Gosford City Waterways

The Health of Gosford City Waterways Report 2015

Avoca Lagoon

Booker Bay

Cockle Creek

Cockrone Lagoon

Erina Creek

Kincumber Creek

Narara Creek

Terrigal Lagoon

Wamberal Lagoon

Woy Woy Bay

Council Amalgamation

Gosford City Council and Wyong Shire Council amalgamated to form Central Coast Council on 12 May 2016 as part of Local Government reforms. Results in this document reflect the sampling and laboratory arrangements and management actions during the assessment period.

The Health of Gosford Waterways Report 2015

Acknowledgements:

Data used in this report was collected and analysed by Leah Hitchenson with the assistance of Jessica Weafer, Alexander Beavis and Liana Parry of Gosford City Council. Laboratory analysis was conducted by Sydney Water Corporation. The photograph on the front cover is Avoca Lagoon taken by Councils Project Officer Marjo Patari.

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Executive Summary

This report provides water quality data collected from 10 sites during 2015. The report determines the aquatic ecosystem health based on the comparison of water quality with target scores and trigger values set using ANZECC 2000 for slightly disturbed ecosystems and historical water quality data.

Readers interested in public health and water quality in comparison with the *Guidelines for Managing Risks in Recreational Waters* should refer to the State of the Beaches report produced by the Office of Environment and Heritage.

The information in this report is for use by the community for information and research purposes. If additional information is required water quality data reports are available on request.

Type	Location	2015 Water Quality Rating	2015 Water Quality Descriptor	Target Score Met	Comparison with last year's results
Lagoon	Avoca Lagoon	C+	Fair	No	Maintained
	Cockrone Lagoon	B-	Good	No	Maintained
	Terrigal Lagoon	B+	Good	Yes	Improved
	Wamberal Lagoon	B+	Good	Yes	Maintained
Estuary	Booker Bay	A-	Very Good	Yes	Maintained
	Cockle Creek	A-	Very Good	Yes	Maintained
	Woy Woy Bay	A-	Very Good	Yes	Improved
Creek	Erina Creek	B-	Good	No	Maintained
	Kincumber Creek	B-	Good	No	Maintained
	Narara Creek	C+	Fair	No	Declined

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1.0 Background

This report represents an overview of the water quality data collected from 10 sites throughout the Gosford City Council Local Government Area (LGA) during 2015. Water quality data is collected and is used to monitor the environmental health of waterways and monitor changes and trends over time. The analysis and reporting of data assists Council with the setting of objectives, targets and management plans to improve waterways, and maintain and/ or prevent further degradation.

This report does not contain water quality data collected and used to monitor public health suitability of recreational waterways. This information can be found on the Gosford City Council website http://www.gosford.nsw.gov.au/environment-and-waste/environmental-management-and-planning and the Office of Environment and Heritage's Beach watch Unit
http://www.environment.nsw.gov.au/beachapp/default.aspx.

Gosford City Council commenced the water quality monitoring program in 1999. Annual water quality reports have been produced for 2008, 2009, 2010, 2011 and 2012. Water quality data was analysed in 2013 and 2014. Water quality data for 2004 and 2005 is reported in quarterly statistics. A historical water quality data review and analysis was conducted by WBM Oceanics Australia in 2003. These documents are all available on request to Councils Environmental Health team.

There are a range of estuaries and coastal wetlands in the Gosford City Council LGA including Brisbane Water and its tributaries, Broken Bay and the Hawkesbury River estuary (including Mooney Mooney, Mullet and Patonga Creeks) and a number of important coastal lagoons including Wamberal, Terrigal, Avoca, Cockrone, and the perched lagoon at Pearl Beach.

Estuaries, lagoons and wetlands are dynamic living entities, and are an important part of the natural environment. These systems are integral to landscape processes such as nutrient cycling, detention and slow release of flood water, and trapping of sediments. They also form a vital component of regional and national biodiversity by providing habitat for a wide range of animals and plants.

Coastal wetlands include estuarine rivers, lakes and lagoons, coastal floodplain forests, and mangrove and saltmarsh swamps. Wetlands on the coast are subject to threats such as exposure of acid sulphate soils and intense urban development. These threats have created a landscape where many wetland ecosystems are fragmented or endangered.

Our wetlands also have high intrinsic value by providing habitat for a wide range of animals including waterbirds, fish, frogs and invertebrates, and water-loving plants such as sedges, rushes and various tree species.

Wetlands provide shelter, breeding grounds and nurseries for a variety of fauna, particularly insects, fish, frogs and waterbirds. Wetlands support many threatened species and ecological communities.

Gosford's four coastal lagoon systems are another significant geographic feature of the Gosford region.

Within the Gosford City LGA, it has been estimated that there is approximately 870 hectares of mangroves, 160 hectares of saltmarsh, and 620 hectares of seagrass.

Since the release of the NSW Governments Estuary Management Manual in 1992, Gosford City Council has worked with other government bodies, industry and the community to appropriately manage activities in and around estuaries. This has been achieved by guiding conservation and rehabilitation efforts, supporting land managers who have wetlands on their property, and educating the community about the importance of estuaries and wetlands for the wellbeing of the region.

2.0 Council objectives and actions to improve water quality

Council has recently invested approximately $30 million to improve the performance, reliability and capacity of the major sewage transfer system that services Forresters Beach, Terrigal, North Avoca, Avoca and Kincumber. This project boosted the operation and capacity of the existing system located in the vicinity of Avoca Lake.

Council is currently investing approximately $36 million to improve the performance, reliability and capacity of the sewerage reticulation system, sewerage pumping stations and sewerage treatment plants throughout the LGA. These projects include renewals, rehabilitation, augmentations as well as condition assessment and investigations, to meet the objectives of the Environment Protection Licence, improve the reliability of the sewerage systems and treatment plant and reduce the frequency of sewage overflows within Gosford LGA.

Upgrades to sewer are nearing completion in North Avoca, Avoca and Kincumber, including upgrades to three sewage pumping stations in North Avoca, Avoca and Kincumber. These works will protect the community and environment against overflows and odours. Tenders for the design and construction of the permanent replacement of the temporary sewer main across Terrigal Lagoon have been invited and works commenced in August 2016. The works will improve the amenity of the Lagoon and minimise potential environmental impacts.

The Cockle Bay Towns Sewerage Project is currently under construction with connection anticipated to be available in mid to late 2016. This project will deliver an improved sewer service to over 300 properties located within the townships of Empire Bay, Bensville and Kincumber South. Ninety-six percent of these properties currently manage their sewer on-site. So far, two-thirds of properties have agreed to connect once the system is available, which could see a significant improvement in environmental outcomes for downstream areas.

Two water harvesting and re-use schemes are in place including 1.6 million litres of underground storage, a water treatment plant and reticulation in Terrigal and a similar plant in East Gosford. These plants reduce the volume of storm water released to Terrigal Beach and Erina Creek.

Gosford City Council is responsible for an extensive storm water drainage network. Works undertaken to improve the quality of storm water entering receiving waters include: installation of storm water quality improvement devices such as gross pollutant traps, trash racks, silt traps and basins; vegetative filter systems and constructed wetlands; installation of dog poo bins in popular dog walking areas; storm water community education projects; riparian rehabilitation; and enforcement of the council's erosion, sediment and nutrient control regulations.

Gosford City Council has invested in storm water quality improvement devices at a number of key strategic locations including drainage outlets at Umina, Ettalong, Copacabana, Avoca, Terrigal and Wamberal. These devices are regularly inspected and maintained as part of the council's routine maintenance program.

Gosford City Council monitors on-site sewage management systems throughout the council area, including 80 pump-out systems, 1636 aerated wastewater treatment systems, 2878 septic tank systems with irrigation areas, and approximately 40 commercial systems and 38 miscellaneous systems. All on-site sewage management systems are subject to development approval process and conditions of consent.

Urban aquatic ecosystems are particularly complex systems due to the significantly altered hydrology of the system. Council's primary management aims are to:

- Define the water body using scientific information and monitoring data
- Define the water body by ecosystem classification
- Determine the environmental values
- Determine the level of protection required
- Identify environmental concerns
- Determine the natural and human induced factors affecting the ecosystem
- Determine management and action goals to improve water quality.

Gosford City Councils objectives for coastal wetlands are to place emphasis on conservation, land use planning and rehabilitation. Cooperation between state and local government is essential for identifying these wetlands and for their ongoing management.

Council uses the latest scientific information, combined with community and stakeholder feedback, to develop plans which aim to:

- Protect, rehabilitate and improve the natural estuarine environment
- Manage the estuarine environment to ensure its health and vitality for the benefit of the public
- Improve the recreational amenity of estuarine waters and foreshores

- Recognise and accommodate natural processes and climate change
- Ensure ecologically sustainable development and use of resources.

Coastal Zone Management Plans are being implemented for all catchments within the local government area. These plans provide direction and guidance for the management of estuaries and their catchments to achieve long-term improvements in waterway health. Plans have been developed for the Lower Hawkesbury River (2009), Brisbane Water (2012), Pearl Beach Lagoon (2014), Gosford Coastal Lagoons (2015) and Gosford Beaches (2016).

Further information is available on the Gosford City Council website http://www.gosford.nsw.gov.au/environment-and-waste/environmental-management-and-planning

2.1 Factors affecting water quality

Water quality is closely linked to the surrounding environment and land use. Other than in its vapour form, water is never pure and is impacted by community uses such as agriculture, urban and industrial use, and recreation. The modification of natural stream flows by dams and weirs can affect water quality. Groundwater close to urban or industrial development is vulnerable to contamination. The weather can have a major impact on water quality, particularly in Australia which is periodically affected by droughts.

Generally the water quality of rivers is best in the upper reaches of the catchment, where rainfall is often abundant. Water quality often declines as rivers flow through regions where land use and water use is intense and pollution from agriculture, large towns, industry and recreation areas increases.

There are, of course, exceptions to the rule and water quality may improve downstream, behind dams and weirs, at points where tributaries meet, or better quality groundwater enters the mainstream, and in wetlands.

Rivers frequently act as conduits for pollutants by collecting and carrying storm water from catchments and, ultimately, discharging it into lagoons, estuaries and the ocean. Storm water, which can also be rich in nutrients, organic matter and pollutants, finds its way into rivers, lagoons, estuaries and oceans mostly via the storm water drain network. Water quality may also be affected by bacteria from sewer overflows or other runoff into storm water drains.

2.2 How can you, as a resident, improve water quality?

- Pick up litter in the park or on the street.
- Sweep your gutter and driveway regularly and place the sweepings on the garden, the compost or in the bin.
- Do not allow soil or mulch to be washed or blown from the garden.
- Clean up pet droppings and dispose of them in the garden, rubbish bin or in the toilet.
- Rake up leaves or lawn clippings and use them as mulch on the garden or place them in the compost.
- Stabilise and replant areas of disturbed or bare soil.
- Consider natural alternatives to pest control chemicals in the garden.
- Use a minimal amount of detergent for cleaning outside.
- Wash paint brushes and rollers over a sand filter on the lawn.
- Make sure your household sewerage pipes are not connected illegally to the storm water system.
- Install rainwater tanks (where Council permits), and use this water on your garden.
- Replace impermeable surfaces (e.g. concrete) with permeable surfaces such as timber decks and pavers (with gaps between pavers).
- Maintain your car making sure there are no oil leaks.
- Wash cars on the lawn or gravel and use minimal detergent. Empty the soapy water down the sink or toilet. Even better, take your car to a car wash where the water gets treated and recycled.
- Join a community group such as Stream watch, Water watch, Clean up Australia, Keep Australia Beautiful, Coast care, Land care and Australian Trust for Conservation Volunteers. GCC runs a Bush care Partnership Program between Council staff and volunteers. More information can be found here http://www.gosford.nsw.gov.au/environment-and-waste/bushland-and-wildlife/bushcare-program

3.0 Councils Water Quality Monitoring Program

The Gosford LGA covers an area of approximately 1029 square kilometres, stretching east to the Tasman Sea, south to the Hawkesbury River, west to the Judge Dowling Range and north to meet the Cessnock City and Wyong shire on a border through Kulnura, Lisarow and Forresters Beach. The water quality of 10 waterways is monitored throughout the Gosford LGA. These waterways include Avoca Lagoon, Booker Bay, Cockle Creek, Cockrone Lagoon, Erina Creek, Kincumber Creek, Narara Creek, Terrigal Lagoon, Wamberal Lagoon and Woy Woy Bay.

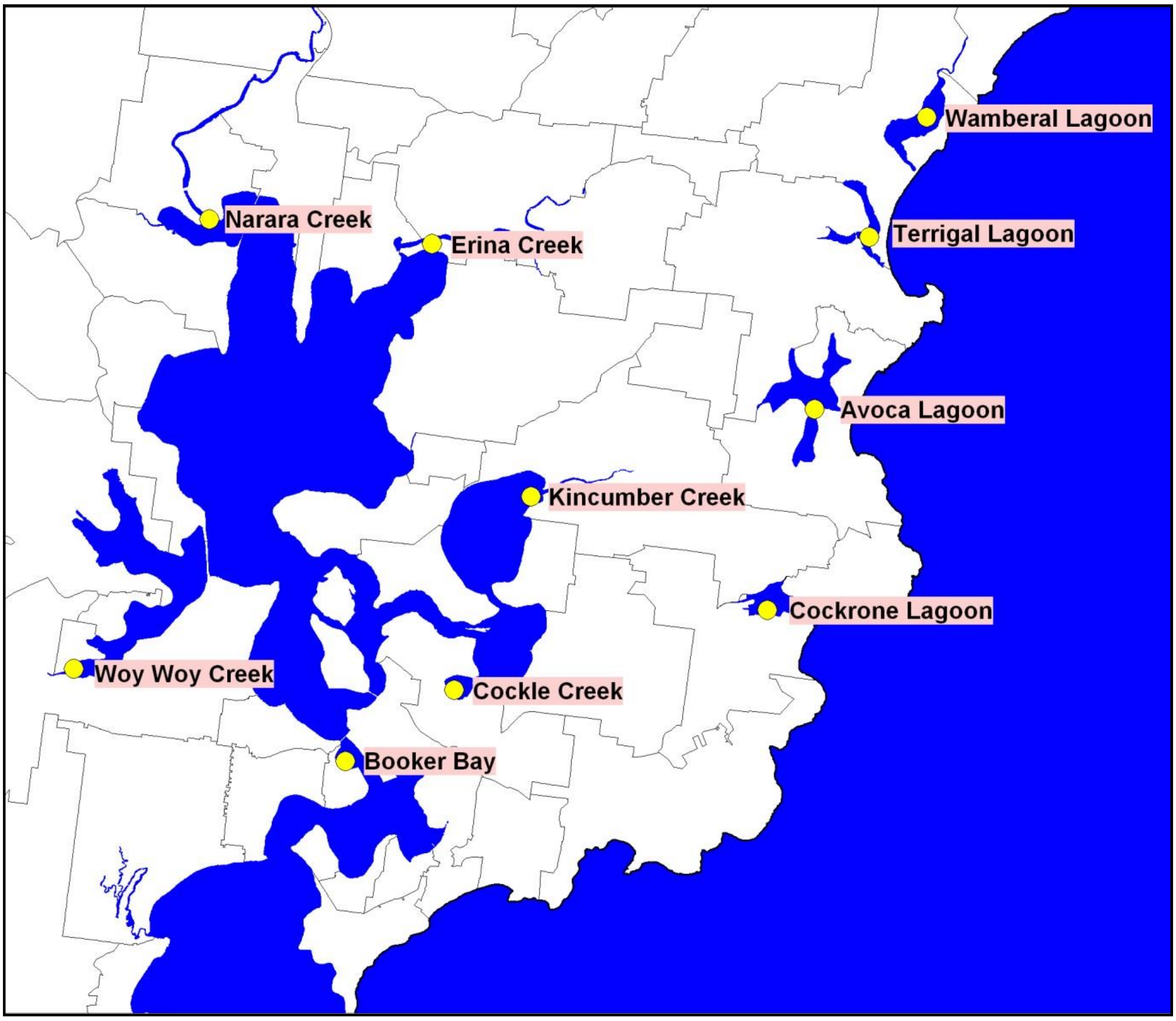

Figure 1: shows approximate locations of sampling points in the Gosford LGA.

At each site physical and chemical water quality parameters including temperature, salinity, total dissolved solids, conductivity, dissolved oxygen, oxidation reduction potential, pH and turbidity are measured with a portable water quality meter. General observations of the appearance of the water and any surface scum's, algae, oily films, odours, weather, wind, rain and tide/ flows are recorded. Water samples are collected for laboratory analysis for enterococci, chlorophyll-a, ammonia, soluble reactive phosphorus, total nitrogen, total phosphorus and oxidised nitrogen. Further information on water quality parameters can be found in Section 9.0 Glossary.

3.1 Compound Water Quality Index and Scorecard for Gosford Council Waters

The Water Quality Index and Scorecard currently used by Council for reporting is based on methods recommended by the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC 2000), Australian and New Zealand Environment and Conservation Council, and the Agriculture and Resource Management Council of Australia and New Zealand.

As recommended in Chapter 3 of the ANZECC 2000, trigger values for Gosford Waters were set by using a combination of the default approach and using historic water quality data collected for Gosford Council during the period 1999 to 2002.

The default approach involves deriving trigger values for physical and chemical stressors using statistical reference data collected within five geographical regions across Australia and New Zealand, which is contained in ANZECC 2000.

The parameters contributing to the scorecard for Gosford Waters include turbidity, dissolved oxygen, ammonia, oxidised nitrogen, total nitrogen, orthophosphate, total phosphorus and chlorophyll a which are generally consistent with ANZECC 2000 default trigger values.

Therefore the default values for Gosford waters were set by using the majority of parameters from the ANZECC 2000 for south east Australia for 'slightly disturbed ecosystems'; and historic data for Gosford waters.

For each water quality parameter, the measured concentration is compared to a criteria set, and categorised into one of four ranges. A summary is provided in table 1.

Table 1: Gosford Water Quality Index Ranges.

Parameter	Range 1 (value = 1)	Range 2 (value = 2)	Range 3 (value = 3)	Range 4 (value = 4)
Turbidity	0 – 5 NTU	5 – 15 NTU	15 – 30 NTU	> 30 NTU
Dissolved Oxygen	> 6.5 mg/L	4.0 – 6.5 mg/L	2.0 – 4.0 mg/L	< 2.0 mg/L
Ammonia	0 – 0.01 mg/L	0.01 – 0.03 mg/L	0.03 – 0.05 mg/L	> 0.05 mg/L
Oxidised Nitrogen	0 – 0.02 mg/L	0.02 – 0.05 mg/L	0.05 – 0.10 mg/L	> 0.10 mg/L
Total Nitrogen	0 – 1.0 mg/L	1.0 – 1.5 mg/L	1.5 – 2.0 mg/L	> 2.0 mg/L
Orthophosphate	0 –0.01 mg/L	0.01 – 0.03 mg/L	0.03 – 0.05 mg/L	> 0.05 mg/L
Total Phosphorus	0 – 0.05 mg/L	0.05 – 0.10 mg/L	0.10 – 0.20 mg/L	> 0.20 mg/L
Chlorophyll-a	0 – 2 µg/L	2 – 5 µg/L	5 – 10 µg/L	> 10 µg/L

Range 1 represents good, 4 represents poor results. Summing the individual scores and then dividing by the number of parameters which were included in the assessment creates a number which can be used to score the health of the waterway.

That number is then compared to the basic scorecard index to represent the results as a score out of 10. 10 is the highest scorecard which can be achieved as shown in Table 2.

Table 2: Gosford Water Quality Basic Score Index.

Basic Scorecard Index	Scorecard value	Water Quality descriptor	Report Value
1.00 – 1.09	**10**	Very good	A+
1.10 – 1.24	**9**	Very good	A-
1.25 – 1.49	**8**	Good	B+
1.50 – 1.74	**7**	Good	B-
1.75 – 1.99	**6**	Fair	C+
2.00 – 2.39	**5**	Fair	C-
2.40 – 2.79	**4**	Poor	D+
2.80 – 3.19	**3**	Poor	D-
3.20 – 3.59	**2**	Very poor	E+
3.60 – 4.00	**1**	Very poor	E-

3.2 Water Quality Parameter Trigger Values

Individual parameter trigger values have been set based on ANZECC 2000 and historical water quality for each site. Table 3 shows the comparison between ANZECC 2000 trigger values for slightly disturbed ecosystems and Council set trigger values. These trigger values are based on estuarine ecosystem types for all sites except Piles Creek which is based on lowland rivers. Water quality results either below the lower limit or above the upper limit are not desirable and will negatively impact on the scorecard and meeting the target score.

Table 3. Default trigger values for physical and chemical stressors for south east Australia for slightly disturbed ecosystems and Gosford City Council set trigger values based on historic water quality data sets.

Water Quality Parameter	ANZECC 2000 Marine and Estuarine Waters	GCC Estuarine trigger values
Chlorophyll a	<4 ug/L	<2 ug/L
Total Phosphorus	<0.03 mg/L	<0.05 mg/L
Filterable Reactive Phosphate	<0.005 mg/L	<0.01 mg/L
Total Nitrogen	<0.3 mg/L	<1.0 mg/L
Oxides of nitrogen	<0.015 mg/L	<0.02 mg/L
Ammonia	<0.91 mg/L	<0.01 mg/L
Dissolved oxygen	Between 80% and 110% saturation	>75%
pH	7.0- 8.5	7.0- 8.5
Turbidity	<10 NTU	<5 NTU

3.3 Quality Control/ Quality Assurance

The accuracy of the Gosford Waters Monitoring Program is maintained by the following:

- All water sampling, in situ field testing and observations are conducted by Councils Environmental Health Officers who are trained in the *AS/NZS 5667.1:1998 Water Quality- Sampling- Guidance on the design of sampling programs, sampling techniques and the preservation and handling of samples*. All of Councils Environmental Health Officers hold a Bachelor Degree as a minimum requirement of the position.
- The Gosford City Waterways Water Quality Monitoring Instruction Manual is maintained and adhered to by Environmental Health Officers to ensure consistency between Council staff.
- The field instrument used to gain *in situ* (on-site) field data is calibrated prior to use and maintained as per service requirements and accurate records are kept.
- Laboratory analysis is conducted by a National Association of Testing Authorities (NATA) accredited laboratory and all laboratory analysis is signed off and authorised by a NATA signatory.
- Quality assurance/ quality control samples are taken for each sampling event to ensure contamination does not occur during sample collection, preservation and transportation.
- All samples collected and sampling techniques are collected using aseptic techniques.

4.0 Results & Discussion

4.1 2015 Scorecard Value for Gosford Waters Locations

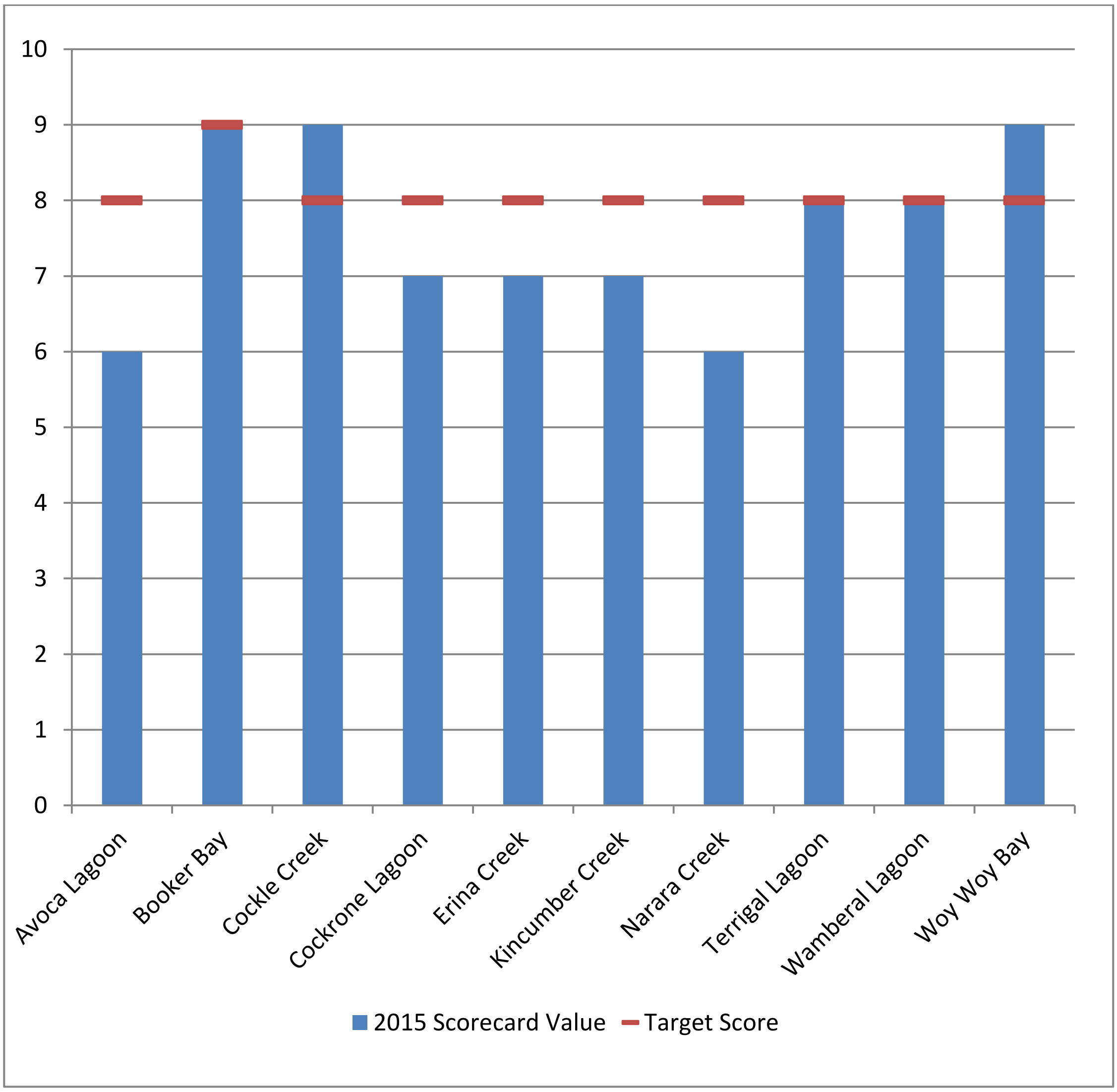

Figure 2: shows the 2015 average scorecard results from January 2015 to December 2015 for the 10 water quality monitoring sites, based on analytical results of physical and chemical parameters (turbidity, dissolved oxygen, ammonium, oxidised nitrogen, total nitrogen, orthophosphate, total phosphorus and chlorophyll a). The scorecard is based on trigger values set for Gosford City Council using ANZECC 2000 and Gosford Councils historical water quality data for the protection of slightly disturbed ecosystems.

Figure 2 shows the Annual Scorecard value for each of the waterways tested from the January to December 2015 period. Half of the sites met or exceeded their target score and half did not meet their target score. Cockle Creek and Woy Woy Bay exceeded their target scores. Booker Bay, Terrigal Lagoon and Wamberal Lagoon met their target scores. Avoca Lagoon, Cockrone Lagoon, Erina Creek, Kincumber Creek and Narara Creek did not meet target scores during the period.

Overall the Brisbane Water Estuarine sites received the highest scores showing very good water quality.

Most sites average scores were identical with results from 2014 demonstrating that water quality had been maintained over the period at these sites. Terrigal Lagoon and Woy Woy Bay increased their scores by 1 indicating water quality improved over the period. Narara Creek decreased by one score indicating water quality declined over the 2015 period.

4.2 2008- 2015 Scorecard Values for Gosford Waters Locations

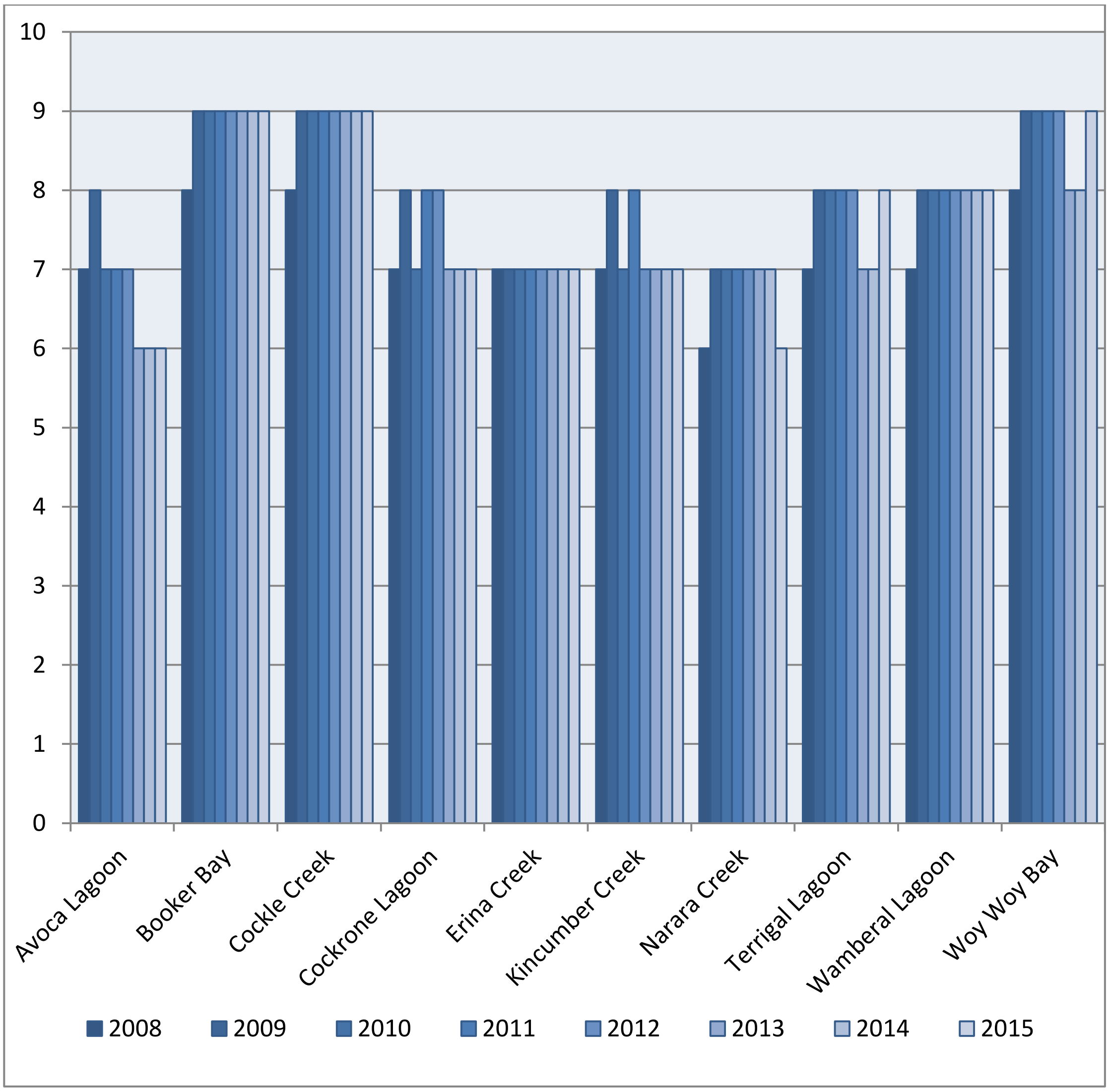

Figure 3: shows the Annual scorecard results from 2008 until 2015 for the 10 water quality monitoring sites.

Figure 3 shows that over the last eight years most sites have improved or maintained their water quality. It also shows there are many variations over time where sites improve, decline or are maintained. For example, Terrigal Lagoon improved in 2009 from 2008 water quality, maintained water quality over four years from 2009 to 2012, declined in 2013, maintained in 2014 and improved in 2015. Avoca Lagoon and Narara Creek have exhibited the lowest scores, whilst the estuarine sites (Booker Bay, Cockle Creek and Woy Woy Bay) exhibited the highest scores showing the best water quality over the period.

4.3 Intermittently Closing and Opening Lakes and Lagoons

Gosford has four coastal lagoon systems; Wamberal, Terrigal, Avoca and Cockrone. These are a significant geographic feature of the region. The lagoon systems are a highly valued natural resource for local residents and visitors alike and support a network of significant ecological communities as well as a diverse range of recreational uses.

These lagoons belong to a special class of estuary known as Intermittently Closing and Opening Lakes and Lagoons (ICOLLs). An ICOLL is a shallow coastal water body that is separated from the ocean by an entrance barrier, that is connected at least intermittently to the ocean by one or more restricted inlets. They have a low tolerance of external pressures compared to other estuary types, so they need to be carefully managed and conserved in order to prevent significant environmental degradation.

Further information on Councils Coastal Management Planning can be found on http://www.gosford.nsw.gov.au/environment-and-waste/environmental-management-and-planning

The ICOLLS samples sites have sandy bottoms and are shallow therefore experience higher turbidity's and nutrient levels during high wind events and during wet weather flows as bottom sediments are easily suspended. They also act as a sink to the surrounding catchment.

4.3.1 Avoca Lagoon Catchment

2015 Water Quality Rating:
C+

The catchment to Avoca Lagoon covers an area of approximately 11.87 square kilometres, the surface area of the lagoon accounting for approximately 9% of the catchment.

Much of the upper catchment is rural land, predominantly farm land or undeveloped forest and the lower slopes in the vicinity of the lagoon contain significant urban development. The lagoon is roughly star-shaped, comprising four irregular arms and has a considerable area of wetlands around its perimeter. Bareena Island is approximately the centre of the lagoon. The main tributary to the lagoon is Saltwater Creek which enters the lagoon on the western side and drains an area of 6.7 square kilometres, almost 60% of the catchment.

The average bed level of the lagoon generally varies from 0.8-0.9m AHD although there are dredge holes down to -4.0m AHD. The lagoon entrance barrier is generally closed but is periodically mechanically opened.

The entrance berm is mechanically opened by Council when lagoon levels reach 2.1m AHD. Avoca Lagoon was opened to the ocean by Council two times during 2015 and remained open for approximately one month each time. The lagoon was also opened once illegally and remained open for approximately three weeks.

A sand extraction operation was based within the lake, on the south western arm from the late 1980's until early 1994.

The water within Avoca Lagoon was monitored monthly during 2015. The monitoring location is accessed via Ficus Avenue (Figure 4). The sample site is shallow (less than one metre), is predominantly closed, has a sandy bottom and is located in a dog exercise area.

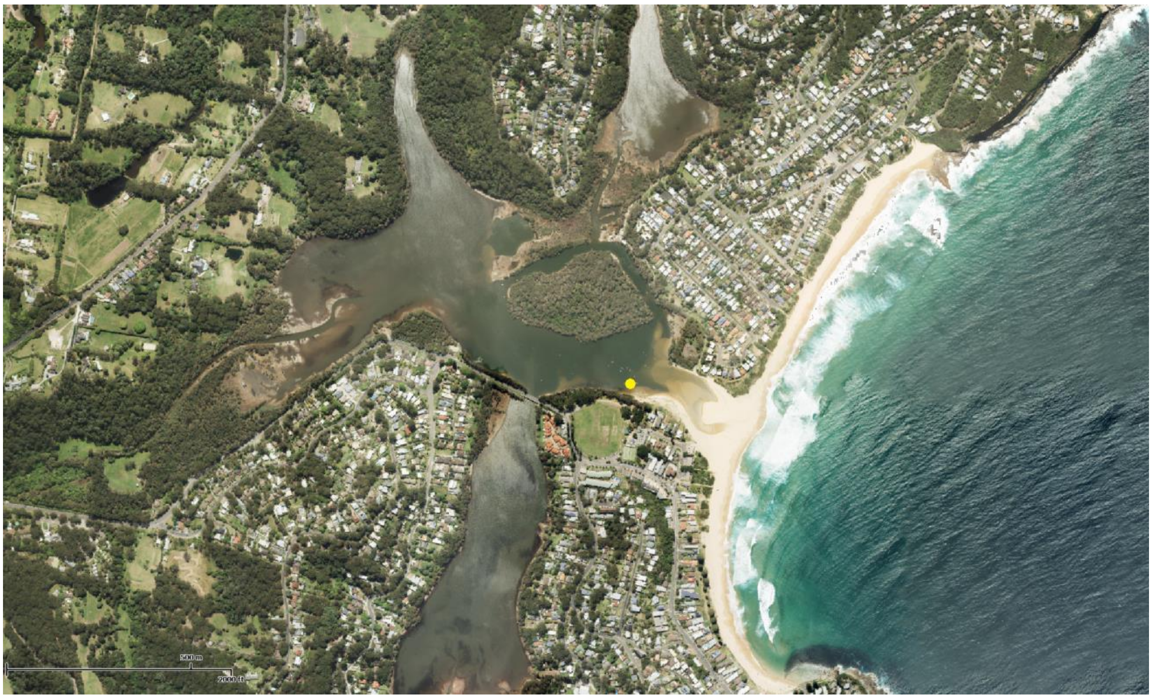

Figure 4: Avoca Lagoon monitoring location indicated by yellow circle.

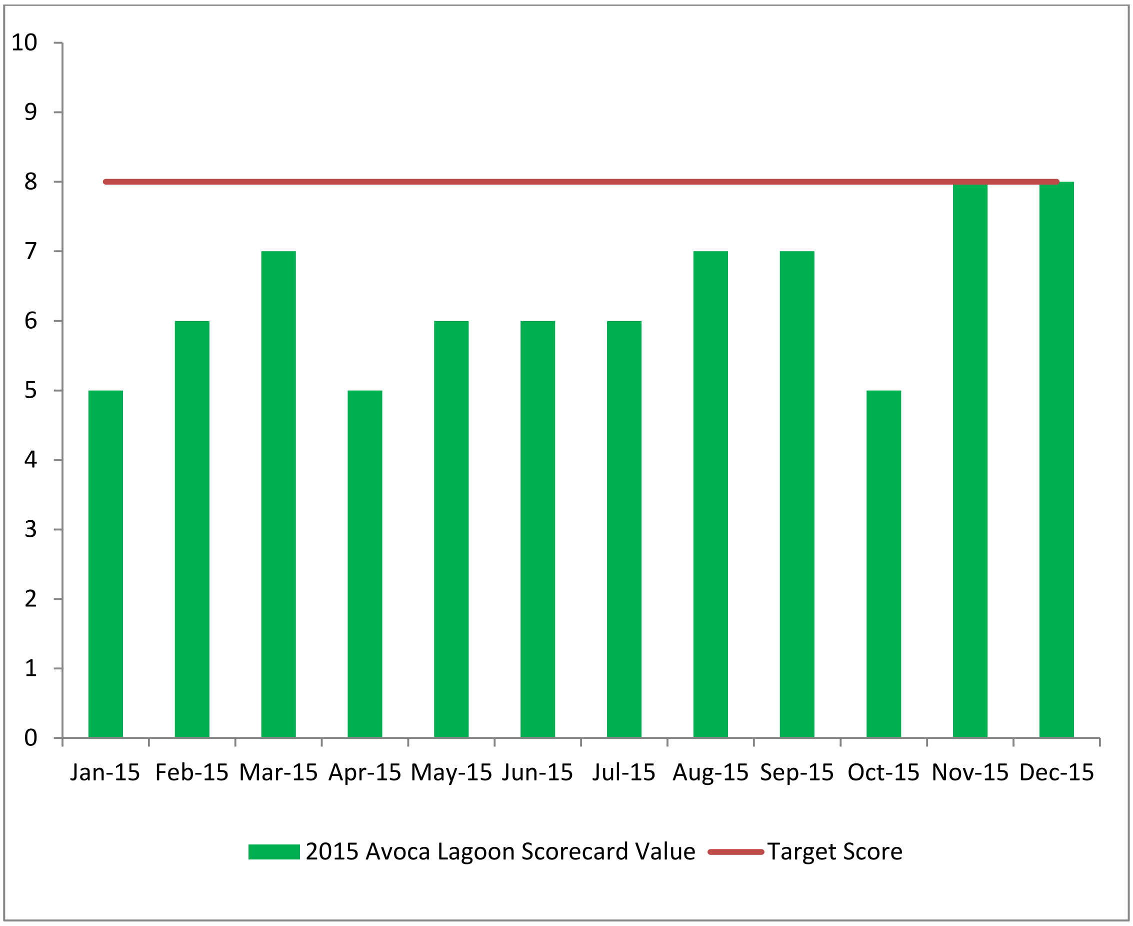

Figure 5: Scorecard results for Avoca Lagoon during 2015 based on analytical results of physical and chemical parameters (turbidity, dissolved oxygen, ammonium nitrogen, oxidised nitrogen, total nitrogen, orthophosphate, total phosphorus and chlorophyll a).

Avoca Lagoon met the prescribed target score 2 times during the year of 2015 (Figure 5).

The prescribed target score was not met ten times during the 2015 period, due to elevated levels of chlorophyll a, oxidised nitrogen and turbidity (Section 5.3.5).

The results of 2015 showed water quality results remained consistent compared with 2013 and 2014 results, showing neither an improvement nor decline; however the trend since 2009 shows a slow decline in water quality (Figure 3).

4.3.2 Cockrone Lagoon Catchment

2015 Water Quality Rating:
B-

Cockrone Lagoon catchment covers an area of approximately 7.2 square kilometres. The surface area of the lagoon is approximately 0.38 square kilometres and is around 6% of the total catchment area.

The vast majority of the catchment is undeveloped rural land, predominantly forest with farms on the lower slopes.

The main tributary, known as Cockrone Creek, enters the lagoon on the western side and drains an area of 4.2 square kilometres which is almost 60% of the catchment. Several other tributaries including Merchants Creek to the north, have catchment areas between 0.25 and 0.65 square kilometres, and drain the remainder of the catchment.

The bed level of the lagoon appears to slope fairly uniformly from the west/northwest shores down to -0.1m AHD near the beach berm. The average bed depth is between 0.4 and 0.6m AHD. The outlet to the ocean through MacMasters Beach is predominantly closed by the beach berm and water levels inside the lagoon are not usually influenced by ocean tides.

The lagoon water level is managed by Council. It is mechanically opened when the lagoon level reaches 2.53 m AHD. Cockrone Lagoon was opened once to the ocean by Council during 2015. It opened itself twice during 2015 during wet weather events.

The water within Cockrone Lagoon was monitored monthly during 2015. The monitoring location is accessed via Del Monte Place, Copacabana (Figure 6). The sample site is shallow (less than one metre), is predominantly closed, has a sandy bottom and is located in close proximity to a dog exercise area.

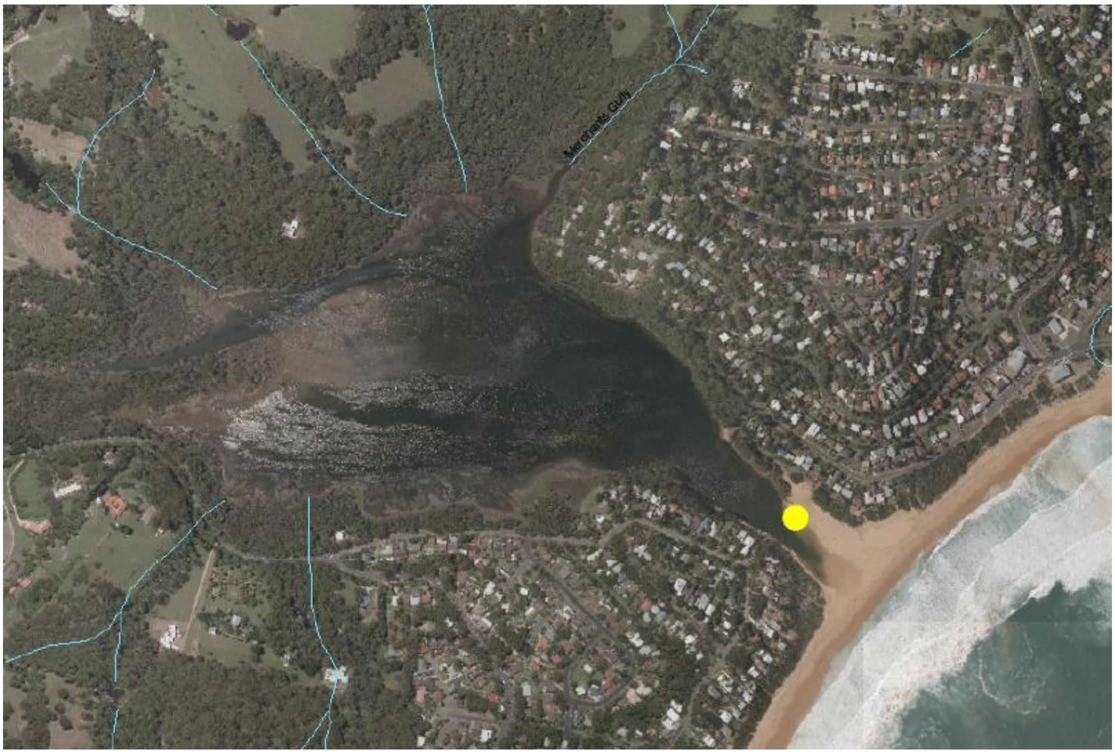

Figure 6. Cockrone Lagoon monitoring location indicated by yellow circle.

Figure 7: Scorecard results for Cockrone Lagoon during 2015 based on analytical results of physical and chemical parameters (turbidity, dissolved oxygen, ammonium, oxidised nitrogen, total nitrogen, orthophosphate, total phosphorus and chlorophyll a).

During 2015 the target score was exceeded once in January. All other months the target score was not met (Figure 7).

Results show water quality has been maintained since 2013 and compares with 2010 and 2008 results (Figure 3).

Cockrone Lagoon did not exceed the upper limit for ammonia and soluble reactive phosphorus during 2015 (section 5.3.5). Oxidised nitrogen and chlorophyll- a were frequently above the upper limit.

4.3.3 Terrigal Lagoon Catchment

2015 Water Quality Rating:
B-

Terrigal Lagoon lies between Wamberal Lagoon and Avoca Lagoon and covers an area of approximately 8.9 square kilometres. The surface area of the lagoon accounts for approximately 3% of the total catchment area, with 36% urban area, 44% rural and 16% forested.

A large part of the upper catchment area is rural land most of which has been cleared. The lower slopes in the vicinity of the lagoon contain extensive urban development.

The average bed level of the lagoon varies from -0.5m to +0.7m AHD although there are dredge holes down to -3.0m AHD dating back to the mid 1960's. Dredging took place at this time to enable reclamation for residential development on the adjacent foreshore. The lagoon entrance barrier is generally closed but is periodically mechanically opened.

The ocean entrance berm is mechanically opened by Council when the lagoon level reaches 1.23m AHD. Terrigal Lagoon was opened to the ocean by Council twelve times and opened naturally three times during 2015.

The water within Terrigal Lagoon was monitored monthly during 2015. The monitoring location is accessed from Pacific Street (Figure 8). The sample site is shallow (less than one metre), is predominantly closed, has a sandy bottom and is located in close proximity to a dog exercise area.

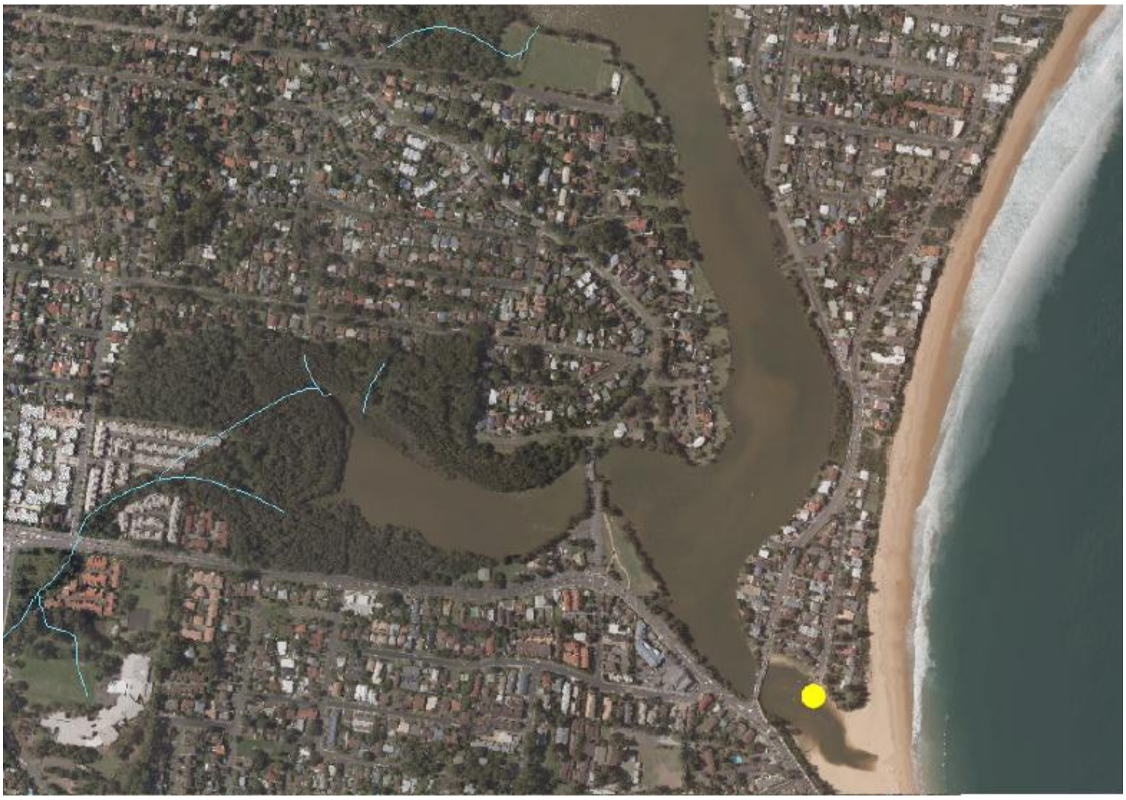

Figure 8. Terrigal Lagoon monitoring location indicated by yellow circle.

Figure 9: Scorecard results for Terrigal Lagoon during 2015 based on analytical results of physical and chemical parameters (turbidity, dissolved oxygen, ammonium, oxidised nitrogen, total nitrogen, orthophosphate, total phosphorus and chlorophyll a).

Terrigal Lagoon exceeded its target scores twice in 2015. The target score was met four times in 2015. The target score was not met six times (Figure 9).

During the months in which the target score was not met chlorophyll- a and oxidised nitrogen were elevated (Section 5.3.5).

Compared with 2014 water quality results, water quality data in 2015 has improved (Figure 3).

4.3.4 Wamberal Lagoon Catchment

2015 Water Quality Rating:
B+

Wamberal Lagoon is the most northerly of the four Gosford Coastal Lagoons, and has a small part of the catchment in the Wyong Council area. The majority of the catchment lies to the north of the lagoon and is largely undeveloped rural land. The area of the lagoon water surface is around 9% of the catchment, with 31% being urbanised.

Wamberal Lagoon itself is substantially contained within the Wamberal Lagoon Nature Reserve which has been dedicated under the *NSW National Parks and Wildlife Act*, 1974. The nature reserve is subject to a Plan of Management administered by the Office of Environment and Heritage (NSW National Parks and Wildlife Service) and affords a measure of protection to the plants and animals contained within its boundaries.

The average bed level of the lagoon varies from +0.9m to +1.0 AHD although there are areas down to -1.5m AHD. The lagoon entrance barrier is generally closed but is periodically mechanically opened.

The entrance berm is mechanically opened by Council when lagoon levels reach 2.4m AHD . The lagoon was mechanically opened by Council twice during 2015 and opened itself twice. It remained open from two days up to two weeks during 2015.

The water within Wamberal Lagoon was monitored monthly during 2015. The monitoring location is accessed from Remembrance Drive Reserve, Wamberal (Figure 10). The sample site is shallow (less than one metre), is predominantly closed and has a sandy bottom.

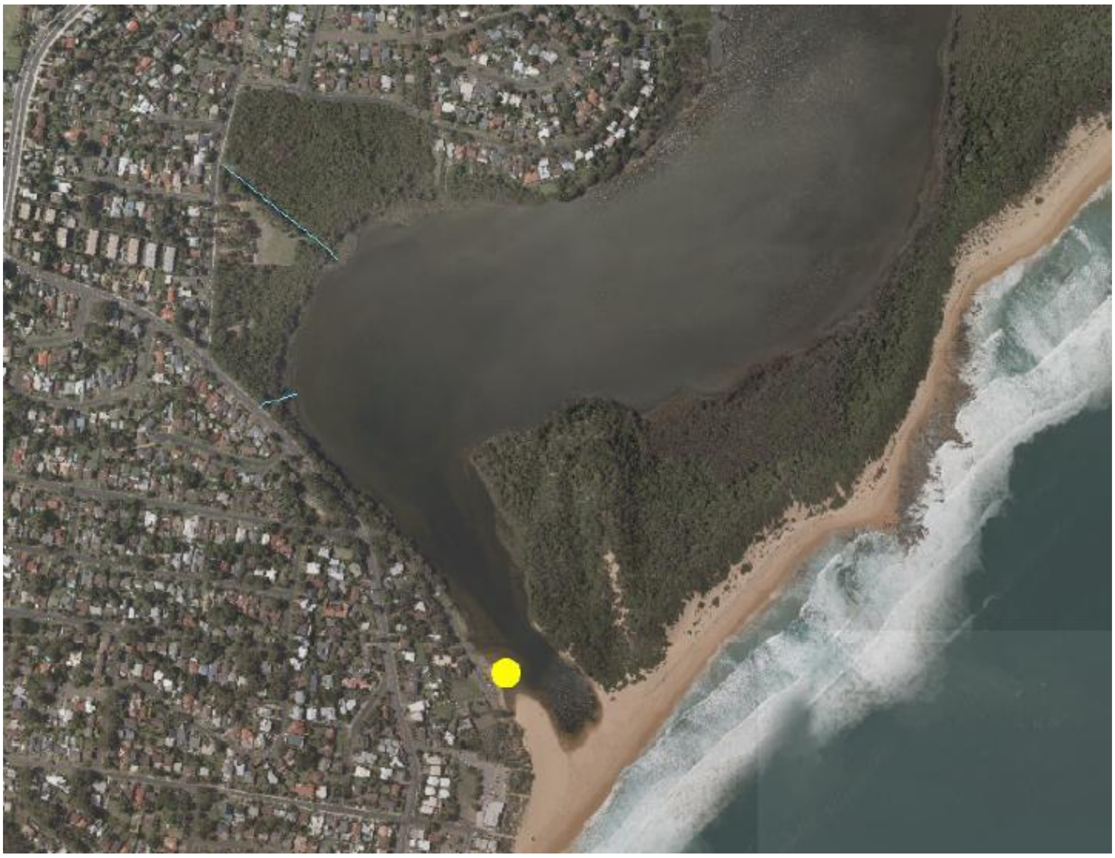

Figure 10. Wamberal Lagoon monitoring location indicated by yellow circle.

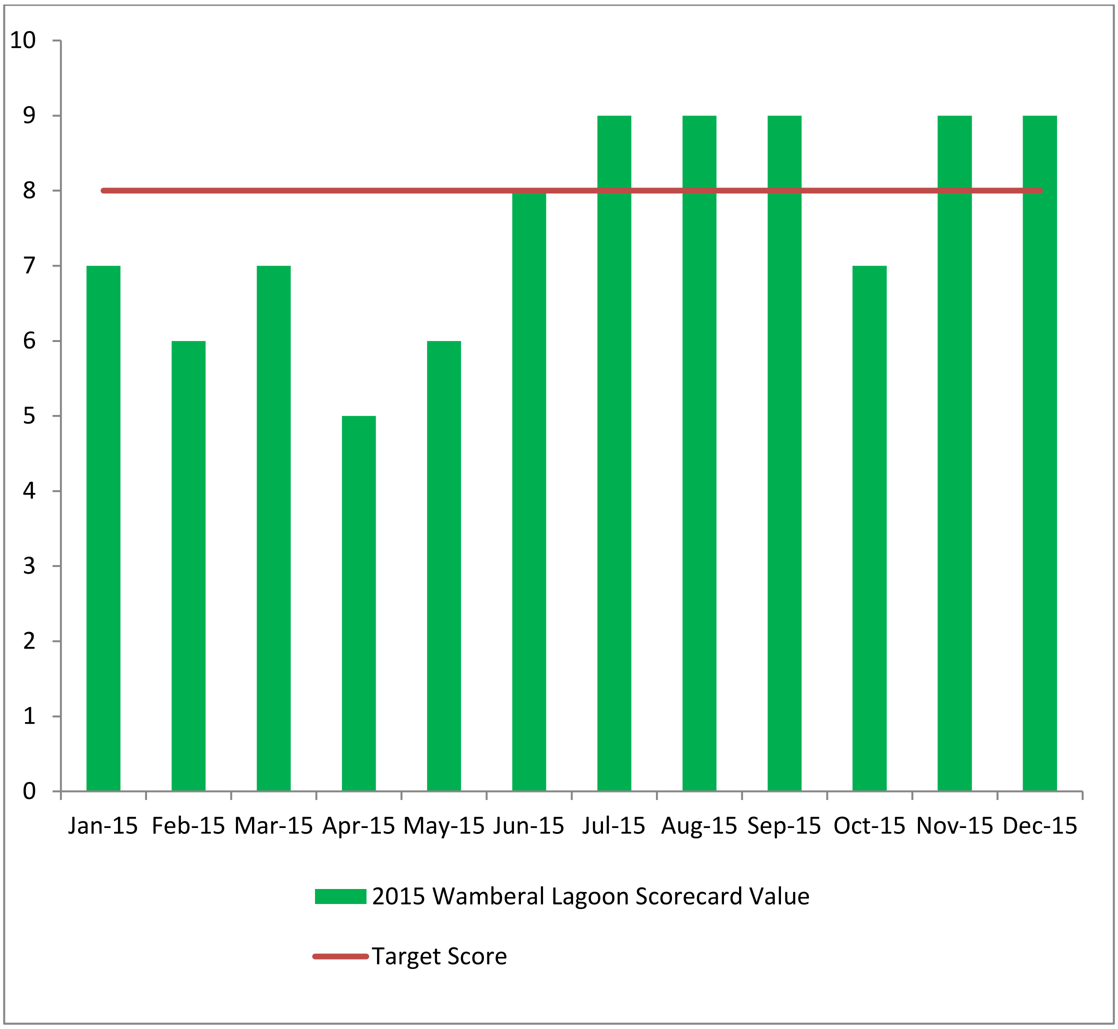

Figure 11: Scorecard results for Wamberal Lagoon during 2015 based on analytical results of physical and chemical parameters (turbidity, dissolved oxygen, ammonium, oxidised nitrogen, total nitrogen, orthophosphate, total phosphorus and chlorophyll a).

Wamberal Lagoon exceeded its target score five times during 2015 (Figure 11). The target score was met once and the target score was not met six times during 2015.

During 2015 water quality results were maintained compared with water quality data since 2009 (Figure 3).

Section 5.3.5 shows that the highest recorded levels of soluble reactive phosphorus, oxidized nitrogen, total nitrogen, total phosphorus and turbidity were recorded after a significant wet weather event in April 2015 when the lagoon remained closed.

4.3.5 ICOLLS Water Quality Parameters

4.3.5.1 Ammonia

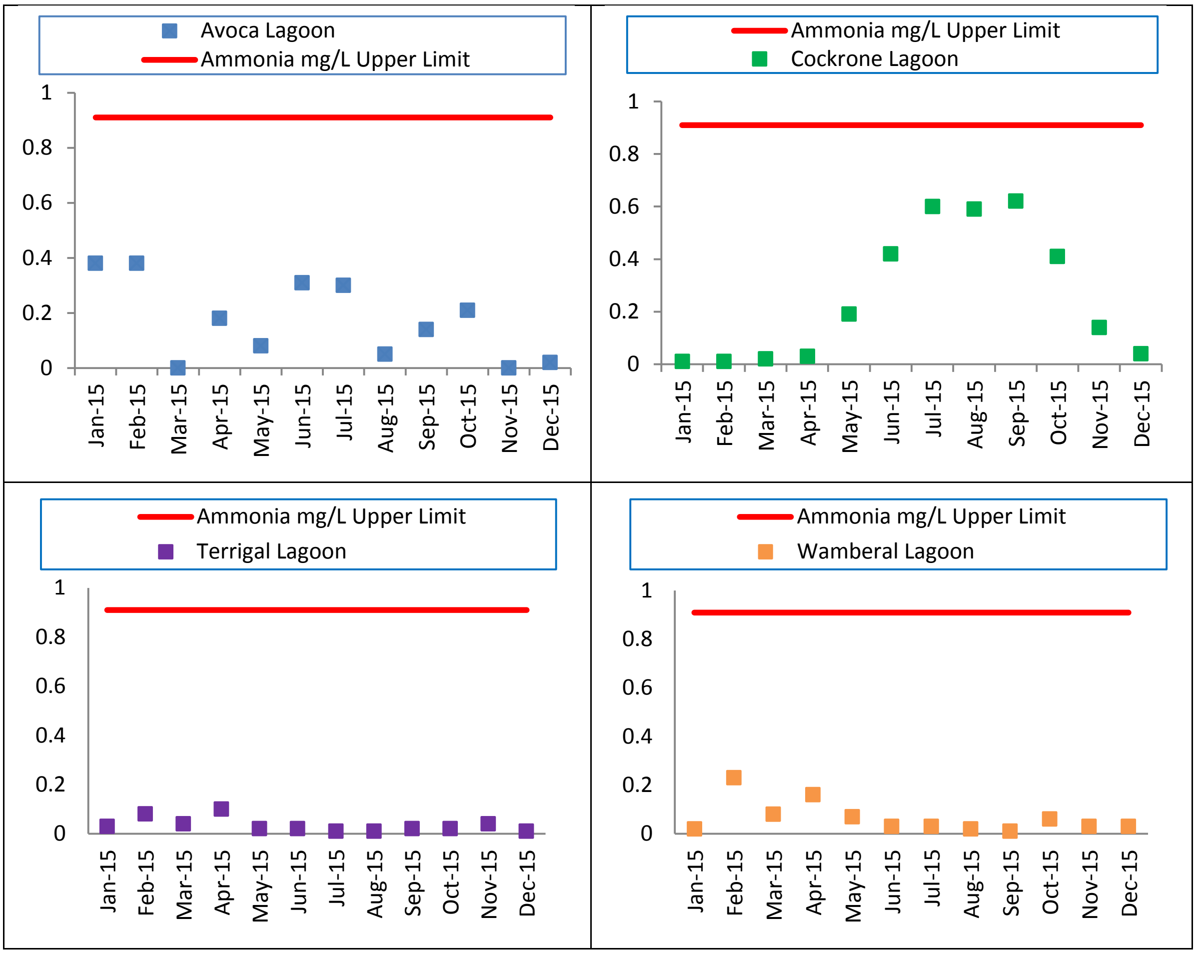

Figure 12: Ammonia results for ICOLLS during 2015. The upper limit trigger values are based on ANZECC 2000 guidelines and historical data for the site.

Ammonia results at all 4 four coastal lagoons were below the upper limit trigger value for all months in 2015. Cockrone Lagoon exhibited the highest ammonia levels in comparison to the other lagoons, with the highest value in July, August and September 2015.

4.3.5.2 Chlorophyll a

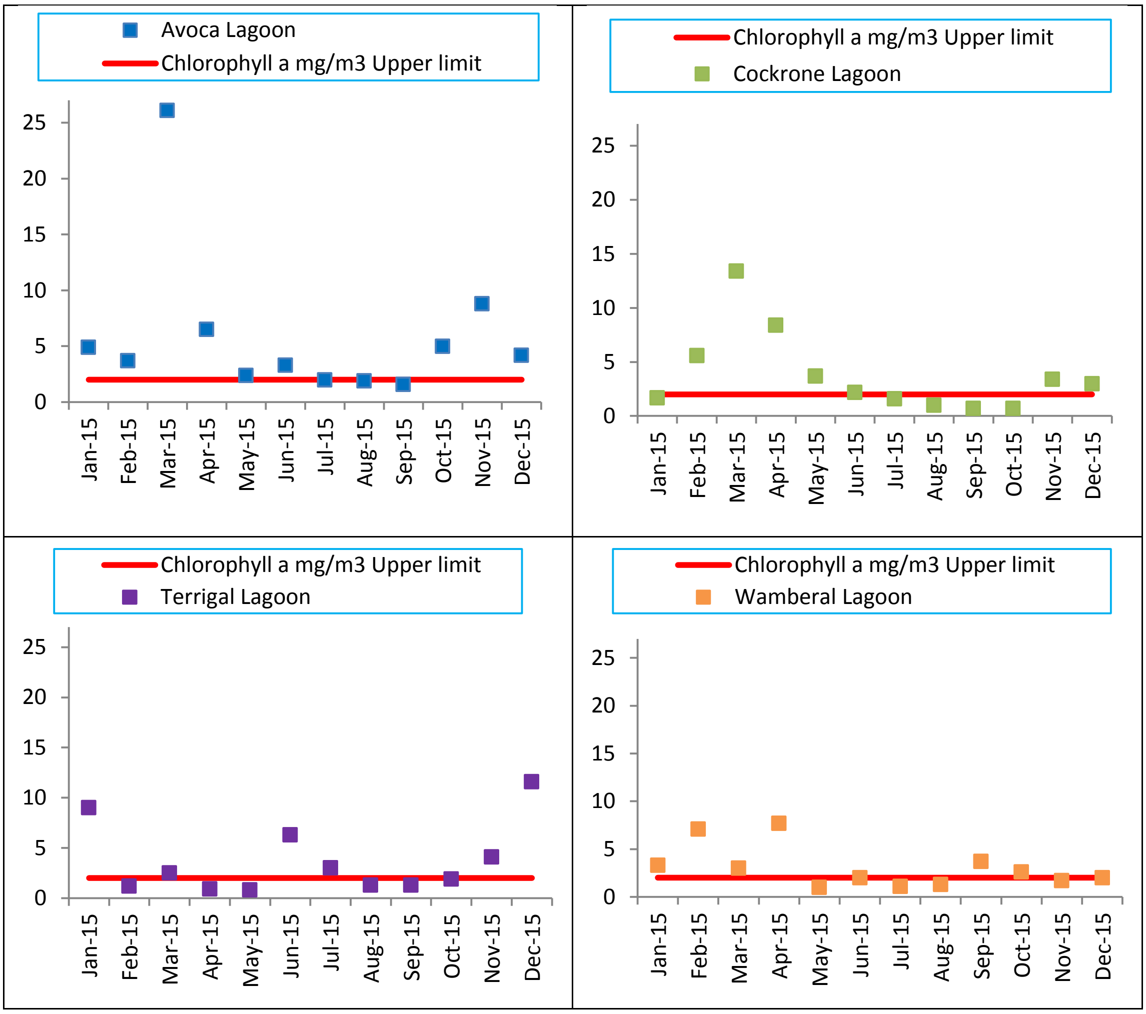

Figure13: Chlorophyll a results for ICOLLS during 2015. The upper limit trigger values are based on ANZECC 2000 guidelines and historical data for the site.

Chlorophyll a results were frequently above the upper limit for all four coastal lagoons in 2015. The highest result was recorded at Avoca Lagoon in March 2015. Chlorophyll a results were generally lowest at all lagoons during the winter months.

4.3.5.3 Dissolved Oxygen

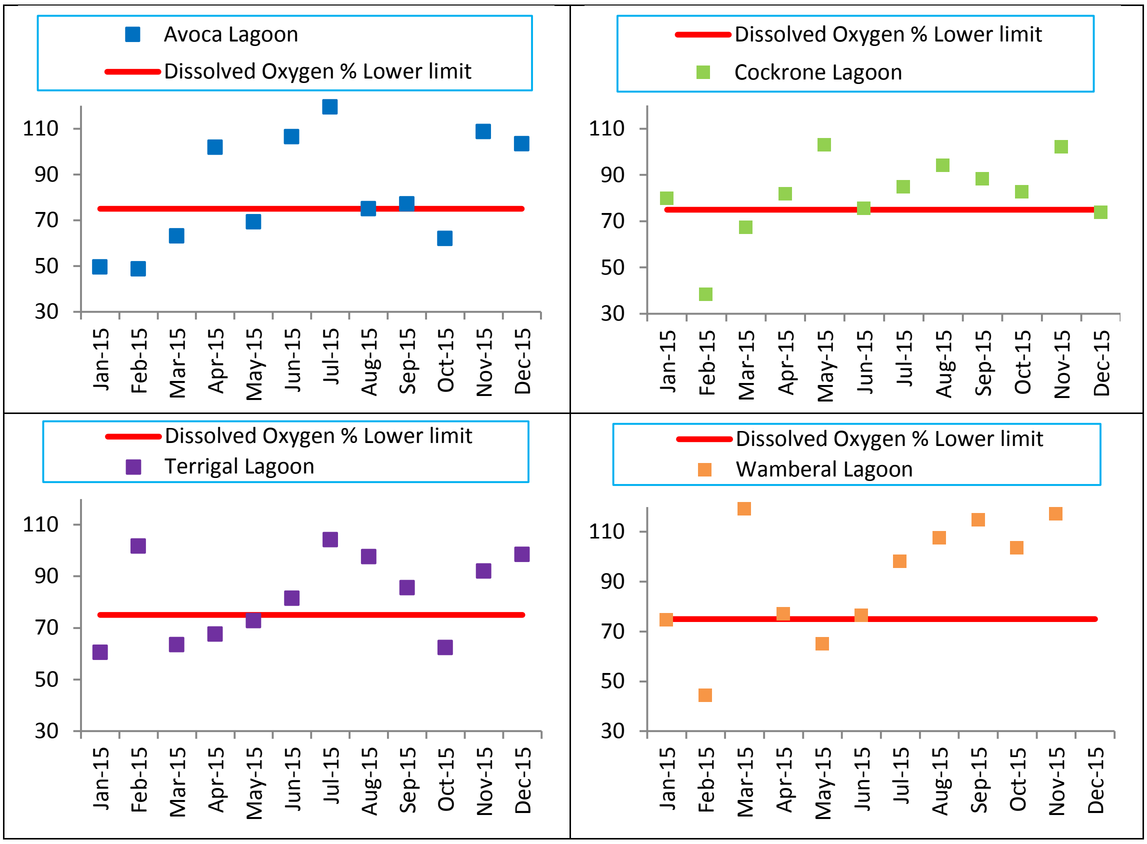

Figure 14: Dissolved Oxygen results for ICOLLS during 2015. The upper and lower limit trigger values are based on ANZECC 2000 guidelines and historical data for the site.

Dissolved oxygen values were frequently above the lower limit trigger value. During and after the warmer months of January, February and March and May dissolved oxygen levels were generally at their lowest at most lagoons.

4.3.5.4 Soluble Reactive Phosphorus

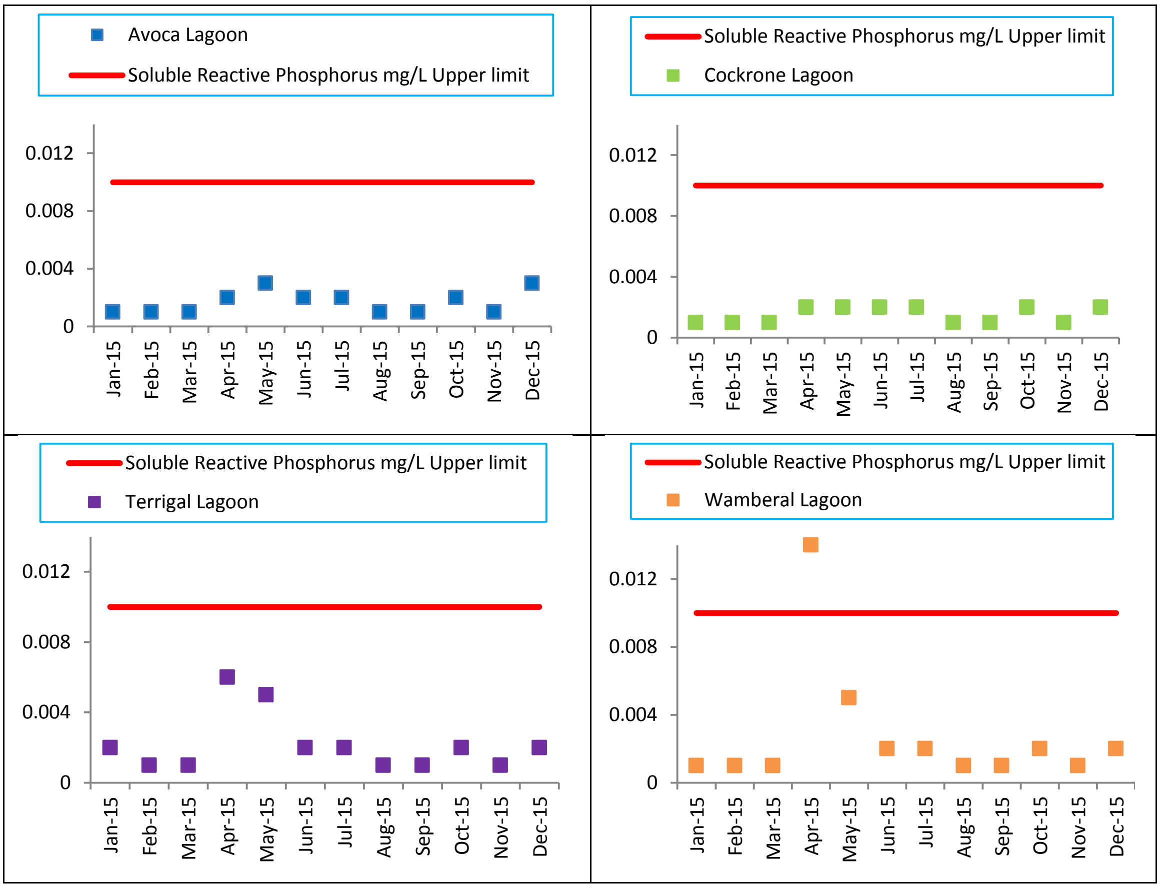

Figure 15: Soluble Reactive Phosphorus results for ICOLLS during 2015. The upper limit trigger values are based on ANZECC 2000 guidelines and historical data for the site.

Soluble reactive phosphorus was frequently below the upper limit for all four coastal lagoons. Wamberal Lagoon recorded the highest value for soluble reactive phosphorus in April 2015.

4.3.5.5 Oxidised Nitrogen

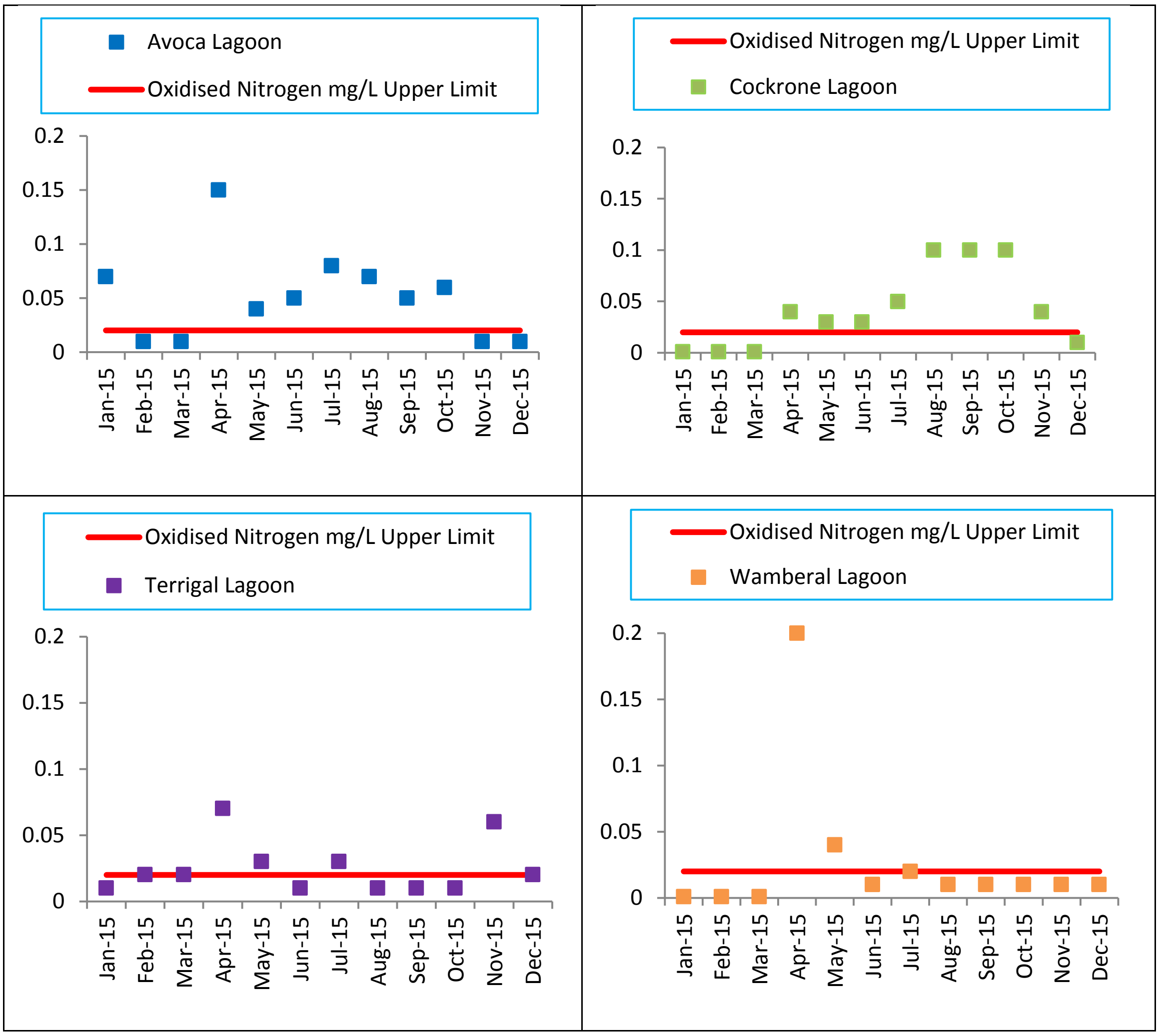

Figure 16: Oxidised Nitrogen results for ICOLLS during 2015. The upper limit trigger values are based on ANZECC 2000 guidelines and historical data for the site.

Oxidised nitrogen results were frequently above the upper limit trigger values at Avoca, Cockrone Lagoon and Terrigal Lagoon. Wamberal Lagoon was frequently below the upper limit trigger value, however the highest value was at Wamberal Lagoon in April 2015.

4.3.5.6 Total Nitrogen

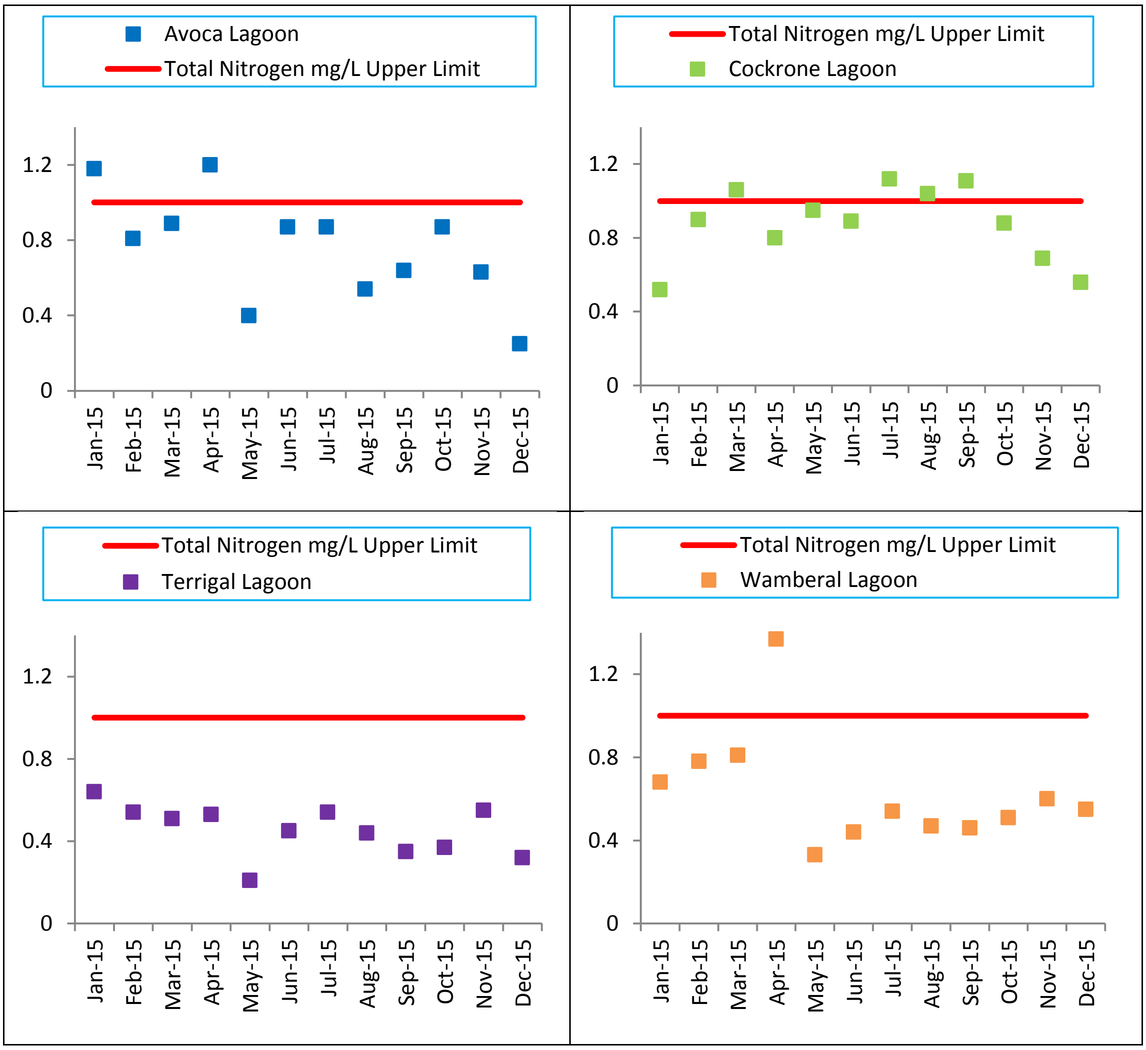

Figure 17: Total Nitrogen results for ICOLLS during 2015. The upper limit trigger values are based on ANZECC 2000 guidelines and historical data for the site.

All four coastal lagoons were frequently below the upper limit trigger value level for total nitrogen. The highest level was recorded at Wamberal Lagoon in April 2015.

4.3.5.7 Total Phosphorus

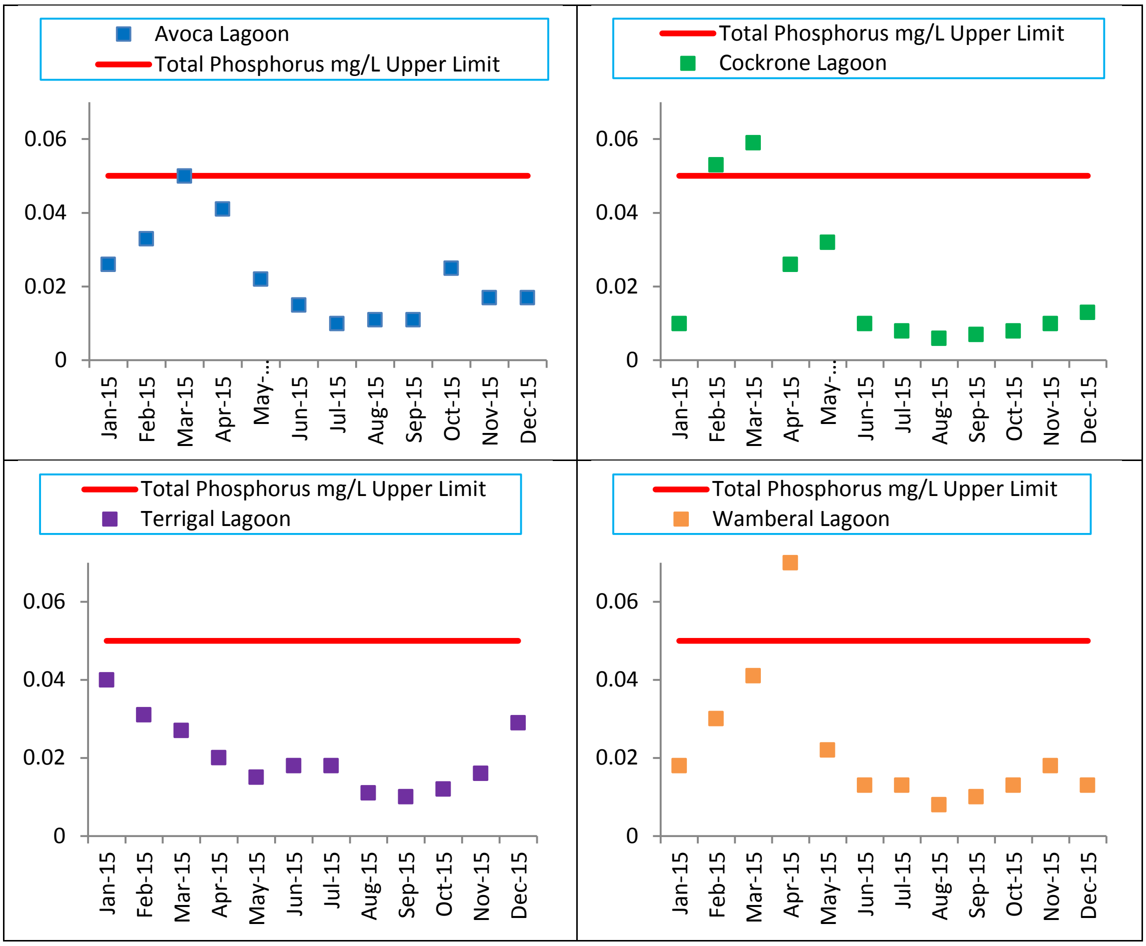

Figure 18: Total Phosphorus results for ICOLLS during 2015. The upper limit trigger values are based on ANZECC 2000 guidelines and historical data for the site.

All four sites were frequently below the upper limit trigger value for total phosphorus. The highest value was at Wamberal Lagoon in April 2015.

4.3.5.8 Turbidity

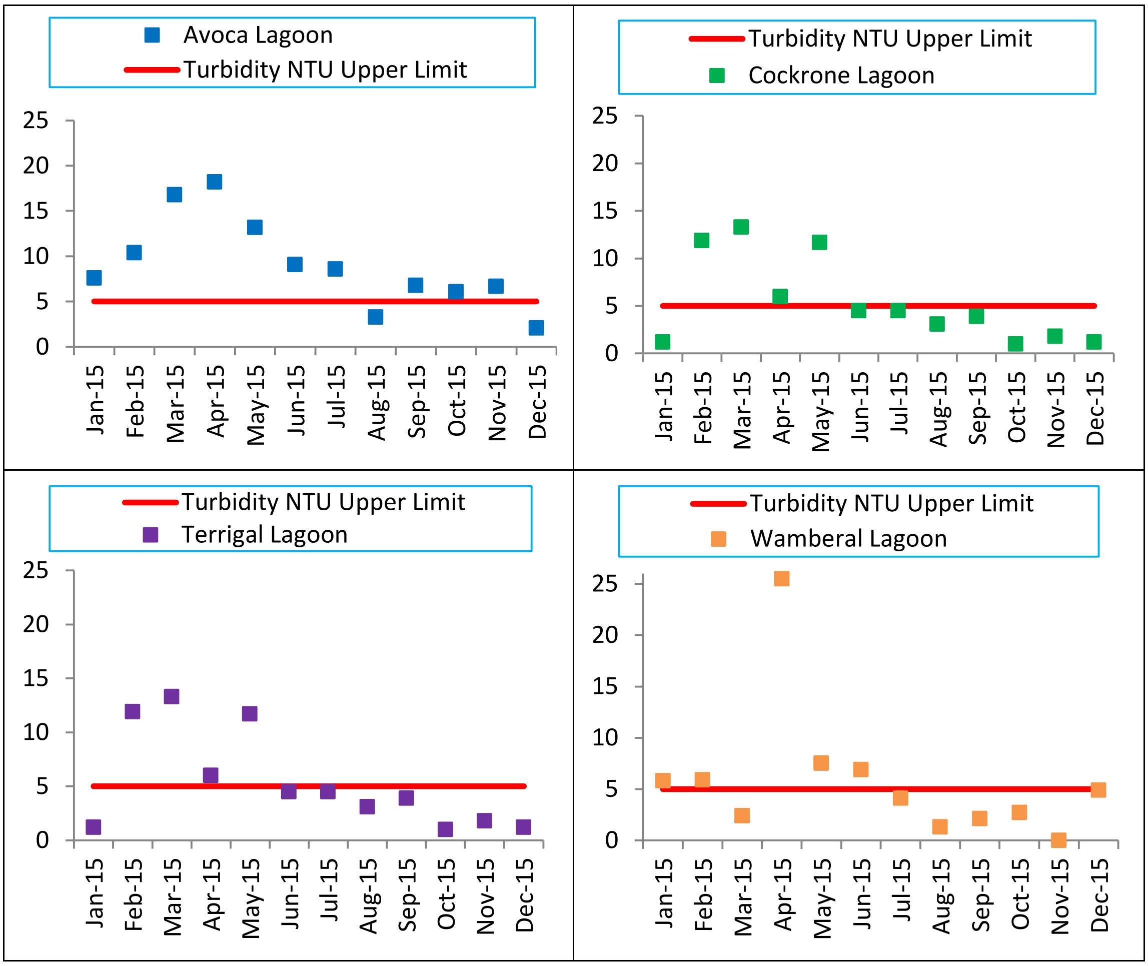

Figure 19: Turbidity results for ICOLLS during 2015. The upper limit trigger values are based on ANZECC 2000 guidelines and historical data for the site.

Avoca Lagoons turbidity levels were frequently above the upper limit trigger value. Cockrone, Terrigal and Wamberal Lagoon were more frequently below the upper limit. Wamberal Lagoon recorded the highest value in April 2015.

4.4 Brisbane Water Estuary and its tributaries

The Brisbane Water Estuary has a relatively small catchment size of 165 km compared with the size of the waterway, comprising of a range of rural, residential and industrial development.

The principle aspects of the catchment that affect Brisbane Water are the variations, temporal and spatial, in runoff and nutrient loads delivered to the waterway. As a result of the small catchment size versus the large body of water of the Estuary itself, catchment flows and associated turbidity and nutrients loads have very little impact on sites tested in the Brisbane Water Estuary. However creek sites such as Narara, Kincumber and Erina creek are expected to have more impacts from catchment flows.

4.4.1 Booker Bay

2015 Water Quality Rating:
A-

The Booker Bay catchment is large, comprising a section of Brisbane Water close to Broken Bay. The land surrounding this sample site is urbanised with mostly residential development.

Booker Bay was monitored monthly during 2015. The monitoring location is accessed from Guyra Street, Booker Bay (Figure 20). The site is close to the outlet of the Brisbane Water Estuary; is deep (more than one metre) and experiences tidal movements and a high degree of flushing. The site has a sandy substrate.

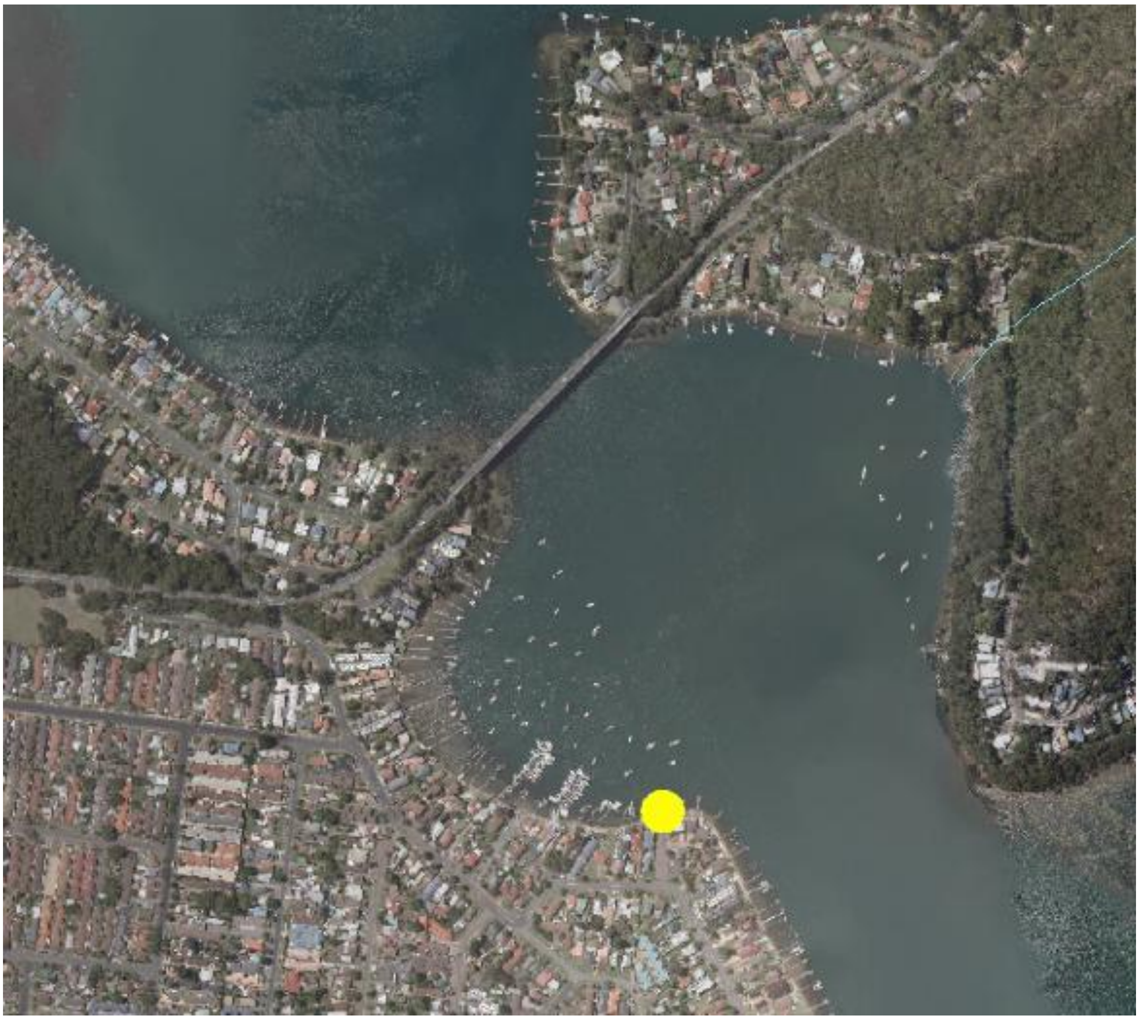

Figure 20. Booker Bay monitoring location indicated by yellow circle.

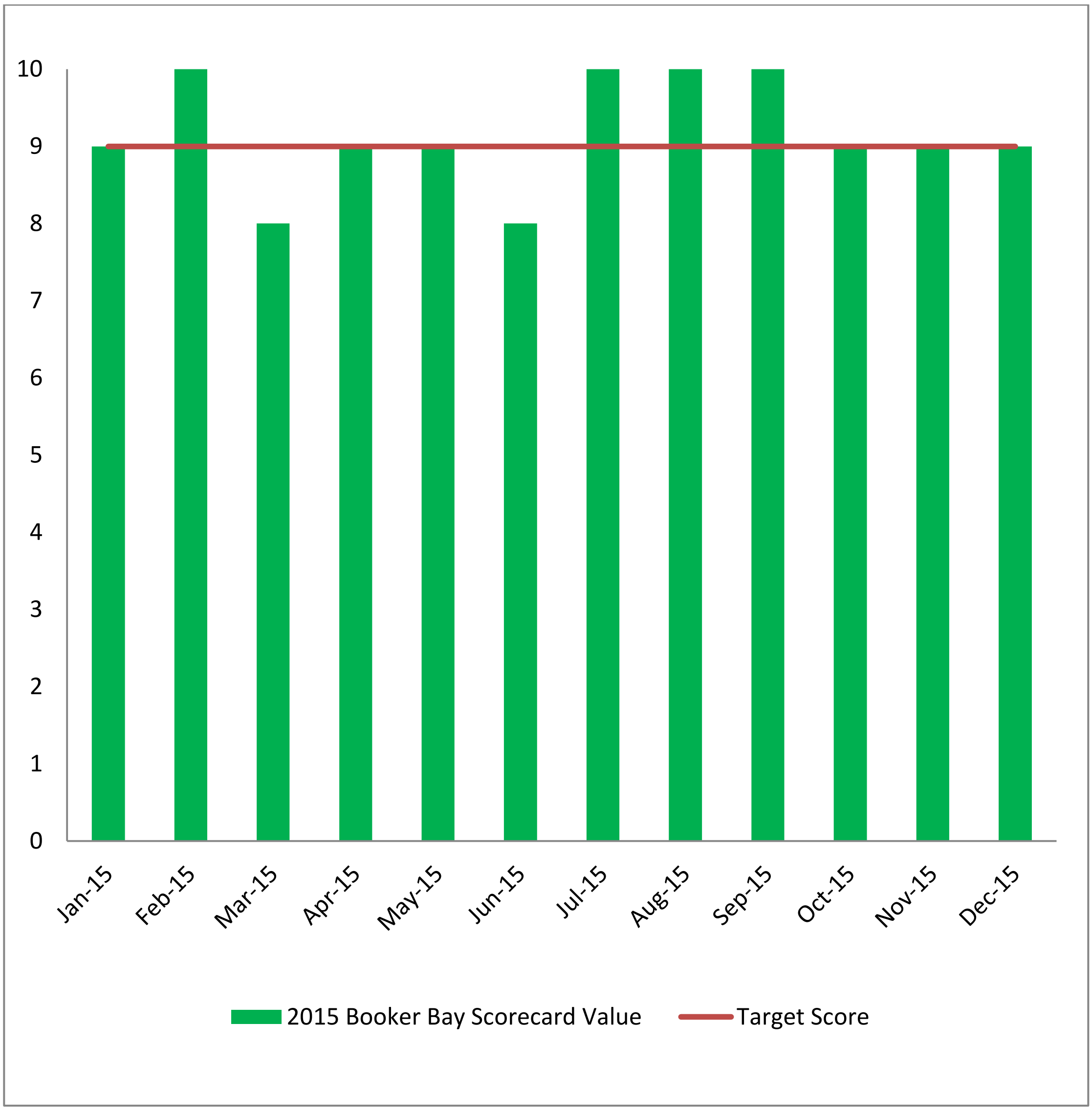

Figure 21: Scorecard results for Booker Bay during 2015 based on analytical results of physical and chemical parameters (turbidity, dissolved oxygen, ammonium, oxidised nitrogen, total nitrogen, orthophosphate, total phosphorus and chlorophyll a).

The target score was exceeded four times during 2015 (Figure 21), indicating very good water quality. The target score was met six times and not met twice during 2015.

The results of 2015 showed water quality results remained consistent compared with results from 2009 through to 2014, showing water quality has been maintained over the seven year period (Figure 3).

Booker Bay did not exceed the upper limit trigger value for all parameters tested excluding outlier elevated results for soluble reactive phosphorus and oxidized nitrogen during 2015 (Section 5.4.4).

4.4.2 Cockle Creek Catchment

2015 Water Quality Rating:
A-

The Cockle Creek catchment contains residential development and substantial areas of significant vegetation.

Cockle Creek was monitored monthly during 2015. The monitoring location is on Shelly Beach Rd, Empire Bay (Figure 22). The site is deep (more than one metre), experiences tidal movements and a high level of flushing. The bottom substrate is sand.

Figure 22. Cockle Creek monitoring location indicated by yellow circle.

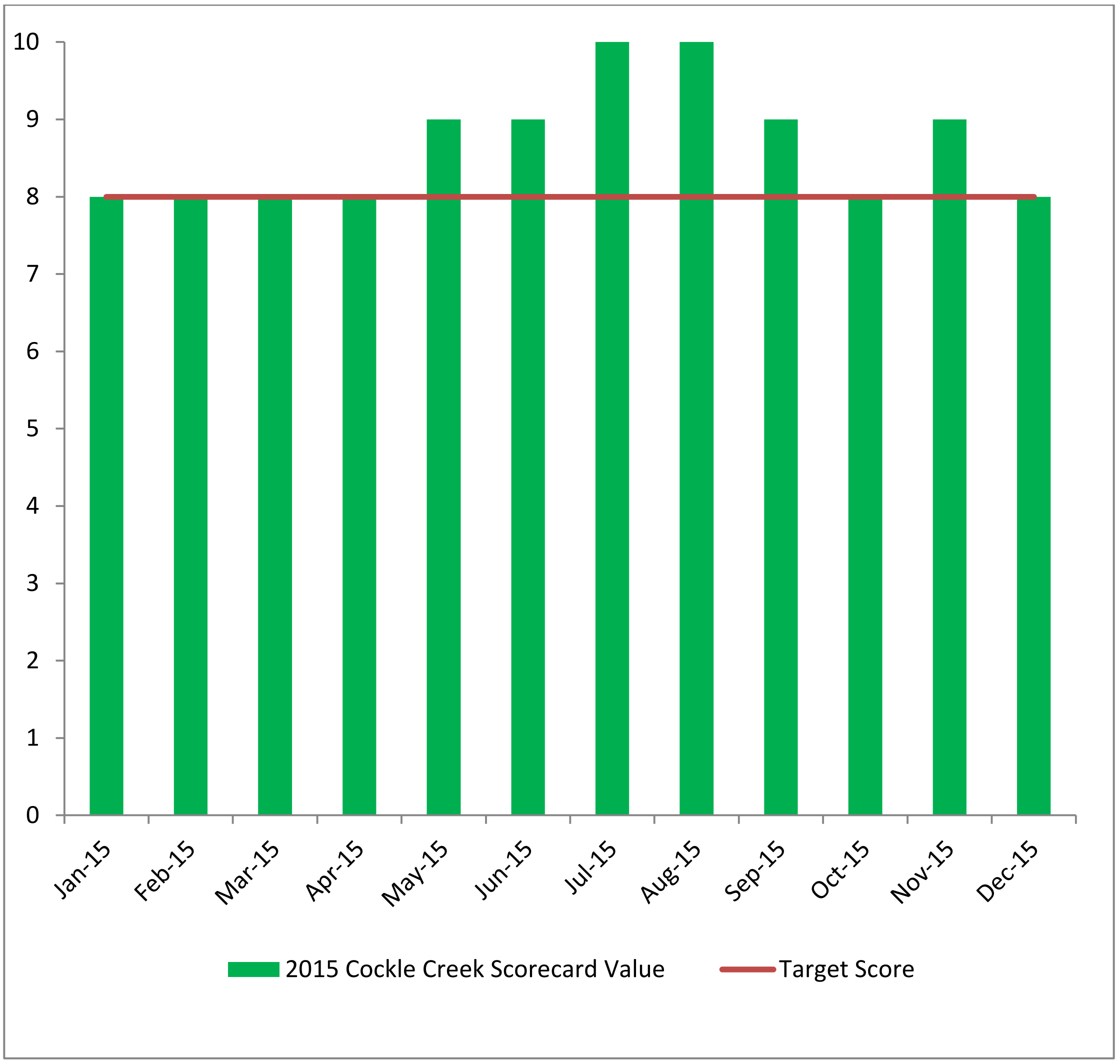

Figure 23. Scorecard results for Cockle Creek during 2015 based on analytical results of physical and chemical parameters (turbidity, dissolved oxygen, ammonium, oxidised nitrogen, total nitrogen, orthophosphate, total phosphorus and chlorophyll a).

The target score was exceeded six (6) times and the target score was met six (6) times during 2015 (Figure 23). The water quality of Cockle Creek was very good for 2015 and has remained consistent since 2009, indicating that water quality has been maintained (Figure 3).

Cockle Creek did not exceed the upper limit for ammonia, soluble reactive phosphorus, oxidized nitrogen, total nitrogen and total phosphorus during 2015 (Section 5.4.4).

Chlorophyll a and turbidity were rarely slightly elevated above the upper limit.

4.4.3 Woy Woy Bay Catchment

2015 Water Quality Rating:
A-

The Woy Woy Bay catchment is relatively undisturbed. The Woy Woy Landfill and Woy Woy Sewage Treatment Plant are located within the Woy Woy Bay Catchment. The final effluent from the Woy Woy Sewage Treatment Plant is disposed of into Winney Bay Ocean Outfall.

Woy Woy Bay was monitored monthly during 2015. The monitoring location is accessed from Pier Street, Woy Woy (Figure 24). The sample site is deep (more than one metre) and experiences tidal movements and moderate flushing.

Figure 24. Woy Woy Bay monitoring location indicated by yellow circle.

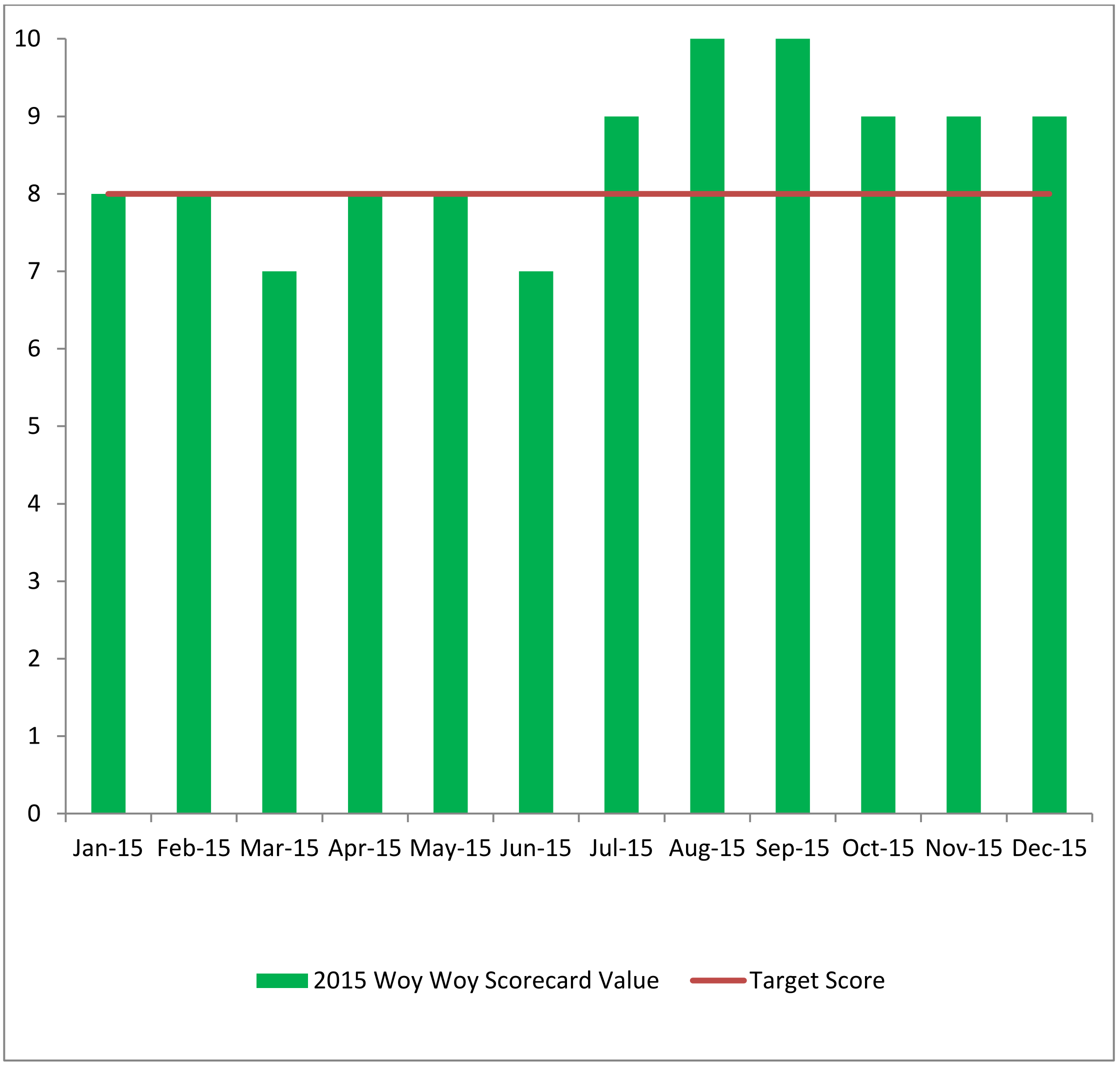

Figure 25: Scorecard results for Woy Woy Bay during 2015 based on analytical results of physical and chemical parameters (turbidity, dissolved oxygen, ammonium, oxidised nitrogen, total nitrogen, orthophosphate, total phosphorus and chlorophyll a).

Woy Woy Bay water quality results exceeded the target score six times during 2015. The target score was met four times (Figure 25).

Throughout 2015 Woy Woy Bay has exhibited very good water quality. Water quality results have improved from 2014 results and are equivalent with 2009, 2010, 2011 and 2012 results (Figure 3).

Woy Woy Bay did not exceed the upper limit for ammonia, total nitrogen, total phosphorus during 2015 (Table 14).

Chlorophyll a, soluble reactive phosphorus, oxidized nitrogen and turbidity were occasionally elevated above the upper limit.

4.4.4 Brisbane Water Estuary Water Quality Parameters

4.4.4.1 Ammonia

Figure 26: Ammonia results for Brisbane Water Estuary sites during 2015. The upper limit trigger values are based on ANZECC 2000 guidelines and historical data for the site.

Ammonia results were well below the upper limit at all three estuarine sites.

4.4.4.2 Chlorophyll a

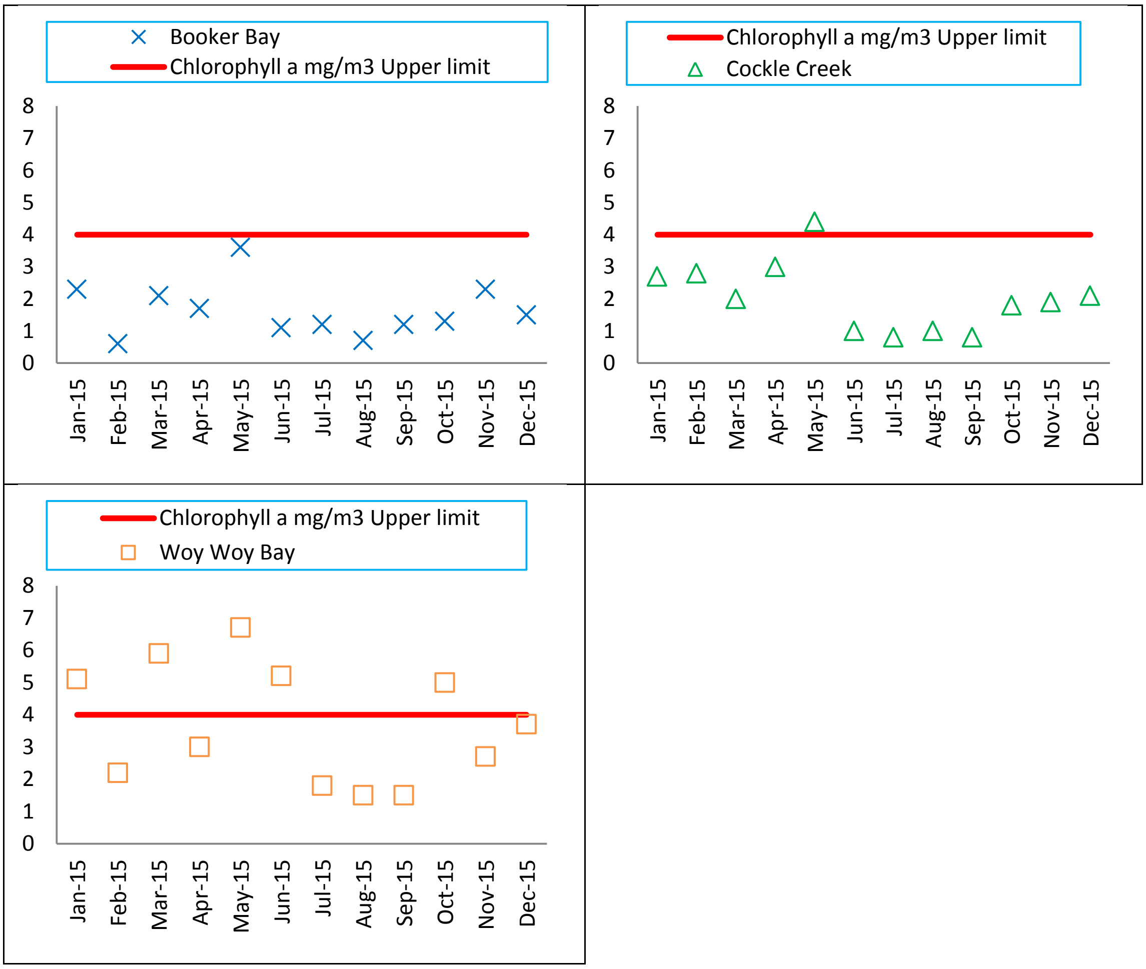

Figure 27: Chlorophyll a results for Brisbane Water Estuary sites during 2015. The upper limit trigger values are based on ANZECC 2000 guidelines and historical data for the site.

Chlorophyll a results were frequently below the upper limit for all three estuarine sites. Results were generally at their lowest during the colder months (July, August and September). Woy Woy Bay results were the highest of the estuarine sites.

4.4.4.3 Dissolved Oxygen

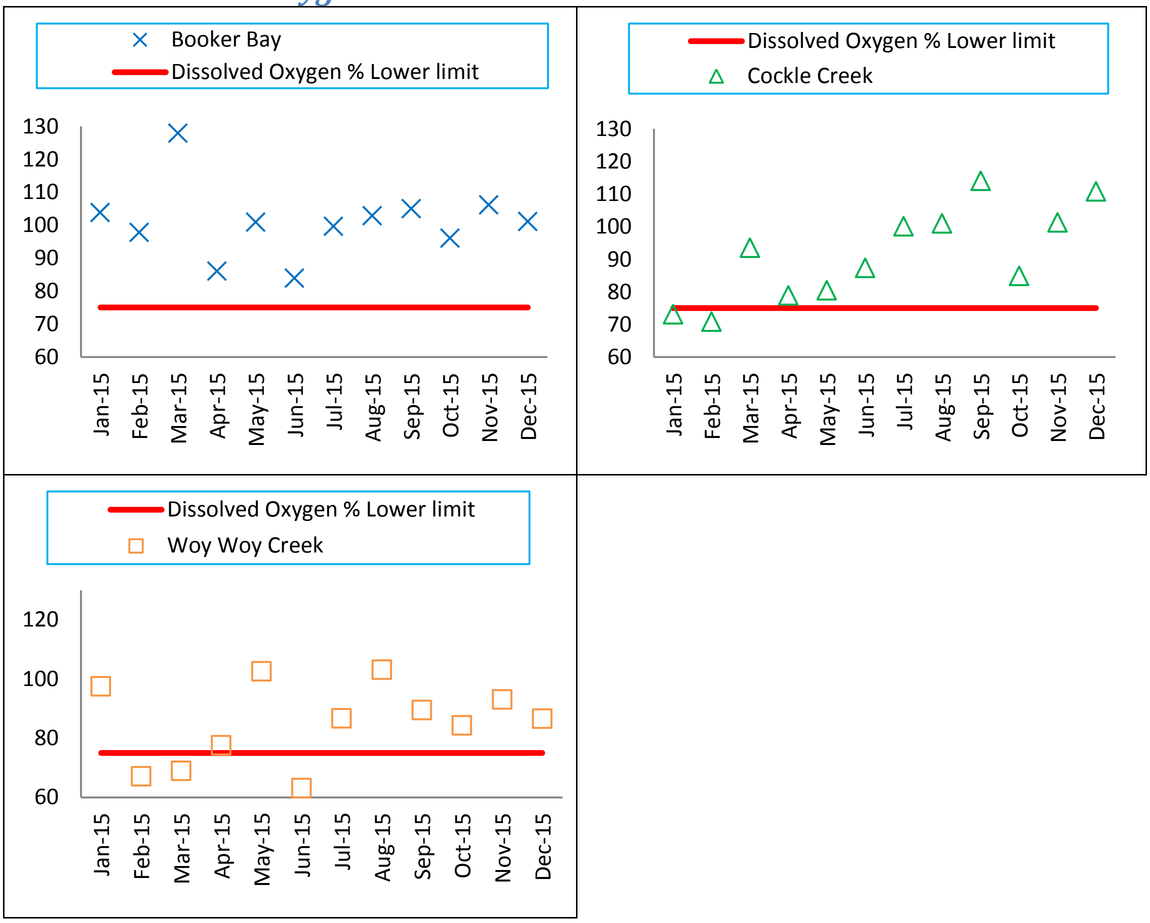

Figure 28: Dissolved oxygen results for Brisbane Water Estuary sites during 2015. The lower limit trigger values are based on ANZECC 2000 guidelines and historical data for the site.

Dissolved oxygen levels were frequently above the lower limit for all three estuarine sites.

4.4.4.4 Soluble Reactive Phosphorus

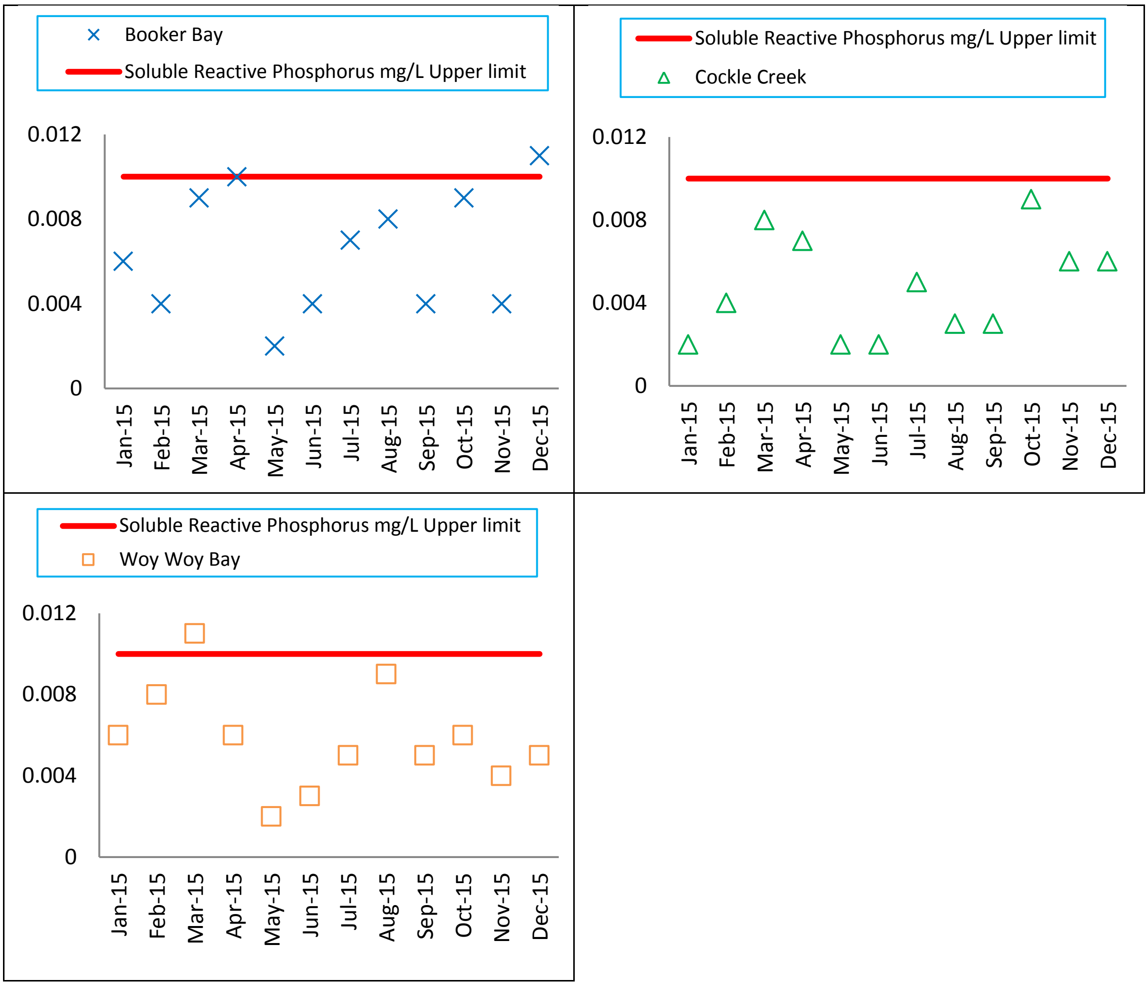

Figure 29: Soluble Reactive Phosphorus results for Brisbane Water Estuary sites during 2015. The upper limit trigger values are based on ANZECC 2000 guidelines and historical data for the site.

All three estuarine sites were frequently below the upper limit for soluble reactive phosphorus.

4.4.4.5 Oxidised Nitrogen

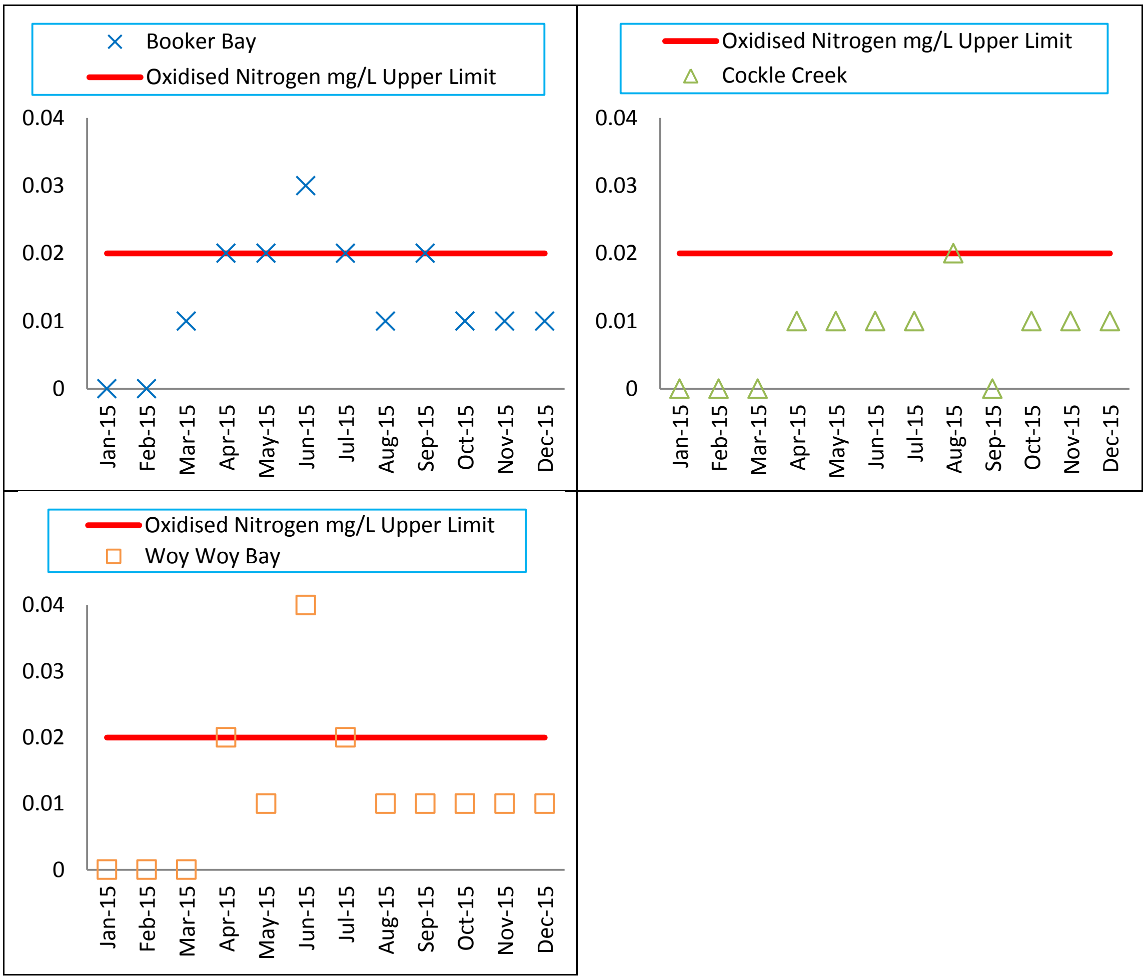

Figure 30: Oxidised Nitrogen results for Brisbane Water Estuary sites during 2015. The upper limit trigger values are based on ANZECC 2000 guidelines and historical data for the site.

Oxidised nitrogen results were frequently below the upper limit at all three estuarine sites. Woy Woy Bay recorded the highest level in June 2015.

4.4.4.6 Total Nitrogen

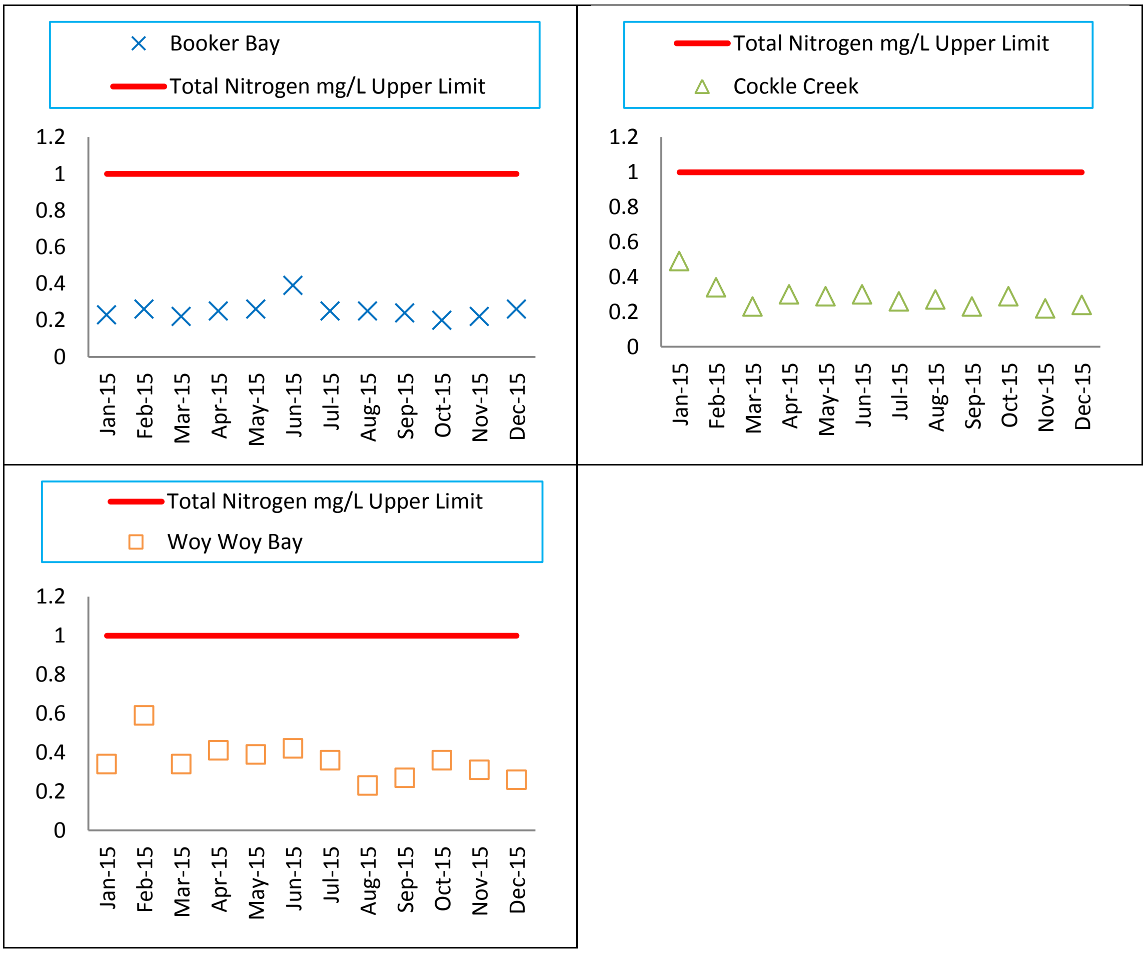

Figure 31: Total Nitrogen results for Brisbane Water Estuary sites during 2015. The upper limit trigger values are based on ANZECC 2000 guidelines and historical data for the site.

All three estuarine sites were frequently below the upper limit for total nitrogen.

4.4.4.7 Total Phosphorus

Figure 32: Total Phosphorus results for Brisbane Water Estuary sites during 2015. The upper limit trigger values are based on ANZECC 2000 guidelines and historical data for the site.

All three estuarine sites were below the upper limit for total phosphorus.

4.4.4.8 Turbidity

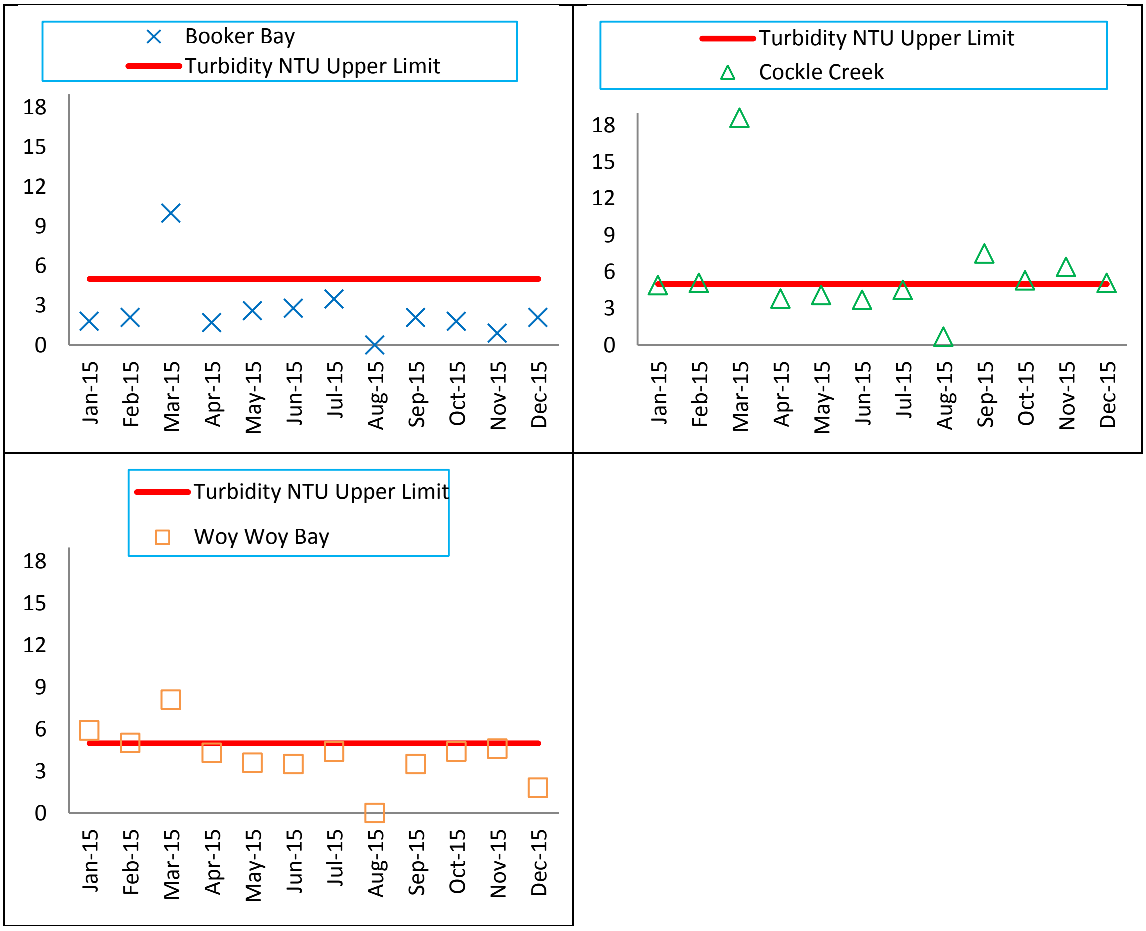

Figure 33: Turbidity results for Brisbane Water Estuary sites during 2015. The upper limit trigger values are based on ANZECC 2000 guidelines and historical data for the site.

Turbidity results for all three estuarine sites were more frequently below the upper limit trigger value. The highest value was recorded at Cockle Creek in March 2015.

4.4.5 Erina Creek Catchment

2015 Water Quality Rating:
B-

The Erina Creek catchment contains a range of land use activities including residential housing, industrial/commercial business, conservation areas and small rural holdings.

Erina Creek was monitored monthly during 2015. The monitoring location is accessed from the boat ramp near the Punt Bridge, Erina (Figure 34). The site experiences tidal movements, has mangroves and a muddy substrate.

Figure 34. Erina Creek monitoring location indicated by yellow circle.

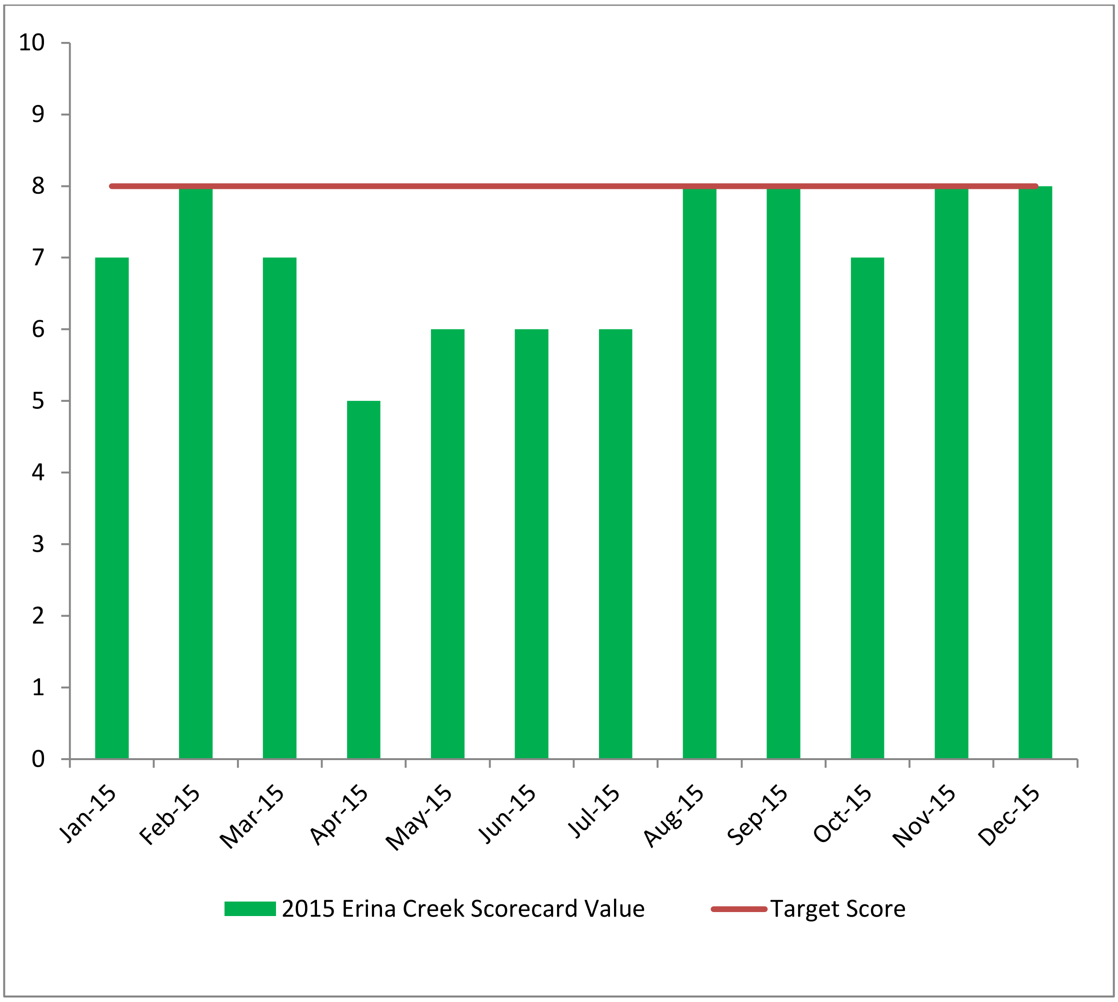

Figure 35: Scorecard results for Erina Creek during 2015 based on analytical results of physical and chemical parameters (turbidity, dissolved oxygen, ammonium, oxidised nitrogen, total nitrogen, orthophosphate, total phosphorus and chlorophyll a).

The target score was not exceeded during the 2015 period (Figure 35). The target score was met five times and was not met seven times during 2015.

Compared with annual results since 2008 Erina Creek has neither improved nor declined, indicating water quality has been maintained (Figure 3).

Generally, during months in which the target score was not met ammonia, chlorophyll a, oxidised nitrogen and turbidity were elevated (section 5.4.8).

4.4.6 Kincumber Creek Catchment

2015 Water Quality Rating:
B-

The Kincumber Creek catchment is urbanised with residential and industrial/commercial development.

Kincumber Creek was monitored monthly during 2015. The monitoring location is close to the discharge point of Kincumber creek and is accessed from Carrak Road, Kincumber (Figure 36). The site is shallow, experiences tidal movements, has mangroves and the bottom substrate is muddy. It is frequented by ducks and is often turbid during tidal movements and windy conditions.

Figure 36. Kincumber Creek monitoring location indicated by yellow circle.

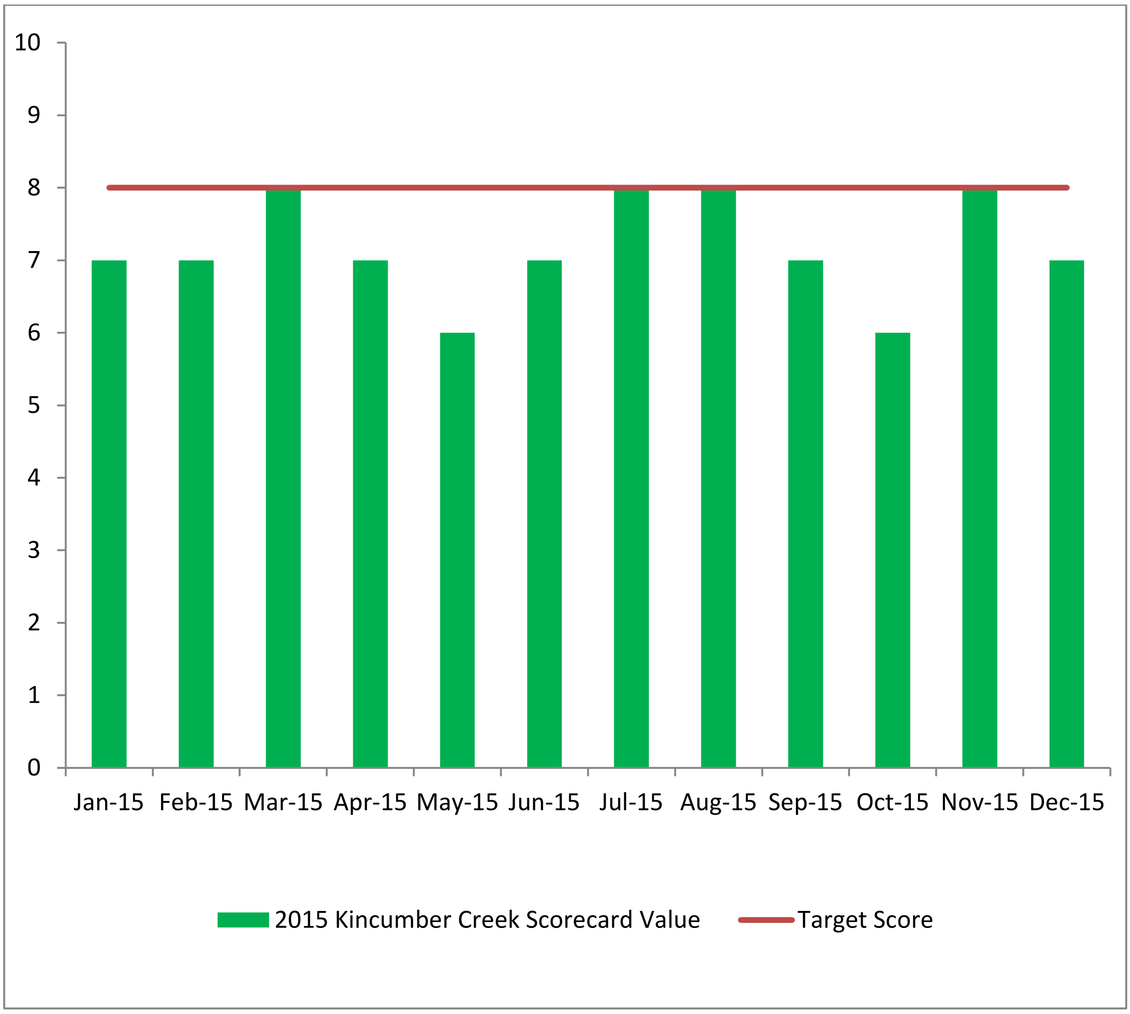

Figure 37: Scorecard results for Kincumber Creek during 2015 based on analytical results of physical and chemical parameters (turbidity, dissolved oxygen, ammonium, oxidised nitrogen, total nitrogen, orthophosphate, total phosphorus and chlorophyll a).

The target score was met four times and the target score was not met eight times during 2015 (Figure 37).

Compared with results since 2012 water quality data, water quality collected for Kincumber Creek has remained consistent, showing water quality has been maintained (Figure 3).

During the months in which the target score was not met ammonia, chlorophyll a, oxidised nitrogen and turbidity were slightly elevated (Section 5.4.8).

4.4.7 Narara Creek Catchment

2015 Water Quality Rating:
C+

The Narara Creek catchment contains a range of land use activities including residential housing and industrial/commercial business. Upper Narara Creek is predominantly surrounded by residential development. Lower Narara Creek is predominantly surrounded by industrial/commercial developments.

Narara Creek was monitored monthly during 2015. The monitoring location is accessed from The Central Coast Highway, West Gosford (Figure 38). The site is shallow, experiences tidal movements, has mangroves and the bottom substrate is muddy.

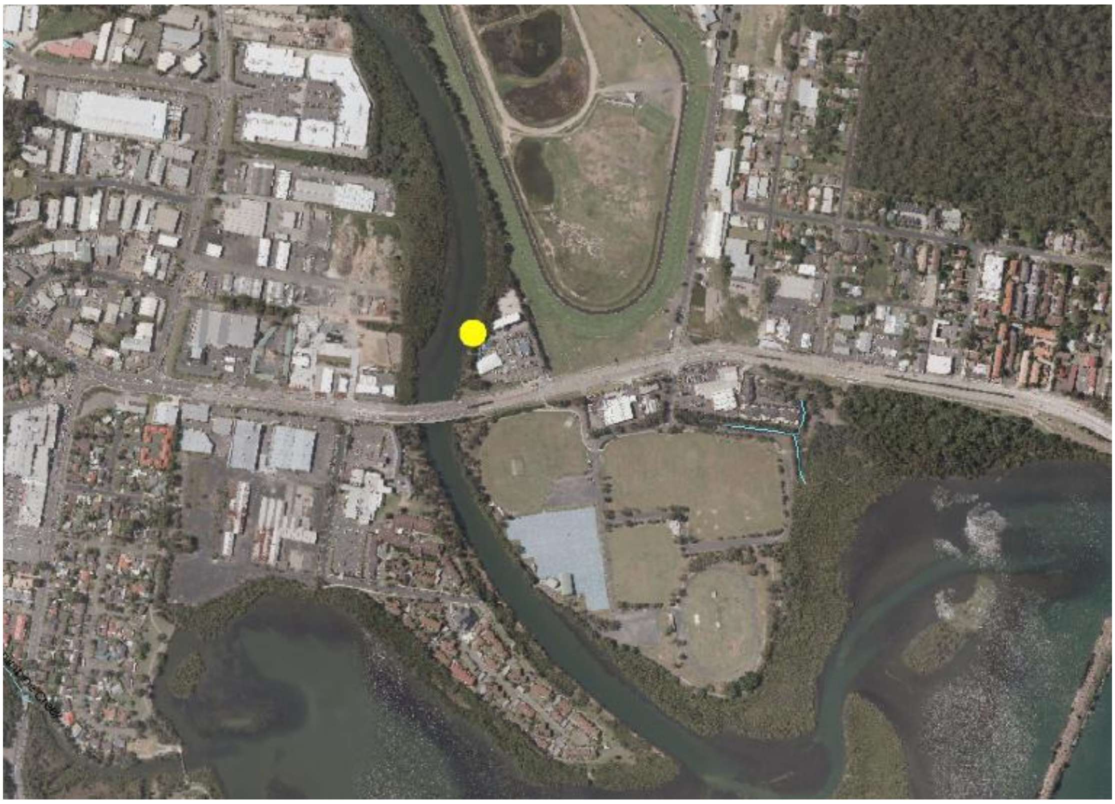

Figure 38. Narara Creek monitoring location indicated by yellow circle.

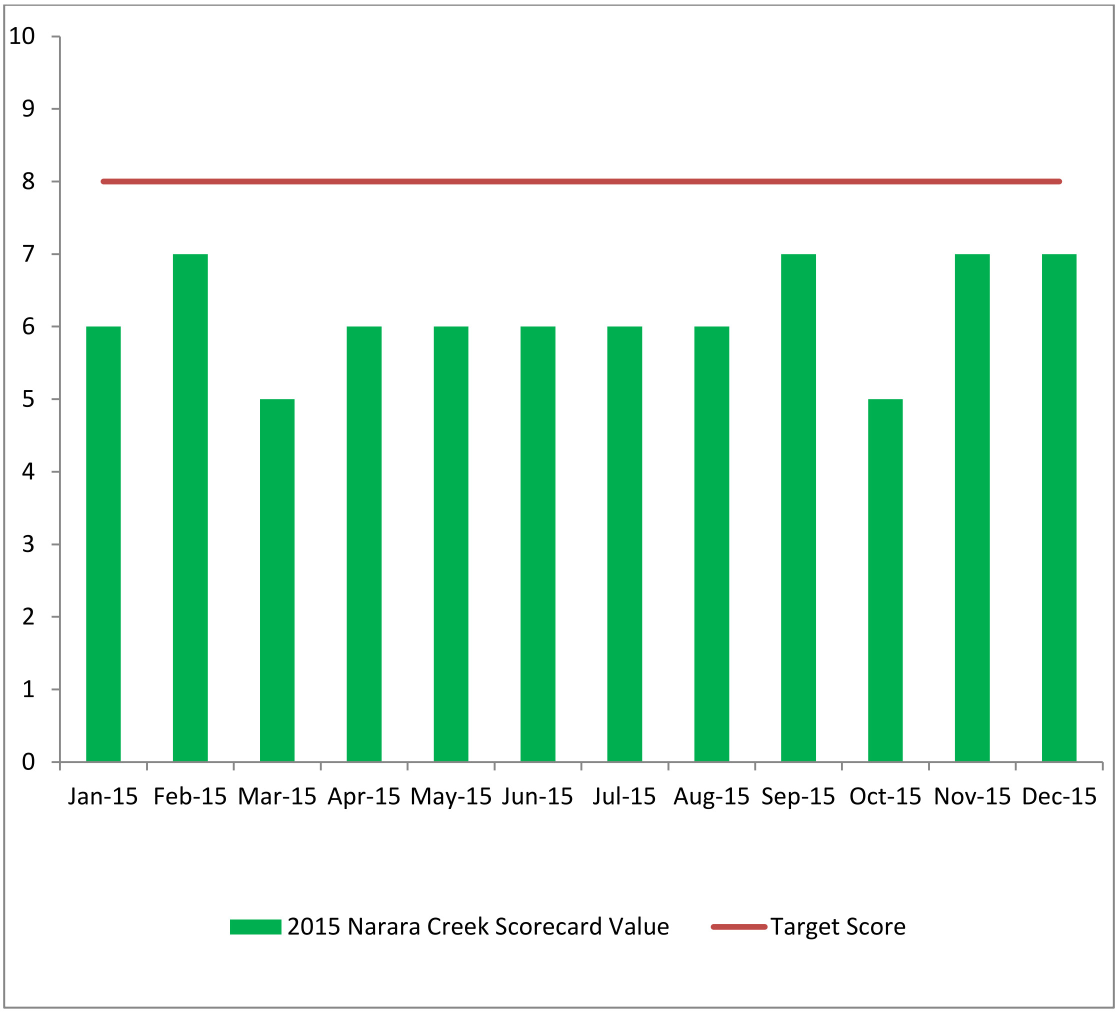

Figure 39: Scorecard results for Narara Creek during 2015 based on analytical results of physical and chemical parameters (turbidity, dissolved oxygen, ammonium, oxidised nitrogen, total nitrogen, orthophosphate, total phosphorus and chlorophyll a).

Narara Creek's water quality results did not exceed or meet its target score during 2015 (Figure 39).

Compared with results from 2009 through to 2014 the water quality score has declined by one point; however the 2015 result is equivalent to 2008 results (Figure 3).

During the months that the target score was not met elevated ammonia, chlorophyll a, oxidised nitrogen and turbidity levels were common (Section 5.4.8).

4.4.8 Brisbane Water Estuary Creek Water Quality Parameters

4.4.8.1 Ammonia

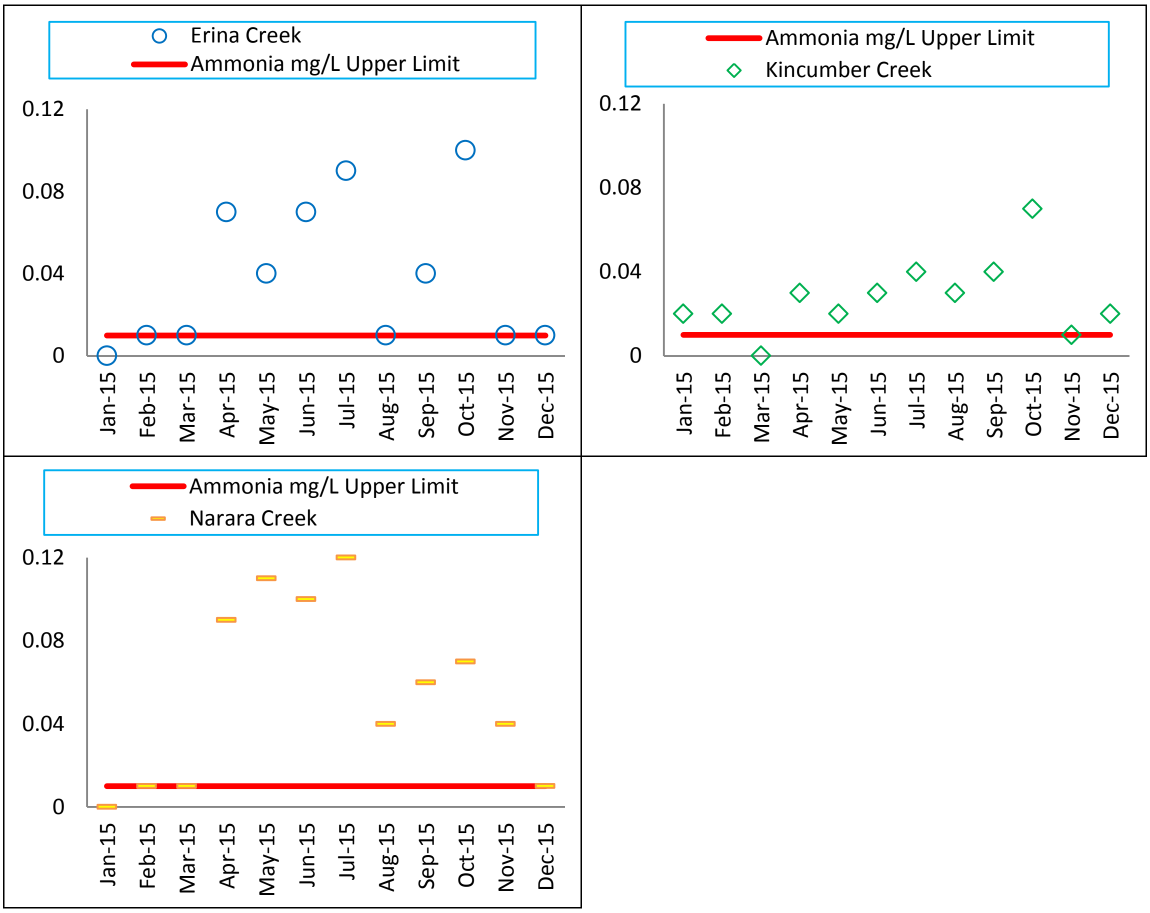

Figure 39: Ammonia results for Brisbane Water Estuary Creek sites during 2015. The upper limit trigger values are based on ANZECC 2000 guidelines and historical data for the site.

Ammonia results at all three creek sites were frequently above the upper limit threshold.

4.4.8.2 Chlorophyll a

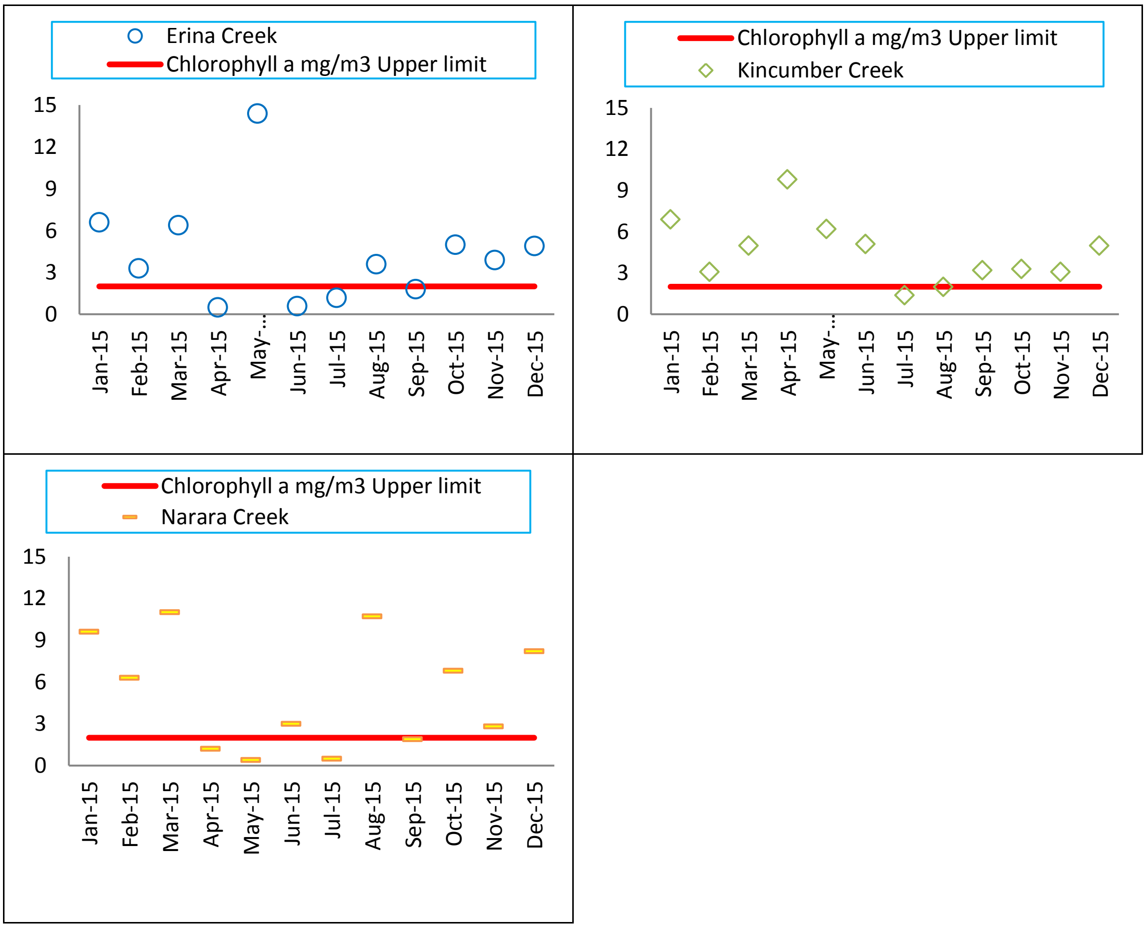

Figure 40: Chlorophyll a results for Brisbane Water Estuary Creek sites during 2015. The upper limit trigger values are based on ANZECC 2000 guidelines and historical data for the site.

Chlorophyll a results were frequently above the upper limit threshold at all three creek sites. Results were highest in and after the warmer months (January to April inclusive).

4.4.8.3 Dissolved Oxygen

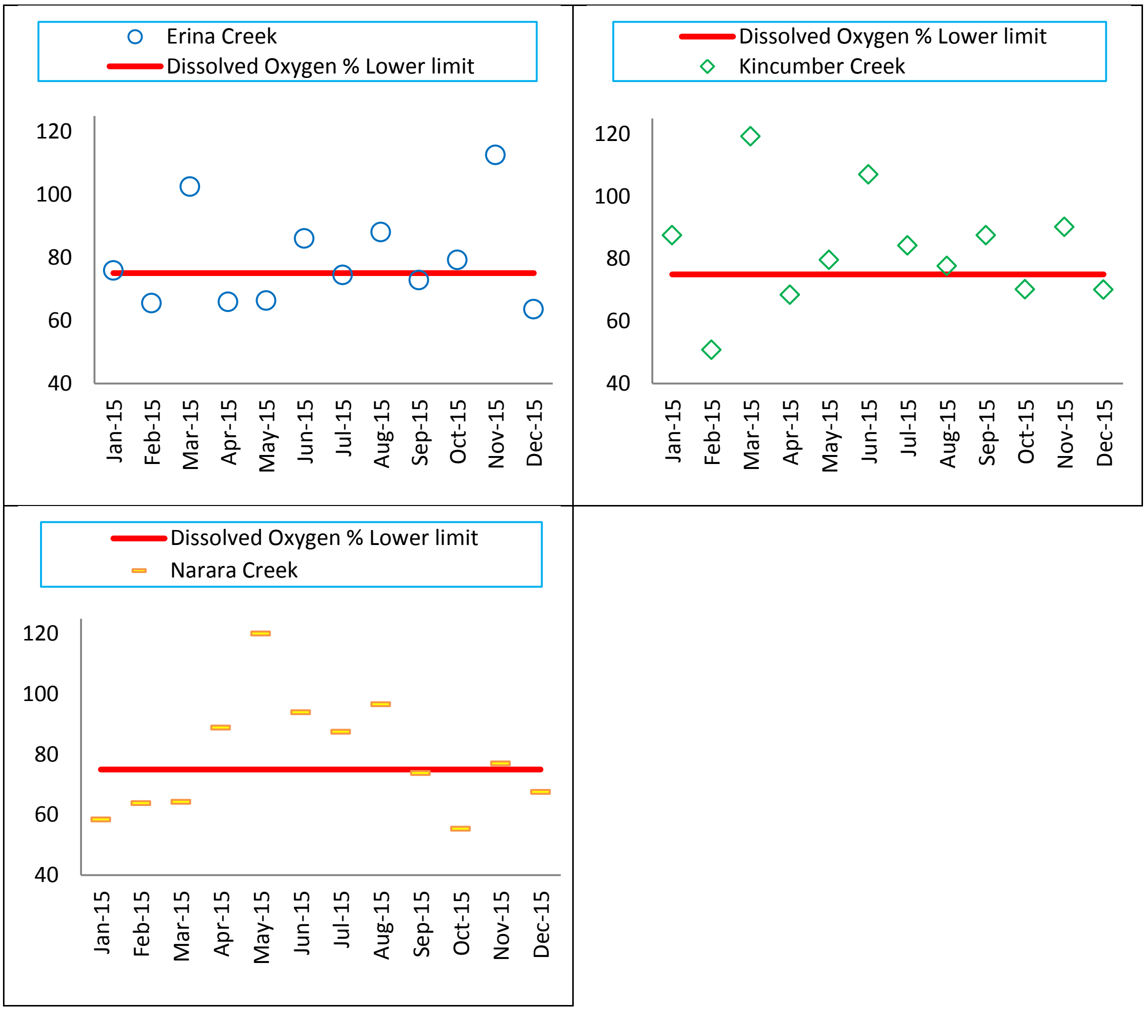

Figure 41: Dissolved Oxygen results for Brisbane Water Estuary Creek sites during 2015. The upper limit trigger values are based on ANZECC 2000 guidelines and historical data for the site.

Dissolved oxygen levels were frequently above the lower limit threshold for all three sites.

4.4.8.4 Soluble Reactive Phosphorus

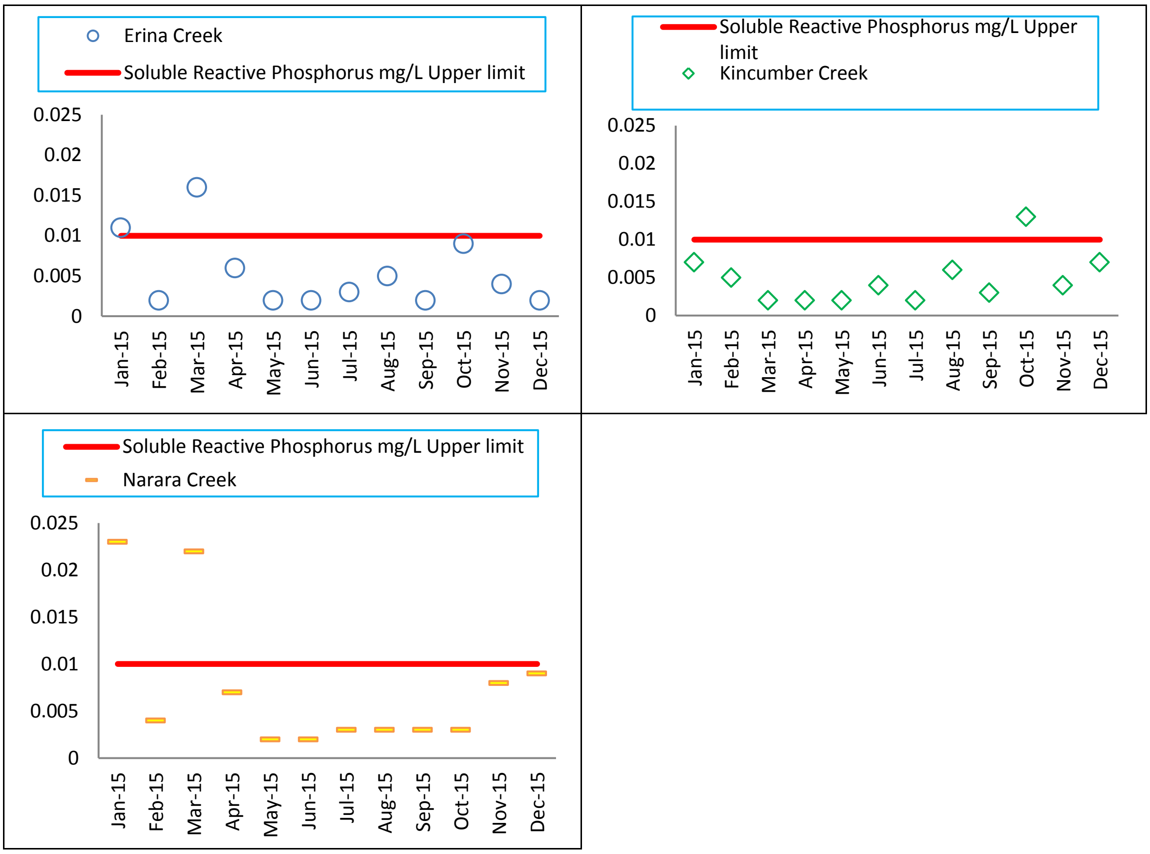

Figure 42: Soluble reactive phosphorus results for Brisbane Water Estuary Creek sites during 2015. The upper limit trigger values are based on ANZECC 2000 guidelines and historical data for the site.

All three sites were frequently below the upper threshold for soluble reactive phosphorus.

4.4.8.5 Oxidised Nitrogen

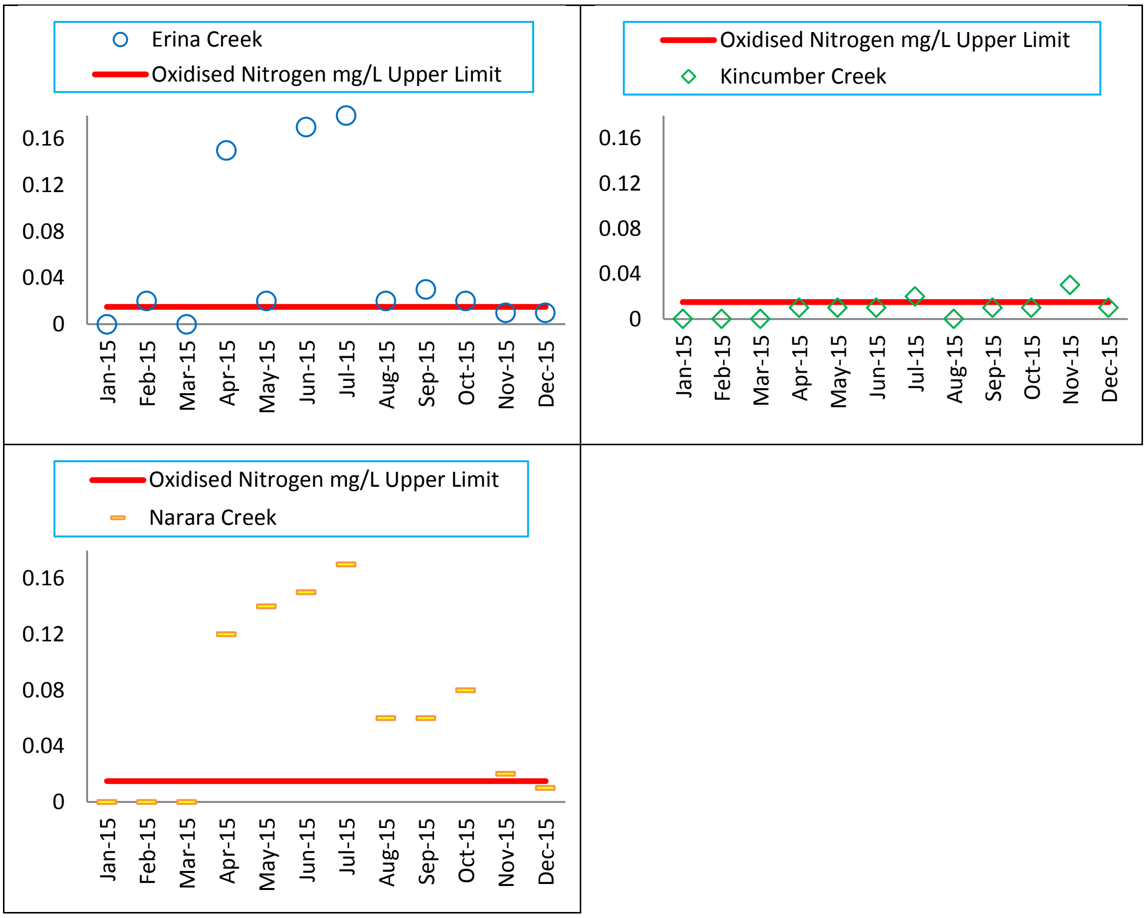

Figure 43: Oxidised Nitrogen results for Brisbane Water Estuary Creek sites during 2015. The upper limit trigger values are based on ANZECC 2000 guidelines and historical data for the site.

Erina Creek and Narara Creek were frequently above the upper threshold limit for oxidised nitrogen, whilst Kincumber Creek was frequently below.

4.4.8.6 Total Nitrogen

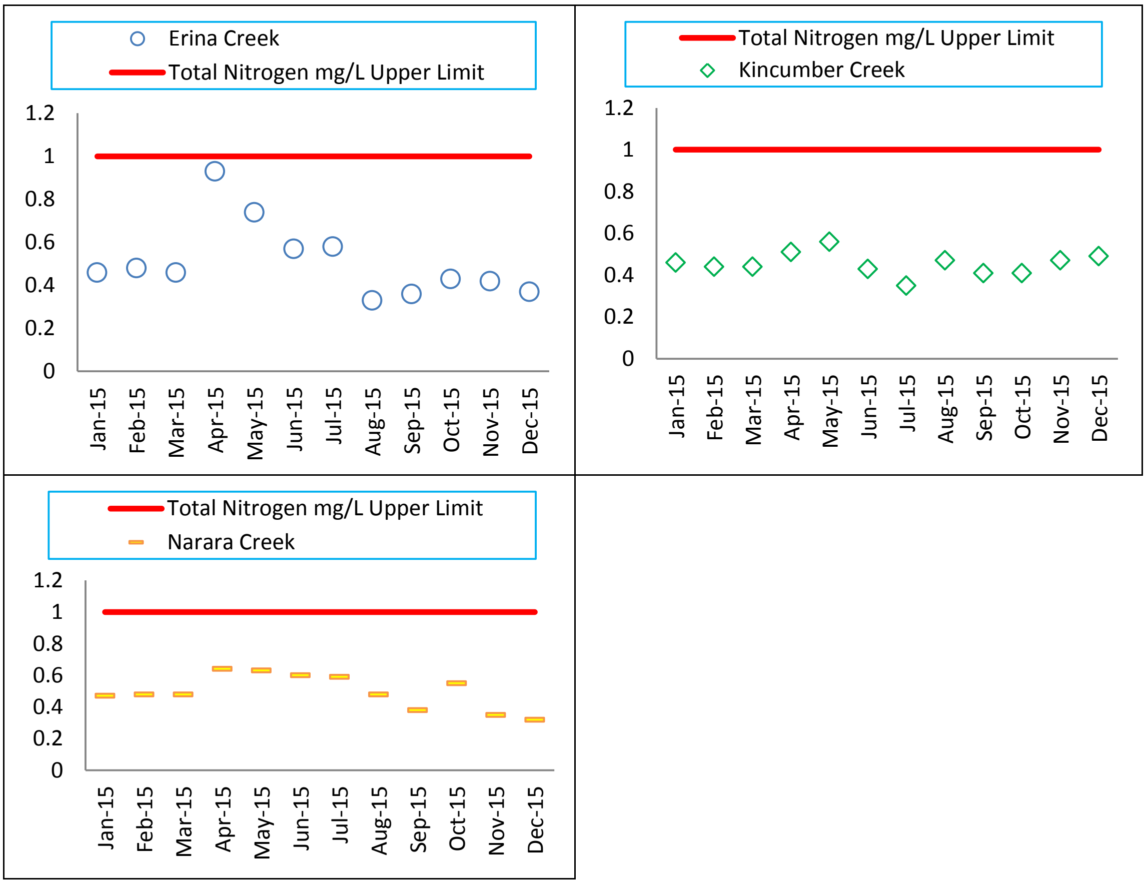

Figure 44: Total Nitrogen results for Brisbane Water Estuary Creek sites during 2015. The upper limit trigger values are based on ANZECC 2000 guidelines and historical data for the site.

All three creek sites were below the upper limit threshold for total nitrogen.

4.4.8.7 Total Phosphorus

Figure 45: Total Phosphorus results for Brisbane Water Estuary Creek sites during 2015. The upper limit trigger values are based on ANZECC 2000 guidelines and historical data for the site.

All three creek sites total phosphorus levels were frequently below the upper limit threshold.

4.4.8.8 Turbidity

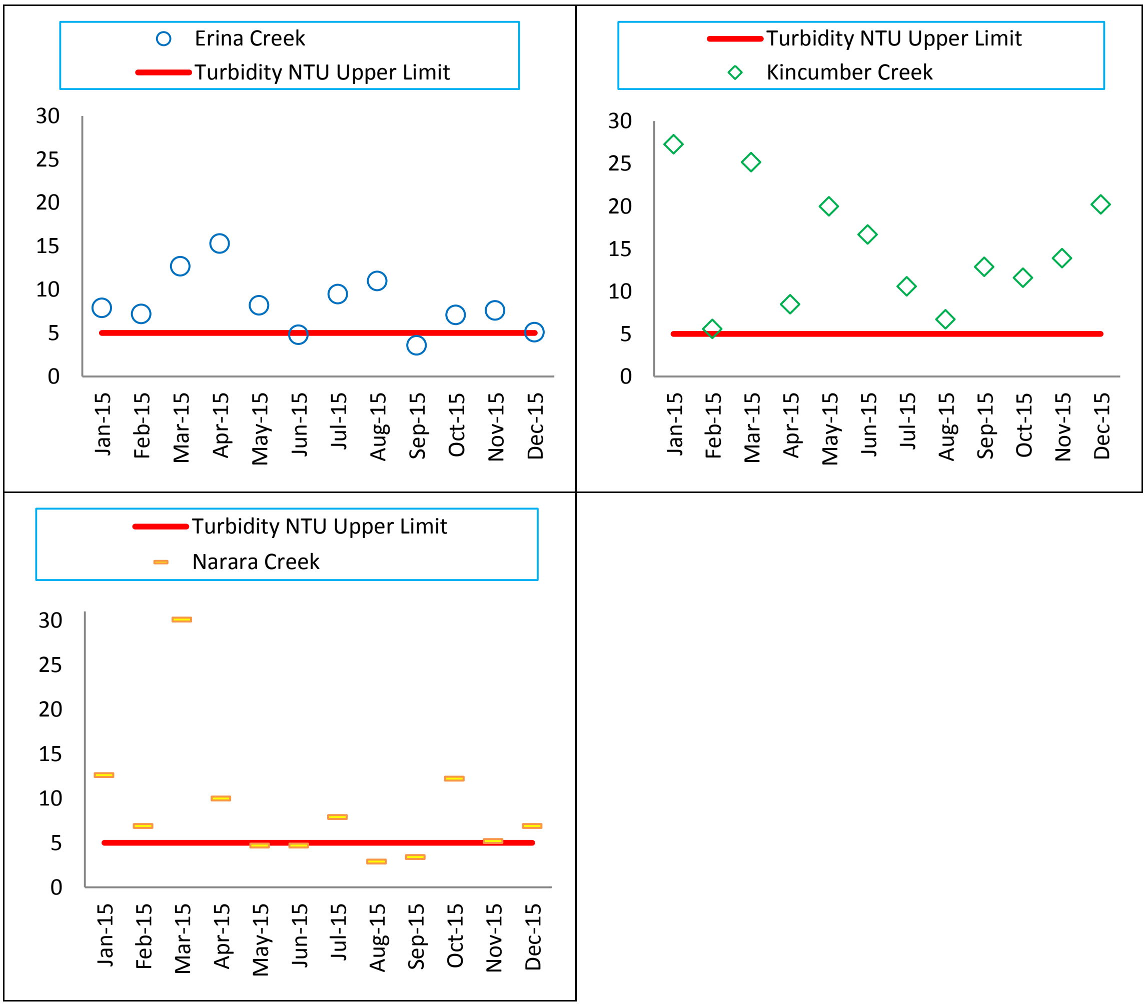

Figure 46: Turbidity results for Brisbane Water Estuary Creek sites during 2015. The upper limit trigger values are based on ANZECC 2000 guidelines and historical data for the site.

Turbidity levels were frequently higher than the upper limit threshold at all three creek sites.

5.0 Conclusions

Overall the water quality of Gosford City Waterways is predominantly good to very good. Eight (8) sites out of 10 sites received a scorecard value of seven and above, with corresponding report values ranging from B- to A+ (Figure 2). Compared with results from previous years as early as 2008, most sites water quality results were maintained or improved during the 2015 reporting period. The only exception was Narara Creek which declined by one score (Figure 3), bringing the site in line with the score card value received for 2008.

During 2015 water quality results showed very good water quality at all the Brisbane Water Estuarine sites of Booker Bay, Cockle Creek and Woy Woy Bay. These sites are large deep bodies of water with sandy substrates, tidal movements and a high degree of flushing. Water quality at these sites was maintained or improved compared with water quality data collected over the past 7 years.

The ICOLLS received a range of water quality scores, with Terrigal Lagoon and Wamberal Lagoon receiving the best results in 2015, showing good water quality. Cockrone Lagoon also returned a good water quality result. These three lagoon sites maintained or improved their water quality compared with previous years. Avoca lagoon showed fair water quality results which are consistent with results received in 2014 and 2013, showing water quality has been maintained. The lagoon sample sites are shallow predominantly closed systems that receive flushing and tidal movements in the days and weeks when the lagoons are open to the ocean. Terrigal lagoon is open to the ocean more often than the others which may have resulted in improved water quality. Scientific studies at Avoca lagoon has shown a high influence of groundwater input into the catchment which may explain the high nutrient levels at this location (Damien Maher, Mitchel Callm Isaac Santos, Paul Macklin and Bradley Eyre, 2014).

The Brisbane Water Creek sites received good to fair results, with Erina Creek and Kincumber Creek showing slightly better water quality than Narara Creek. Erina Creek and Kincumber Creeks water quality were maintained compared with previous years, however Narara Creeks results showed a one point decline from the last 6 years. The Creek sites are shallow, with muddy substrates that are influenced by tidal movements and a moderate level of flushing.

Waterway monitoring is only one means by which the environmental health of a catchment is understood. Other monitoring which could contribute to a better understanding of the environmental health of a catchment includes macro invertebrate surveys and vegetation assessments. As water quality monitoring provides only a 'snap shot' of the current health of a waterway, when water quality information is collected and used in conjunction with other monitoring methods the health of a waterway can be better understood.

Council has continued to undertake management actions and objectives identified in the Brisbane Water Estuary Management Plan, the Coastal Zone Management Plan for Brisbane Water, and Coastal Lagoons Management Plan for Gosford Coastal Lagoons. The major elements of these plans are focused on improving water quality through planning, compliance, works, education and research and monitoring.

6.0 Recommendations

- The Gosford City Waterways routine water quality monitoring program should continue into the future.

- Council to continue to undertake management actions and objectives listed in Council Management Plans.

- Historical water quality data should continue to be compiled and analysed to determine trends.

- Future Gosford City Waterways reports should continue to compare historical data with data from the preceding reporting years to determine whether the Gosford Waters are improving or declining.

- Undertake catchment audit/s at sites that decline or exhibit fair, poor and very poor water quality grades.

- Continue to review current reporting methods and current target scores for each monitoring site to ensure they are appropriate.

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8.0 Glossary

Algae: simple chlorophyll- bearing plants which are capable of photosynthesis. They may occur in all aquatic environments and may be microscopic in size.

Ammonia: Ammonia is present naturally in surface and wastewaters and its concentration is generally low in groundwater because it absorbs to soil particles and clays and is not leached readily from sills (Rowe and Abdel- Magid, 1995). It is a nitrogen source for algae (CSIRO, 1996.) Ammonia is largely produced by de-aeration of organic nitrogen-containing compounds and by hydrolysis of urea (Rowe and Abdel- Magid, 1995).

Chlorophyll a: Chlorophyll a is a biological pigment which enables plants, including algae, to photosynthesize. The pigment concentration is measured in water samples to provide an indication of the amount of phytoplankton (microscopic, suspended plants) in the water. High concentrations may identify undesirable growth of phytoplankton.

Conductivity: Conductivity or electrical conductivity is a measure of the ability of an aqueous solution to conduct an electrical current (APHA, 1998). This ability depends on the presence of ions; on their total concentration, mobility and valance; and on the temperature of measurement. Solutions of most inorganic compounds are relatively good conductors whilst molecules of organic compounds that do not ionize in solution conduct current very poorly.

Dissolved Oxygen: Oxygen in water is measured as dissolved oxygen (DO). The saturated concentration of DO in water is dependent on temperature, altitude and the presence of other solutes. Pure water at equilibrium with moist air at sea level is 100% saturated when the concentration of oxygen at $0^{O}C$ equates to 14.63mg oxygen per litre of water. Low DO% saturation may indicate eutrophication problems. Super saturated conditions, when DO is greater than 100% may occur in waters when oxygen input, due to algal or plant photosynthesis, exceeds that lost from the water-air interface by respiration or diffusion to the atmosphere.

Enterococci: A group of streptococcal bacteria, usually non-pathogenic, found in the human and animal intestinal tract.

Nitrogen: The principle anthropogenic sources of N which may reach the coastal zone are agricultural runoff and sewage discharges (Brodie, 1995). Other sources of nitrogenous compounds include decaying organic vegetation, leachate from landfill, animal faeces, industrial wastewater and fertilizers, urban runoff and atmospheric fallout of gaseous nitrogenous compounds. The dissolved forms of nitrogen include ammonia (NH_3 and NH_4) and oxidised nitrogen (NO_2 and NO_3). The particulate form of nitrogen is mainly organic. Nitrogen is essential to plant growth but in large amounts can contribute to excessive plant growth (possibly favoring exotic or algal species or algal blooms) that can cause eutrophication of waters.

pH: pH is a measure of the hydrogen ion concentration in the water and is an indicator of the acidity or alkalinity of water. The pH scale ranges from 0 which is extremely acidic to 14 which is extremely alkaline. A pH of 7 is neutral. pH can affect the toxicity of pollutants such as ammonia, aluminium and cyanide and the rate at which pesticides break down soils.

Phosphorus: Phosphorus is one of the main nutrients required for algae and aquatic plants. The major anthropogenic inputs of phosphorus to coastal waters are agricultural runoff and sewage discharges (Brodie, 1995). Phosphorus concentrations are one indicator of a rivers potential for algal production. Human activity may increase the amount of phosphorus entering rivers such as from stock or human effluent, as a residue from fertilizer application or attached to eroded soil particles. The dissolved form of phosphorus is mainly phosphate (PO4).

Suspended Solids: Suspended solids refer to the mass of material suspended in the water. Water clarity will decrease with increasing concentrations of suspended solids (Sinden and Wainsbrough, 1996). High levels of suspend solids have the potential to reduce the amount of light available to benthic organisms and aquatic organisms for their metabolism and photosynthesis.

Temperature: Temperature is the basic physical characteristic of the water body (Sinden and Wainsbrough, 1996). Temperature fluctuations occur naturally between seasons, however unnatural variation to the season cycle can be detrimental to an aquatic ecosystem.

Turbidity: Turbidity is the measure of the light scattering properties of water. It indicates how much silt, algae and other material are suspended in the water column. Highly turbid water may harm aquatic organisms. Some streams are naturally turbid due to the clay soils in their catchment.

9.0 Appendix A

9.1 Raw Data for Gosford Waters 2008- 2015

All **monthly raw field data from 2008- 2015** is available upon request by emailing ask@centralcoast.nsw.gov.au Attention: Environmental Health Officer, Development and Compliance.

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