formally recognised by taxonomists of any given organism.
Taxonomic Level	Refers to the classification type of an organism; kingdom, phylum, class, order, family, genus, species.
Tolerant organism	Is an organism that can survive in highly variable environmental conditions.
Turbidity	A measure of the amount of suspended solids (usually fine clay or silt particles) in water and thus the degree of scattering or absorption of light in the water.
Univariate Analyses	Refers to the statistical analysis of data containing one variable.
WSUD	Water Sensitive Urban Design

3 Acronyms and abbreviations

Acronyms/ Abbreviation	Meaning
ANZECC	Australian and New Zealand Environment and Conservation Council
ANOVA	Analysis of Variance
AUSRIVAS	Australian River Assessment System
CFU	Colony Forming Unit
EPT	Ephemeroptera, Plecoptera, Trichoptera
LGA	Local Government Area
mg/L	Milligrams per litre
MDS	Multi-Dimensional Scaling
NATA	National Association of Testing Authorities of Australia
NTU	Nephelometric Turbidity Units
SIGNAL-SF	Stream Invertebrate Grade Number Average Level – Sydney Family
SIGNAL2	Stream Invertebrate Grade Number Average Level – National scores (2003)
µg/L	Micrograms per litre
µS/cm	Micro-siemens per centimetre (unit of conductivity)

4 Introduction

4.1 Background

Water quality monitoring is carried out by the City of Ryde to inform environmental management and development decisions. This report will provide:

- physical and chemical water analysis of five major creeks within the City of Ryde LGA during dry weather
- diversity and abundance of macroinvertebrate communities at five creeks within study area
- environmental and ecosystem health data which will assist in monitoring the effect of future developments, creek restoration, stormwater management, bushland rehabilitation and general anthropogenic activities and incidents within the catchment
- on-going information to assist the direction of future water quality monitoring plans

Biological and chemical monitoring enables the City of Ryde to:

- build on baseline data that enables the temporal evaluation and analysis of the health of the catchments of the strategy
- identify and track new and existing impacts affecting the catchments
- provide direction and monitor potential infrastructural works within the LGA, i.e. in-stream or riparian rehabilitation and stormwater treatment projects
- build on the known taxa list for each catchment and to aid in the identification of key indicator taxa

4.2 Study area

4.2.1 Catchment

The City of Ryde LGA has a total area of 40.651 km^2 and is located 12 km north west of central Sydney. It is comprised of 16 suburbs and 14 separate stormwater catchments dominated by residential housing. It also includes several important retail centres and light industry/manufacturing sectors.

There is limited areas of natural bushland fringing urban infrastructure including several important natural bush corridors and areas of open space that support recreation and sporting activities. There are small sections of Lane Cove National Park present on the eastern and northern borders of Shrimptons, Porters and Buffalo creeks. The creeks surveyed all drain into the greater Parramatta River catchment. Archers Creek enters Parramatta River directly and the remaining creeks through the Lane Cove River catchment.

4.2.2 Sampling sites

The five core sites sampled for macroinvertebrates and water quality are shown in Table 1 and Figure 1. The eight additional water quality sites are shown in Table 2 and Figure 1. Sites were sampled for water quality and macroinvertebrates across November 23rd and 24th 2016.

Table 1 Core sampling sites (water quality and macroinvertebrate sampling sites)

Site code	Site name	Latitude / Longitude
CR1S	Shrimptons Creek	-33.780530, 151.118628
CR2A	Archers Creek	-33.805555, 151.074272
CR3T	Terrys Creek	-33.765792, 151.098345
CR4B	Buffalo Creek	-33.816451, 151.125705
CR5P	Porters Creek	-33.783362, 151.137671

Table 2 Water quality only sites

Site code	Site name	Latitude / Longitude
CR1SA	Shrimptons Creek @ Kent Road	-33.789246, 151.113419
CR1SB	Shrimptons Creek @ Bridge St	-33.794061, 151.109779
CR1SC	Shrimptons Creek @ Quarry Rd	-33.796856, 151.106775
CR4BA	Buffalo Creek Downstream Burrows Park	-33.814392, 151.116656
CR4BB	Buffalos Creek Upstream Burrows Park	-33.815060, 151.113502
CR5PA	Porters Creek @ Main Branch	-33.786500, 151.134839

Figure 1 Map of macroinvertebrate and water quality sampling sites

5 Methods

All field sampling and laboratory methods adhered to internal methods and ISO/IEC 17025 requirements. NATA accreditation details are summised in Table 3.

Table 3 Sydney Water laboratories' NATA accreditation numbers

Field of Testing	Number	Accredited	Standard
Chemical Testing	63	1952	ISO/IEC 17025
Biological Testing	610	1966	ISO/IEC 17025

5.1 Sampling methods

5.1.1 Water quality sampling

The water quality monitoring program design including site locations were determined through consultation between City of Ryde and Sydney Water.

Samples were collected in bottles pre-labeled with a unique identification number, site code, location and date of collection. Field measurements and observations for each site were recorded at the time of sampling. Aseptic techniques were followed to ensure sample integrity.

Samples were collected from 20-30 cm below the water surface. In shallower waterways, surface samples were collected, to avoid collecting benthic sediment. Surface samples may contain surface contaminates, such as scum, dust or pollen, which may not be present below the waterway surface. If a surface sample was collected, it would be recorded.

Some water chemistry analytes must be analysed in the field using various instruments (Table 4). Field observations were also recorded at each site. This includes sample clarity, algae presence, recent rain, visual pollution and flow rate (visual assessment).

Table 4 Water chemistry parameters and field analysis methods

Analyte	Method
Dissolved Oxygen (%)	WTW Multiliner Universal Meter
Dissolved Oxygen (mg/L)	WTW Multiliner Universal Meter
Conductivity (µS/cm)	WTW Multiliner Universal Meter
pH (pH units)	WTW Multiliner Universal Meter
Turbidity (NTU)	HACH Turbidimeter
Temperature (°C)	Digital Thermometer

5.1.2 Macroinvertebrate sampling and identifications

Macroinvertebrate sampling was completed in accordance with AUSRIVAS protocols for New South Wales (Turak et al. 2004) and in-house test methods. For each sampling site, two edge habitats were sampled with a hand-held dip net. Edge habitats were defined as areas with little to no current. The sampling net was swept across the habitat, to the length of 10 m. In the process, silt and detritus on the bottom of the stream were stirred up so that benthic animals were suspended and captured.

The contents of the net were emptied into a large white sorting tray with a small amount of water. The live macroinvertebrate specimens were extracted with fine forceps and pipettes for a minimum period of 40 minutes (Figure 2). If new taxa were collected between 30 and 40 minutes, sorting continued for a further 10 minutes, if not, picking ceased. If new taxa were found, the 10-minute processing cycle continued up to a maximum of 60 minutes. There is not a set maximum animals to be collected under the NSW AUSRIVAS protocols (Turak et al. 2004).

Specimens were preserved in small glass specimen jars containing 85% un-denatured ethanol with a label indicating site code, location, date, habitat, replicate number, name of sampler and name of picker.

Macroinvertebrates were identified and enumerated to the family taxonomic level, except the family Chironomidae, which were identified to sub-family. For AUSRIVAS analysis specimens were combined for Oligochaeta at class and Acarina at order level.

Figure 2 Sample jars and a picked specimen, Hemipteran, Notonectidae *Enithares* (Back-swimmer)

5.2 Data analysis methods

5.2.1 Water quality

Water quality results allow characterisation of each study creek against Australian and New Zealand Environment and Conservation Council (ANZECC 2000) guidelines for Aquatic Ecosystems (Lowland River in south eastern Australia) and Recreational Water Quality and Aesthetics (Secondary) (Table 5).

Although the ANZECC (2000) guidelines/trigger values, were for slightly disturbed ecosystems, they do provide an indication of water quality compared to other systems within south eastern Australia.

Daily rainfall data was collected from the Sydney Water rain gauge at West Ryde Pumping Station.

Water hardness categories based on values are presented in Table 6. Analytes that have trigger values that vary per water hardness are summarised in Table 7 with their adjusted trigger values.

Table 5 ANZECC (2000) indicators and guideline values. H indicates trigger values that depend on water hardness values.

Indicator	Guideline value	Unit	Guideline reference
Dissolved Oxygen	85 to 110	% saturation	Protection of aquatic ecosystem (ANZECC 2000)
pH	6.5 to 8.5	pH unit	Protection of aquatic ecosystem (ANZECC 2000)
Turbidity	6 to 50	NTU	Protection of aquatic ecosystem (ANZECC 2000)
Conductivity	125 to 2,500	µS/cm	Protection of aquatic ecosystem (ANZECC 2000)
Ammonia nitrogen	20	µg/L	Protection of aquatic ecosystem (ANZECC 2000)
Oxidised nitrogen	40	µg/L	Protection of aquatic ecosystem (ANZECC 2000)
Total nitrogen	350	µg/L	Protection of aquatic ecosystem (ANZECC 2000)
Total phosphorus	25	µg/L	Protection of aquatic ecosystem (ANZECC 2000)
Faecal coliforms	1,000	CFU/100 mL	Secondary contact recreation (ANZECC 2000)
Chromium H	0.001	mg/L	Toxicants at 95% level of protection
Manganese	1.9	mg/L	Toxicants at 95% level of protection
Iron	ID	mg/L	Toxicants at 95% level of protection
Copper H	0.0014	mg/L	Toxicants at 95% level of protection
Zinc H	0.008	mg/L	Toxicants at 95% level of protection
Arsenic	0.013	mg/L	Toxicants at 95% level of protection
Cadmium H	0.002	mg/L	Toxicants at 95% level of protection
Lead H	0.0034	mg/L	Toxicants at 95% level of protection
Mercury B	ID	mg/L	Toxicants at 95% level of protection

Table 6 ANZECC (2000) trigger value adjustments for water hardness

Hardness category (mg $CaCO_3$ /L)	Hardness range (mg $CaCO_3$ /L)	Chromium (Cr)	Cadmium (Cd)	Copper (Cu)	Lead (Pb)	Zinc (Zn)
Soft	0-59	TV	TV	TV	TV	TV
Moderate	60-119	x 2.5	x 2.7	x 2.5	x 4.0	x 2.5
Hard	120-179	x 3.7	x 4.2	x 3.9	x 7.6	x 3.9
Very hard	180-240	x 4.9	x 5.7	x 5.2	x 11.8	x 5.2
Extremely hard	400	x 8.4	x 10.0	x 9.0	x 26.7	x 9.0

Table 7 Water hardness adjusted trigger values

Hardness category (mg/L as $CaCO_3$)	Hardness range (mg/L as $CaCO_3$)	Chromium (Cr) mg/L	Cadmium (Cd) mg/L	Copper (Cu) mg/L	Lead (Pb) mg/L	Zinc (Zn) mg/L
Soft	0-59	0.001	0.002	0.001	0.003	0.008
Moderate	60-119	0.0027	0.0005	0.0035	0.0136	0.02
Hard	120-179	0.0042	0.00074	0.00546	0.02584	0.0312
Very hard	180-240	0.0057	0.00098	0.00728	0.04012	0.0416
Extremely hard	400	0.01	0.00168	0.0126	0.09078	0.072

5.2.2 Macroinvertebrate Analyses

Macroinvertebrate data was analysed per the three methods listed below. Descriptions of these analyses are introduced and briefly at the start of each respective results section.

Univariate Analyses;

- Taxa Richness
- EPT Taxa Richness

Biological Indices;

- SIGNAL2
- SIGNAL-SF
- AUSRIVAS

6 Site observations

CR3 Terrys Creek

The Terrys Creek sampling site is located within Somerset Park under the M2 overpass in the suburb of Epping. The surrounding land use is residential, and the creek flows through a bushland corridor. The surrounding riparian area and bank edge is a mix of native and exotic plant species. The creek bed is predominately bedrock, gravel and sand. There were no notable site observations recorded in spring 2016.

Figure 3 Edge habitat at Terrys Creek, (L-R) spring 2007 and spring 2013.

CR1 Shrimptons Creek

The Shrimptons Creek core sampling site is located within Wilga Park in the suburb of Macquarie Park and the surrounding land use comprises a mix of residential, commercial and light industrial. The creek flows through a thin riparian/vegetation corridor, which is a mix of native and exotic species. The riparian area is periodically cleared but at times has been overgrown with exotic plant species. The creek bed is predominately bedrock and sand/silt.

There are gross pollutant traps placed at points along the sampling site, however domestic rubbish, excessive organic debris and other refuse has been periodically observed at the site. During spring 2016 sampling, rubbish and leaf litter was observed in the gross pollutant trap. Deceased animals have been observed at this sampling site, including spring 2016.

Figure 4 Shrimptons Creek: sampling site facing downstream (L) sampling site facing upstream (R).

CR1SA Shrimptons Creek at Kent Road

The Kent Road site is situated amongst a residential area and is lined by a thin section of riparian vegetation that completely shades the creek and comprises a mix of native and exotic species. Odours have regularly been noted at this site, generally linked to the breakdown of organic debris and or urban run-off.

CR1SB Shrimptons Creek at Bridge Street

The Bridge Street site is located at the downstream section of Burrows Park, just before it flows under Bridge St and is surrounded by residential areas. Burrows Park consists largely of cleared grass fields.

The riparian area has at times been thickly vegetated with native and exotic weeds and shrubs that have choked the creek. More recently growth has been predominately *Eleocharis* and *Myriophylum sp* and various grasses and weeds (Figure 5).

CR1SC Shrimptons Creek at Quarry Road

The Quarry Road site is located at the upstream section of Burrows Park, at the point where Shrimptons Creek emerges from the underground stormwater system. This site has experienced similar changes as Bridge St with clearing and revegetation. Odour, oil and scum has been observed on the water surface with organic and domestic debris during recent and past surveys (Figure 5).

Figure 5 Shrimptons Creek, spring 2013, Bridge St (L) and Quarry Rd (R).

CR5 Porters Creek

The Porters Creek core sampling site is located on the eastern boundary of the Ryde City Depot (Macquarie Park) where Porters Creek emerges after flowing mostly underground in its upper reaches. Water quality samples were collected within the Ryde Waste Disposal Depot close to where Porters Creek drains from an underground system. Macroinvertebrates were collected within the boundaries of the Lane Cove National Park just downstream of the depot and the bridge for the main park access road.

The surrounding riparian area is dominated by native plants with a small amount of exotic species. The creek bed is mostly bedrock with some cobble, boulder and sand. No macrophyte growth has been observed at the site however there has been varying levels of algal growth present. The water was noticeably milky and turbid in spring 2016, which is consistent with historical observations. Observed odours, rubbish, scum and oil is likely due to the proximity of the depot and waste disposal site.

Figure 6 Porters Creek, autumn 2013 (L) and spring 2016 (R).

CR5PA Porters Creek at Main Branch

The Main Branch site is located on the western boundary of the depot and consists of an open concrete channel. The sampling point is in a retention basin at the end of the channel immediately before the creek flows underground for the remainder of its path through the depot. There is usually extensive algal growth along the edge of the concrete channel and there is often a varying amount of oil and scum on the water surface.

CR5PB Porters Creek at Spur Branch

The Spur Branch site is located in the north-western corner of the depot in an underground drainage pit where several underground stormwater lines meet before joining and draining to the main Porters Creek line. In spring 2013 the drainage grate and surrounding concrete had collapsed (Figure 7), rendering the site impossible to sample. The site still could not be sampled in spring 2016, and an alternative site will be determined.

Figure 7 Porters Creek at Spur Branch in spring 2013 (L) and Wicks Rd in autumn 2014 (R).

CR5PC Porters Creek at Wicks Road

The Wicks Road site is located at the first point that Porters Creek drains from the underground stormwater system. The site is surrounded by commercial and industrial land uses and the vegetation mostly consists of exotic trees and shrubs. Oil and scum has been regularly observed on the water surface. This site could not be accessed in spring 2016 due to construction of a new stormwater system.

CR4 Buffalo Creek

The Buffalo Creek core sampling site is located in a bush corridor in the suburb of Gladesville and is accessed through private property. The surrounding land use is a mix of residential, light industry/commercial and reserves. The surrounding vegetation is a mix of native and exotic species however the exotic species dominate. The southern bank is mostly manicured lawns.

The creek bed is mostly a mix of sand, silt and gravel. There is usually some macrophyte growth, *Egeria* and *Potamogeton*, and little algal growth has been observed. Sedimentation has occurred periodically, along with a significant amount of organic debris and domestic rubbish (Figure 8).

Figure 8 **Buffalo Creek, CR4B facing upstream in spring 2009 (L) and in autumn 2014 (R).**

CR4BA Buffalo Creek downstream of Burrows Park

The downstream Burrows Park site is accessed off Buffalo Rd and is positioned just before the creek flows under the road. The surrounding land use is residential and Burrows Park consists mostly of a bush corridor. There are usually obvious signs of bird activity around this site, including extensive bird droppings. During the current surveys wood duck and ibis were present at the site. There have been increased turbidity levels observed at this site most notably in autumn 2008 (Figure 9, left) and on several non-sampling site visits.

Figure 9 **Buffalo Creek, downstream Burrows Park in spring 2008 (L) and upstream Burrows Park in autumn 2014 (R).**

CR4BB Buffalo Creek upstream of Burrows Park

The upstream Burrows Park site is about 300 metres upstream of Buffalo Rd, and lies in the middle of a bush corridor. The site is surrounded by vegetation that completely shades the creek. The creek is shallow at this point and has little flow. The site is positioned just downstream from a stormwater tributary/pipe. There has been little observable change at this site throughout the survey periods.

CR2 Archers Creek

The core Archers Creek sampling site is located at Maze Park in the suburb of West Ryde and is positioned just upstream of the Victoria Rd crossing. The surrounding land use is mostly residential and a golf course is present downstream. There is mostly native vegetation along both banks of the creek. The creek bed is mostly bedrock with banks of sediment (sand, silt and organic matter). There is thick growth of various native and exotic plants along most of the sampling area including both terrestrial and semiaquatic species (Figure 10). There is also extensive algal growth within much of the creek.

Figure 10 Archers Creek in autumn 2008 (L) and spring 2016 (R).

7 Rainfall results and interpretation

Rainfall information provides context for water quality and macroinvertebrate data. Rainfall plays an important role in driving water quality in urban streams through input of pollutants and increased flow.

Rainfall events can cause bank erosion, resulting in a loss of habitat and altered channel complexity (Walsh 2005). Urban catchments often have a high amount of connected impervious surfaces, such as roads and building. This results in increased storm water runoff, which often discharges into streams. This can cause an increase in turbidity, nutrients and other pollutants.

Daily rainfall data between June and December 2016 is summarised in Figure 11. There were large rainfall events within the analysed period. Most notable was the storm event June 4 – 6, with 109.5mm recorded in one 24-hour period and 232.5mm across the whole event. All other rainfall events were much lower and similar to rainfall in the 2013/2014 period. There was a low rainfall event (6mm) in between the macroinvertebrate and water quality sampling. Overall November had the second lowest total rainfall of the analysed period, with 26.5mm recorded.

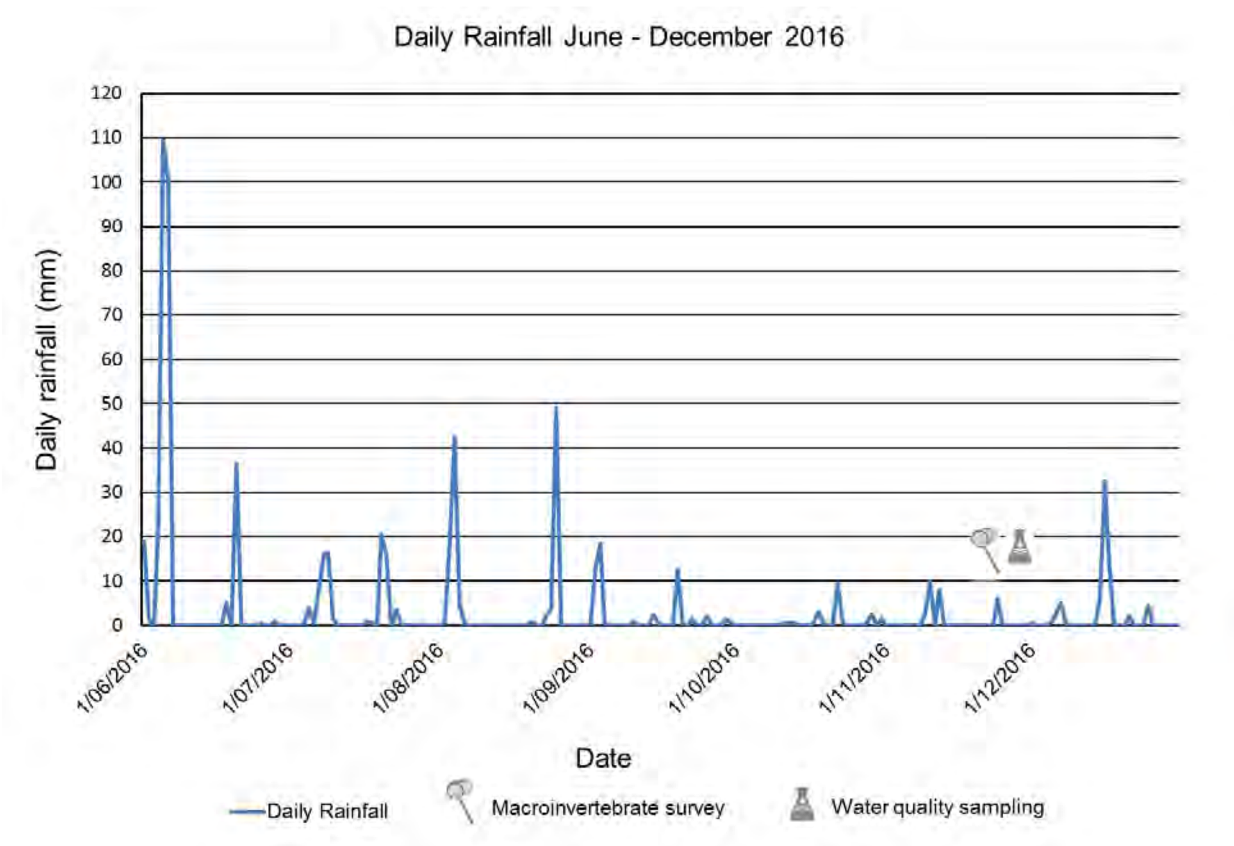

Figure 11 Daily rainfall data June – December 2016

8 Water quality results and interpretation

8.1 Results

The data presented in this section includes historical medians (2004-2014, or where available) and spring 2016 data. All water quality sites, for the current period, were sampled on 29/11/2016. The water quality results are presented in the following sections, by location, then site. Each section will cover results for:

- physico-chemical variables
- alkalinity and hardness
- bacteriological and nutrients
- metals

Arrows indicating the changes between spring and historical median results are added to the tables in the results section to aid with visual interpretation of the data. Values that exceed the recommended ANZECC (2000) guidelines appear in red text. The metals results are presented under the elemental symbols, chromium (Cr), manganese (Mn), iron (Fe), copper (Cu), zinc (Zn), arsenic (As), cadmium (Cd), lead (Pb) and mercury (Hg).

Two sites at Buffalo Creek (CR5PA and CR5PB) were not able to be sampled due to access restrictions, no data will be presented for these sites.

8.1.1 Terrys Creek

There was a decrease in dissolved oxygen and an increase in temperature and conductivity for spring 2016 compared the historical median (Table 8). Results have fallen outside the recommended guidelines for dissolved oxygen only.

Water hardness fell into the moderate category (60-119 mg $CaCO_3$/L) for both spring 2016 and the historical median (Table 9). Magnesium, calcium and hardness had decreased in spring 2016, however, alkalinity had increased.

Ammonia, Total nitrogen, oxidised nitrogen and total phosphorus exceeded the recommended guideless for spring 2016 (Table 10). Ammonia increased in spring 2016 to 7.5x the historical median. All metals were within the recommended guidelines except for Copper in spring 2016, 0.0049 mg/L (trigger value 0.0035 mg/L, Table 11).

Table 8 Terrys Creek physico-chemical results

Analyte		Temperature	Dissolved Oxygen	Dissolved Oxygen	pH	Turbidity	Conductivity
Unit		°C	mg/L	% saturation	pH units	NTU	µS/cm
Guideline		NA	NA	85-110	6.5-8.5	50	125-2200
CR3T	*Historical Median*	15.695	6.5	**64.85**	7.2	2.5	150
	Spring 2016	18.8 ↑	3. 1 ↓	**33.6** ↓	7.11 ↓	3.02 ↑	331 ↑

Table 9 Terrys Creek alkalinity and hardness results

Analyte		Total Magnesium	Total Calcium	Hardness	Alkalinity
Unit		mg/L	mg/L	mg/L $CaCO_3$	mg/L $CaCO_3$
Guideline		NA	NA	NA	NA
CR3T	*Historical Median*	8.65	32.75	117.5	61.9
	Spring 2016	5.54 ↓	23 ↓	80 ↓	77 ↑

Table 10 Terrys Creek bacteriological and nutrient results

Analyte		Faecal coliform	Ammonia NH_3-N	Total Nitrogen	Total Kjeldahl Nitrogen	Oxidised Nitrogen NO_x-N	Total Phosphorus
Unit		CFU/100ml	µg/L	µg/L	µg/L	µg/L	µg/L
Guideline		1000	20	350	NA	40	25
CR3T	*Historical Median*	150	20	**580**	350	**170**	**32**
	Spring 2016	370 ↑	**150** ↑	**780** ↑	640 ↑	**140** ↓	**140** ↑

Table 11 Terrys Creek metal results, * indicates trigger values for moderate water hardness

Analyte		Total Cr	Total Mn	Total Fe	Total Cu	Total Zn	Total As	Total Cd	Total Pb	Total Hg
Unit		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Guideline		0.00054*	1.9	NA	0.0035*	0.02*	0.013	0.0025*	0.0136*	0.0006
CR3T	*Historical Median*	0.0005	0.0235	0.6935	0.0035	0.015	0.0005	0.0005	0.0005	0.00015
	Spring 2016	0.0004 ↓	0.0736 ↑	1.74 ↑	**0.0049** ↑	0.012 ↓	0.0011 ↑	<0.0001 ↓	0.0013 ↑	<0.0003 ↓

8.1.2 **Shrimptons Creek**

- CR1S – Shrimptons Creek at Wilga Park
- CR1SA - Shrimptons Creek at Kent Road
- CR1SB - Shrimptons Creek at Bridge Street (downstream of Santa Rosa Park)
- CR1SC - Shrimptons Creek at Quarry Road (upstream of Santa Rosa Park)

All Shrimptons Creek Sites were similar for physico-chemical results. Recommended guideline exceedances were restricted to dissolved oxygen (Table 12). In spring 2016, CR1S, CR1SA and CR1SB were all below recommended guidelines (64.7%, 35.3% & 51.1%), whilst CR1SC was within the recommended guidelines at 100.4%.

All sites for both time periods fell into the category of moderate hardness (Table 13). Magnesium results in spring 2016 were all lower than the historical median, as was calcium, with the exception of CR1S. At CR1S and CR1SA there was an increase in alkalinity, whereas CR1SB and CR1SA had a decrease.

All faecal coliform results were within the recommended guidelines (Table 14), however, there were exceedances for ammonia, total nitrogen, oxidised nitrogen and total phosphorus. All sites for both time periods exceeded the recommended guidelines for total nitrogen and total phosphorus. Spring 2016 only had one oxidised nitrogen exceedance at CR1SC. Ammonia results exceeded for spring 2016 at all sites except CR1SB.

There were no exceedances for metals in spring 2016. The historical medians for CR1S for copper and zinc were above recommended guidelines (Table 15).

Table 12 Shrimptons Creek physico-chemical results

Analyte		Temperature	Dissolved Oxygen	Dissolved Oxygen	pH	Turbidity	Conductivity
Unit		°C	mg/L	% saturation	pH units	NTU	µS/cm
Guideline		NA	NA	85-110	6.5-8.5	50	125-2200
CR1S	*Historical Median*	17.2	4.31	**45.6**	7.1	4.91	360
	Spring 2016	19.9 ↑	6.01 ↑	**64.7** ↑	7.16 ↑	7.58 ↑	303 ↓
CR1SA	*Historical Median*	16.95	4.65	**48.35**	7.075	4.36	438.5
	Spring 2016	20.3 ↑	6.49 ↑	**35.3** ↓	7.12 ↑	3.88 ↓	331 ↓
CR1SB	*Historical Median*	17.55	5.65	**58.75**	7.07	4.94	664.5
	Spring 2016	20.5 ↑	4.55 ↓	**51.1** ↓	7.16 ↑	4.15 ↓	319 ↓
CR1SC	*Historical Median*	17.65	7.05	**73.5**	7.3	3.335	901
	Spring 2016	19.1 ↑	9.17 ↑	100.4 ↑	7.95 ↑	3.08 ↓	314 ↓

Table 13 Shrimptons Creek alkalinity and hardness results

Analyte		Total Magnesium	Total Calcium	Hardness	Alkalinity
Unit		mg/L	mg/L	mg $CaCO_3$/L	mg $CaCO_3$/L
Guideline		NA	NA	NA	NA
CR1S	*Historical Median*	5.935	26.3	89.95	66.5
	Spring 2016	4.66 ↓	26.5 ↑	85 ↓	79 ↑
CR1SA	*Historical Median*	7.12	24.75	91.05	64.1
	Spring 2016	6.96 ↓	20.1 ↓	79 ↓	68 ↑
CR1SB	*Historical Median*	8.82	30.55	112.6	82.8
	Spring 2016	7.17 ↓	18.9 ↓	77 ↓	64 ↓
CR1SC	*Historical Median*	11.17	27.3	114.05	80.85
	Spring 2016	7.66 ↓	18.1 ↓	77 ↓	54 ↓

Table 14 Shrimptons Creek bacteriological and nutrient results

Analyte		Faecal coliform	Ammonia NH_3-N	Total Nitrogen	Total Kjeldahl Nitrogen	Oxidised Nitrogen NO_{x}-N	Total Phosphorus
Unit		CFU/100ml	µg/L	µg/L	µg/L	µg/L	µg/L
Guideline		1000	20	350	NA	40	25
CR1S	*Historical Median*	420	**25**	**635**	480	**95**	**53**
	Spring 2016	560 ↑	**120** ↓	**690** ↑	650 ↑	40 ↓	**145** ↑
CR1SA	*Historical Median*	450	**635**	**635**	475	**65**	**41**
	Spring 2016	270 ↓	**40** ↓	**530** ↓	490 ↑	40 ↓	**54** ↑
CR1SB	*Historical Median*	235	**550**	**550**	400	25	**25.5**
	Spring 2016	180 ↓	20 ↓	**440** ↓	410 ↑	30 ↑	**32** ↑
CR1SC	*Historical Median*	475	**35**	**1425**	515	**670**	**55**
	Spring 2016	60 ↓	**180** ↑	**820** ↓	420 ↓	**400** ↓	**18** ↓

Table 15 Shrimptons Creek metal results, * indicates trigger values for moderate water hardness

Analyte		Total Cr	Total Mn	Total Fe	Total Cu	Total Zn	Total As	Total Cd	Total Pb	Total Hg
Unit		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Guideline		0.00054*	1.9	NA	0.0035*	0.02*	0.013	0.0025*	0.0136*	0.0006
CR1S	*Historical Median*	0.0005	0.042	0.953	**0.004**	**0.0255**	0.00075	0.0005	0.00125	0.00015
	Spring 2016	0.0005 -	0.0755 ↑	1.7 ↑	0.0031 ↓	0.016 ↓	0.0011 ↑	<0.0001 ↓	0.0015 ↑	<0.0003 -
CR1SA	*Historical Median*	0.0005	0.0485	1.1425	0.0015	0.015	0.0005	0.0005	0.0005	0.00015
	Spring 2016	<0.0002 ↓	0.0382 ↓	1.19 ↑	0.0018 ↑	0.005 ↓	0.0007 ↑	<0.0001 ↓	0.0005 -	<0.0003 -
CR1SB	*Historical Median*	0.0005	0.0815	1.84	0.0015	**0.022**	0.0005	0.0005	0.0005	0.00015
	Spring 2016	<0.0002 ↓	0.0165 ↓	0.974 ↓	0.0023 ↑	0.007 ↓	0.0006 ↑	<0.0001 ↓	0.0005 -	<0.0003 -
CR1SC	*Historical Median*	0.0005	0.0305	0.304	0.002	0.0155	0.0005	0.0005	0.0005	0.00015
	Spring 2016	<0.0002 ↓	0.0064 ↓	0.141 ↓	0.0023 ↑	0.005 ↓	0.0004 ↓	<0.0001 ↓	0.0002 ↓	<0.0003 -

8.1.3 Porters Creek

- CR5P – Porters Creek downstream of council depot
- CR5PA – Porters Creek at Main Branch
- CR5PB – Porters Creek at Spur Branch (could not be sampled – data no included)
- CR5PC – Porters Creek at Wicks Road (could not be sampled – data no included)

Only one value was outside of recommended guidelines in spring 2016 for the physico-chemical analytes, CR5P with 77.6% dissolved oxygen (Table 16). The historical median of dissolved oxygen at CR5PA was lower than recommended guideline but in spring 2016 the result was within recommended guidelines.

Magnesium and calcium increased in spring 2016 for both sites (Table 17). Water hardness differed greatly, both spatially and temporally, ranging from moderate to very hard. CR5PA in spring 2016 had much higher values for all alkalinity and hardness results, compared to the historical median. This site had the highest concentration of $CaCO_3$ out of all sites sampled in spring 2016.

Ammonia exceeded the recommended guidelines for all time periods except CR5PA in spring 2016 (Table 18). Total nitrogen results exceeded recommended guidelines at both Porters Creek sites, historically and in spring 2016. Oxidised nitrogen and total phosphorus exceeded at CR5P (historically & in spring 2016) and CR5PA (historically only).

Due to the varying water hardness results, the trigger values for were not included in Table 19 for the impacted values.

The adjusted trigger values for moderate, hard and very hard can be found in Table 7. There were two values over that exceeded the trigger values, chromium (0.001 mg/L, trigger value for very hard water 0.00054 mg/L) and zinc (0.026mg/L, trigger value for very hard water 0.02 mg/L) both at CR5PA in spring 2016.

Table 16 Porters Creek physico-chemical results

Analyte		Temperature	Dissolved Oxygen	Dissolved Oxygen	pH	Turbidity	Conductivity
Unit		°C	mg/L	% saturation	pH units	NTU	µS/cm
Guideline		NA	NA	85-110	6.5-8.5	50	125-2200
CR5P	*Historical Median*	18	8.4	91.3	7.63	3.89	610
	Spring 2016	19.9 ↑	7.04 ↓	77.6 ↓	7.57 ↓	13 ↑	926 ↑
CR5PA	*Historical Median*	17.7	7.85	78.45	7.13	3.535	350.5
	Spring 2016	23.6 ↑	8.18 ↑	97.8 ↑	7.44 ↑	2.52 ↓	816 ↑

Table 17 **Porters Creek alkalinity and hardness results, water hardness indicated by * moderate, ** hard, ***very hard**

Analyte		Total Magnesium	Total Calcium	Hardness	Alkalinity
Unit		mg/L	mg/L	mg $CaCO_3$/L	mg $CaCO_3$/L
Guideline		NA	NA	NA	NA
CR5P	*Historical Median*	10.28	40.6	144 **	86.3
	Spring 2016	15.4 ↑	50.9 ↑	190 ** ↑	223 ↑
CR5PA	*Historical Median*	6.455	19.45	75.05 *	90
	Spring 2016	26.1 ↑	77.2 ↑	300 *** ↑	334 ↑

Table 18 **Porters Creek bacteriological and nutrient results**

Analyte		Faecal coliform	Ammonia NH_3-N	Total Nitrogen	Total Kjeldahl Nitrogen	Oxidised Nitrogen No_{x}-N	Total Phosphorus
Unit		CFU/100ml	µg L^{-1}	µg L^{-1}	µg L^{-1}	µg L^{-1}	µg L^{-1}
Guideline		1000	20	350	NA	40	25
CR5P	*Historical Median*	350	580	2350	1100	1200	26
	Spring 2016	680 ↑	8970 ↑	11200 ↑	9490 ↑	1690 ↑	65 ↑
CR5PA	*Historical Median*	54.5	90	730	580	165	37.5
	Spring 2016	22 ↓	10 ↓	660 ↓	650 ↑	10 ↓	18 ↓

Table 19 **Porters Creek metal results, * indicates trigger values that are determined by water hardness**

Analyte		Total Cr	Total Mn	Total Fe	Total Cu	Total Zn	Total As	Total Cd	Total Pb	Total Hg
Unit		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Guideline		*	1.9	NA	*	*	0.013	*	*	0.0006
CR5P	*Historical Median*	0.0005	0.0445	1.041	0.003	0.02	0.0005	0.0005	0.0005	0.00015
	Spring 2016	0.0008 ↑	0.0988 ↑	1.68 ↑	0.003 -	0.011 ↓	0.0009 ↑	<0.0001 ↓	0.0003 ↓	<0.0003 ↓
CR5PA	*Historical Median*	0.001	0.0385	0.671	0.004	0.026	0.0005	0.0005	0.0015	0.00015
	Spring 2016	0.0005 ↓	0.0417 ↑	0.239 ↓	0.0019 ↓	0.019 ↓	0.0009 ↑	<0.0001 ↓	0.0004 ↓	<0.0003 ↓

8.1.4 Buffalo Creek

- CR4B – Buffalo Creek at Higginbotham Road
- CR4BA – Buffalo Creek downstream of Burrows Park
- CR4BB – Buffalo Creek upstream of Burrows Park

Dissolved oxygen percent saturation (Table 20) was outside of recommended guidelines for all sites in spring 2016, 59.4% at CRBA and 67% at CR4BB. CR4B and CR4BA historically had low dissolved oxygen percent concentration.

Water hardness varied from moderate to very hard for all sites over time (Table 21). All sites had an increase in water hardness in spring 2016 compared to the historical median. This was reflected in the magnesium, calcium and alkalinity results.

Total nitrogen, oxidised nitrogen and total phosphorus results at all sites across time exceeded the recommended guidelines (Table 22). The ammonia results for all sites were within the guidelines for spring 2016, which is a change from the historical median. Only one site had a faecal coliform result exceeding the recommended guideline, 1000 CFU/mL at CR4B, the only faecal coliform exceedance from spring 2016.

All the metal results with trigger values that are not impacted by water hardness, were within the recommended guidelines (Table 23). As the water hardness varied between three categories, the trigger values were not included in the table, the trigger value summary can be found in Table 7. The only exceedances were for copper and zinc. In spring 2016 there was only one exceedance, copper at 0.0081 mg/L at CR4BB (trigger value 0.0054 mg/L for hard water). Historically CR4BA and CR4BB both exceeded the trigger value for copper and zinc.

Table 20 Buffalo Creek physico-chemical results

Analyte		Temperature	Dissolved Oxygen	Dissolved Oxygen	pH	Turbidity	Conductivity
Unit		°C	mg/L	% saturation	pH units	NTU	µS/cm
Guideline		NA	NA	85-110	6.5-8.5	50	125-2200
CR4B	*Historical Median*	17.2	6.8	**70.4**	7.3	5.1	667
	Spring 2016	21.1 ↑	7.03 ↑	**80** ↑	7.34 ↑	2.88 ↓	662 ↓
CR4BA	*Historical Median*	17.8	7.55	**79.3**	7.19	7.25	1136
	Spring 2016	21.6 ↑	5.22 ↓	**59.4** ↓	7.03 ↓	7.71 ↑	1139 ↑
CR4BB	*Historical Median*	17.45	8	**84.3**	7.64	4.32	934
	Spring 2016	20.6 ↑	6 ↓	**67.7** ↓	7.47 ↓	3.23 ↓	864 ↓

Table 21 Buffalo Creek alkalinity and Hardness results

Analyte		Total Magnesium	Total Calcium	Hardness	Alkalinity
Unit		mg/L	mg/L	mg $CaCO_3$/L	mg $CaCO_3$/L
Guideline		NA	NA	NA	NA
CR4B	*Historical Median*	8.495	23.85	94.8*	77
	Spring 2016	12.1 ↑	26.6 ↑	120** ↑	83 ↑
CR4BA	*Historical Median*	11.53	30.25	123**	95.1
	Spring 2016	18.7 ↑	39.5 ↑	180*** ↑	131 ↑
CR4BB	*Historical Median*	8.93	28.4	108.05*	102
	Spring 2016	12.7 ↑	39.1 ↑	150** ↑	139 ↑

Table 22 Buffalo Creek bacteriological and nutrients results

Analyte		Faecal coliform	Ammonia NH_3-N	Total Nitrogen	Total Kjeldahl Nitrogen	Oxidised Nitrogen NO_{x}-N	Total Phosphorus
Unit		CFU/100ml	µg/L	µg/L	µg/L	µg/L	µg/L
Guideline		1000	20	350	NA	40	25
CR4B	*Historical Median*	170	660	660	420	250	37
	Spring 2016	3000 ↑	20 ↓	570 ↓	440 ↑	130 ↓	40 ↑
CR4BA	*Historical Median*	840	1010	1010	490	550	45
	Spring 2016	490 ↓	20 ↓	690 ↓	610 ↑	80 ↓	101 ↑
CR4BB	*Historical Median*	515	1460	1460	450	890	61
	Spring 2016	910 ↑	10 ↓	1470 ↑	720 ↑	750 ↓	233 ↑

Table 23 Buffalo Creek metal results, * indicates trigger values that are determined by water hardness

Analyte		Total Cr	Total Mn	Total Fe	Total Cu	Total Zn	Total As	Total Cd	Total Pb	Total Hg
Unit		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Guideline		*	1.9	NA	*	*	0.013	*	*	0.0006
CR4B	*Historical Median*	0.0005	0.033	1.072	0.0035	0.0165	0.0005	0.0005	0.0005	0.00015
	Spring 2016	<0.0002 ↓	0.0253 ↓	0.807 ↓	0.0026 ↓	0.009 ↓	0.0006 ↑	<0.0001 ↓	0.0004 ↓	<0.0003 ↓
CR4BA	*Historical Median*	0.0005	0.0915	1.365	0.006	0.034	0.0005	0.0005	0.001	0.00015
	Spring 2016	0.0004 ↓	0.25 ↑	1.95 ↑	0.0029 ↓	0.016 ↓	0.0009 ↑	<0.0001 ↓	0.0009 ↓	<0.0003 ↓
CR4BB	*Historical Median*	0.0005	0.0325	0.4885	0.011	0.043	0.00075	0.0005	0.0005	0.00015
	Spring 2016	0.0005 -	0.0375 ↑	0.626 ↑	0.0081 ↓	0.028 ↓	0.0011 ↑	<0.0001 ↓	0.0005 -	<0.0003 ↓

8.1.5 Archers Creek

- CR2A – Archers Creek at Maze Park

Archers creek had low dissolved oxygen percent saturation both historically and in spring 2016 (Table 24). All other physico-chemical results were with the recommended guidelines.

Water hardness dropped in spring 2016 into the moderate category (Table 25), from the hard category, this was reflected in the results for magnesium, calcium and alkalinity.

There were several exceedances in the bacteriological and nutrients results in spring 2016 (Table 26). Ammonia, total nitrogen, oxidised nitrogen and total phosphorus exceeded but faecal coliforms did not. The spring 2016 the ammonia result was much less than the historical result and is much closer to the recommended guideline.

There were two results that exceeded the adjusted trigger values for metals, zinc from the historical median (0.0875mg/L, TV for moderate hardness 0.02mg/L) and copper in spring 2016 (0.0023mg/L, TV for soft water 0.001mg/L) (Table 27).

Table 24 Archers Creek physico-chemical results

Analyte		Temperature	Dissolved Oxygen	Dissolved Oxygen	pH	Turbidity	Conductivity
Unit		°C	mg/L	% saturation	pH units	NTU	µS/cm
Guideline		NA	NA	85-110	6.5-8.5	50	125-2200
CR2A	*Historical Median*	17.44	5.83	60	7.15	2.71	427.5
	Spring 2016	20 ↑	5.13 ↓	57.7 ↓	7.15 -	1.32 ↓	301 ↓

Table 25 Archers Creek alkalinity and hardness results

Analyte		Total Magnesium	Total Calcium	Hardness	Alkalinity
Unit		mg/L	mg/L	mg $CaCO_3$/L	mg $CaCO_3$/L
Guideline		NA	NA	NA	NA
CR2A	*Historical Median*	9.05	25.75	101.4	74
	Spring 2016	5.77 ↓	16.9 ↓	66 ↓	57 ↓

Table 26 Archers Creek Bacteriological and nutrients results

Analyte		Faecal coliform	Ammonia NH_3-N	Total Nitrogen	Total Kjeldahl Nitrogen	Oxidised Nitrogen NO_x-N	Total Phosphorus
Unit		CFU/100ml	µg/L	µg/L	µg/L	µg/L	µg/L
Guideline		1000	20	350	NA	40	25
CR2A	*Historical Median*	310	**565**	**565**	365	**75**	**40**
	Spring 2016	670 ↑	**40** ↓	**1150** ↑	530 ↑	**620** ↑	**53** ↑

Table 27 Archers Creek metal results, * indicates trigger values for moderate water hardness

Analyte		Total Cr	Total Mn	Total Fe	Total Cu	Total Zn	Total As	Total Cd	Total Pb	Total Hg
Unit		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Guideline		0.0027*	1.9	NA	0.0035*	0.02*	0.013	0.0005*	0.0136*	0.0006
CR2A	*Historical Median*	0.0005	0.8065	0.874	**0.00275**	**0.0875**	0.0005	0.0005	0.0005	0.00015
	Spring 2016	<0.0002 ↓	0.0127 ↓	0.161 ↓	**0.0023** ↓	0.004 ↓	0.0006 ↑	<0.0001 ↓	0.0002 ↓	<0.0003 ↓

8.2 Water quality interpretation

Aquatic ecosystems comprise the animals, plants and micro-organisms that live in water, and the physical and chemical environment and climatic regime with which they interact. It is predominantly the physical components (e.g. light, temperature, mixing, flow and habitat) and chemical components (e.g. organic and inorganic carbon, oxygen and nutrients) of an ecosystem that determine what lives and breeds in it, and therefore the structure of the food web (ANZECC 2000).

The current water quality sampling regime wasn't reflective of a sampling frequency suggested by ANZECC (2000). It did, however, allow for the characterisation of water quality at all sampling sites against ANZECC (2000) guidelines for Aquatic Ecosystems (Lowland River SE Australia), Recreational Water Quality and Aesthetics (Secondary) and Toxicants (at 95% species protection level).

The five creeks sampled under the Ryde Council monitoring program are categorised as highly disturbed systems. This is due to the creeks flowing through highly urbanised systems that receive substantial road and stormwater runoff (ANZECC 2000). Despite this, they each still retain ecological and conservation values. A realistic objective would be to maintain present water quality to retain a functional, albeit modified, ecosystem that would support the management goals assigned to it.

Physico-chemical analytes

Temperature in waterways varies with water depth, shading and flow, and can affect several other water quality parameters. Temperature can fluctuate throughout the day, particularly in shallow creeks. The temperature data must be analysed with respect to the time and conditions of the sampling event. Temperature fluctuations may affect: chemical and biochemical reaction rates; chemical solubility; growth and respiration rates of aquatic organisms; and reproduction and competitive interaction cues of aquatic organisms.

All temperature results in spring 2016 were above the historical median for combined autumn and spring seasons at all sites. To remove any temporal bias, historical medians for spring were calculated and compared, showing that all sites had elevated temperatures. This may be due to the spring 2016 sampling events taking place in late November. Historically samples were collected between mid-September to mid-November. Higher than average ambient air temperatures and low rainfall were recorded in late November for Sydney.

Dissolved oxygen concentrations are an important water quality indicator for the survival of aquatic organisms and the control of many important physico-chemical processes. The oxygen balance in waters is dependent upon physical, chemical and biochemical conditions in the water body. Oxygen input is the result of diffusion from the atmosphere and photosynthesis by phytoplankton and other aquatic plants. Dissolved oxygen removal is due to respiration by aquatic organisms, decomposition of organic matter, oxidation of chemically reduced compounds and loss to the atmosphere. The solubility of oxygen in water decreases with increasing temperature but in contrast the respiratory rate of aquatic organisms increases with temperature (Connell, 1993).

Dissolved oxygen concentrations are often subject to large diurnal and seasonal fluctuations, a result of changes in temperature and photosynthetic rates. Therefore, a dissolved oxygen measurement taken at one time of the day may not truly represent the oxygen regime in the water body.

In the previous 2013/14 report all sites had dissolved oxygen levels below the recommended guidelines. This was similar in spring 2016, except for Shrimptons creek (CR1SC) and Porters creek (CR5P) where they were in the recommended range. There was concern over the low results at Archers Creek (17.3% and 9.6%) from 2013/14 sampling. Archers Creek has since improved with spring 2016 moving to 57.7%. This result is still below the recommended guideline but is an improvement on previous years. There was low algae and organic debris recorded in spring 2016, which may explain some of the variation in results. The lowest result overall for dissolved oxygen in spring 2016 was 33.6% at Terrys Creek.

Turbidity is an indicator of sediment input from runoff. It did not exceed the recommended guideline for spring 2016. There was one result, at Archers Creek, where turbidity increased compared to historical results but was still within the recommended guidelines.

pH influences many biological and chemical processes and is an important water quality parameter. pH can change diurnally through photosynthetic and respiration rates. pH readings for all sites were within the recommended ANZECC (2000) guideline range for spring 2016, which is consistent with the historical medians.

Alkalinity and hardness

Water hardness is influenced by the concentration of magnesium and calcium ions in the water column. Porters and Buffalo Creek sites had an increase in magnesium, calcium and alkalinity this season. Archers Creek showed the opposite, with a decrease in the three analytes. Terrys Creek had a decrease in magnesium and calcium but an increase in alkalinity. The same was true for Shrimptons Creek at Kent Road (CRS1A). Shrimptons Creek at Bridge road (CR1SB) and Quarry Road (CR1SC) had all three analytes decrease.

Overall there was consistency in hardness results for sites within each creek system. Buffalo and Porters Creek had increased hardness, while Terrys, Shrimptons, and Archers Creek all had decreased hardness. Porters Creek at Main Branch (CR5PA) had the highest hardness results and moved up two hardness categories from the historical median.

Nutrients and bacteria

The indicator species used for faecal coliforms are naturally occurring and harmless inhabitants of the digestive tract of all warm-blooded animals (Boey 1993). The occurrence of large numbers of these bacteria signifies the presence of faecal pollution and, therefore, the possible presence of pathogenic organisms that occur in faeces.

The presence of widespread faecal contamination will often coincide with elevated nutrient levels, particularly the nitrogen based forms. Elevated nutrient levels, however, can often be experienced without the presence of faecal contaminants. A variety of factors including urban runoff, presence of waterfowl and other wildlife, waste depots, illegal dumping of waste and sewer overflows can influence faecal and nutrient contamination of urban streams.

Faecal coliform densities exceeded the ANZECC guidelines once in spring 2016 at Buffalo Creek at Higginbotham Road (CR4B). In spring 2013 there were very high exceedances recorded at the other two Buffalo Creek sites. These were 3 orders of magnitude greater than the exceedance recorded in spring 2016. Consequentially, a follow up sampling event similar to what was conducted in spring 2013, was not required.

There was a large amount of spatial variation in the ammonia, nitrogen and phosphorus results. Only Buffalo Creek had consistent results amongst sites for ammonia, all were below recommended guidelines and were two orders of magnitude lower than the historical median. All other locations had results that mostly exceeded for ammonia. Total nitrogen and phosphorus exceeded at all sites except for Porters creek at main branch (CR5PA), which had total phosphorus within the recommended guidelines but total nitrogen exceeding. There was no consistent trend with the spring 2016 results compared to historical, with values deviating from above the median to below the median.

Overall the bacteria and nutrients results were consistent with the historical data, being representative of impacted urban creeks. Compared to the previous report, the creeks had less faecal coliform exceedances but roughly average ammonia, nitrogen and phosphorus results.

Metals

Metals were found in very low concentrations at the five creeks for spring 2016. Cadmium, mercury, chromium, arsenic and lead were all below the detection limits for all sites. This was the second year of metals testing.

Copper was the only metal tested that exceeded recommended guidelines in spring 2016. The sites that exceeded were Terrys Creek (CR3T), Buffalo Creek (CR4BB) and Archers Creek (CR2A). The result for copper at CR4BB was the only site of the three that had historical median that exceeded, which was still higher than the recorded spring 2016 result. This was an improvement on the results from the previous and only reported period of 2013/14. There were numerous zinc and copper exceedances in that period, which have since decreased. This may be driven by rainfall, as the 2013/14 sampling events were after periods of rainfall. Sampling in 2016 had very low rainfall leading up the sampling event.

Results of the current spring water quality sampling at all five creeks support results of the previous surveys, which have indicated that urban pollution transport is having an impact on in-stream water quality. This impact is indicated by low levels of dissolved oxygen and high concentrations of nutrients, especially nitrogen forms. The spatially variable pollutant concentrations indicate that they originate from varying locations and sources within these systems over time.

9 Macroinvertebrate results and interpretation

9.1 Results

9.1.1 Taxa richness

Taxa richness is the overall variety (total taxa) of macroinvertebrates in a given community assemblage. It is an indicator of ecosystem health that can be measured at any specific taxonomic level and operates under the assumption that taxa richness will be higher in healthy systems and lower in systems of poor health.

Taxa richness results presented as the average number of macroinvertebrate families from 2004-2014 compared to spring 2016 samples are graphed below in Figure 12.

Archers and Porters creeks recorded the highest taxa diversity in 2016 with an average of 16 and 14.5 families collected respectively. For both creeks this was consistent with the mean taxa richness from 2004-2014. There appears to be a moderate decrease in the average number of taxa at Terrys Creek and Buffalo Creek when compared to previous sampling seasons.

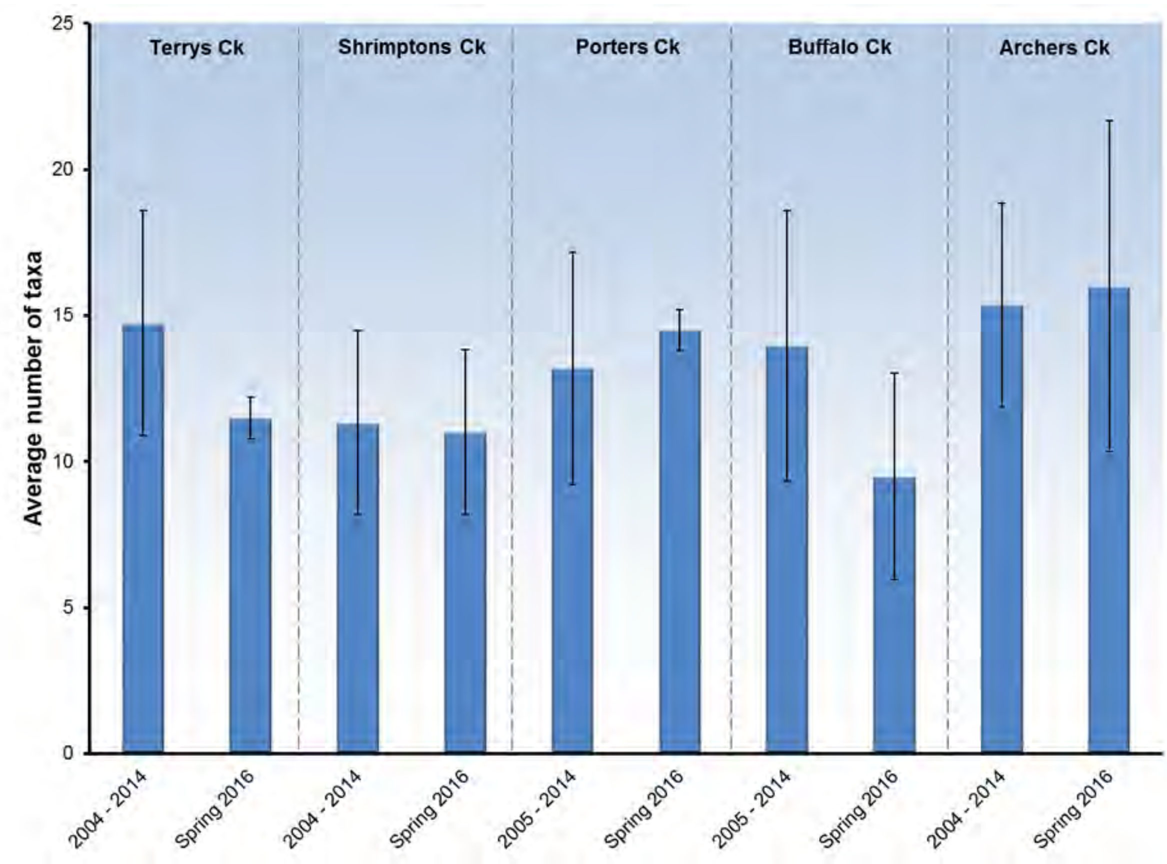

Figure 12 Mean ± SD taxa richness per site between 2004-2014 compared to spring 2016.

9.1.2 EPT taxa richness

> EPT taxa richness shows the abundance of highly sensitive Ephemeroptera (mayfly) Plecoptera (stonefly) and Trichoptera (caddisfly) orders. High EPT richness indicates increased health of an aquatic ecosystem.

In spring 2016, the average number of EPT taxa found at each of the 5 macroinvertebrate study sites was less than 1 per site where only one family, Hydroptilidae (Trichoptera), was found. This remains consistent with historical data from 2004-2014 from all sites where the average number of EPT taxa is below 1. No EPT taxa were found at Terrys and Shrimptons Creeks for spring 2016 and no site had more EPT taxa than the historical average.

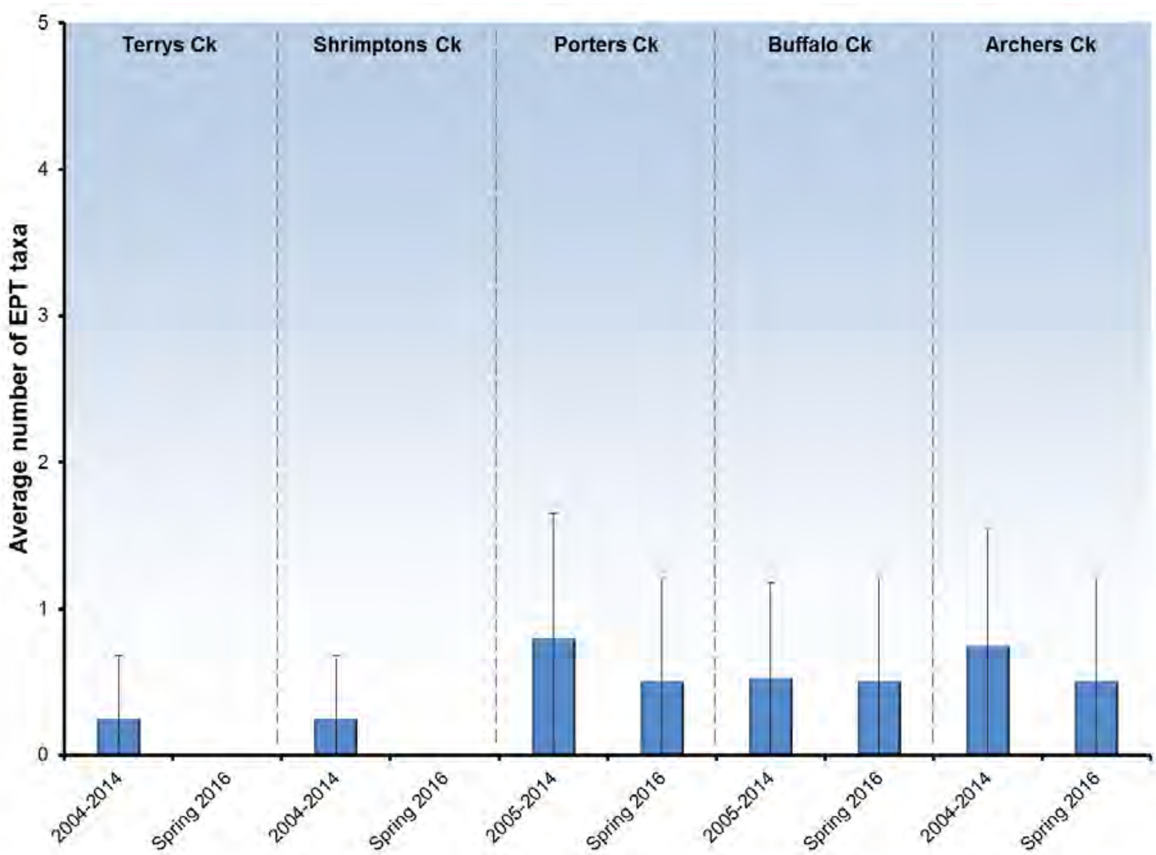

Figure 13 **Mean ± SD EPT taxa collected in spring 2016 compared to 2004-2014.**

9.1.3 Signal2

SIGNAL2 (Stream Invertebrate Grade Number Average Level) biotic index is a relatively simple method used to assess the health of an aquatic ecosystem. This index assigns 'sensitivity scores' to macroinvertebrate taxa. A final SIGNAL score combined with the total taxa then places a sample within a quadrant based on potential pollution type.

Mean SIGNAL2 scores are presented in Figure 14 with associated bi-plot placement in Figure 15. All creeks were similarly scored between 2 and 4 for 2013 and 2016. There was a slight decrease in all creeks for spring 2016 except for Archers Creek which remained consistent with the historical mean.

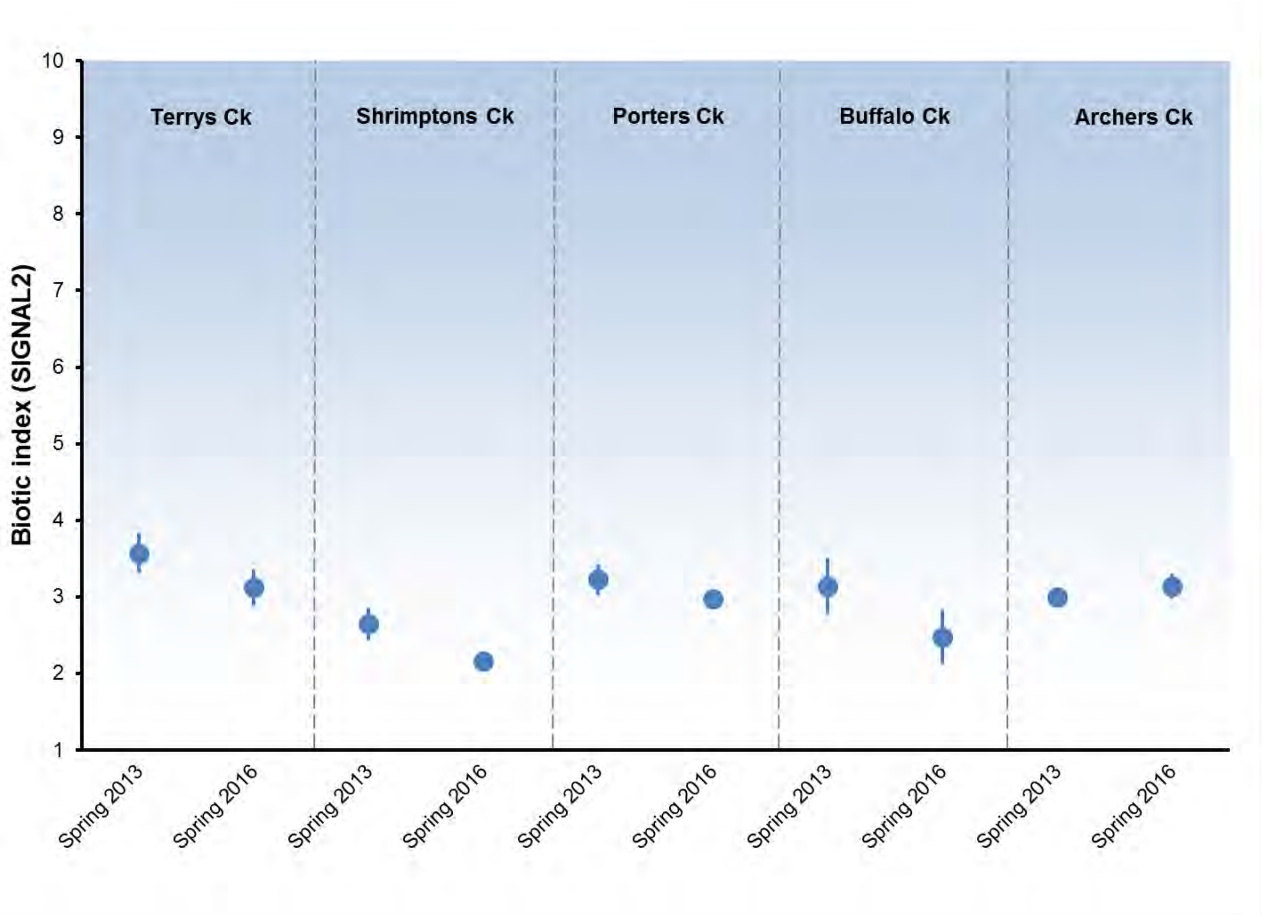

Figure 14 Mean ± SD SIGNAL2 scores for spring 2013 and Spring 2016.

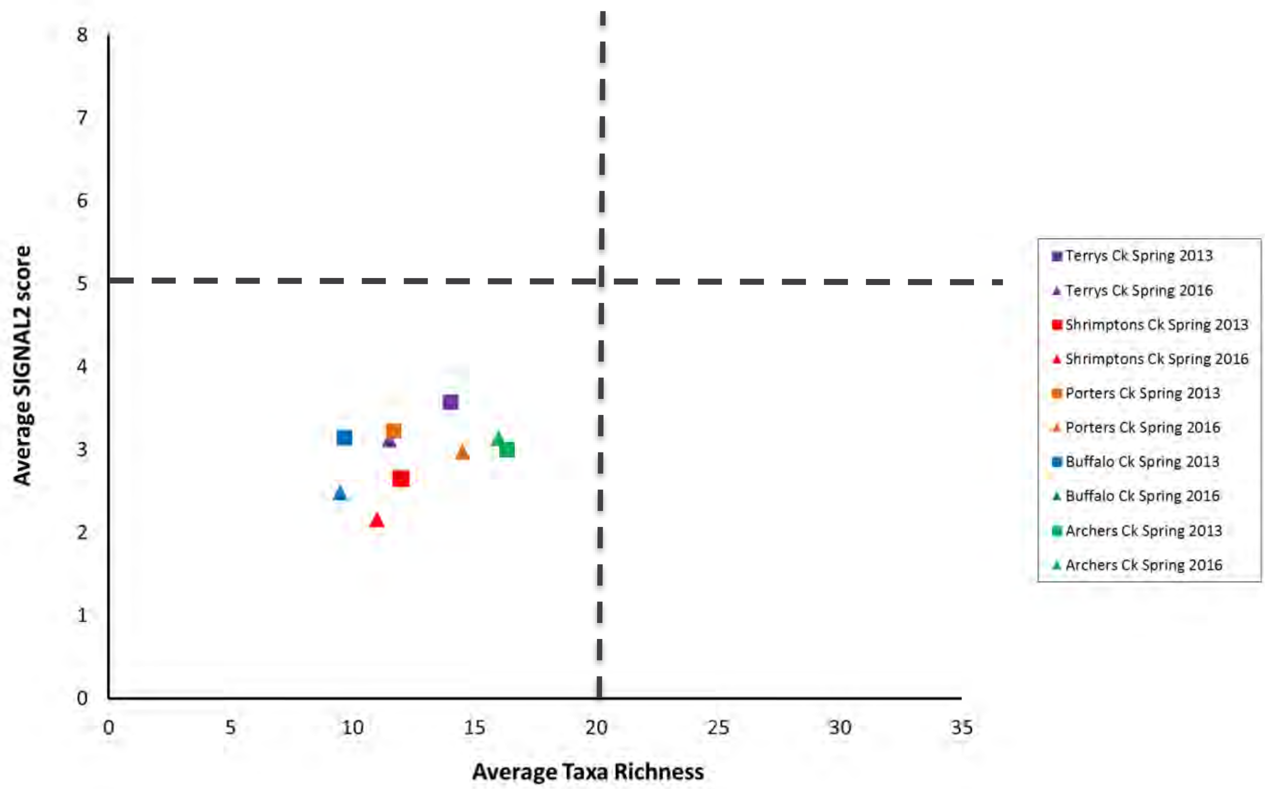

Figure 15 **Mean SIGNAL2 bi-plot for spring 2013 and 2016.**

9.1.4 Signal-SF

SIGNAL-SF *Stream Invertebrate Grade Number Average Level - Sydney Family* biotic index is a relatively simple method used to assess the health of an aquatic ecosystem. This index assigns 'sensitivity scores' from 1 being tolerant to 10 being very sensitive to each individual macroinvertebrate taxa.

SIGNAL-SF results for all macroinvertebrate sites sampled from spring and autumn, 2004 – 2014 compared to spring 2016 are shown below in Figure 16. All SIGNAL-SF scores are below the "natural water quality" level of 6.5 indicating moderate organic pollution at all sites. However the scores are consistent with those recorded in other comparable urbanised streams in the Sydney metropolitan area.

The SIGNAL-SF scores remained relatively similar to the mean SIGNAL-SF score from the previous 10 years. Buffalo, Terrys, Archers and Porters creeks showed a small increase in SIGNAL-SF for spring 2016 where Shrimptons showed a small decrease.

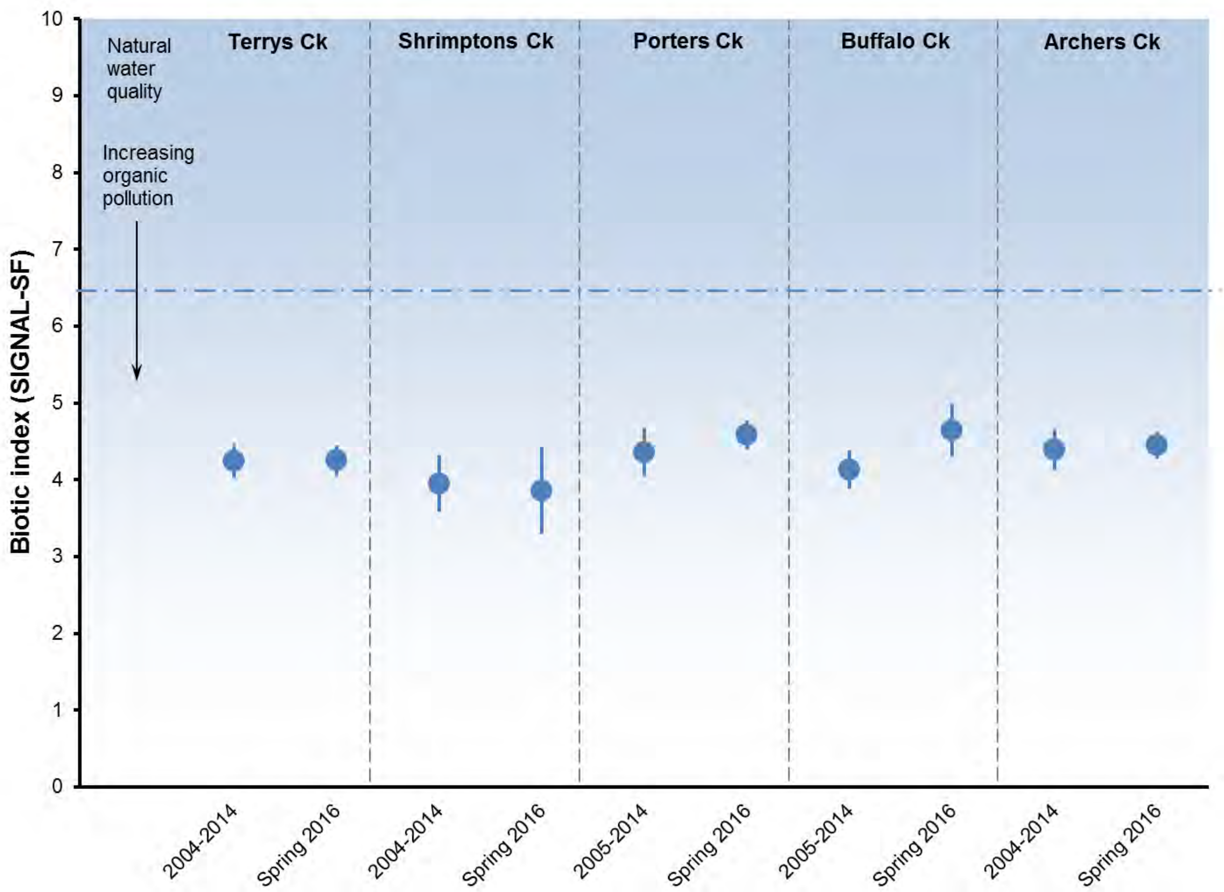

Figure 16 Mean ± SD Signal-SF scores at all sites for 2004-2014 compared to spring 2016.

9.1.5 AUSRIVAS

An OE0 and OE50 calculation for Porters Creek in spring 2016 was not possible due to the water quality and macroinvertebrate data not suiting the AUSRIVAS database. A suitable reference creek that was comparable to generate an AUSRIVAS assessment of this creek was not found and therefore not reported elsewhere in this report. It is believed this may be due to the high alkalinity recorded at this site of 223 mg CaCO3/L. The closest measurement from spring 2016 to this was 83 mg CaCO3/L recorded at Buffalo Creek.

AUSRIVAS OE0 SIGNAL

AUSRIVAS OE0 SIGNAL is an indice calculated from the AUSRIVAS predictive model, comparing the macroinvertebrates from a current assessment site to macroinvertebrate data previously collected from reference sites with similar physical and chemical characteristics. The OE0 SIGNAL indice is a ratio of the observed SIGNAL (Chessman, 1995) values from the assessment site to the expected taxa from the reference sites. The ratio uses all (100%) of the observed and expected taxa in the calculation. This comparison can also help determine the 'condition' or 'health' of the aquatic ecosystem.

Terrys Creek recorded the highest average score in spring 2016 scoring the slightly higher than the historical average from 2004 – 2013. Archers Creek also scored slightly higher than its historical average compared to Buffalo and Shrimptons creeks which scored lower than their historical average.

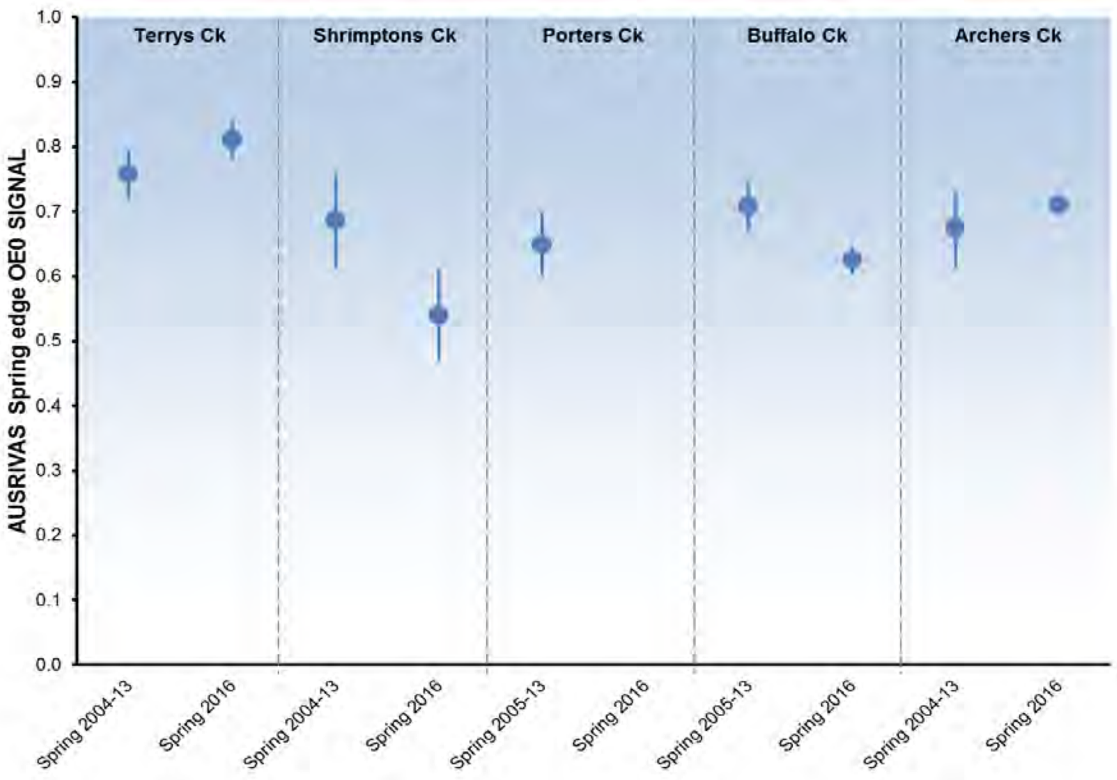

Figure 17 Mean ± SD OE0 Signals comparing 2004-2014 and spring 2016.

AUSRIVAS OE50

AUSRIVAS OE50 is an indice calculated from the AUSRIVAS predictive model, comparing the macroinvertebrates from a current assessment site to macroinvertebrate data previously collected from reference sites with similar physical and chemical characteristics. The OE50 indice compares only the macroinvertebrates from the assessment site with a greater than 50% chance of occurring at the reference site. This comparison can help determine the 'condition' or 'health' of the aquatic ecosystem.

The mean spring 2016 and historical OE50 scores were in Band C for all creeks with no significant deviation from historical scores. Whilst a 2016 spring score was unable to be generated for Porters Creek, the historical mean OE50 score is in Band C remaining consistent with other creeks.

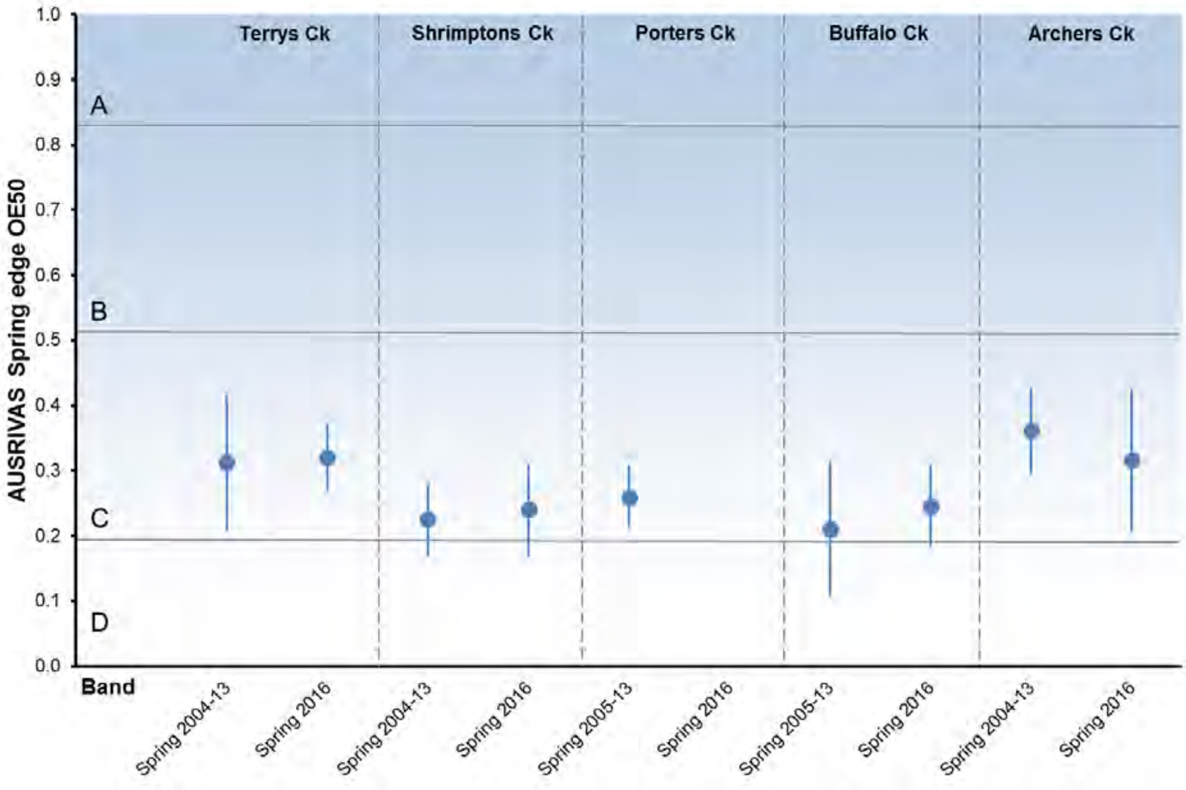

Figure 18 **Mean ± SD AUSRIVAS OE50 score for spring 2016.**

9.2 Macroinvertebrates interpretation

Macroinvertebrates are widely recognised as key indicators because their presence or absence is a result of their exposure to changing water quality over periods of time. They also reflect changes in physical habitats, including sediment deposition and altered hydrology, as well as changes in biological interaction such as the introduction of pest plant and animal species. Macroinvertebrates are also ubiquitous, they are found in almost all water bodies and as such, the type and diversity of macroinvertebrates present can indicate what stressors may be acting upon a given aquatic system.

The taxa richness observed in spring 2016 was relatively similar to what has been previously observed at most of the creeks. The exception was Buffalo and Terrys creeks which had a lower number of average taxa compared to the historical range. The dominant taxa that comprise a significant proportion of the total community assemblages have historically been within the Mollusca (snails and mussells), Diptera (true flies) and Odonata (dragonflies and damselflies) taxa groups. In spring 2016, the Mollusca and Dipterans have again heavily dominated the community assemblage's at all five creeks. The significant absentee was the Odonata, which had no significant presence at Buffalo, Porters, Shrimptons and Terrys creeks. The only exception was Archers Creek where families Lestidae, Libellulidae, Isostictidae and Hermicorduliidae were all present and contributed to the community assemblage.

EPT taxa richness was again very low in spring 2016, a typical result from the previous surveys. Two creeks, Shrimptons and Terrys, did not register a single EPT specimen. Historically no creek in the survey had an average of one EPT taxa (collected from each replicate). The usefulness of this measure for the survey and City of Ryde has been questioned in previous reports (Sydney Water 2014) and the current results reflect this is likely to continue. The environmental conditions required to support healthy populations of even relatively tolerant EPT taxa is likely not possible within the catchments of the City of Ryde. EPT taxa generally require freely available high oxygen levels, relatively natural flowing clear water bodies and they are also very susceptible to toxicants and other pollutants. Water quality parameters such as those measured during spring 2016 at CR5 of total nitrogen at 11 200 ug/L, represent conditions above toxicity thresholds for EPT taxa families like Ephemeroptera. Research by Beketov et al., (2004), on 6 species of ephemeropterans indicates the lethal concentration to inhibit 50 % of the population (LC50) for nitrogen in the form of ammonia, nitrite and nitrate to be as low as 4950 ug/L and as high as 37490 ug/L. Nitrogen measurements recorded in this study exceed LC50 values for EPT taxa and act as one of the water quality parameters limiting their establishment.

The recommended approach for displaying SIGNAL2 data is using the quadrat bi-plot. This resulted in all five creeks being placed in quadrat 4, representative of urban, industrial or agricultural pollution. Placement in this quadrat is due to a combination of samples low SIGNAL2 scores and low taxa counts. However, the placement of the quadrat boundaries is arbitrary and preferably with the aid of reference sites. This is not possible for the City of Ryde, and the boundaries were placed with data from reference sites from the Sydney region located in relatively natural catchments. Returning the creeks and catchments to a natural and reference like condition is highly unlikely in the City of Ryde locale. Whilst this helps to represent the conditions present, the measure in this format is limited in its usefulness for ongoing monitoring and site assessment for City of Ryde.

The SIGNAL-SF results in spring 2016 were reflective of what had been previously recorded for all five creeks. Porters and Buffalo creeks average score increased slightly on the historical average in spring 2013 and the remaining creeks average scores deviated very little from the historical average. Historically the SIGNAL-SF average scores have had a lower variability through time compared to the other univariate and biological indices, however shifts in creek health have been evident. Shrimptons Creek has historically had the biggest variation through time. This index has shown lower sample variability through time and has allowed for a clear tracking of ongoing changes in the creeks within the context of the naturally occurring variation in the macroinvertebrate communities. This biological index is likely the best option for tracking the health of the five creeks and for monitoring impacts or improvements within the catchments.

The AUSRIVAS OE50 scores are calculated by comparing the observed taxa at a site to the expected taxa. The expected taxa are derived from reference site taxa lists matched to physical/chemical data from the survey creeks. The reference taxa list consists of the animals that are expected to those with a greater than 50% chance of occurring. The AUSRIVAS spring edge OE50 results indicated several changes from the historical averages. All creeks in spring 2016 average scores were above the historical average scores except Archers Creek average score which was below the historical average score. All spring 2016 and historical average scores were placed in the Band C, representing severely impaired creek conditions. The OE50 scores have high sample variation both historically and in spring 2016, this complicates the tracking and assessment of clear changes in stream health.

The AUSRIVAS spring edge OE0 SIGNAL average scores from spring 2016 were above the historical average at Terrys and Archers creeks and below the historical average at Shrimptons and Buffalo creeks. The OE0 SIGNAL index has less sample variation both historically and in spring 2016 compared to the OE50 index. The reference sites used by AUSRIVAS are very limited in the Sydney region. Given this and the creeks being within a heavily urbanised environment, the ability for AUSRIVAS to track creek health through time is potentially limited. This is clear in the inability of the program to calculate a score for Porters Creek due to the high alkalinity recorded.

Sampling was carried out as close to baseline flows as possible. Results of the current analyses indicate taxa and abundance have made a shift from historical data, this does not necessarily suggest a decline in creek health. Analysis of all creeks suggest the health has remained consistent with the historical mean after associated error is considered. It is suggested that SIGNAL-SF is likely a more robust and suitable indice for tracking the conditions of creek health for the City of Ryde monitoring strategy.

10 References

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