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CooksRiver ALLIANCE

Cooks River Catchment
2013/14 River Health Monitoring Technical Report

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Abbreviations

Abbreviation	Description
ANZECC	Australian and New Zealand Guidelines for Fresh and Marine Water Quality
CRA	Cooks River Alliance
DO	Dissolved oxygen
EC	Electrical conductivity
EPT	Ephemeroptera (mayfly), Plecoptera (stonefly) and Trichoptera (caddisfly)
LGA	Local Government Area
NOx-N	Oxidised nitrogen as N
RARC	Rapid Appraisal of Riparian Condition
SIGNAL	Stream Invertebrate Grade Number Level
TN	Total nitrogen
TP	Total phosphorus

Executive summary

This report presents the findings of aquatic ecosystem monitoring conducted between March 2013 and November 2014 at 10 locations located across the Cooks River catchment. As part of the Cooks River Alliance River Health monitoring program, CTENVIRONMENTAL was engaged to assess the current condition of waterways throughout the catchment.

Monitoring sites were classified as: urban creeks, urban wetlands or estuarine. Aquatic macroinvertebrates, water quality and riparian vegetation condition were monitored at freshwater sites and water quality was monitored by automated water quality monitoring buoys in the estuarine reach of the catchment. Additional data collected from six reference streams in the neighbouring Georges River catchment was included to formulate region specific guidelines for the assessment of urban and industrial waterways of the catchment.

Results from 2013/2014 monitoring show macroinvertebrate communities of both urban creeks and urban wetlands were dominated by pollution tolerant taxa and overall community structure of these sites varied significantly when compared to reference creeks. In addition, macroinvertebrate indices of richness, SIGNAL scores and pollution sensitive %EPT taxa were lower when compared to reference creeks, results which are indicative of ecosystem stress.

Water quality across all sites has shown signs of degradation with nutrients, pH, turbidity and salinity found to be elevated at all sites and dissolved oxygen was frequently below guideline limits. In addition, riparian vegetation condition was found to be degraded at all sites with exception of Upper Bardwell Creek.

River Health grades show a spectrum of degradation across sites ranging from moderate to severe. The application of waterway health grades to describe the current ecological condition of Cooks River catchment waterways provides a clear and easily understood interpretation of complex ecological data.

Recommendations of this report will assist the development of the River Health program and future sustainable management of waterways within the Cooks River catchment.

1 Introduction

River Health monitoring of the Cooks River catchment was conducted by CTENVIRONMENTAL and GRCCC between March 2013 and November2014. The River Health Monitoring Program commenced in the Cooks River catchment in 2012 and has since monitored the ecological condition of a selection of streams, wetlands and estuarine reaches within the catchment with results presented in the annual River Health Report Card.

Central to River Health Monitoring Program is the assessment of multiple ecological indicators, or River Health indices, which include freshwater macroinvertebrate communities, water quality and riparian vegetation condition.

Freshwater macroinvertebrates are widely adopted as sensitive and effective indicators of the ecological condition of freshwater ecosystems (Beavan et al. 2001; Paul and Meyer 2001; Walsh et al. 2001). Macroinvertebrates were surveyed in spring and autumn and identified to the taxonomic level of order. This level of identification has been demonstrated to generate sufficient information for impact identification of freshwater ecosystems (Wright et al. 1995) and has been successfully applied to studies multiple studies within the neighbouring Georges River catchment (Tippler et al 2012; Tippler et al 2013).

Water quality samples were collected at five urban stream sites and three urban wetlands. In addition water quality was monitored by autonomous water quality logging buoys at two sites in the mid and lower estuarine reaches of the Cooks River. Sampling frequency varied across sites with water quality sampled at monthly intervals at three urban stream sites and during spring and autumn at the remaining freshwater sites. Estuarine water quality is monitored at 15 minute intervals by automated water quality logging buoys (Table 1).

Water quality is monitored at both freshwater and estuarine reaches of the catchment. Three freshwater sites are monitored at a monthly frequency and four are monitored on a seasonal frequency during spring and autumn. Two automated water quality monitoring buoys are located in the mid and lower estuarine sections of the catchment and record water quality conditions at 15 minute intervals.

Riparian vegetation community condition was surveyed at all freshwater sites in 2012 and will be surveyed at three to five year intervals. No vegetation surveys have been conducted in the estuarine reaches of the catchment.

This combination of River Health indices provides a detailed snap-shot of the ecological condition of the waterways within the Cooks River catchment. Each monitoring site is graded according to ecosystem condition with results reported in the format of ''River Health Report Cards'' which is based on the method outlined by the south-east Queensland Healthy Waterways Program (EHMP 2008).

Report cards have become a popular and effective method to communicate complex ecological information in a simplified format to a wide ranging audience which, in the Cooks River catchment, includes students, community groups and Council personnel.

This report presents a summary of 2013/14 River Health grades for the Cooks River catchment. In addition a summary of the methods applied and results of River Health monitoring are presented and recommendations for future monitoring and sustainable waterway management are made.

Table 1. Cooks River catchment 2013/14 River Health monitoring sites, waterway classification, water quality monitoring frequency and GPS coordinates.

River Health Monitoring Site	Waterway Classification	Frequency of water quality monitoring	Latitude/Longitude
Chullora Wetlands	Urban Wetland	Spring/Autumn	-33°53’23"S 151°02'51"E
Yarrowee Rd Wetland	Urban Wetland	Spring/Autumn	-33°53'02"S 151°04'30"E
Cup and Saucer Creek Wetland	Urban Wetland	Spring/Autumn	-33°54'55"S 151°07'11"E
Upper Cooks River	Urban Stream	Monthly	-33°53'04"S 151°04'30"E
Wolli Creek at Turella Weir	Urban Stream	Monthly	-33°55'46"S 151°08'17"E
Bardwell Creek at Coolibah Reserve	Urban Stream	Monthly	-33°55'59"S 151°08'00"E
Upper Bardwell Creek	Urban Stream	Spring/Autumn	-33°56'42"S 151°07'07"E
Cox's Creek	Urban Stream	Spring/Autumn	-33°54'16"S 151°04'04"E
Mid Cooks River	Estuarine	15 minutes	-33°54'52"S 151°07'20"E
Lower Cooks River	Estuarine	15 minutes	-33°55'59"S 151°09'41"E

Study area

The Cooks River catchment is located to the south and west of the Sydney CBD and includes 13 Local Government Areas. The catchment has an area of 10,920 ha (CRA 2014) in which approximately 500,000 people reside (Jakuba et al 2010). Sub-catchment imperviousness is high (up to 81%) (Jakuba et al 2010) and 86% of waterways within the catchment are modified (Earth Tech 2007). Throughout the catchment, 73% of channel length has been concreted (Earth Tech 2007). Land use within the Cooks River catchment is mixed and includes urban (~80%), parkland (~10%) and industrial (~9%) (CRA 2014) and as a result waterways within the Cooks River catchment are highly modified from natural condition.

The Cooks River Alliance (CRA) and its member Councils of Ashfield, Bankstown, Canterbury, City of Sydney, Hurstville, Marrickville, Rockdale and Strathfield play a key role in the sustainable management of the Cooks River which is reflected in the mission statement ***“Councils working together with communities for a healthy Cooks River catchment”.***

As part of the sustainable management of the Cooks River catchment, the CRA supports the River Health monitoring project which is conducted in partnership with the Georges River Combined Councils’ Committee (GRCCC). River Health monitoring within the Cooks River catchment is conducted at eight freshwater and two estuarine sites (Figure 1).

Figure 1. Cooks River Catchment, Local Government boundaries and indicative location of 2013/14 River Health monitoring sites. 1= Chullora Wetlands, 2=Upper Cooks River, 3= Yarrowee Road Wetland, 4= Cox's Creek, 5 = Cup and Saucer Wetland, 6 = Bardwell Creek at Coolibah Reserve, 7 = Upper Bardwell Creek, 8 = Wolli Creek at Turrella Weir, 9 = Mid Cooks River, 10 – Lower Cooks River. (map: GSLLS 2014)

2 2013/14 River Health Grades

Calculation of River Health grades for the Cooks River catchment is based on methods applied by the South East Queensland Healthy Waterways Program (EHMP 2008). This program is widely recognised as the leading broad scale waterway assessment in Australia. Waterway health grades provide a snap shot of ecosystem condition at the time of sampling. Table 2 shows waterway health grades and corresponding ecological condition. Detailed methods for River Health data collection, grade calculation and data analysis can be found in section 3 of this report.

Table 2. River Health grades, ecosystem condition and description.

Grade	Condition	Description
A^+	Excellent	All indicators comply with guideline values. Waterways have high ecological value and experience little to no human disturbance.
$A – B^+$	Good	Most indicators equivalent to reference conditions and comply with regional guidelines. Waterways have favourable water quality, complex habitat structure and support a diverse macroinvertebrate community.
$B – C^-$	Fair	Numerous indicators outside regional guideline limits and show signs of departure from reference conditions. Periodic episodes of degraded water quality are likely and the macroinvertebrate community and stream habitat are commonly degraded.
D^+-F^-	Poor	Most indicators non-compliant with guidelines and show significant departure from reference conditions. Waterways have degraded water quality and poor habitat reflected by a macroinvertebrate community dominated by pollution-tolerant species.

2.1 2013/14 River Health Site Summaries and River Health Grades

River Health grades were variable across the Cooks River catchment and the ecological condition of sites ranged from fair to poor (Table 3). Chullora Wetland received the highest overall grade of B- indicating fair ecological condition. Grades of B for water quality, B+ for macroinvertebrates and C+ for riparian vegetation condition contributed to this.

The ecological condition of Upper Bardwell Creek was also fair as indicated by the overall grade of C+. Grades of B for water quality, E- for macroinvertebrates and A for riparian vegetation condition, which enhanced the overall score, were recorded (Table 3).

All other freshwater sites recorded grades of D+ to F+ indicating the ecological condition of these sites was poor. Upper Cooks River and Cox's Creek recorded overall grades of D+, Bardwell Creek at Coolibah Reserve recorded a slightly lower overall grade D-, and Wolli Creek at Turella Reserve recorded an E and Yarrowee Wetland and E-.

The lowest overall grade, F+, was recorded for Cup and Saucer Wetland with grades of C- for water quality, F for macroinvertebrates and F- for riparian vegetation condition contributed to the low overall grade (Table 3).

The results reported for the 2013/14 monitoring period and are to be expected, given the high degree of catchment modification, urban land use and impervious surfaces.

Waterway health grades and summaries for each monitoring site are presented in the following section and provide a snapshot of the ecological condition of each site at the time of monitoring.

Table 3. 2013/14 River Health grades for Cooks River catchment monitoring sites.

Site	Overall Grade	Water Quality Grade	Macroinvertebrate Grade	Vegetation Grade
Chullora Wetlands	B-	B	B+	C+
Upper Cooks River	D+	A	C-	F-
Yarrowee Road Wetland	E-	D	E	F-
Cox's Creek	D+	B+	D+	F+
Upper Bardwell Creek	C+	B	E-	A
Cup and Saucer Wetland	F+	C-	F	F-
Bardwell Creek at Coolibah Reserve	D-	C+	D	F-
Wolli Creek at Turrella Weir	E	B-	F-	F
Mid Cooks River Estuary	n/a	C+	n/a	n/a
Lower Cooks River Estuary	n/a	C	n/a	n/a

2.2 Bardwell Creek at Coolibah Reserve

The ecological condition of Bardwell Creek at Coolibah Reserve is poor reflected by an overall River Health grade of D- (Table 4, figure 2). During the 2013/14 monitoring period conditions at this site were typical of a highly urbanised waterway. Creek water was periodically discoloured and turbid with bottom sediments comprised of fine clay and organic material. Creek banks appeared scoured, undercut and eroded (figure 3), reflective of high flows and frequent flooding. A significant amount of litter was present along both creek banks and channel.

Results of water quality monitoring show persistently low dissolved oxygen, frequent nitrogen pollution and occasional elevated phosphorous concentrations. The riparian vegetation community at this site is in poor condition, a result of a narrow vegetation corridor, and lack of complex canopy structure (figure 2). The degraded condition of this site is reflected by the macroinvertebrate community. Results of monitoring indicate low richness and biodiversity with a SIGNAL score indicative of a creek affected by urbanisation.

Table 4.Overall River Health grade and River Health index grades for Bardwell Creek at Coolibah Reserve.

OVERALL GRADE	WATER QUALITY	MACROINVERTEBRATES	VEGETATION
D-	C+	D	F-

Figure 2. Bardwell Creek at Coolibah Reserve monitoring site. Panoramic photograph. Left to right = upstream to downstream.

2.3 Wolli Creek at Turrella Weir

The ecological condition of Wolli Creek at Turrella Weir is poor, reflected by an overall River Health grade of E- (Table 5). During the 2013/14 monitoring periodic surface scum was observed and bottom sediment comprised of building site rubble, litter and fine organic material. Creek banks upstream of Turrella Weir are undercut, a result of high flow and flooding which regularly occurs after periods of intense rainfall. Creek banks have a high cover of invasive weeds; however remnant native species are present (Figure 3).

Results of water quality monitoring show low dissolved oxygen and elevated nitrogen persisted throughout the year. In addition elevated phosphorous and salinity were periodically recorded. The riparian vegetation community at this site is in poor condition. The narrow vegetation corridor, lack of complex canopy structure and high proportion of invasive species contribute to the low River Health grade. Low SIGNAL scores, low richness and low biodiversity index was recorded at this site and is typical of macroinvertebrate communities in degraded urban waterways.

Table 5. Overall River Health grade and River Health index grades for Wolli Creek at Turella Weir.

OVERALL GRADE	WATER QUALITY	MACROINVERTEBRATES	VEGETATION
E	B-	F-	F

Figure 3.Wolli Creek at Turella Weir monitoring site panoramic photograph. Left to right = downstream to upstream.

2.4 Upper Bardwell Creek

The ecological condition of Upper Bardwell Creek is fair, reflected by an overall River Health grade of C+ (Table 6). During autumn 2014 sampling possible sewage pollution was evident with debris typical of a sewerage overflow observed in parts of the creek. In addition, creek banks and channel were littered with plastics and other debris. The creek channel has been modified with sandstone blockwork and weirs with bottom sediments consisting of fine organic material and larger rocks typical of building debris and road base. A remnant patch of native vegetation, maintaining good condition, is present in this upper section of Bardwell Creek. This is an unusually good feature in such a modified urban catchment (Figure 4).

Results of water quality monitoring show both nitrogen and phosphorus concentrations were above guideline limits in both spring 2013 and autumn 2014 sampling periods. Additionally low dissolved oxygen was recorded in the spring 2013 monitoring period. Although water quality was found to be fair, results of macroinvertebrate monitoring show the in-stream aquatic ecosystem at this site is degraded. A low SIGNAL score is reflected by both low richness and biodiversity which is evidence these site experiences episodes of severe water pollution.

Table 6.Overall River Health grade and River Health index grades for Upper Bardwell Creek.

OVERALL GRADE	WATER QUALITY	MACROINVERTEBRATES	VEGETATION
C+	B	E-	A

Figure 4. Upper Bardwell Creek monitoring site panoramic photograph. Left to right = upstream to downstream.

2.5 Cox's Creek

The overall River Health grade for Cox's Creek is D+ indicating poor ecological condition (Table 7). Cox's Creek is highly modified with the majority of creek channel being concrete lined. The creek channel at the monitoring site is overgrown with aquatic plants, the majority of which are weeds with only a small and narrow remnant patch of riparian vegetation existing on the southern bank. At the time of sampling the bottom sediment of the creek consisted of fine clays, rubble and building waste (Figure 5). Downstream of the monitoring site the creek is piped to a concrete channel before discharging to the Cooks River.

Water quality monitoring showed most parameters complied with guideline limits; however salinity was up to four and a half times the recommended guideline. This site is above the tidal limit and therefore the source of high salinity is likely derived from upstream anthropogenic sources. It is likely this result, combined with the highly modified nature of the site has an adverse effect on the macroinvertebrate community with low SIGNAL scores, low richness and low biodiversity recorded during both spring 2013 and autumn 2014 sampling seasons.

Table 7. Overall River Health grade and River Health index grades for Cox's Creek.

OVERALL GRADE	WATER QUALITY	MACROINVERTEBRATES	VEGETATION
D+	B+	D+	F+

Figure 5.Cox's Creek monitoring site panoramic photograph. Left to right = upstream to downstream

2.6 Upper Cooks River

The overall River Health grade for the Upper Cooks River is D+ indicating poor ecological health (Table 8.). This section of the Cooks River has undergone bank naturalisation in recent years however the river channel at this monitoring point is overgrown with aquatic vegetation and although some riparian vegetation is present, it is of low complexity and limited habitat value (Figure 6). During periods of intense and/or high rainfall this stretch of the Cooks River is subject to flooding and high velocity flows. Throughout the monitoring period occasional discoloration of river water was apparent and plastic debris and other litter was present along the river banks and channel.

Results of water quality monitoring show most parameters complied with guidelines. However, at times, elevated nitrogen and phosphorous and low dissolved oxygen levels were recorded. Although results of water quality monitoring show conditions were often reasonable, the macroinvertebrate community at this site does not reflect these results. Reduced macroinvertebrate richness and biodiversity are reflected by a low SIGNAL score indicating periodic episodes of urban and/or industrial pollution affect this site. Similar results are common in urban waterways, as results of water quality monitoring provide only a snap shot of conditions at the time samples were collected. However, the macroinvertebrate provide a longer tem diagnosis of waterway condition.

Table 8.Overall River Health grade and River Health index grades for Upper Cooks River

OVERALL GRADE	WATER QUALITY	MACROINVERTEBRATES	VEGETATION
D+	A	C-	F-

Figure 6. Upper Cooks River monitoring site panoramic photograph. Left to right = downstream to upstream

2.7 Chullora Wetlands

The overall River Health grade for Chullora Wetlands is B- indicating good to fair ecological health (Table 9). Although this site is a constructed wetland designed to capture and treat stormwater, it provides valuable aquatic habitat to a range of bird and frog species. At the time of monitoring, water had a clear appearance and bottom sediment was comprised of fine clay and decaying organic material. The wetland was fringed by thick, and in places impenetrable aquatic vegetation. The riparian vegetation community contained mostly low mid-story shrub and grass species and scattered canopy species (Figure 7). No litter was observed in the wetland during spring 2013 and autumn 2014 sampling periods.

Most water quality parameters complied with guideline limits however low dissolved oxygen was recorded in both spring 2013 and autumn 2014 monitoring periods and high phosphorus in spring 2013. The macroinvertebrate community recorded at this site is the most rich and biodiverse of all Cooks River catchment monitoring sites. However, low SIGNAL scores, influenced by the low abundance of pollution sensitive macroinvertebrates, indicate degradation due to urban and industrial stormwater, a result which would be expected given the surrounding landuse and purpose of this site.

Table 9. Overall River Health grade and River Health index grades for Chullora Wetlands

OVERALL GRADE	WATER QUALITY	MACROINVERTEBRATES	VEGETATION
B-	B	B+	C+

Figure 7.Chullora Wetlands monitoring site panoramic photograph (source streamwatch.org)

2.8 Yarrowee Road Wetland

The ecological condition of Yarrowee Road Wetland is poor, a result which is reflected by an overall River Health grade of F- (Table 10). This site is a constructed wetland designed to capture and treat stormwater and in extended periods of low rainfall, surface water dries up resulting in the loss of aquatic habitat. During the 2013/14 monitoring period wetland vegetation was thick and dominated by aquatic plant species however the fringing riparian vegetation community lacked canopy complexity and habitat value (Figure 8). A thick algal mat was present in the wetland and bottom sediment consisted of thick layer of fine silt and decaying organic materials. Some aquatic weeds were observed in the wetland outlet channel.

During the spring 2013 monitoring period the wetland was dry and no monitoring was undertaken. However, autumn 2014 water quality monitoring results show dissolved oxygen, turbidity, nitrogen and phosphorus levels were outside guideline limits. Poor water quality combined with dry periods and silty, organic bottom sediment provide less than ideal conditions to support a diverse macroinvertebrate community. Low macroinvertebrate richness, biodiversity and SIGNAL score reflect the degraded condition of the aquatic ecosystem at this site.

Table 10. Overall River Health grade and River Health index grades for Yarrowee Road Wetland

OVERALL GRADE	WATER QUALITY	MACROINVERTEBRATES	VEGETATION
E-	D	E	F-

Figure 8. Yarrowee Wetland monitoring site panoramic photograph.

2.9 Cup and Saucer Wetland

The overall River Health grade for Cup and Saucer wetlands is F+ indicating very poor ecological health (Table 11). Although this site is a constructed wetland which is designed to capture and treat stormwater the size of the treatment area is less than desired to effectively treat flows from the catchment (pers. comms. Canterbury City Council). However this site provides important habitat to a range of bird species and amenity to local residents. At the time of monitoring water had a turbid appearance and bottom sediment was comprised of a thick layer of fine silt and decaying organic matter The wetland was fringed by thick, and in places impenetrable aquatic vegetation and the surrounding riparian vegetation community contained mostly native low mid-story shrub and grass species with few non-native weed species observed (Figure 9). No litter was observed in the wetland during spring 2013 and autumn 2014 sampling periods.

Results of water quality monitoring show nitrogen, phosphorus, turbidity and dissolved oxygen were outside guideline limits. This result is reflected by a depauperate macroinvertebrate community which lacked richness and biodiversity. In addition, SIGNAL scores for the sampling period indicate this site is subject to episodes of urban and/or industrial pollution.

Table 11.Overall River Health grade and River Health index grades for Cup and Saucer Wetland

OVERALL GRADE	WATER QUALITY	MACROINVERTEBRATES	VEGETATION
F+	C-	F	F-

Figure 9. Cup and Saucer Wetland monitoring site panoramic photograph.

2.10 Mid and Upper Cooks River Estuarine Water Quality Monitoring Buoys

Results of water quality monitoring in the Cooks River Estuary show fair conditions for both Mid and Lower Estuarine sites reflected by River Health grades of C and C+ respectively (Table 12). Both sites had poor compliance with guideline limits for dissolved oxygen, turbidity and chlorophyll-*a* with results slightly better in the upper estuarine section of the river. In addition, mean turbidity, dissolved oxygen and chlorophyll-*a* were above guideline limits for both sites.

Due to inaccessibility of water quality logging buoys no site photographs were taken.

Table 12.River Health water quality grade for Mid and Lower Cooks River Estuary.

Lower Cooks Estuary WATER QUALITY	Mid Cooks Estuary WATER QUALITY
C	C+

3 River Health Monitoring – Method and Results

The methods applied by the River Health Monitoring Program are common indicators applied to ecosystem monitoring and provide a robust method as assessing the condition of aquatic ecosystems.

3.1 Data Collection

3.1.1 Monitoring sites and monitoring frequency

River Health monitoring within the Cooks River catchment occurs at 10 sites across eight waterways (Figure 1). Three sites are classified as urban wetlands, five sites as urban streams and two as estuarine (Table 13). Frequency of monitoring varies across sites with water quality sampled at three freshwater sites on a monthly basis with the remaining sites sampled once during both spring and autumn. Water quality at the two estuarine sites is monitored at 15 minute intervals by automated water quality monitoring buoys.

Aquatic macroinvertebrate communities are assessed during spring and autumn at all freshwater sites and riparian vegetation condition of freshwater sites was surveyed in 2012 and is due for resurvey by 2015.

Due to the extent of urbanisation in the Cooks River catchment, no suitable reference sites exist for assessment of ecological condition. Therefore data from six undisturbed reference creeks in the Georges River are used for assessment (Table 13).The approach to selection of reference sites as outlined in the ANZECC guidelines (ANZECC 2000) qualifies the Georges River reference creeks as suitable for use to assess freshwater ecosystems of the Cooks River as these creeks are located within the same biogeographic region, have similar climate, geology, soils and topography.

Table 13.2013/14 River Health monitoring sites, waterway classification, water quality monitoring frequency and location

River Health Monitoring Site	Waterway Classification	Frequency of water quality monitoring	Latitude/Longitude
Chullora Wetlands	Urban Wetland	Spring/Autumn	-33°53’23"S 151°02'51"E
Yarrowee Rd Wetland	Urban Wetland	Spring/Autumn	-33°53'02"S 151°04'30"E
Cup and Saucer Creek Wetland	Urban Wetland	Spring/Autumn	-33°54'55"S 151°07'11"E
Upper Cooks River	Urban Stream	Monthly	-33°53'04"S 151°04'30"E
Wolli Creek at Turrella Weir	Urban Stream	Monthly	-33°55'46"S 151°08'17"E
Bardwell Creek at Coolibah Reserve	Urban Stream	Monthly	-33°55'59"S 151°08'00"E
Upper Bardwell Creek	Urban Stream	Spring/Autumn	-33°56'42"S 151°07'07"E
Cox's Creek	Urban Stream	Spring/Autumn	-33°54'16"S 151°04'04"E
Mid Cooks River	Estuarine	15 minutes	-33°54'52"S 151°07'20"E

Lower Cooks River	Estuarine	15 minutes	-33°55'59"S 151°09'41"E
Illuka Creek	Reference	Spring/Autumn	-34°14’29"S150°43'15"E
Cobbing Creek	Reference	Spring/Autumn	- 34°10'35"S150°50'24"E
Upper Georges River	Reference	Monthly	- 34°12'39"S150°47'46"E
Maddens Creek	Reference	Monthly	-34°14’20”S 150°55’05”E
O’Hares Creek	Reference	Spring/Autumn	- 34°05'41"S150°50'09"E
Woronora River	Reference	Spring/Autumn	- 34°03'47"S150°59'43"E
Stokes Creek	Reference	Spring/Autumn	- 34°09’49"S150°49'34"E

3.1.2 Aquatic macroinvertebrates

Macroinvertebrates were sampled in spring 2013 and autumn 2014 following the Australian National River Health Program protocols (DEST et al. 1994; Chessman 1995). This involved collection using a ‘kick’ net, with 250-µm mesh and square 30×30 cm net frame. The standard approach to sampling is to collect macroinvertebrates samples from both edge and fast flowing shallow water habitats. However most monitoring sites in the Cooks River catchment lack riffle habitat therefore edge habitat only was selected for sampling.

At creek monitoring sites a total of 10 m of stream habitat was sampled within a 100 m section of each site. At urban wetland sites 10 m of bank habitat was sampled. In urban wetlands with multiple ponds all ponds were sampled and combined to provide a representative sample of the site. Samples were live picked in the field on a sorting tray, and identified to the taxonomic level of Order in the field using the recommended Australian taxonomic keys (Hawking and Smith 1997). Once identified samples are preserved in ethanol and stored.

Three common macroinvertebrate indices were calculated for each sample:

- Family taxonomic richness (Rosenberg and Resh 1993) – a measure of the number of invertebrate orders recorded at the time of sampling, and
- Shannon biodiversity index (Krebs 1989) – a biodiversity measure that reflects taxa richness and evenness of taxa distribution.
- Weighted Order level SIGNAL 2 scores (Chessman 2003) – a biotic index based on the presence/absence of pollution tolerant/intolerant invertebrate taxa. Results are interpreted by displaying SIGNAL score and family richness on a bi-plot following the method outlined by Chessman (2003).

3.1.3 Water quality

Freshwater

Physicochemical water quality parameters were measured in-situ at all sites using a calibrated TPS 90FLMV multi probe meter. Parameters monitored were; electrical conductivity (EC), dissolved oxygen percent saturation (DO%), turbidity (NTU), pH, and temperature. In addition, surface water grab samples were taken at each site for analysis of total nitrogen (TN) total phosphorus (TP).

Grab samples were collected in decontaminated, acid-preserved sample containers provided by the testing laboratory. After collection, samples were stored in a chilled esky and delivered to a commercial laboratory for analysis. All grab samples were analysed using standard methods (APHA 1998) by a National Associations of Testing Authorities (NATA) accredited laboratory.

Samples collected from creek sites were collected from the creek bank at a depth no greater than 30 cm. Samples collected from urban wetlands were collected at similar depth as close the wetland outlet as possible.

Estuarine

Two automated water quality monitoring buoys stationed in the estuarine section of the mid and lower Cooks River collect and log water quality data at 15 minute intervals. Parameters monitored were electrical conductivity (EC), turbidity (NTU), dissolved oxygen (DO%), and chlorophyll-a (Chl-*a*).

Water quality data is remotely transmitted by each buoy to a database managed by the Greater Sydney Local Land Service (GSLLS). These buoys are part of the Botany Bay Water Quality Improvement Program (BBWQIP), which commenced in 2011 as an initiative of the Sydney Metropolitan Catchment Management Authority (recently absorbed by the GSLLS).

3.1.4 Riparian Vegetation Condition

The ecological condition of stream channel and riparian vegetation was surveyed at each monitoring site in autumn 2012 using the ‘Rapid Appraisal of Riparian Condition’ (RARC) Version 2 (Jenson et al. 2004). RARC applies 15 indicators of riparian condition divided into sub-indexed categories that reflect the functional aspects of the physical vegetation community and landscape features of the riparian zone to assess riparian vegetation community condition.

Due to the variability of access to sampling sites and the often limited spatial extent of urban riparian communities, a modified approach suited to the urban context was applied where a 100 m stretch of stream bank was assessed using four transects set perpendicular to the stream channel. Each transect was limited to a maximum of 40 m. For wetland assessment, four transects of a maximum 40 m, perpendicular to the bank and set on cardinal points were applied.

3.1.5 Quality Control/Quality Assurance

QA/QC procedures were implemented in the field and laboratory to ensure data integrity. This included collection and analysis of duplicate and field blank water quality samples which were collected and analysed at a ratio of 10 field samples: 1 field duplicate: 1 field blank. Additional QA/QC procedures were implemented by the commercial laboratory where water samples were despatched for analysis.

Macroinvertebrate identification to the taxonomic level of order is a relatively straight for forward procedure for experienced field personal. However to ensure the quality of data collected each sample, identified to order level in the field, was checked by a second experienced sampler for consistency of identification. Any discrepancies in identification were corrected. Following identification samples were preserved in ethanol and stored by the Georges River Combined Councils’ Committee.

3.2 Statistical Analysis

Multivariate analysis was applied to investigate the apparent differences between macroinvertebrate communities recorded in the Cooks River catchment and reference streams. Multivariate analysis has been demonstrated to be a powerful and useful approach to evaluate the ecological condition of macroinvertebrates exposed to freshwater pollution (e.g. Marchant et al. 1994; Wright et al 1995). Non-metric multidimensional scaling (NMDS) performed on a similarity matrix calculated with fourth-root transformed macroinvertebrate data, using the Bray-Curtis similarity measure (Clarke 1993; Warwick 1993). Two-dimensional ordination plots were generated to give representation of the dissimilarity among invertebrate communities at monitoring sites. Data were grouped, by reference streams, urban steams and urban wetlands. A two-way analysis of similarity (ANOSIM: Clarke 1993) was applied to test for significant difference between macroinvertebrate communities of reference sites reference streams, urban steams and urban wetlands and between season of sampling (spring 2013 and autumn 2014).

The influence of particular invertebrate families among land use groups was quantified using the similarity percentage procedure (SIMPER). These procedures were applied for analysis of 2014 data.

Multivariate analyses were conducted using the software package PRIMER version 5 (Clarke 1993).

Due to the low number of sites within waterway categories and therefore the lack of replication within and between waterway categories statistical analysis was not conducted on water quality results for freshwater sites. In addition no statistical analysis was performed on estuarine water quality data due to the absence of reference data.

Observational comparison was made between water quality and riparian vegetation condition results from the 2013/14 monitoring period and mean reference condition and ANZECC water quality guidelines for lowland rivers (ANZECC 2000).

3.3 Report Card Grades

Waterway health grades have become a popular and effective tool to communicate technical scientific information in a format easily understood by a diverse audience. Calculation of waterway health grades for the Cooks River catchment is based on the method applied by the South East Queensland Healthy Waterways Program (EHMP 2008). This approach has been applied by numerous waterway managers including the GRCCC which initiated the River Health Monitoring Program in the Georges River catchment in 2009.

The application of waterway health grades to describe the current ecological condition of waterways within the Cooks River catchment and provides a clear and easily understood interpretation of complex ecological data. The application of waterway health grades is based on robust scientific method; however, it is important to consider that some grades (e.g. water quality) reflect the condition of the monitoring site at the time of monitoring. Waterway health grades are calculated using three indices of ecosystem condition, each representative of different spatial and temporal impacts:

1. Water quality results provide information on conditions at the site at the time of sampling.

2. Riparian vegetation and channel condition indicates stream habitat quality in the immediate vicinity of the monitoring site, often a result of longer-term impacts.

3. Macroinvertebrates provide an indication of longer-term catchment and water quality conditions.

The combination of these indices provides a snap shot of both past and present conditions at a monitoring site. The formulation of waterway health grades involves a multi-index approach and it is not uncommon for one index to score poorly while others score more favourably.

In summary the process of River Health grade calculation involves the comparison of macroinvertebrate, water quality and riparian vegetation condition data collected from Cooks River waterways to the worst case scenario and the guideline for each parameter. This comparison enables the calculation of a standardised score for each parameter, which are then averaged to provide an overall standardised score for each monitoring site. Standardised scores represent the degree by which a site differs from reference condition. River Health grades are issued based on the corresponding standardised score for each monitoring site and reflect ecosystem condition of the waterway at the time of sampling.

River Health grades are calculated by use of the following steps:

Step 1. Formulation of Region Specific Guidelines

The ANZECC water quality guidelines for lowland rivers (ANZECC 2000) provide guidelines to assess water quality within the Cooks River catchment. Guidelines do not exist for macroinvertebrates or riparian vegetation condition however ANZECC (2000) encourage a catchment/waterway specific approach to monitoring macroinvertebrates and other ecological indices.

In this case it is necessary to formulate region specific guidelines for the Cooks River catchment, and the rationale set out in Chapter 3 ‘Aquatic Ecosystems’ of the ANZECC guidelines (ANZECC 2000) was applied. This process involves defining guidelines for macroinvertebrate indices and riparian vegetation condition by applying the 80th and/or 20th percentile values of data obtained from six reference streams within the Georges River catchment.

Step 2. Calculation of Worst Case Scenario (WCS)

‘Worst case scenarios’ (WCS) represent the ‘unhealthiest’ conditions for waterways within the Cooks River catchment. Worst case scenarios are calculated using the 10th and 90th percentiles of all data from all monitoring sites. The WCS is equal to the 90th percentile for stressors that cause problems at high concentrations and the 10th percentile for stressors that are problematic at low concentrations and for macroinvertebrate communities and riparian vegetation condition.

Step 3. Calculation of Standardised Score

Standardised scores for stream ecosystem health indices are calculated by comparing data for each waterway health parameter (WQ, macroinvertebrates and riparian vegetation) with the corresponding region specific guideline (RSG) and worst case scenario (WCS). Standardised scores for each parameter are calculated using the following equation:

Standardised Score = 1- (x – guideline)/ (WCS – guideline)

Where: x = the value of the waterway health parameter,

guideline = corresponding guideline,

WCS = corresponding worst case scenario.

In the case of dissolved oxygen where the WCS is often below the guideline, the value (x) and WCS are instead subtracted from the guideline to produce the standardised score. Where standardised scores are greater than one, values are rounded down to equal one and where standardised scores are less than zero values are rounded to zero. A standardised score close to one for an indicator reflects that the indicator met or exceeded the region specific guideline, whereas values lower than one reflect a departure from reference conditions.

Average standardised scores for each parameter are calculated. Following this, parameter standardised scores are averaged providing standardised scores for each index (water quality, macroinvertebrates and riparian vegetation), and finally index standardised scores are averaged to provide a standardised score for each sample site.

Step 4. River Health Grading

Following the calculation of standardised scores River Health grades are assigned to the indices of water quality, macroinvertebrates and riparian vegetation condition and an overall River Health grade assigned to each site. Table 14 shows standardise scores, corresponding River Health grade and ecological condition.

Table 14. Waterway health grading table displaying standardised scores, corresponding waterway health grade and ecosystem condition

Standardised Score	Grade	Ecological Condition	Description
>0.95 - 1.00	A+	Excellent	All indicators comply with guideline values. Waterways have high ecological value and experience little to no human disturbance.
>0.90 - 0.95	A	Good	Most indicators equivalent to reference conditions and comply with regional guidelines. Waterways have favourable water quality, complex habitat structure and support a diverse macroinvertebrate community.
>0.85 - 0.90	A-		
>0.80 - 0.85	B+		
>0.75 - 0.80	B	Fair	Numerous indicators outside regional guideline limits and show signs of departure from reference conditions. Periodic episodes of degraded water quality are likely and the macroinvertebrate community and stream habitat are commonly degraded.
>0.70 - 0.75	B-		
>0.65 - 0.70	C+		
>0.60 - 0.65	C		
>0.55 - 0.60	C-		
>0.50 - 0.55	D+	Poor	Most indicators non-compliant with guidelines and show significant departure from reference conditions. Waterways have degraded water quality and poor habitat reflected by a macroinvertebrate community dominated by pollution-tolerant species.
>0.45 - 0.50	D		
>0.40 - 0.45	D-		
>0.35 - 0.40	E+		
>0.30 - 0.35	E		
>0.25 - 0.30	E-		
>0.20 - 0.25	F+		
>0.15 -0.20	F		
0-0.15	F-		

4 Results

4.1 Macroinvertebrates

A total of 1909 macroinvertebrates from 13orders were collected during the 2013/14 monitoring period. The most abundant orders were Diptera (flies) (618 individuals) followed by Gastropod (snails) (314 individuals) and Hemiptera (true bugs) (250 individuals), all pollution tolerant taxa. Only 3% of the total macroinvertebrate abundance belonged to pollution sensitive taxa, a result that is typical of urban waterways.

Results from 2013/2014 monitoring show Cox's Creek recorded the highest SIGNAL score of 3.43, however this result is below mean reference condition and non-compliant with the calculated region specific guideline. SIGNAL scores for all other sites were below mean reference condition and non-compliant with the recommended regional guideline (Table 15).

Macroinvertebrate richness was highest at Chullora Wetlands with 11 orders recorded in spring 2013 and 12 in autumn 2014. These results are comparable with mean reference condition and compliant to the recommended regional guideline. At all other sites macroinvertebrate richness was below mean reference condition and non-compliant with the recommended regional guideline (Table 15). In addition the Shannon biodiversity index recorded for Chullora Wetlands and Upper Cooks were comparable to the recommended regional guidelines (Table 15).

Table 15. Aquatic macroinvertebrate indices of SIGNAL score, family richness, Shannon biodiversity index for Cooks River catchment waterways for spring 2013 and autumn 2014 monitoring and recommended regional guidelines. Bold red font indicates non-compliance with guidelines.

		SIGNAL Score	Richness (Order)	Shannon Index
***Regional guideline**		**>4.00**	**>10**	**>1.87**
Mean Reference (n=6)		**5.23**	**11**	**1.96**
Chullora Wetland	Autumn 2014	**2.86**	12	1.94
	Spring 2013	**3.03**	11	1.83
Upper Cooks River	Autumn 2014	**2.91**	10	**1.77**
	Spring 2013	**2.50**	**8**	**1.44**
Yarrowee Rd Wetland	Autumn 2014	**2.55**	**8**	**1.26**
	Spring 2013	No Data – Site Dry		
Cox's Creek Reserve	Autumn 2014	**3.33**	**8**	**1.45**
	Spring 2013	**3.43**	**6**	**1.48**
Cup and Saucer Creek Wetland	Autumn 2014	**2.14**	**5**	**1.45**
	Spring 2013	**2.14**	**6**	**1.41**
Wolli Creek Turella Weir	Autumn 2014	**2.58**	**3**	**0.83**
	Spring 2013	**2.25**	**5**	**1.08**
Upper Bardwell Creek	Autumn 2014	**2.12**	**6**	**0.99**
	Spring 2013	**3.22**	**8**	**1.34**
Bardwell Creek Coolibah Reserve	Autumn 2014	**2.94**	**7**	**1.58**
	Spring 2013	**2.55**	**8**	**1.47**

***Applied to report card grade calculation**

The SIGNAL bi-plot (Figure 10) provides a useful tool to interpret macroinvertebrate data. The bi-plot, combines SIGNAL score and order richness with results falling into one of four quadrants, each of which provides an indication of factors that may be affecting the macroinvertebrates at the site, such as water and habitat quality.

Boundaries in the SIGNAL vs macroinvertebrate family richness bi-plot (Figure 10) have been set following the rational set out by Chessman (2003) using reference creek data from the Georges River catchment collected during spring 2013 and autumn 2014. These reference sites are not located in the Cooks River catchment and represent the nearest non-urban 'natural 'streams.

Results of monitoring show all Cooks River waterways fall within quadrants two and four, indicating environmental conditions at these sites are affected by urban and/or industrial pollution and high nutrient and/or salinity.

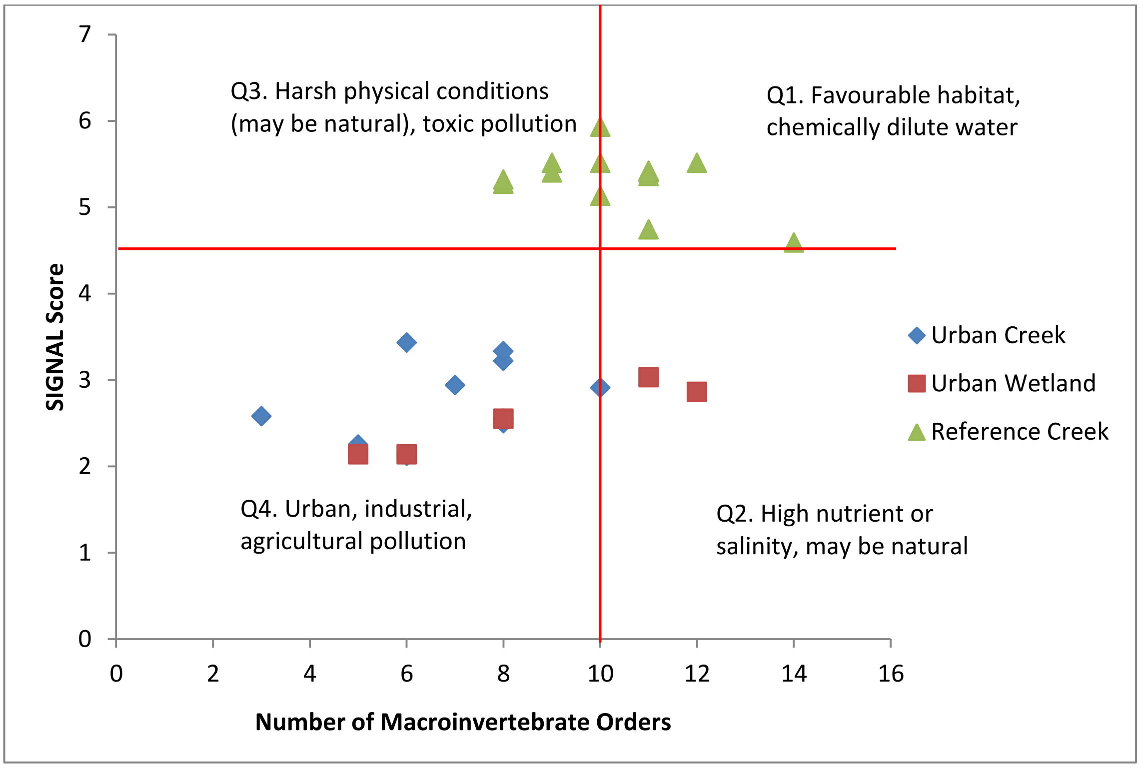


Figure 10. Bi-plot of SIGNAL scores and order richness from 2013/ 2014 macroinvertebrate sampling of Cooks River catchment waterways and reference streams in the Georges River catchment.

2-Dimensional NMDS ordination plots provide a visual representation of the similarity or dissimilarity between macroinvertebrate assemblages across sampling seasons. For general interpretation of ordination plots, discreet and separate clusters of marker points are representative of dissimilarity between sampling seasons while an overlapping pattern with minimal discreet clustering of marker points represents similarity between samples.

The pattern of community structure dissimilarity between waterway class can be seen in the nMDS 2-D ordination with reference creek samples (green triangles) clustering separately and discreetly from all other samples. In contrast, urban wetlands (blue squares) and urban streams (blue triangles) show a pattern of overlap, indicating community structure similarity between these urban waterway classes (Figure 11).

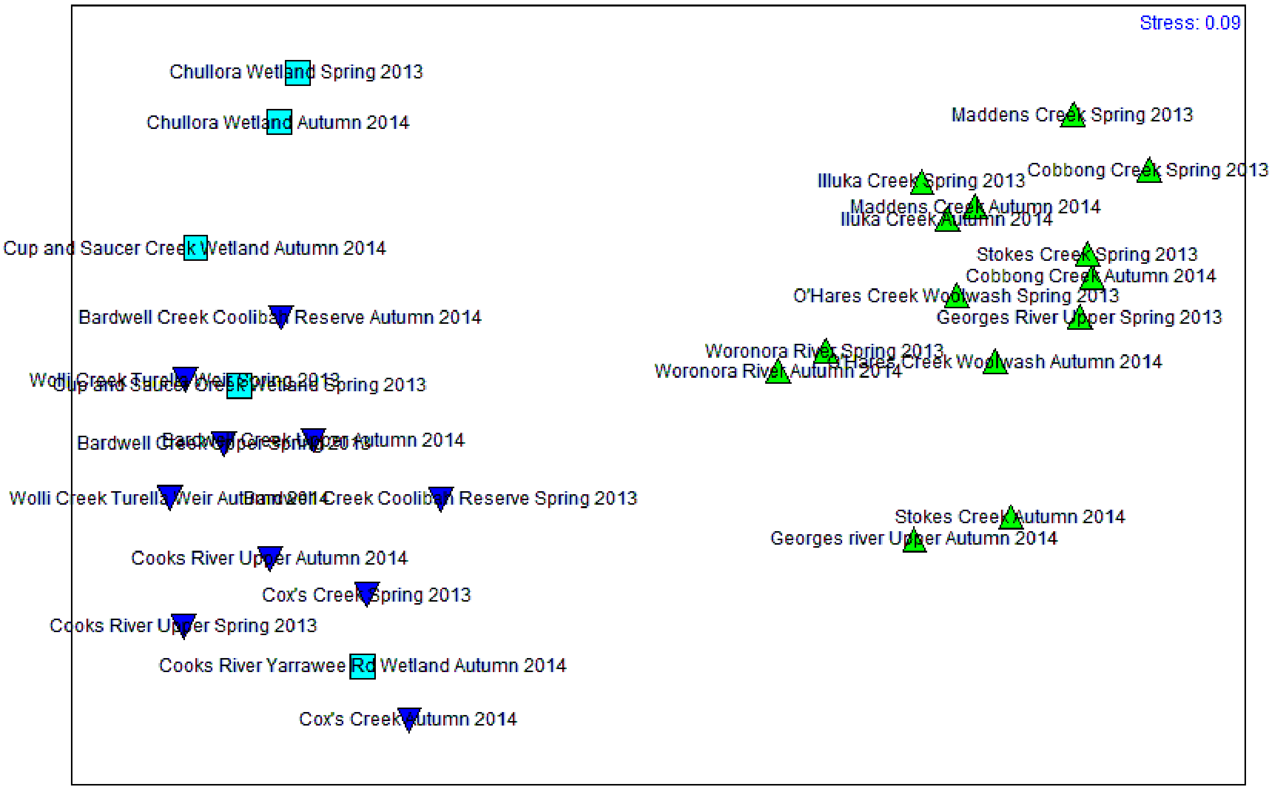


Figure 11.NMDS plot (4th root transformed data) of macroinvertebrate community structure for Cooks River waterways and reference streams, spring 2013/autumn 2014. Samples grouped according to waterway classification. Green triangles = reference stream, blue triangle = urban stream and blue square = urban wetland.

Seasonal differences in macroinvertebrate community structure between spring 2013 and autumn 2014 samples are not evident in the NMDS plot (Figure 12). Spring and autumn samples show a high degree of overlap with no discreet clustering. However, the pattern of difference between waterway categories is evident in Figure 12.

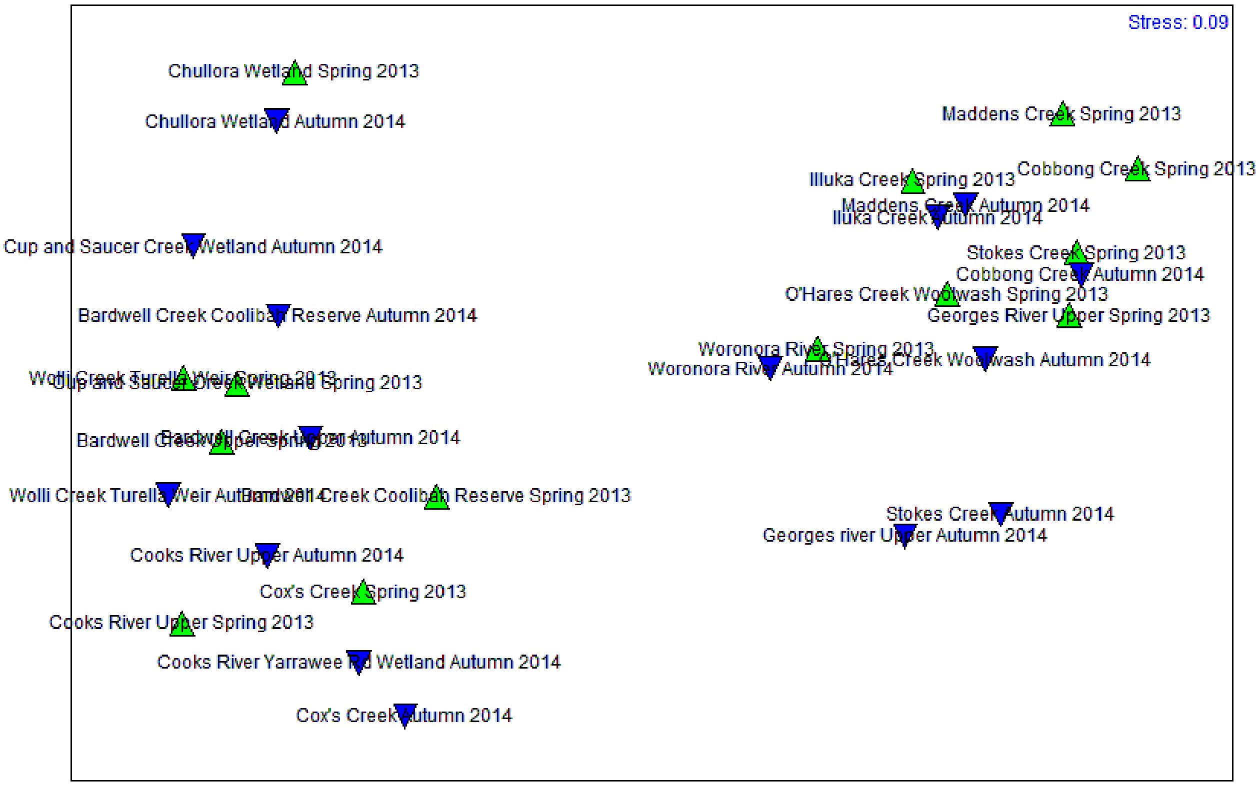


Figure 12.NMDS plot (4th root transformed data) of macroinvertebrate community structure for Cooks River waterways and reference streams, spring 2013/autumn 2014. Samples grouped according to season of sampling. Blue triangle = autumn 2014 and green triangles = spring 2013

Results of the ANOSIM procedure confirm patterns seen in ordination plots and reveal macroinvertebrate community structure varied significantly according to waterway classification (reference stream, urban stream and urban wetland) (Global R = 0.886, p = 0.001). Community structure of reference sites varied significantly when compared to urban streams (R=0.993, p = 0.001) and urban wetlands (R=0.994, p=0.001). In contrast differences in macroinvertebrate community structure of urban streams and urban wetlands were not significant and no seasonal difference was evident.

SIMPER analysis was applied to determine the contribution of macroinvertebrate orders to community structural differences between reference streams, and urban streams and urban wetlands. Results show Ephemeroptera (mayfly), Tricoptera (caddisfly), Acarina (water mite), Decapoda (freshwater shrimp) and Coleoptera (beetles) contributed 53% of dissimilarity between reference streams and urban streams. Similarly these five orders contribute to 51% of dissimilarity between reference streams and urban wetlands. All of these are taxa with moderate to high sensitivity to pollution (Gooderham and Tsyrlin 2002).

4.2 Water quality and, riparian vegetation condition

4.2.1 Freshwater Sites

Results of water quality monitoring show pH at routine monitoring sites and seasonal monitoring sites complied with ANZECC lowland river guideline range of 6.50 -8.50 (ANZECC 2000) throughout the 2013/14 monitoring period, however at times pH at most sites was above mean reference condition (Table 16).

Electrical Conductivity (EC) complied with ANZECC guidelines for most sites with exception of Wolli Creek at Turrella Reserve where mean EC was 2836 µS/cm and Cox's Creek where 9390 µS/cm and 5670 µS/cm was recorded in spring 2013 and autumn 2014 respectively. However when compared to reference conditions all sites recorded EC levels above mean reference EC of 136+/-60µS/cm (Table 16).

It is likely the result for Turrella Reserve is influenced by periodic tidal incursions however the Cox's Creek site is above the tidal limit therefore the very high salinity recorded at this site is likely to originate from anthropogenic sources.

Mean DO recorded at routine monitoring sites complied with the ANZECC guideline range 80% - 110% saturation (ANZCC 2000) at Upper Cooks River (87% saturation) however non-compliance was recorded at Bardwell Creek at Coolibah Reserve (30% saturation) and at Wolli Creek at Turrella Weir (50% saturation), results which were also well below mean reference condition of 83 +/- 17 % saturation (Table 16).

Results of seasonal monitoring DO did not comply with guideline limits at all sites during spring 2013. Yarrowee Road Wetland recording the lowest DO of 6% saturation and Cox's Creek the highest with 112% saturation, a result marginally exceeding the upper guideline limit. Results from autumn 2014 show Upper Bardwell Creek was the only site to record DO within guideline limits and comparable to reference creek condition (Table 16).

Mean turbidity at all seasonal monitoring sites complied with the ANZECC guideline. However the maximum turbidity recorded at Bardwell Creek at Coolibah Reserve (53 NTU) slightly exceeded the 50 NTU guideline limit. Turbidity at seasonal complied with guideline limits with exception of Yarrowee Road Wetland and Cup and Saucer Wetland during spring 2013 which recorded turbidity of 127 NTU and 65 NTU respectively (Table 16).

Mean total nitrogen exceeded the ANZECC guideline of 0.50 mg/L and mean reference condition of 0.25 +/- 0.35 mg/L at all routine monitoring sites. The highest concentration of 27.3 mg/L was recorded at Bardwell Creek at Coolibah Reserve. This result is more than five times the guideline limit. Maximum TN at Wolli Creek, Turrella Weir was 10.5 mg/L, twice the guideline limit. Results such as these are common to waterways with extensive urban development and catchment imperviousness (Tippler et al 2012). The Upper Cooks River was the only routine monitoring site to record TN within the recommended guideline limits (Table 16).

Seasonal monitoring of TN in autumn 2014 showed all sites, with exception of Chullora Wetland recorded TN concentration exceeding the ANZECC guideline. Cup and Saucer Wetland recorded the highest concentration in both spring 2013 and autumn 2014 with 4.1 mg/L and 3.4 mg/L respectively. Only Chullora Wetland and Cox's Creek recorded TN concentration comparable to mean reference creek condition (Table 16).

Mean total phosphorus exceeded the ANZECC guideline of 0.05 mg/L at all routine monitoring sites. The highest concentration of 0.28 mg/l was recorded at Wolli Creek, Turrella Weir, followed closely by 0.24 mg/L recorded at Upper Cooks River. With exception of the result for Cox's Creek in spring 2013, total phosphorous exceeded the guideline limit at all seasonal sites. The highest concentration for spring 2013 was recorded at Cup and Saucer Wetland (0.69 mg/L) and the highest for autumn 2014 recorded at Upper Bardwell Creek (0.14 mg/L). Total phosphorus recorded across most Cooks River sites was comparable to results from reference creeks. (Table16).

Riparian vegetation condition was initially surveyed in 2012; therefore results for the 2013/2014 monitoring period are based on data collected from the initial survey.

Riparian vegetation at most areas scored poorly due to industrial, commercial and housing development limiting width of riparian corridor, clearing of canopy and understory and presence of invasive species. Cup and Saucer Wetland recorded the lowest RARC score of 13.5. This result indicates a significance departure from reference conditions where the mean RARC score is 38.1. In contrast Upper Bardwell Creek recorded the highest RARC score of 34.75 a result only marginally lower than the regional guideline and reflective of the complex riparian habitat that is found at this site (Table 16).

Observational evidence suggests improved riparian condition at Yarrowee Road Wetland, Cup and Saucer Wetland and Bardwell Creek at Coolibah Reserve with vegetation at these sites showing clear signs of improvement. However the extent to which the vegetation community at these sites had changed over time cannot be quantified until vegetation condition is resurveyed.

Table 16. Water quality and riparian vegetation condition results for spring 2013 and autumn 2014 monitoring of Cooks River waterways, recommended guidelines and ANZECC lowland river guidelines. Red bold font indicates where mean or seasonal result exceeds guideline.

	pH		EC (uS/cm)		DO (%)		Turbidity (NTU)		TN (mg/L)		TP (mg/L)		RARC (x/50)
	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	
Routine													
Bardwell Creek Coolibah Reserve	6.97	6.19-7.58	744	310-1114	**31**	5 - 60	28	8-53	**9.6**	0.9-27.3	**0.07**	0.02-0.17	**19**
Wolli Creek at Turrella Weir	6.81	6.16-7.62	**2836**	388 - 9130	**50**	26-95	7	3-15	**4.7**	0.7-10.5	**0.09**	0.02-0.28	**20.38**
Upper Cooks River	7.57	6.84 -8.21	554	310 - 773	87	55 - 115	8	1 - 42	**1.1**	0.4 - 2.8	**0.13**	0.04 - 0.24	**18.75**

	pH		EC (uS/cm)		DO (%)		Turbidity (NTU)		TN (mg/L)		TP (mg/L)		RARC (x/50)
Seasonal	Spring 2013	Autumn 2014	Spring 2013	Autumn 2014	Spring 2013	Autumn 2014	Spring 2013	Autum n 2014	Spring 2013	Autumn 2014	Spring 2013	Autumn 2014	
Upper Bardwell Creek	7.14	7.27	217	194	**50**	95	13	43	**3.6**	**2.5**	**0.14**	**0.14**	**34.75**
Chullora Wetland	6.82	7.68	321	391	**13**	**32**	9	2	**1.0**	0.3	**0.23**	**0.06**	**29.75**
Yarrowee Rd Wetland*	6.70	*	2020	*	**6**	*	**127**	*	**1.6**	*	**0.27**	*	**18**
Cox's Creek	7.72	7.49	**9390**	**5670**	**112**	**73**	3	3	**0.7**	**0.6**	0.05	**0.08**	**21**
Cup and Saucer Wetland	6.69	7.04	607	887	**15**	**41**	**65**	15	**4.1**	**3.4**	**0.69**	**0.08**	**13.5**
Mean Reference (n=6)	6.28 +/-0.96		136+/-60		83 +/- 17		3 +/- 4		0.25 +/- 0.35		0.04 +/- 0.23		38.1+/-3
ANZECC Lowland River Guideline	6.50 - 8.50		50 - 2200		80-110		5-50		0.5		0.05		>36.25^

***No result, wetland dry. ^ Regional Guideline applied for River Health grade calculation**

4.2.2 Estuary Sites

Dissolved oxygen as measured by BBWQIP buoys were frequently outside the ANZECC guideline range for estuaries of southeast Australia of 85–100% saturation (Table 17). Mean DO for the Mid Cooks River was 72% and for the Lower Cooks River 63%. These results are below the lower ANZECC guideline of 80% saturation. The highest (260% saturation) and lowest DO (0% saturation) for the 2013-14 monitoring period were recorded at the Mid Cooks River.

A total of 25,006 DO samples were recorded for the Mid Cooks River, of which 34%complied with the ANZECC guidelines. A total of 23,150 were recorded for the Lower Cooks River with 29%of results complying with guidelines limits (Table 17).

Table 17. Results of dissolved oxygen monitoring at Mid and Lower Cooks River water quality monitoring sites for spring 2013-autumn 2014 monitoring period.

	Dissolved Oxygen (% Saturation)				% compliance to guideline	No. of Samples
	Mean	Minimum	Maximum	ANZECC Guideline		
Mid Cooks River	72	0	260	80-110	34	25,006
Lower Cooks River	63	0	225		29	23,150

Mean turbidity, as measured by BBWQIP buoys, for the Mid and Lower Cooks estuary monitoring sites exceeded the ANZECC guideline for estuaries of south east Australiaof10NTU (Table 18). The Mid Cooks River recorded the highest mean turbidity of 299 NTU and highest maximum turbidity of 3000 NTU. Mean turbidity at the Lower Cooks River was 54 NTU; with a maximum result of 700 NTU.

A total of 27,397 turbidity samples were recorded for the Mid Cooks River, of which 36%complied with the ANZECC guideline. A total of 27,141 samples were recorded for the Lower Cooks River with 39%compliancetoguidelines (Table 18).

Table 18. Results of turbidity monitoring at Mid and Lower Cooks River water quality monitoring sites for spring 2013-autumn 2014 monitoring period

	Turbidity (NTU)				% compliance to guideline	No. of Samples
	Mean	Minimum	Maximum	ANZECC Guideline		
Mid Cooks River	299	0	3000	10	36	27,397
Lower Cooks River	54	0	700		39	27,141

4.2.3 Chlorophyll-a

Mean chlorophyll-a (Chl-*a*) as measured by BBWQIP buoys, for the Mid and Lower Cooks estuary monitoring sites exceeded the ANZECC guideline range for estuaries of south eastAustraliaof4µg/L. Mean Chl-*a* for the Lower Cooks River was 9 µg/L with a maximum concentration of 222 µg/L. Mean Chl-*a* for the Mid Cooks River was 6 µg/L, with a maximum concentration of 234 µg/L (Table 19).

A total of 29,715 Chl-*a* samples were recorded for the Mid Cooks River, of which 59%complied with the ANZECC guideline and 31,445samples were recorded for the Lower Cooks River with 40%compliancetoguidelines (Table 19).

Table 19. Results of Chlorophyll-a monitoring at Mid and Lower Cooks River water quality monitoring sites for spring 2013-autumn 2014 monitoring period

	Chlorophyll-*a*(μg/L)				**% compliance to guideline**	**No. of Samples**
	Mean	Minimum	Maximum	ANZECC Guideline		
Mid Cooks River	6	0	234	4	59	29,715
Lower Cooks River	9	0	222		40	31,445

5 Discussion

Results from 2013/14 River Health monitoring indicate that aquatic ecosystems of urban streams, urban wetlands and estuarine reaches within the Cooks River catchment show signs of moderate to severe degradation. When compared to ANZECC water quality guidelines and reference creeks, water quality and macroinvertebrate communities all show signs of degradation. Additionally riparian vegetation condition is in fair to poor condition at most sites with exception of Upper Bardwell Creek where a patch of native remnant bushland remains in good condition.

The ecological conditions of Cooks River waterways are typical of those with highly urbanised catchments and the degraded state of these waterways is reflected by relatively low River Health grades.

Urbanisation is a significant factor contributing the degradation of urban streams with the major driver being the cover of impervious surfaces within waterway catchments. Studies have shown as little as 5% impervious cover is required to trigger the onset of stream ecosystem decline (Meyer et al 2005, Walsh et al 2004, Tippler et al 2012, Tippler et al 2013). Jakuba et al (2010) documented catchment imperviousness as high as 80% in the Cooks River catchment. Major factors that affect both freshwater and estuarine ecosystems due to urbanisation include; degraded water quality commonly attributed to waste water sources such as wet weather overflows of sewerage systems, illegal connection to sewer, fertilizer and household and industrial chemicals entering the stormwater system, soil erosion and channel scouring as a result of increased stream flow and velocity. Loss of aquatic habitat due to higher rates of sedimentation, loss of sensitive macroinvertebrate taxa, degraded riparian vegetation communities (Meyer et al 2005, Walsh et al 2004, Tippler et al 2012), pollution of riparian soils (Grella et al 2014) and increased colonisation of invasive aquatic species (Shield et al 2014).

Results of water quality monitoring cross the Cooks River catchment show high nutrient and chlorophyll-a concentrations, elevated salinity and turbidity and low dissolved oxygen are common. These conditions are likely attributed to storm water, use of fertilizers on golf courses, industrial discharges, urban run-off and sewage contamination from sewer leaks and overflows.

At most sites, riparian vegetation condition was degraded, and vegetation community fragmented often with a high degree of weed invasion. This is reflected by RARC scores for most Cooks River sites which when compared to reference creeks are considerably lower. In addition, most stream channels were affected by erosion and bank undercutting, and stream and wetland sediment was often deep and consisted of fine clay and decaying organic material. In urban wetlands which are specifically designed to capture sediment, a layer of fine particulates is an indicator the wetland is performing the design function of sediment capture. However in urban creeks, excessive fine clays and silts such as those found in the Cooks River and tributaries are problematic as this causes the infill of deep holes and the sedimentation of creek channels which eventually leads to the loss of aquatic habitat.

Aquatic macroinvertebrates are commonly used as indicators of waterway ecosystem condition and results of monitoring show communities recorded at all Cooks River sites exhibit moderate to extreme degradation. When compared to reference condition and region specific guidelines most sites recorded a combination of fewer macroinvertebrate families, lower SIGNAL scores and a reduction or absence of pollution-sensitive EPT taxa. In addition multivariate analysis confirmed significant differences in macroinvertebrate community structure were evident between reference condition and urban waterways

SIGNAL score and %EPT taxa have been demonstrated as the most sensitive indices for assessment of urban streams (Walsh 2006) and these results provide further evidence that, all waterways within the current study display various degrees of degradation when compared to reference condition.

The results of 2013/14 River Health monitoring were similar to those found in 2012/13 (GRCCC 2013) and by other studies of waterways within the Sydney region (eg. Davies et al 2010, Tippler et al 2012, Hornsby Council 2012, Tippler et al 2013,)

Assessment of waterways in this study was based on the development of region specific guidelines macroinvertebrate indices and riparian and channel condition and ANZECC water quality guidelines for lowland rivers of south east Australia (ANZECC 2000). To formulate region specific guidelines to assess Cooks River waterways the method used by the South East Queensland Healthy Waterways Program (EHMP 2008) was applied This follows the rationale set out in Chapter 3 'Aquatic Ecosystems' of the ANZECC guidelines (ANZECC 2000) and utilises combined data collected from six reference streams located within the Georges River catchment. This approach provides a locally relevant context in which to assess stream impacts and incorporates the traditional generic guidelines that have been developed for application to streams across a wide geographic area.

The development and application of region specific guidelines for macroinvertebrate indices applied in this study take into account naturally occurring low SIGNAL scores that are typical of streams with undisturbed catchments and a dominant geology of Hawkesbury sandstone (Tippler et al 2012, Hornsby Council 2012). For example the default SIGNAL score interpretation guide suggests streams with SIGNAL scores of 4-5 suffer moderate impairment. However SIGNAL scores for reference streams within this study area are typically in the range of 4-5. Therefore if applying the generic SIGNAL interpretation, reference streams which are typically in 'near pristine' condition, would be assessed as moderately impaired.

The development of region specific guidelines is a dynamic and ongoing process which requires regular update of reference stream data to account for temporal changes which may occur. Additionally, regular update and review of reference data will promote the scientifically robust assessment of waterways based on locally relevant conditions and reduce the reliance on default guidelines for application across broad geographical areas, i.e. ANZECC water quality guidelines and default SIGNAL model.

The application of River Health grades and report cards to describe the current ecological condition of waterways in the Cooks River catchment provides a clear and easily understood interpretation of complex ecological data (Bunn et al 2010). The application of waterway health grades is based on robust scientific method; however, it is important to consider that some grades (e.g. water quality) reflect the condition of the monitoring site at the time of monitoring. Waterway health grades are calculated using three indices of ecosystem condition, each representative of different spatial and temporal impacts:

1. Water quality results provide information on conditions at the site at the time of sampling
2. Riparian vegetation and channel condition indicates stream habitat quality in the immediate vicinity of the monitoring site, often a result of longer-term impacts.
3. Macroinvertebrates provide an indication of longer-term catchment and water quality and habitat conditions over a period of months to years

The combination of these indices provides a snap shot of both past and present conditions at a monitoring site. The formulation of waterway health grades involves a multi-index approach and it is not uncommon for one index to score poorly while others score more favourably. An example of this can be seen in results from the Upper Cooks River which recorded a waterway health grade for water quality of A, C- for macroinvertebrates and F- for riparian vegetation condition. Although water quality at this site at the time of sampling was good, the macroinvertebrate and riparian vegetation grades indicate degraded conditions. As macroinvertebrates are reliable indicators of water quality and catchment conditions, the grade of C- indicates the water quality in the creek is, at times, degraded which negatively affects the macroinvertebrate community.

All sites, within the highly urbanised Cooks River catchment scored River Health grades indicating ecosystem degradation. These results are similar to grades for urban waterways monitored by similar programs in Hornsby Shire Council Area (Hornsby Shire Council 2012) and south east Queensland (EHMP 2012).

6 Recommendations

Based on the results from 2013/14 monitoring and consultation with the River Health program coordinator the following recommendations are provided to enhance both the River Health project and the sustainable management of waterways within the Cooks River catchment. A number of recommendations align with the outcomes of the recent Review of the RiverScience and River Health Programs (BMTWBM 2014).Site specific recommendations are provided in a separate document.

6.1 Recommendations for the sustainable management of the Cooks River catchment

1. It is recommended the Councils of the Cooks River catchment investigate opportunities for the implementation of a strategic approach to Water Sensitive Urban Design (WSUD) with a particular focus on stormwater treatment and reducing catchment effective imperviousness (portion of the catchment directly connected to waterways via stormwater infrastructure). This approach is applicable to all waterways within the catchment. The implementation of WSUD throughout the catchment will contribute to reductions in nutrient and sediment loads to local waterways and result in future improvement in the overall ecological condition of waterways. This recommendation will assist in achieving the multiple outcomes identified by the Cooks River Alliance Action Plan, 2014-2017 (CRA 2014).

2. To complement the implementation of WSUD across the catchment it is recommended that CRA and member Councils adopt site-specific actions to improve ecological conditions of waterways. When compared to reference condition the majority of sites monitored by this study have degraded riparian and channel condition. Riparian restoration works are often achievable for Council and cost significantly less than major infrastructure works. By improving riparian vegetation communities, public amenity and stream health and consequently River Health grades will likely improve, however, it is important to note vegetation restoration is not the only solution to improving ecosystem health, and should be integrated with other catchment works (e.g. WSUD implementation).

3. Weed removal and bush regeneration are identified by the Cooks River Alliance Action Plan, 2014-2017 (CRA 2014) as an objective for collaboration and community participation and both are important drivers to improve the ecological health of the Cooks River catchment. It is recommended efforts for bush regeneration and weed removal take an evidence based approach to site selection to maximise the potential benefit of these actions. The Sydney Metropolitan Catchment Management Authority (SMCMA) Waterway Health Strategy (Earth Tech 2007) identified 22% of the Cooks River catchment is suitable for vegetation regeneration. It is recommended a tool such as this is used to prioritise on-ground works to achieve maximum ecological benefit.

4. To evaluate the success of Cooks River Alliance's (CRA) waterway management programs and to prioritise future works, it is beneficial the CRA and member Councils documents/maps previous and future catchment/stream restoration works and development. This will help interpret future monitoring of stream health against catchment improvements or impacts. Not only will this evaluate the effectiveness of restoration projects, it will provide prioritisation of future management recommendations.

5. It is most likely significant sources of ecological degradation to the waterways monitored in this study is the urban stormwater system. However it is unclear of the location of point sources that contribute to waterway pollution. Therefore it is recommended the CRA and member Council's conduct detailed catchment surveys to identify point sources of pollution and implement the appropriate management actions. It would be beneficial for the CRA and member Council's to partner with Sydney Water and work in conjunction to identify sewer and mains leaks and overflows.

6. Contemporary studies of urban waterways place an emphasis on the percentage of a sub-catchment covered by impervious surfaces such as roads, roofs and car parks. It well documented that imperviousness is a major driver of urban stream degradation. The addition of an imperviousness measure to an aquatic ecosystem monitoring program allows for a more detailed examination of sub-catchment condition and provides assistance to identify waterways best suited to stream restoration. It is recommended that CRA and member Councils explore options to calculate sub-catchment imperviousness and include this important factor in future monitoring.

7. The Cooks River has a strong history of community participation and engagement with collaboration and community engagement identified as a key long term outcome for the sustainable management of the Cooks River catchment (CRA 2014). To encourage and monitor the participation and outcomes of community engagement and participation in on-ground works it is recommended that CRA introduce a mapping system such as Creek link (Maund 2014). Creek link provides simple, interactive online maps to local environmental community groups. The Creek link mapping tool enables groups to record key information about their local waterways, and then use that information to assist them achieve waterway rehabilitation goals.

6.2 Recommendations for the River Health Monitoring Program

1. It is recommended to continue further macroinvertebrate sampling on seasonal (spring and autumn) frequency as recommended by the national framework, however samples should be identified to family level. The current program identifies to order level in the field which provides a good overall assessment of stream conditions however may not allow subtle difference between sites to be detected. Family level identification will enhance the sensitivity of the data collected and allow for more subtle analysis and comparison of waterway condition. Ongoing monitoring will provide CRA and member Councils with long-term data to assist with waterway management, assess impacts of land use change and stream restoration projects.

2. Tippler et al (2014) showed seasonal difference between macroinvertebrate community structure, identified to family level, did not vary between spring and autumn for waterways in the Georges River catchment and in Kuringai, Hornsby and Blacktown Council areas. Invertebrate samples for the 2013/14 River Health monitoring period were identified to family level however these results were not used for assessment in this current monitoring period. This data will provide an important historical resource for future assessment and if

the recommendation to implement family level identification is introduced, seasonal comparisons can be made. The results of which will likely indicate no significant seasonality in which case sampling of macroinvertebrates could be dropped to one season per year and resources previously dedicated to twice yearly sampling redirected elsewhere. However this decision should only be made once sufficient data has been collected.

3. The current River Health program utilises macroinvertebrates as indicators of aquatic ecosystem condition. Aquatic macroinvertebrates are a well-known to respond to changes in catchment conditions. However in highly urbanised streams this group of indicators may not be sensitive enough to respond to subtle changes in water quality, especially in relation to a response to changes in nutrient concentration. Given the high nutrient concentrations recorded at all sites during the 2013/14 monitoring period and the recommendation of actions to reduce stormwater and sewage pollution, which are notable sources of nutrients to urban stream systems, it is recommended algal diatom sampling be introduced to the monitoring program. Diatoms have been identified as better indicators of nutrient enrichment, while macroinvertebrates were better integrative indicators of catchment disturbance (Sonneman et al 2001). Diatoms have been successfully used in similar waterway health monitoring programs by Hornsby Shire Council (Hornsby Council 2012).

4. From observation and communication with Cooks River residents it is likely that waterways of the Cooks River catchment experience episodes of pollution from wastewater and the potable water supply. Findlay et al (2012) found the majority of potable water input to base flow in streams in northern Sydney probably comes from leaks in the reticulated water supply and sewers. Findlay et al (2012) used fluoride as an indicator to detect the presence of reticulate water in urban streams and to estimate the percentage of base flows that the reticulated water supply contributes to urban creeks. It is recommended fluoride monitoring be introduced to the River Health program and the rationale presented by Findlay et al (2012) be followed to estimate the percentage of base flow attributed to the reticulated water supply. Results of this monitoring can be integrated into the report card grading system and assist in meeting Sydney Water, who are the operators of the reticulated supply, related objectives set out in the Cooks River Alliance Action Plan.

5. Water quality assessment for the Cooks River catchment is based on comparing data collected in the field to the ANZECC water quality guidelines for lowland rivers of south east Australia (ANZECC 2000). However, the default ANZECC guidelines do not reflect typical background water quality and chemistry for creeks within many parts of Sydney, including the Cooks River catchment (Tippler et al 2013). In these situations, an assessment of water quality monitoring data against the ANZECC default values can suggest the condition of the waterway is inside the normal range, or not polluted, when in fact conditions vary significantly from what should be considered as ‘clean’. To counter these problems, the ANZECC framework encourages the development of region/catchment specific guidelines to better reflect local

conditions. In addition, the performance of catchment and stream improvement projects are often determined against the change in water quality and ecological indicators, from pre-intervention to post intervention using the ANZECC guidelines.

These approaches are fraught with problems in highly urban catchments due to the significance of the degradation and multiple causative factors contributing to poor water and ecological health. Further the default parameters used in the ANZECC guidelines are designed to reflect natural to slightly disturbed ecosystem conditions and are often unrealistic as a guideline to measure against the poor and highly variable water quality experienced by urban streams. Given these challenges urban creek ecosystem monitoring and restoration projects can be set up to fail from the outset due to unrealistic expectations and benchmark targets.

It is recommend catchment specific guidelines and targets that reflect local conditions and disturbance are formulated to provide a relevant assessment of waterway condition. Tippler et al (2013) suggest guidelines for urban stream assessment based on a moderate level of catchment disturbance (determined by catchment imperviousness) are used to assess urban streams. By adopting this approach waterways of the Cooks River will be assessed against guidelines adapted specifically for urban streams and on-ground works can be assessed against more realistic targets.

6. The current River Health assessment method for Cooks River waterways is largely based on the comparison with reference creeks in undisturbed, naturally vegetated catchments and ANZECC guidelines for slight to moderately disturbed ecosystems. Due to the highly urbanised nature of waterways within the Cooks River catchment, the application of this departure from reference condition assessment inevitably results in low grades for Cooks River waterways. Continual reporting of low grades for waterways can lead to report card fatigue and disengagement of community stakeholders (Smith 2014). To counter this, it is recommended that future grading of Cooks River waterways feature assessment with relevant urban stream guidelines (see recommendation 5) and grading moves to a results based system where sites are assessed against predetermined targets. This approach will assist in monitoring on-ground works and provide a measure of success/failure relative to select targets and maintain engagement of the community.

7. Estuary water quality monitoring is currently performed by two automated water quality monitoring buoys. These buoys are maintained by Australian Laboratory Services and data is accessed via the Greater Sydney Local Land Service. Access to data for the 2013/14 monitoring period was problematic and reliability of the data was unable to be determined as no quality assurance was included in the data set. These buoys are soon to be decommissioned (pers. comms. GRCCC). Therefore it is recommended an alternative and more thorough assessment method be applied to monitor the estuarine reach of the Cooks River such as those outlined in NSW State Government Assessing Estuary Ecosystem Health: Sampling, data analysis and reporting protocols (NSWOEH 2013). This method provides a

scientifically robust framework to assess the ecological condition of the estuarine reach of the Cooks River and has been successfully incorporated into the Northern River EcoHealth Project (Osborne et al 2011) which shares similarity with the River Health program.

8. It is well known waterways of the Cooks River catchment experience sewage contamination which at times may pose a public health risk. An objective of many community members is to swim in the Cooks River however sewage contamination is a primary obstacle to this goal. It is recommended bacterial analysis be implemented as part of the River Health project and results integrated into the report card. A similar approach is taken by Hornsby Shire Council who report bacterial contamination in their Water Quality Report Card (Hornsby Council 2012).

7 Conclusion

Paul and Meyer (2001) used the phrase ‘urban stream syndrome’ to describe the multiple environmental problems which typify the degradation of urban streams. These symptoms include:

- increased intensity of flow after rainfall
- erosion
- sedimentation
- stream bed and bank scouring
- degraded water quality
- loss of sensitive macroinvertebrate taxa
- and altered riparian vegetation communities.

All of these symptoms apply to waterways within the Cooks River catchment. Central to the urban stream syndrome is the extent of which a stream catchment is covered by impervious surfaces such as roads, roofs and car parks, and studies have shown that after 5% of a catchment is covered by impervious surfaces the onset of stream degradation occurs (Walsh et al. 2007; Tippler et al. 2012). From the results of monitoring it is evident that waterways within the Cooks River catchment display symptoms typical of the urban stream syndrome and the condition of aquatic ecosystems range from moderately disturbed through to highly degraded.

8 References

ANZECC (Australian and New Zealand Environment and Conservation Council) (2000).*Australian and New Zealand guidelines for fresh and marine waters.* Australian and New Zealand Environment and Conservation Council, Canberra.

APHA (American Public Health Association). (1998). *Standard methods for the examination of water and wastewater (20th ed.)*. Washington, DC: American Public Health Association.

Beavan, L., Sadler, J.and Pinder, C. (2001). The invertebrate fauna of a physically modified urban river. *Hydrobiologia,* 445, 97–108.

Bunn SE, Abal EG, Smith MJ, Choy SC, Fellows CS, Harch BD, Kennard MJ, Sheldon F (2010) Integration of science and monitoring of river ecosystem health to guide investments in catchment protection andrehabilitation. Freshwater Biology 55:223 -240

Cairns, J. Jr. and Pratt, J.R. (1993). A history of biological monitoring using benthic macroinvertebrates, in *Freshwater Biomonitoring and Benthic Macroinvertebrates*, Eds. (D.M. Rosenberg and V.H. Resh), Chapman and Hall, London and New York.

Chessman B.C. (1995). Rapid assessment of rivers using macroinvertebrates: A procedure based on habitat-specific sampling, family level identification and a biotic index. *Australian Journal of Ecology* 20:122-129.

Chessman B.C. (2003). New sensitivity grades for Australian river macroinvertebrates. *Marine and Freshwater Research* 54:95-103.

Clarke K.R. and Ainsworth M. (1993). A method of linking multivariate community structure to environmental variables. *Marine Ecology Progress Series* 92:205-219

Clarke, K.R. (1993). Non-parametric multivariate analyses of changes in community structure. *Australian Journal of Ecology*, 18: 117-143.

DEST, EPA, & WRDC. (1994). *River bioassessment manual. Version 1.0,* National River Processes and Management Program, Monitoring River Health Initiative. Canberra: Department of the Environment, Sport and Territories, Environment Protection Agency, and Land and Water Research and Development Corporation.

Davies P.J., I.A. Wright, O.J. Jonasson and S.J. Findlay (2010) Impact of concrete and PVC pipes on urban water chemistry. *Urban Water Journal* Vol. 7, No. 4, 233–241.

Earth Tech. (2007). Sydney Metropolitan CMA Waterways Health Strategy. Earth Tech Pty. Ltd. for Sydney Metropolitan CMA, Sydney, NSW.

EHMP (2008). *Ecosystem Health Monitoring Program 2006–07 Annual Technical Report.* South East Georges River Combined Councils' Committee (GRCCC) (2013) Georges and Cooks Rivers River Health Report Card.

Findlay, S.J, Jonasson, O.J, Davies, P.J, Taylor,, M.P and Gore, D.B, (2012), Extracting base flow to substitute for potable water use – how much is too much for urban stream health?, in Grove, J.R and Rutherford, I.D (eds.) *Proceedings of the 6th Australian Stream Management Conference, Managing for Extremes,* 6 – 8 February, 2012, Canberra, Australia, published by the River Basin Management Society, p.p.1 – 8.

Grella, C., Tippler, C., Renshaw, A. & Wright, I. A. (2014). Investigating the link between riparian weed invasion, riparian soil geochemistry and catchment urbanisation, in Vietz, G; Rutherfurd, I.D, and Hughes, R. (editors), *Proceedings of the 7th Australian Stream Management Conference*. Townsville, Queensland, Pages 434-441.

Hawking, J.H. (1994).*A preliminary guide to keys and zoological information to identify invertebrates from Australian freshwaters*. Cooperative Research Centre for Freshwater Ecology Identification Guide No. 2. Cooperative Research Centre for Freshwater Ecology, Albury.

Hornsby Shire Council (2012). *Water Quality Companion Technical Report – Water Quality Report Card.*

Jansen, A., Robertson, A., Thompson, L., & Wilson, A. (2004).Development and application of a method for the rapid appraisal of riparian condition, *River Management Technical Guideline no. 4*. Canberra: Land & Water Australia.

Krebs, C. (1989). *Ecological methodology*. New York: HarperCollins.

Northern Rivers Catchment Management Authority (NRCMA) (2011). *Bellinger - Kalang Rivers Ecohealth Project Assessment of River and Estuarine Condition Report Card 2011, Technical Report and Calculation of Scores.*

Paul, M.J. and Meyer J.L. (2001). Streams in the urban landscape. *Annual Review ofEcologyandSystematics,* 32:333-365.

Petersen, R.C. Jr. (1992). The RCE: a riparian, channel and environmental inventory for small streams in the agricultural landscape. *Freshwater Biology*, 27: 295-306.

Rosenberg, D.M. and Resh, V.H. (1993).*Freshwater biomonitoring and benthic macroinvertebrates*. Chapman & Hall, New York, London.

Sonneman J.A., Walsh C, J., Breen P., F. and Sharpe A. K. (2001) Effects of urbanization on streams of the Melbourne region, Victoria, Australia. II. Benthic diatom communities. *Freshwater Biology.*46, (4), 553–565.

Tippler C., Wright, I. And Hanlon, A. (2012). Is Catchment Imperviousness a Keystone Factor Degrading Urban Waterways? A Case Study from a Partly Urbanised Catchment (Georges River, South-Eastern Australia).*Water Air and Soil Pollution* 223:5331–5344.

Tippler C., Wright I.A., Davies P.J. and Hanlon A. (2013). Ecosystem Guidelines for the Conservation of Aquatic Ecosystems of the Georges River Catchment: A Method Applicable to the Sydney Basin. *Proceedings of the State of Australian Cities Conference, Sydney, November 2013*.

Tippler C., Wright I. A., Davies P.J, and Hanlon A. (2014). The influence of concrete on the geochemical qualities of urban streams. *Marine and Freshwater Research* (in press).

Walsh, C.J., Leonard, A.W., Ladson, A.R. and Fletcher, T.D (2004). Urban stormwater and the ecology of streams. Cooperative Research Centre for Freshwater Ecology and Cooperative Research Centre for Catchment Hydrology, Canberra.

Walsh C.J. (2006). Biological indicators of stream health using macroinvertebrate assemblage composition: a comparison of sensitivity to an urban gradient. *Marine and Freshwater Research,* 57(1) 37–47.

Walsh, C.J., Sharpe, A.K., Breen, P.F. and Sonneman, J.A. (2001). Effects of urbanisation on streams of the Melbourne region, Victoria, Australia. I. Benthic macroinvertebrate communities. *Freshwater Biology*, 46, 535-551.

Warwick, R.M. (1993). Environmental impact studies on marine communities: pragmatical considerations. *Australian Journal of Ecology*, 18: 63-80.

Wright I.A., Chessman B.C., Fairweather P.G. and Benson L.J. (1995). Measuring the impact of sewage effluent of an upland stream: the effect of different levels of taxonomic resolution and quantification. *Australian Journal of Ecology,* 20:142-149.

Appendix A

Macroinvertebrate Order Abundance

Site	Season	Ephemeroptera	Tricoptera	Acarina	Coleoptera	Bivalvia	Diptera	Odonata	Hemiptera	Isopoda	Oligochaeta	Turbellaria	Gastropoda	Hirudinea
Bardwell Creek Coolibah Reserve	**spring 2013**	0	0	19	0	0	0	6	8	0	2	2	6	1
	autumn 2014	0	1	0	0	0	50	10	37	0	18	4	2	1
Wolli Creek Turrella Weir	**spring 2013**	0	0	0	0	0	50	4	0	0	44	0	0	0
	autumn 2014	0	0	0	0	4	50	1	0	0	14	0	11	0
Upper Cooks River	**spring 2013**	0	4	3	1	20	50	11	0	0	36	3	50	4
	autumn 2014	0	1	0	0	1	50	50	7	0	7	1	50	0
Upper Bardwell Creek	**spring 2013**	0	0	0	0	2	50	2	1	0	14	0	4	0
	autumn 2014	0	7	0	0	0	42	4	1	0	10	2	3	1
Chullora Wetland	**spring 2013**	1	1	9	1	0	50	30	50	4	14	19	1	20
	autumn 2014	3	1	3	2	0	50	9	50	0	16	34	1	16
Yarrowee Wetland	**spring 2013**	No Sample - Wetland Dry												
	autumn 2014	0	2	0	1	0	3	35	6	0	3	1	50	0
Cox's Creek	**spring 2013**	0	12	2	0	0	50	24	0	0	3	1	50	1
	autumn 2014	0	29	0	0	0	23	30	0	0	0	1	50	5
Cup and Saucer Wetland	**spring 2013**	0	0	0	0	0	50	9	46	0	14	0	36	0
	autumn 2014	0	0	0	0	0	50	4	44	0	39	1	0	12

Appendix B

Macroinvertebrate Family Abundance

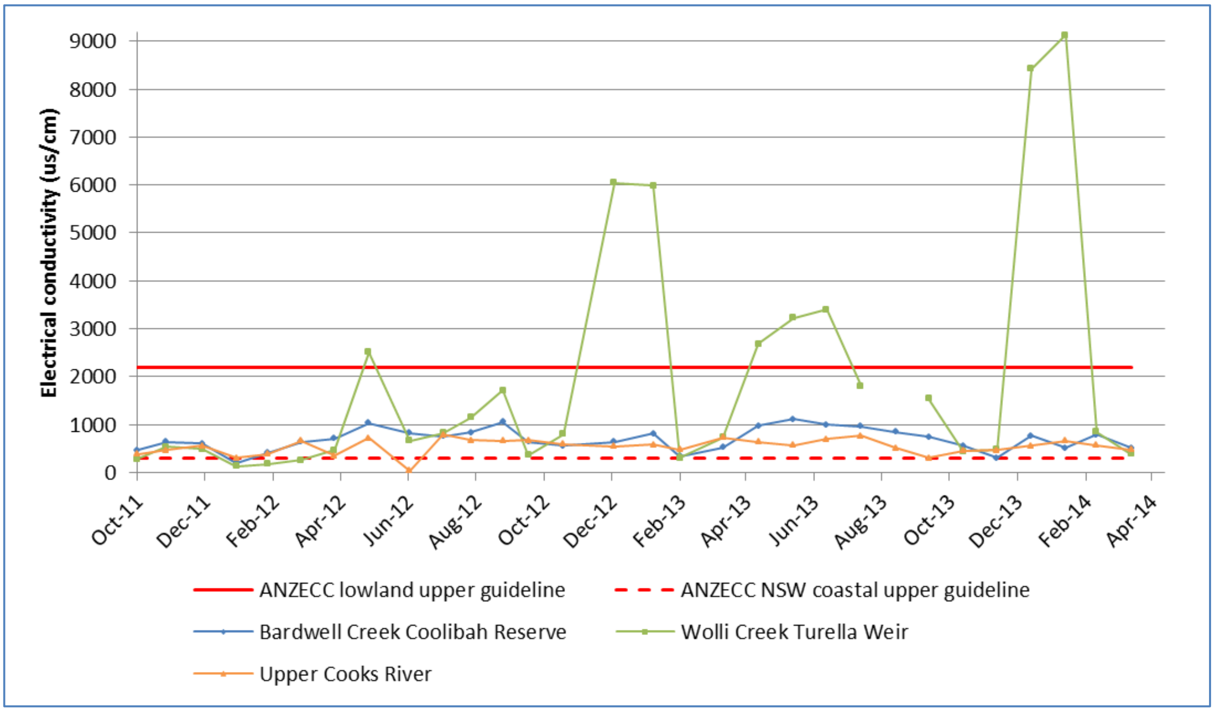
Site	Season	Acarina	Aeshnidae	Ancylidae	Chironomidae	Coenagrionidae	Corbiculidae	Corduliidae	Corixidae	Dixidae	Dugesiidae	Dytiscidae	Elmidae	Gerridae	hirudinea	Hydraenidae	Hydrophilidae	Hygrobiidae
Chullora Wetland	**spring 2013**	6	10	0	88	14	0	0	55	0	12	0	0	4	25	0	5	0
	autumn 2014	3	1	0	83	5	0	0	29	0	11	0	0	6	31	0	0	0
Wolli Creek Turella Weir	**spring 2013**	0	3	0	104	1	0	0	0	0	0	0	0	0	0	0	0	0
	autumn 2014	0	0	0	116	0	0	0	0	0	0	0	0	0	0	0	0	0
Upper Cooks River	**spring 2013**	0	0	0	53	17	0	0	0	0	0	0	0	0	2	0	0	3
	autumn 2014	0	0	0	18	10	0	13	0	0	0	1	1	0	3	0	0	0
Upper Bardwell Creek	**spring 2013**	0	0	0	118	2	2	0	0	0	0	0	0	0	0	0	0	0
	autumn 2014	0	0	0	102	4	0	0	1	0	0	0	0	0	4	0	0	0
Cup and Saucer Wetland	**spring 2013**	0	4	0	83	6	0	0	0	0	7	0	0	12	24	0	0	0
	autumn 2014	0	1	0	118	1	0	0	14	0	4	0	0	2	18	0	0	0
Bardwell Creek Coolibah Reserve	**spring 2013**	4	2	0	123	0	0	0	4	1	1	0	0	1	0	4	0	0
	autumn 2014	0	3	0	81	3	0	0	31	0	1	0	0	0	3	0	1	0
Cox's Creek	**spring 2013**	0	3	0	11	4	0	1	0	0	2	0	0	0	4	0	1	0
	autumn 2014	0	0	0	23	30	0	0	0	0	1	0	0	0	5	0	0	0
Yarrowee Wetland	**spring 2013**	No Sample - Wetland Dry																
	autumn 2014	0	0	0	3	35	0	0	0	0	1	0	0	0	0	0	0	0

Macroinvertebrate Family Abundance continued

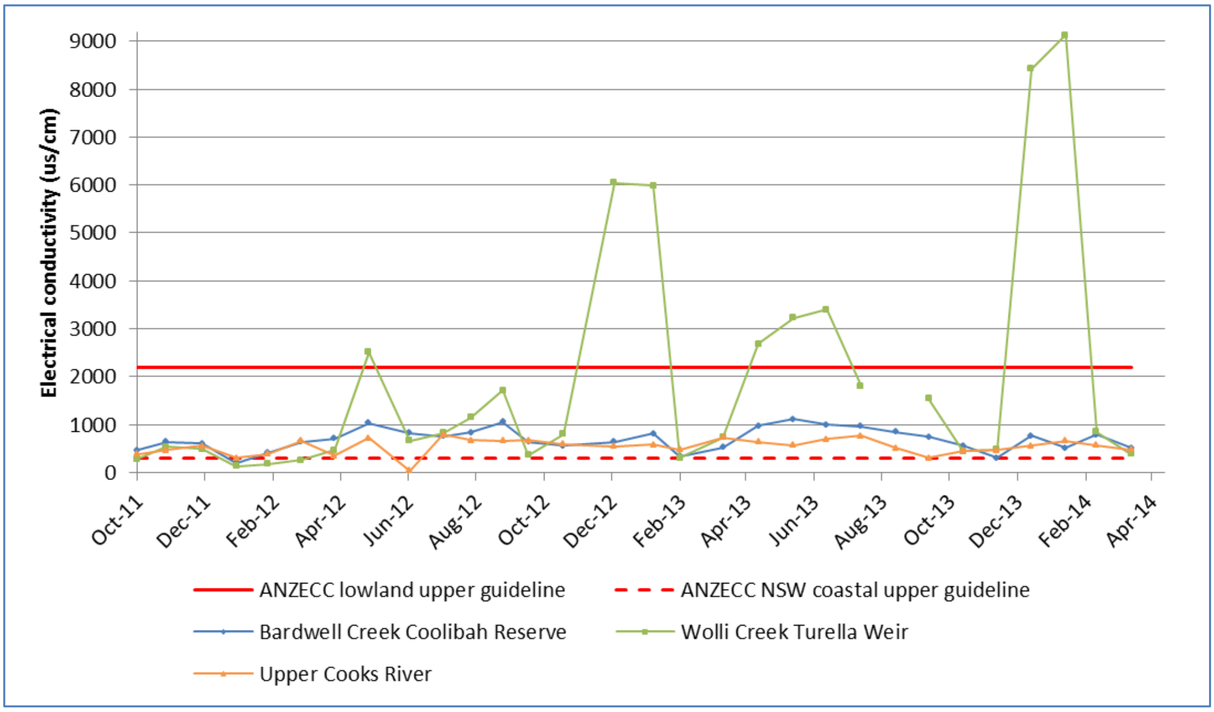
Site	Season	Hyriidae	Isostictidae	Lestidae	Naucoridae	Notonectidae	Oligochaeta	Taetidae	Pleidae	Psychodidae	Physidae	Scirtidae	Simuliidae	Stratiomyidae	Tabanidae	Tipulidae	Baetidae
Chullora Wetland	**spring 2013**	0	0	5	31	55	2	2	3	0	0	3	0	0	0	3	1
	autumn 2014	0	0	3	38	27	22	1	0	0	0	1	0	0	0	0	3
Wolli Creek Turella Weir	**spring 2013**	0	0	0	0	0	14	0	0	0	0	0	0	1	0	0	0
	autumn 2014	3	0	1	0	0	13	8	0	0	0	0	0	0	0	0	0
Upper Cooks River	**spring 2013**	0	0	1	1	0	5	108	0	0	0	0	4	0	0	0	0
	autumn 2014	0	0	1	0	0	21	58	0	0	0	0	0	1	1	0	0
Upper Bardwell Creek	**spring 2013**	0	0	0	0	0	11	11	0	0	0	0	6	0	0	0	0
	autumn 2014	0	0	0	0	0	6	5	0	0	0	0	2	0	0	0	0
Cup and Saucer Wetland	**spring 2013**	0	0	0	0	11	7	0	0	1	0	0	0	1	0	0	0
	autumn 2014	0	0	0	0	16	33	0	0	0	0	0	0	0	0	0	0
Bardwell Creek Coolibah Reserve	**spring 2013**	0	0	3	0	0	7	8	0	0	0	0	0	1	0	0	0
	autumn 2014	0	1	3	6	3	18	2	0	0	0	0	0	0	0	0	0
Cox's Creek	**spring 2013**	0	0	13	0	0	4	91	0	0	0	1	0	0	0	0	0
	autumn 2014	0	0	0	0	0	0	50	0	0	0	0	0	0	0	0	0
Yarrowee Wetland	**spring 2013**	No Sample -Wetland Dry															
	autumn 2014	0	0	0	0	6	3	0	0	0	50	0	0	0	0	0	0

Appendix C

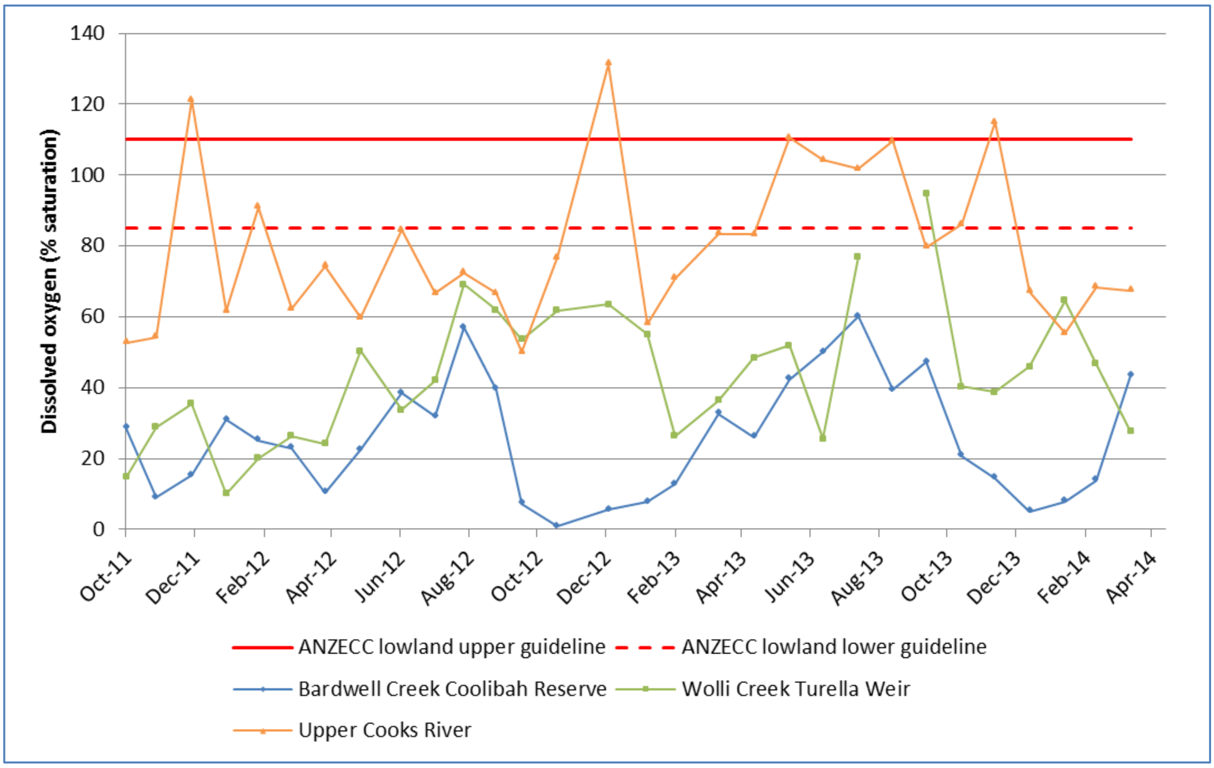
Historical Water Quality Results for Routine Monitoring Sites



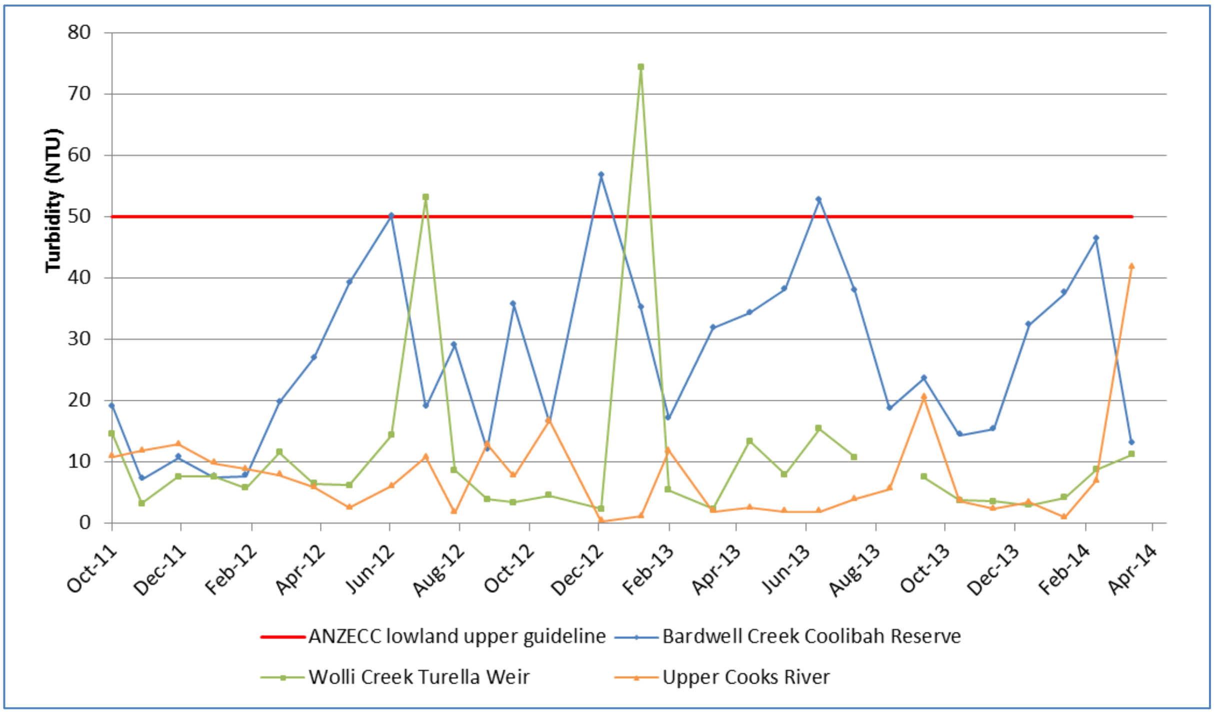
Appendix C1. pH. October 2011 – April 2014



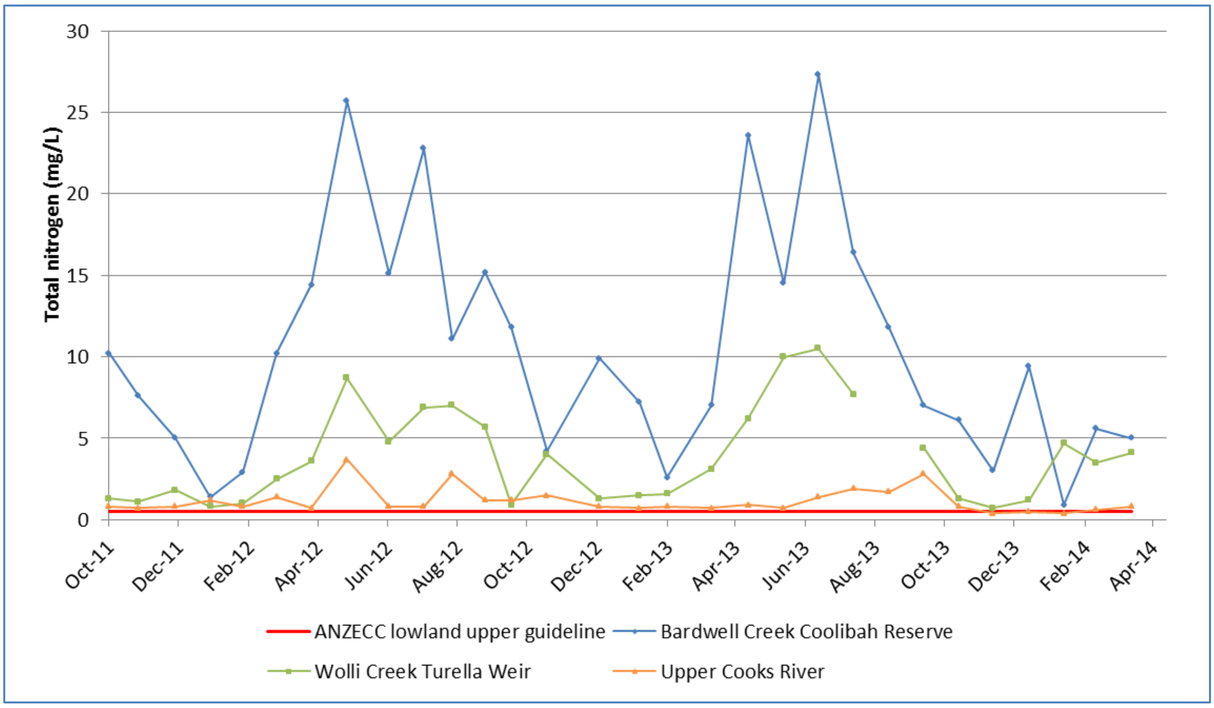
Appendix C2. Electrical Conductivity. October 2011 – April 2014



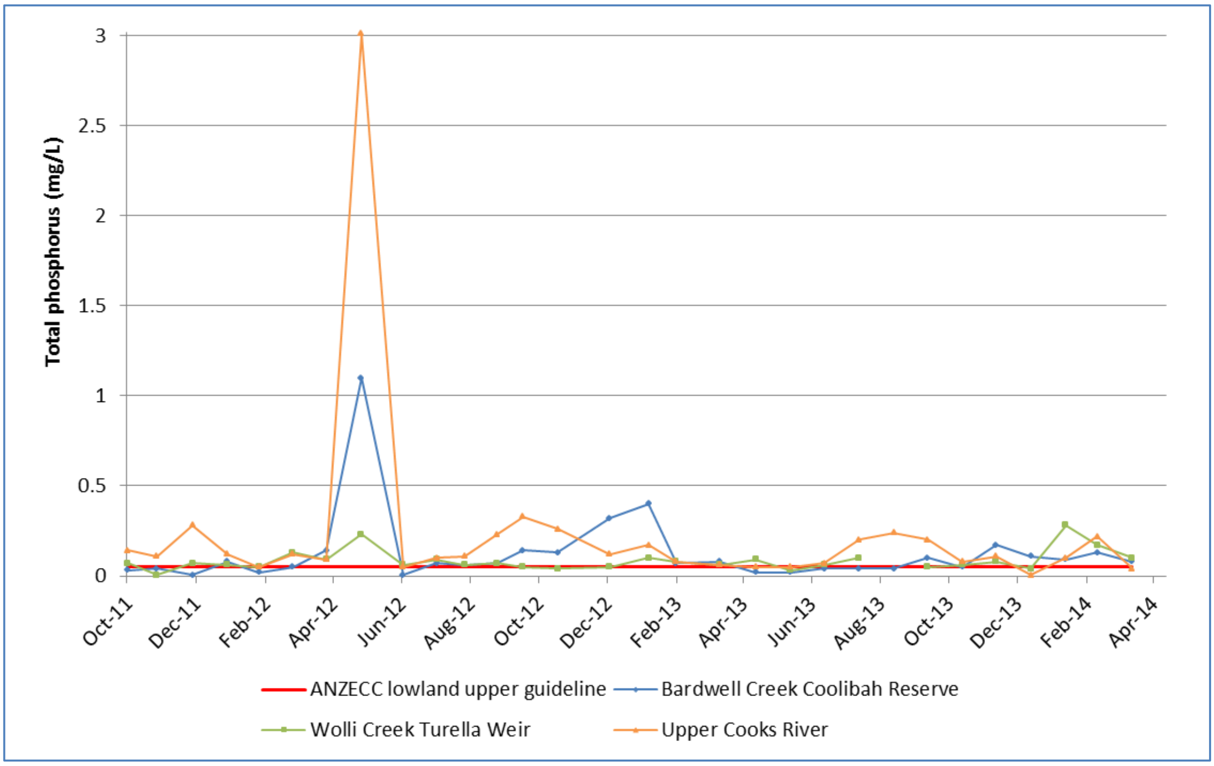
Appendix B3. Dissolved Oxygen. October 2011 – April 2014



Appendix B4. Turbidity. October 2011 – April 2014



Appendix B5. Total Nitrogen. October 2011 – April 2014



Appendix B6. Total Phosphorous. October 2011 – April 2014

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