Water Quality Monitoring Program

2006–2007 Annual Report

Water Catchments Team

Acknowledgements:

Data used in this 2006-2007 Annual Water Quality Monitoring Report was organised and collected by Rosemary Snowdon under the supervision of Anthony Collins and David Beharrell - Catchment Remediation Managers and the direction of Dr Ross McPherson Manager, Water Catchments, Hornsby Shire Council. The report was prepared by Paul Fredrickson. Consultants were GHD for macroinvertebrate and diatom collection, identification and interpretation. Laboratory testing of waters was carried out by ALS Environmental; algal identifications by MicroAlgal Services. Assistance with sampling and data gathering was provided by Rosemary Snowdon, Erran Woodward, Peter Coad, Ross McPherson, David Bolton, Kristy Guise, Neil Keraunos, David Leggett and Katie Clarke. GIS assistance was provided by David Leggett.

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Executive Summary

Hornsby Shire Council established a water quality monitoring program in 1994 to assess the impact of land use on waterways within the Shire through time. The data is utilised by Council for the Catchment Remediation Program, environmental assessments, modelling and education programs, and is made available through the Annual Reports to Community and interested Authorities.

During the 2006-2007 monitoring period 45 sites were monitored regularly. Most water sampling sites have been selected on the basis of different land use types, including urban, industrial, rural, bushland and estuarine, with the aim of assessing ecosystem health downstream of these land uses. Two recreational swimming areas were tested weekly during the summer season. Water was also tested so as to assess performance of catchment remediation devices, of water reuse projects and of devices to treat seepage waters at tip sites. The water quality was compared with reference sites (at undeveloped catchments in National Parks) and with Guidelines set down in the National Water Quality Management Strategy and by the National Health and Medical Research Council.

Physical, Chemical and Bacterial Monitoring

At each site the physico-chemical measurements temperature, conductivity, salinity, pH, dissolved oxygen and turbidity were recorded in-situ with a portable water quality analyser. General observations on appearance, odours, nuisance organisms were also recorded. Water samples were simultaneously collected for laboratory testing for suspended solids, bacteria and nutrients. At selected estuarine sites, where algal blooms have occurred in the past, samples were also collected for chlorophyll-a analysis and for identification and cell counts of planktonic algal species.

In order to assure the integrity of the results obtained, all probe measurements and sample collections are carried out according to strict quality control procedures. Laboratory based chemical and bacterial testing is done by a NATA accredited laboratory.

Biological Monitoring: Macroinvertebrates, Diatoms and Planktonic Algae

Since 2002 monitoring of the environmental health of selected freshwater sites in Hornsby Shire has been carried out by collection and identification of biological indicator species; namely macroinvertebrates and diatoms. The presence and abundance of various species, some very sensitive to pollution and other more tolerant, provide a good indication of decline or improvement in water quality over a longer time frame. In this reporting period this monitoring was carried out by the consultants GHD Pty Ltd. Collection of macroinvertebrates was undertaken using small mesh sieves along stream edges and riffles. The small collected animals were sorted in the field following the standardised methodology. Diatoms were generally collected by scraping adhering growths off rocks removed from riffle sections of streams. Identification of macroinvertebrates and diatoms using the most recent taxonomic keys is carried out by consulting specialists.

Estuarine waters at Berowra Waters have been surveyed since 1997 for algal (phytoplankton) species as part of Council's algal bloom investigations. During the 2006-2007 period samples have been collected monthly at two sites in Berowra Waters and submitted to Microalgal Services for identification.

Continuous monitoring of planktonic algal growths in Berowra Waters using a moored sensor to give real-time chlorophyll-a concentrations is reported separately in the 2006-2007 Estuary Management Report.

Water Quality Findings

Those sampling sites located in areas with the least disturbance, or furthest downstream from land developments, usually had water quality results within or close to the current water quality Guidelines. The two reference creeks, which are located within undeveloped catchments within National Parks, are classified as healthy according to Guideline criteria; these sites provide a good baseline against which to compare other creeks in the Shire.

Most of the creeks draining urban and rural areas conform to most water quality Guideline values much of the time, however, they suffer from occasional high levels of contaminants during both wet or dry times which put severe stress on the aquatic ecosystems downstream.

The highest concentration of contaminants was present in sampling sites close downstream of industrial areas, and often downstream of urban and rural areas, especially after rainfall events. At other times of the years, when drought conditions and very low stream flows occurred, suspended solids and turbidity results were generally acceptable, but associated dissolved oxygen readings were sometimes very low at a number of sites.

Overall the faecal coliform levels were higher than last year, due to numerous short wet weather events causing several peaks in concentrations arising from industrial, urban and rural areas. Failing sewerage infrastructure, frequent sewer overflows and septic seepages are considered to be prime sources of high faecal coliform concentrations found in streams within parts of the Shire.

The nutrients measurements of total nitrogen and phosphorus were consistently high at all 3 industrial sites with the highest levels found at Larool Creek (Site 10) and Sams Ck (site 13). Concentrations of these nutrients in creeks below the urban areas were elevated (compared to Guidelines) at several sites. Sources of nutrients in urban areas are considered to be from fertilisers, detergents, eroding soils, decomposing lawn clippings, pet faeces or sewerage overflows.

Elevated nutrient levels were also found in streams below rural areas, particularly Glenorie Creek (Site 80) where all samples were above nutrient Guidelines. These levels point to leakage from onsite sewage systems. On-site and illegal disposal of effluent can be associated with high faecal coliform and nutrient levels (in particular oxidised nitrogen and ammonia).

Total nitrogen, oxidised nitrogen and chlorophyll-a were slightly elevated in the estuary at Berowra Waters near the car ferry (Site 60) and at Calabash Bay (Site 61). Nitrogen loadings are potentially being received from upper catchment activities such as fertiliser application, failing sewer pipes, on-site sewage systems and treated discharge from Sydney Water's two Sewage Treatment Plants (STPs). The occurrence of algal blooms, when they occasionally occur within the estuary, may be attributed to the elevated concentrations of total nitrogen and nitrate.

The composition of the macroinvertebrate and diatom communities within freshwater creeks in the Shire are strongly influenced by catchment landuse types, water quality and seasonality. In creeks below industrial areas there has been a reduction of diversity and abundance of macroinvertebrates in the 2006/2007 reporting period when compared to previous years, and these macroinvertebrate populations continue to be depauperate and composed of taxa tolerant of disturbed conditions. This indicates that conditions at industrial sites are declining over time, while the urban and rural sites have essentially remained the same. Sites at Colah Creek, Tunks Creek and the reference site, Smugglers Creek are considered to support the healthiest communities. Diatom monitoring indicates that landuse activities within the catchment are influencing the structure of diatom communities. The composition of planktonic algae in the Berowra Creek estuary is similar to previous years with no significant occurrences of problematic species.

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Hornsby Shire

The Hornsby Shire is situated approximately 25 km north west of Sydney and includes extensive areas of bushland and waterways, urban and rural development. The aesthetic values of the bushland and waterways are contributing factors towards attracting people to live within the Shire.

Hornsby Shire contains an area of 510km^2 which of which 67% (342.9km^2) is bushland. Rural landuses constitute 20% (101.2km^2) whilst 13% (65.9km^2) is a mixture of urban and industrial uses. Water catchments within the Shire include Berowra Creek, Lane Cove River, Cowan Creek and Hawkesbury River (Figure 1).

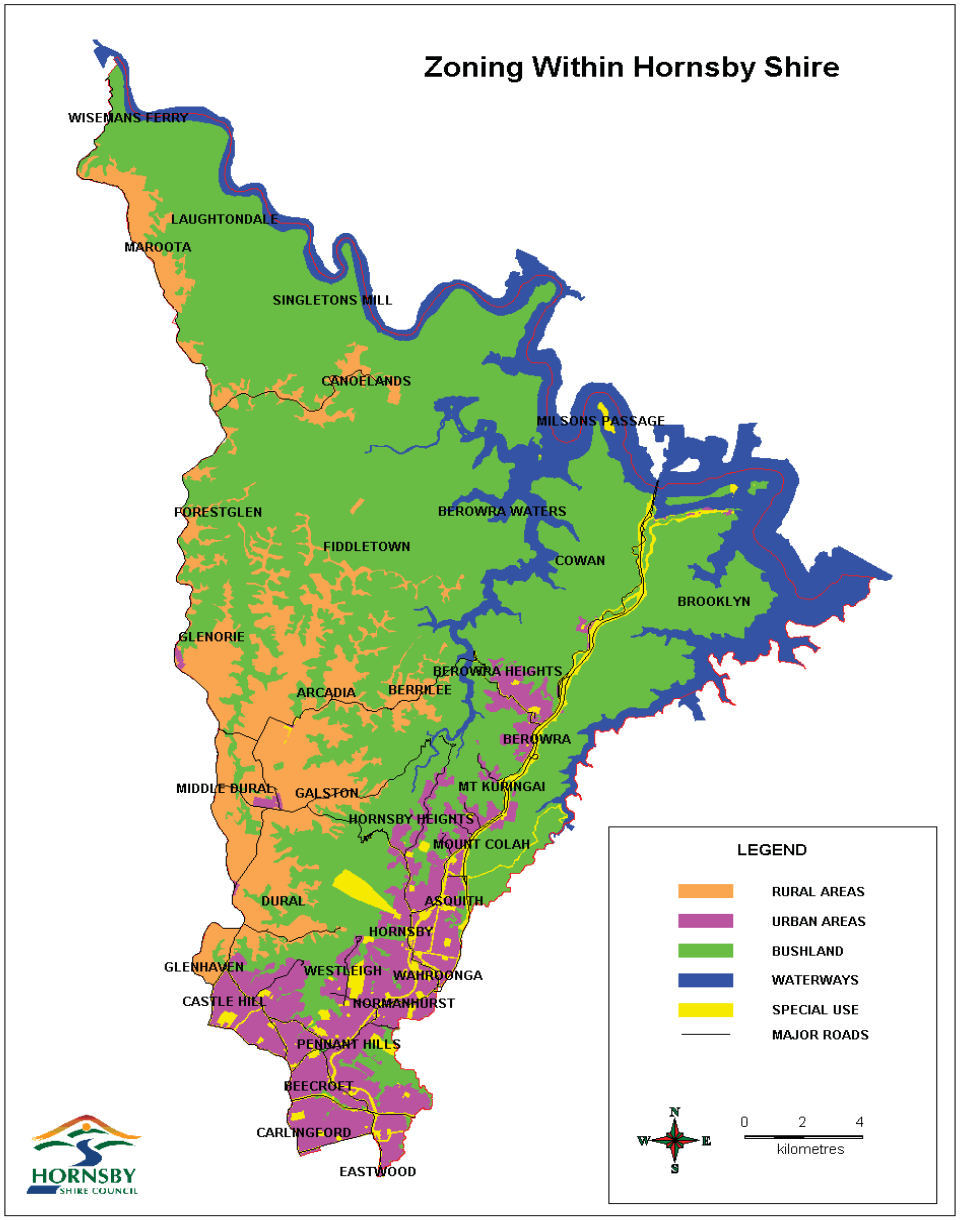


Figure 1: Landuse map of Hornsby Shire

1.1 Berowra Creek Catchment

The Berowra Creek catchment is bounded on the south by Castle Hill Road, to the west by Old Northern Road to the north by the Canoelands Ridge and to the east by the Pacific Highway. All of the Berowra Creek Catchment is within the jurisdiction of Hornsby Shire Council.

This catchment contains significant bushland areas which include Marramarra National Park, Muogamarra Nature Reserve and Berowra Valley Regional Park. Landuses in this catchment include bushland, rural, developed and developing urban, light industrial and commercial. Most urban and industrial activities occur in the eastern and southern regions of the Catchment.

1.2 Lane Cove River Catchment

Seven local government authorities have jurisdiction over the Lane Cove River Catchment. Only the upper reaches of the Lane Cove River Catchment are within Hornsby Shire. This catchment is dominated by developed urban landuses and some commercial areas as well as bushland areas such as the Lane Cove National Park. This is Council's only catchment that drains to Sydney Harbour.

1.3 Cowan Creek Catchment

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

1.4 Hawkesbury River Catchment

The Hawkesbury River Catchment within Hornsby Shire is divided into two areas which includes the Wisemans Ferry/Maroota region as well as the Brooklyn area. These areas drain directly to the Hawkesbury River. Landuses in this area include small farming ventures, market gardening, residential, marinas, boat ramps, aquaculture and fishing (commercial and recreational). A sewage treatment plant (STP) is currently under construction at Brooklyn to treat water from Brooklyn and Dangar Island residences. It is planned to commence discharge of the tertiary treated effluent into the Hawkesbury River from the highway bridge into an area of strong tidal current starting in late 2007.

Water quality monitoring program

The objectives of this program are to:

- Undertake long term monitoring of the catchments within Hornsby Shire to assess trends in water quality from both point and diffuse pollution sources.
- Compare the observed water quality data with nationally accepted Guidelines for fresh and marine waters; specifically for the water values associated with the *protection of aquatic ecosystems* and *recreational water uses*.
- Use biological monitoring (Macroinvertebrates and Diatoms) of representative sites to complement the water quality program
- Determine the effectiveness of Catchments Remediation assets in removing pollutants from the waterways.
- Use water quality data to calibrate and support catchment/pollutant modelling.

The sampling site positions have generally remained unchanged since the program started, with additional sites being included as the need has arisen. For example, additional sites have been

progressively added in order to monitor the effectiveness of devices installed by Council to improve stormwater quality entering local creeks (ie. Catchments Remediation Devices), and to assess baseline data in the Hawkesbury River prior to commissioning of the STP at Brooklyn.

Annual water quality monitoring reports have been produced for periods;

- October 1994 to December 1995
- January 1996 to December 1996
- January 1997 to December 1997
- January 1999 to December 2000
- January 1999 to June 2000
- July 2000 to June 2001
- July 2001 to June 2002
- July 2002 to June 2003
- July 2003 to June 2004
- July 2004 to June 2005
- July 2005 to June 2006

The reports for recent years can be accessed on Council's web site at http://www.hornsby.nsw.gov.au/environment/ (choose subcategories "Water Catchments" then "Water Quality". Earlier reports are available in printed format in local libraries. This report addresses water quality during the July 2006 – June 2007 sampling period.

The Hornsby Shire Council water quality monitoring program commenced in October 1994. Council scientific staff have carried out inspection, on-site water testing and water sample collection at all sites since the program inception. Collected waters are sent for more detailed analysis at specialist, industry accredited laboratories.

At selected representative sites over the past 5 years biological monitoring and reporting (using macroinvertebrate and diatoms as indicator organisms) has been carried out for Council under contract by Australian Museum Business Services and, since 2005 by GHD Pty Ltd. A brief description of the program and results on the macroinvertebrate and diatom monitoring have been included in this report. More detailed data can be accessed via the separate reports produced by the consultants as part of the program.

Water Quality Guidelines

The water quality data obtained in Hornsby Council's monitoring program are compared with current Guidelines for water quality; these are set down in the National Water Quality Management Strategy (NWQMS) and by the National Health and Medical Research Council (NHMRC). Specifically the water values of *aquatic ecosystem protection* and *recreational water use* within local creeks and estuaries are being targeted by Council's water monitoring quality program.

1.5 Aquatic Ecosystem Protection

The objective adopted for the *protection of aquatic ecosystems*, as defined by ANZECC/ARMCANZ (2000) in the NWQMS is to "maintain and enhance the 'ecological integrity' of freshwater and marine ecosystems, including biological diversity, relative abundance and ecological processes". 'Ecological integrity', as a measure of the health or condition of an ecosystem, has been defined by Schofield and Davies (1996) as "the ability of the aquatic ecosystem to support and maintain key ecological processes and a community of organisms with a species composition, diversity and functional organisation as comparable as possible to that of natural habitats within a region."

Biological systems are extremely variable, and coupled with the marked differences in sensitivity of different ecosystems and biological communities to particular pollutants and other stressors makes it essential that management occurs on an ecosystem to ecosystem basis (ANZECC, 1992).

Consequently, this water quality monitoring program has included sites in creeks and estuary located downstream of the various human activities and land uses throughout the Shire. In addition two *reference sites* are monitored which represent the water quality of typical local ecosystem which are essentially free of any anthropogenic impact and influences. These reference sites provide baseline data which, together with the ANZECC/ARMCANZ Guideline values, can be compared with creeks elsewhere in the Shire to determine the type and extent of impacts our activities and developments are having on our creeks and waterways.

Council's program for assessing ecosystem health involves measurement of a number of 'indicators' of ecosystem health; namely (1) *physical and chemical quality of the water*, (2) abundance of *bacteria* typically sourced from human faeces (faecal coliforms and Eschericheri coli and/or enterococci) and (3) abundance and diversity of *indicator organisms.* In the estuary the indicator organisms chosen are the planktonic algae and in the freshwater creeks they are the macroinvertebrates and diatoms

The physical and chemical indicators of water quality have been chosen from the National guidelines published by ANZECC/ARMCANZ (2000). The Guidelines recommend 'trigger' values for different regions around Australia. Hornsby Shire Council has adopted values for South-East Australia and specifically for lowland rivers (Freshwaters) and Estuaries (Marine Waters). Further, the default trigger values are set for 'slightly disturbed' ecosystems. Failure to comply with these criteria indicates that the biological community in the waterway is under threat. Table 1 below sets out the Guideline values that have been used for the current years reporting. Reports prior to 2002 have used the ANZECC 1992 Guidelines.

Table 1: Comparison of ANZECC (1992) and ANZECC/ARMCANZ (2000) Guidelines for the protection of aquatic ecosystem health; physical and chemical stressors

Water Quality Parameter	Fresh Waters		Marine andEstuarine Waters	
ANZECC guideline	1992	2000	1992	2000
PH	6.5 – 9	6.5 - 8.0	<0.2 pH unit change	7.0-8.5
Conductivity	<1.5 ms/cm	<0.3ms/cm	< 5% change from background	NR
Turbidity	<10% change seasonal mean concentration (15 ntu)	<6ntu	<10% change seasonal mean concentration (15 ntu)	<10ntu
Dissolved Oxygen	> 6mg/L (80 to 90% saturation)	Between 85% and 110% saturation	> 6mg/L (80 to 90% saturation)	Between 80% and 110% saturation
Temperature	Less than 2 deg. Celsius increase	Between 11.7 ^{o}C and 20.1 ^{o}C	Less than 2 deg. Celsius increase	NR
Salinity	1ppt	NR	Less than 5% change to background levels	NR
Oxidised nitrogen (NOx)	0.1 - 0.75 mg/L	<0.04mg/L	0.01 - 0.1 mg/L	<0.015mg/L
Ammonia	0.02 –0.03mg/L	<0.02mg/L	NR	<0.015mg/L
Total Nitrogen	0.1 - 0.75 mg/L	<0.350mg/L	0.01 - 0.1 mg//L	<0.3mg/L
Total Phosphorus	0.01 - 0.1 mg/L	<0.025mg/L	0.005 - 0.015 mg/L	<0.03mg/L
Soluble reactive P	NR	<0.02	NR	<0.005
Suspended solids	< 10 mg/L(1)	< 10mg/L(1)	< 10mg/L(1)	NR
Chlorophyll a	2 - 10 *ug*/l	<3 *ug*/l	1 - 10 *ug*/l	<4 *ug*/l

(1) - SPCC (1989), value of 10mg/L for Suspended Solids used as interim Guideline value.

NR - Not recommended

1.6 Recreational Water Quality

The National Health and Medical Research Council (NHMRC, 2006 have released Guidelines for managing risks in recreational water. The Guidelines represent a major revision of the previous

Guidelines (ANZECC, 1992) and concentrate on preventative methods in managing recreational waters.

This approach offers information on the local influences on recreational water quality, as well as numerical information on the likely level of contaminants. The results can be used to:

- Classify beaches in order to support informed personal choice
- Provide on-site guidance to users on the relative safety of the water
- Assist in identifying and promoting effective management interventions
- Provide a basis for regulatory requirements, and an assessment of compliance with such requirements (NHMRC, 2006)

An extract from the NHMRC Guidelines for recreational water quality are summarised in Tables 2 and 3.

Table 2: Summary of recreational water quality Guidelines (NHMRC, 2006)

Characteristic	Guideline	Comment
Microbial activity	Preventative risk management practices should be adopted to ensure that designated recreational waters are protected against direct contamination with fresh faecal material, particularly of human or domesticated animal origin.	The main health risks are from enteric viruses and protozoa
Cyanobacteria and algae	Coastal and estuarine recreational water bodies should not exceed: ≤ 1 cells/mL Karenia brevis and/or have history but no current presence of Lyngbya majuscula and/or Pfiesteria (Surveillance mode) > 1-10 cells/mL K.brevis and/or have L.majuscula and/or Pfiesteria present in low numbers (Alert mode) > 10 cells/mL K.brevis and/or have L.majuscula and/or Pfiesteria present in high numbers (Action mode)	A situation assessment and alert levels framework for the management of alga/cyanobacteria in recreational waters has been developed that allows for a staged response to the presence and development of blooms
pH	6.5 - 8.5	A wider pH of 5 – 9 is acceptable for water with a very low buffering capacity
Dissolved Oxygen	> 80%	When considered with colour, odour and turbidity, dissolved oxygen is an indicator of the extent of eutrophication of the water body
Aesthetic aspects	Recreational water bodies should be aesthetically acceptable to recreational users. The water should be free of visible materials that may settle to form objectionable colour. Odour, taste or turbidity; and substances and conditions that produce undesirable aquatic life.	Consumer complaints area useful guide to the suitability of water for recreational use.

Table 3: Classification of Recreation Water Environments (NHMRC, 2006)

	Microbial water quality assessment category (95th percentiles – intestinal enterococci/100 mL)				**Exceptional circumstances**
Sanitary inspection category (susceptibility to faecal influence)	A ≤ 40	B 41-200	C 201-500	D >500	
Very Low	Very Good	Very Good	Follow up	Follow up	ACTION
Low	Very Good	Good	Follow up	Follow up	
Moderate	Good	Good	Poor	Poor	
High	Good	Fair	Poor	Very Poor	
Very High	Follow up	Fair	Poor	Very Poor	
Exceptional circumstances	ACTION				

In addition to the parameters listed, Council measured a number of physico-chemical parameters (total phosphorus (TP), total nitrogen (TN), turbidity and electrical conductivity (EC)) related to health of aquatic ecosystems which impact on recreational water use. The two sites in Hornsby Shire Council (Hawkesbury River at Brooklyn Baths and Berowra Creek at Crosslands Reserve) are estuarine sites so they were assessed against the parameters in Table 1 for 'marine and estuarine' ecosystem type.

Previous assessments of the two main recreational water sites by Council led to the classification of the Brooklyn Baths site as "Low Risk" and Berowra Creek at Crosslands Reserve as "Moderate Risk" (Hornsby Shire Council, 2006a). This led to the monitoring schedule carried out over summer 2006-2007.

Sampling Sites

1.7 Freshwater Sites

Freshwater streams were selected according to the catchment landuse type. The sampling site on each stream was chosen based on reliability of stream flow, accessibility and ability to monitor during stormwater flows. All sites were monitored for physical, chemical and bacterial parameters and a subset of sites were also monitored for biological parameters (macroinvertebrates/insects and diatoms/algae) (see Table 4). Water sampling occurs at the beginning of each month at a total of 24 freshwater stream sites.

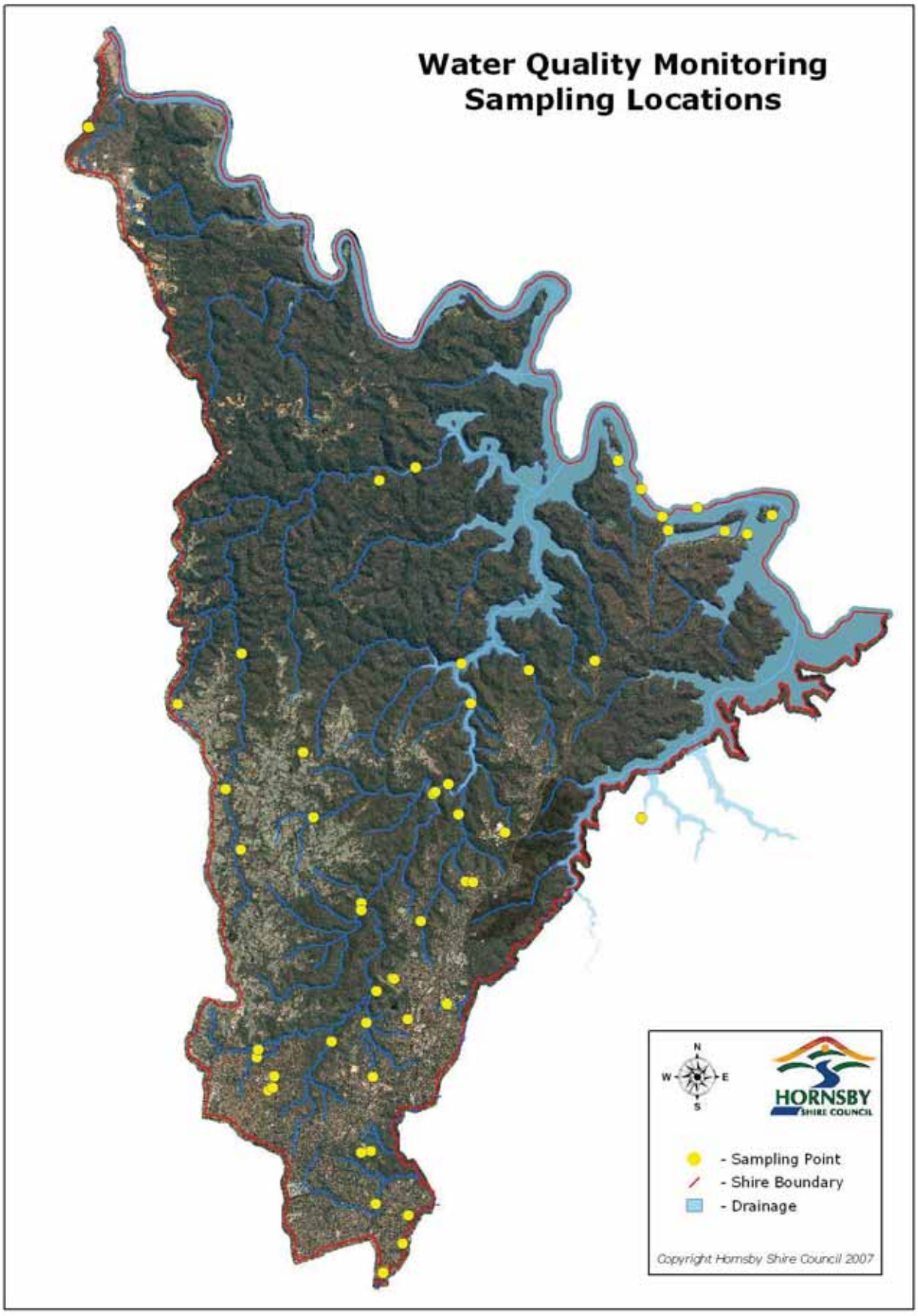
Three of the freshwater sites are located close below industrial/commercial areas in the Shire which are considered to be under more intense landuse pressure and subsequently require a more frequent sampling regime to detect any changes in water quality. Thus they were monitored at fortnightly intervals.

Table 4: Location of Freshwater monitoring sites on freshwater streams

Site	Location	Samples per month	Biological Parameters	Catch-ment
1	Berowra Creek, 200m N of concrete road bridge at Galston Gorge	1	M, D	B
2	Tunks Creek, Galston Gorge under wooden truss bridge	1	M, D	B
4	Berowra Creek, Westleigh 500m down track at end of Barkala Pl	1	M, D	B
5	Pyes Creek, Cherrybrook, end of Christine Place	1	M, D	B
6	Georges Creek, Dural, off Fallon Drive	1	M, D	B
8	Devlins Creek, Sutherland Rd, Cheltenham	1	M, D	LC
10	Larool Creek, Sefton Rd, Thornleigh	2	M, D	B
12	Hornsby Creek, upstream of Leighton Pl road bridge, Hornsby	2	M, D	C
13	Sams Creek, Hamley Rd, Mt Kuring-gai	2	M, D	B
23	Waitara Creek, 100m upstream from WHSTP outfall, Hornsby	1		B
36	Murray Anderson Creek, off Smiths Creek	1		C
37	Smugglers Creek, off Marramarra Creek	1	M, D	B
39	Joe Crafts Creek, above confluence with Berowra Creek	1	M, D	B
42	Colah Creek, upstream of Wylds Road bridge, Glenorie	1	M, D	B
43	Calna Creek, above confluence with Berowra Creek	1		B
45	Berowra Creek, at Fishponds Waterhole, Hornsby	1	M, D, Chl	B
46	Terrys Creek, end of Somerset St Nth, Epping	1	M, D	LC
49	Still Creek, end of Mansfield Road behind tennis court	1	M, D	B
52	Calna Creek, 300m upstream of HHSTP outfall	1		B
62	Cowan Township, accessed via Quarry	1	M, D	B
63	Colah Creek, via Ben Bullen Road	1	M, D	B
64	Galston Village, via Salaway Place	1	M, D	B
77	Gleeson Creek, end of Oxley Dr, Mt Colah	1	M, D	B
80	Glenorie Creek, Tekopa Ave, Glenorie upstream of GPT	1	M, D	B

KEY: M - Macroinvertebrates D- Diatoms Chl – chlorophyll-a
B – Berowra catchment LC – Lane Cove catchment C – Cowan catchment

Figure 2: Location of Water Quality Monitoring Sites (2006-2007)



1.8 Estuarine sites

Sites sampled to obtain indication of the ecosystem health (EH) and recreation water quality (REC) have been continuously monitored on a regular basis as described below (Table 5).

Table 5: Location of Estuarine water quality monitoring sites – ecosystem health

Site	Location	Monitoring Status	Freq
38	Sandbrook Inlet, Hawkesbury River	EH	M
48	Marramarra Creek at orange orchard	EH	M
60	Berowra Creek, 50 m downstream of Berowra Waters Ferry	EH	M
61	Berowra Creek, mid stream at Calabash Point	EH	M
55	Hawkesbury River at Brooklyn Baths	REC	M
90	Berowra Creek at Crosslands Reserve	EH, REC	M, W*
99	Berowra Creek at Crosslands Reserve (2nd ramp)	REC	W*
100	Berowra Creek at Crosslands Reserve (north beach)	REC	W*

M = monthly; W *= weekly over summer for recreational monitoring

1.9 Brooklyn STP Sites

A number of sites on the Hawkesbury River upstream and downstream of the new Brooklyn STP outfall were added to the estuary monitoring program in 2006 to provide baseline data prior to the commissioning of the Brooklyn STP.

Table 6. Location of Sites for Hawkesbury River Baseline Study for Brooklyn STP

Site	Location	Monitoring Status	Freq
103	Mouth of Milsons Passage (Eastern end)	Pre-STP	M
104	Middle of Hawkesbury River off Peat island	Pre-STP	M
105	Under Hawkesbury River Bridge; 2nd pylon Southern end	Pre-STP	M
106	Middle Sandbrook Inlet, off Fenwicks Marina	Pre-STP	M
107	Middle Hawkesbury north off Long Island	Pre-STP	M
108	Hawkesbury off Bradleys Beach Dangar Island	Pre-STP	M

M = monthly

1.10 Water Treatment Sites

In addition to routine water quality monitoring of streams and estuary, the Water Catchments Team collects water samples at several sites to monitor performance of Council's Catchments Remediation Rate stormwater quality improvement devices and water saving projects. These sites include:

- Constructed wetlands
- Recycled backwash water from Epping and Hornsby Aquatic Centres
- Pennant Hills Nursery irrigation water
- Treated leachate from tip sites

Table 7 shows the sites routinely sampled as part of those programs.

Table 7. Location of CRR Devices, leachate treatment devices or water reuse sites

Site	Location	Sampling frequency*	Catchment
27	Clarinda St wetland - downstream	M	Berowra
28	Clarinda wetland - upstream	M	Berowra
18	Arcadia Tip Leachate Pond	M	Berowra
94	Arcadia Tip treated water tank	M	Berowra
95	Foxglove Oval – upstream	M	Berowra
96	Foxglove Oval – outlet tank	M	Berowra
56	Wisemans Ferry Tip Leachate Pond	Quarterly	Hawkesbury
92	Hornsby Park, pool reuse tap	M	Berowra
102	Epping Pool osmosis reuse water	M	Lane Cove
98	Council nursery reuse water	M	Lane Cove

*M = monthly

Sampling Procedure

1.11 Physical Parameters

In-*situ* measurements were made using a YEOKAL 611 Water Quality Analyser. Parameters measured include temperature, pH, conductivity, salinity, dissolved oxygen and turbidity. The instrument was calibrated in accordance with manufacturer's specifications at the commencement of each sampling day, and checked at the end of the day to identify and correct for calibration drift. Alkalinity was measured in stream samples taken and tested by GHD staff at the time of macroinvertebrate monitoring only, using a standardised test kit as recommended in AUSRIVAS methodologies.

At each site general observations were made on weather conditions, rain, tide, nuisance organisms, oily films, froth, odours, flow, weather conditions and water clarity and colour. These observations and portable analyser measurements were recorded in the field on a pocket PC for later download into Council's database.

1.12 Chemical, Bacterial and Algal Parameters

A number of different sample bottles, provided by the contract laboratories, were used to collect samples at each site. Water samples were taken directly into the plastic bottles held 5-10cm below the water surface. Samples for bacterial testing (for faecal coliforms including Escherichera coli and/or enterococci) were taken in sterile 125ml containers. Samples for nutrient tests were taken in 250ml plastic bottles (already containing 0.5mL concentrated sulphuric acid preservative) and a sample for suspended solids was taken in 1 litre plastic bottles. Water samples for chlorophyll-a analysis were taken at selected sites in 1 litre white plastic bottles. Immediately after collection the water bottles were placed in a cooler box with ice then transported the same afternoon to the laboratory.

At two estuarine sites (sites 60 and 61) samples of the top one metre depth profile were taken using a 1m long plastic bailer tube and added to (1) a 1 litre bottle for Soluble Reactive Phosphorous (this was placed on ice in the cooler box) and (2) to a 200 mL bottle for algal identification. In addition a concentrated algal sample was collected using a phytoplankton net towed for 5 minutes behind the boat at estuarine sites 60 and 61. Both of these algal samples were preserved by adding Lugols solution.

At each site, after all water samples had been collected, the Yeokal data and general observations were recorded as described in section 5.1 above

1.13 Biological Parameters

The program of monitoring macroinvertebrates and diatoms in freshwater streams was designed by Hornsby Shire Council and Australian Museum Business Services (AMBS). The 3 year project was completed in 2005 (AMBS 2005). A new contract with GHD Pty Ltd was commenced soon after and completed in Spring 2007 (GHD 2007). The aim of the projects was to provide consistent and detailed information regarding biological indicators within creeks from selected catchments within the Shire. Sampling, sorting and identification were carried out according to standard procedures set out in AUSRIVAS methodology.

The program involves sampling 18 sites along creeks in Spring and Autumn. The sampling sites are located downstream of various land use types including; urban, rural, rural/urban and industrial. Macroinvertebrate and diatom sampling, in situ water quality readings, and habitat assessments are undertaken at each site. At the same time water quality samples for laboratory analysis are collected at each site.

Algal samples collected in Berowra Estuary at sites 60 and 61 each month (described in section 5.2) were posted to Microalgal Services in Victoria for identification of phytoplankton including abundance of major species.

1.14 Laboratory Chemical and Bacterial Testing

Chemical and bacterial analyses were carried out by contract laboratory Australian Laboratory Services Environmental who are NATA accredited for the determination of the analytes measured in this program. Quality Assurance/Quality Control is carried out by the laboratory on each day that samples are submitted. Table 8 sets out the parameters measured and detection limits:

Table 8. Laboratory Parameters: Reporting Limits and Units of Concentration

Water Quality Parameter	Reporting limit	Units of reporting	Water Quality Parameter	Reporting limit	Units of reporting
Oxidised nitrogen (NOX-N)	0.01	mg/L	Suspended solids	1	mg/L
Ammonia (NH3-N)	0.01	mg/L	Chlorophyll a	1	ug/L
Total Nitrogen	0.05	mg/L	Faecal coliforms + E.coli	1	CFU/100mL
Total Phosphorus	0.005	mg/L	Enterococci	1	CFU/100mL
Soluble reactive Phosphorus	0.002	mg/L			

1.15 Quality Assurance/Quality Control

To ensure accurate *in-situ* measurements, the Yeokal probe sensors are calibrated prior to each sampling run using standards to specified levels that have been provided by the manufacturer (YEO-KAL Electronics). Calibration is checked after each sampling run to confirm probe sensors drift is less than 5%.

The contract laboratory supplies new bottles for sampling each uniquely labelled. The lab provides quality control information to Council for each day that samples are taken to the laboratory for analysis. This information is checked and stored with Council's Water Catchments Team.

In addition, each month a duplicate field sample is taken from a random site. This involves taking a water sample in a washed and flushed bucket and pouring the sample into two containers. This effectively provides two samples of the same water which are labelled separately. The results from laboratory analysis provide an indication of the combined variability of sampling at a site and of the laboratory testing.

Further, every three months *field blanks* are taken to the laboratory for analysis. Field blanks are sample bottles filled with high purity deionised water before the run and sent to the laboratory for analysis of all parameters. The results provide an indication of the contamination from the sample bottles or due to transportation and field handling.

Water Quality Monitoring Results

1.16 Introduction

The monitoring program has been designed to obtain data suitable for assessing water quality according to the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC/AMRCANZ, 2000) and the Guidelines for Managing Risks in Rrecreational Water (NHMRC, 2006). The test results can be used to identify trends in the quality of water at sites monitored and to highlight the impact of land use on receiving water quality. Since the commencement of the water quality monitoring program in 1994, Hornsby Shire has experienced considerable population growth. Rapid increases in population intensifies the pressure on nearby waterways. Hornsby Council has endeavoured to alleviate the stress placed on waterways by undertaking catchment remediation works throughout the Shire, imposing strict development construction procedures and consent conditions, auditing environmental aspects of industrial and commercial businesses, and by carrying out community education programs.

Table 9: Land Use Classifications and associated Sample Sites

Land Use	Sample Sites
Reference Sites (National Parks)	36, 37
Urban area	39,4,5,6,46,8
STPs	52, 53, 23, 45, 1
Commercial/Industrial	10, 13, 12
Rural	62, 64, 2, 42, 63, 49, 80
Estuary	60,61, 48, 38, 103, 104, 105, 106, 107, 108
Recreation	55, 90, 99, 100

1.17 Presentation of monitoring data

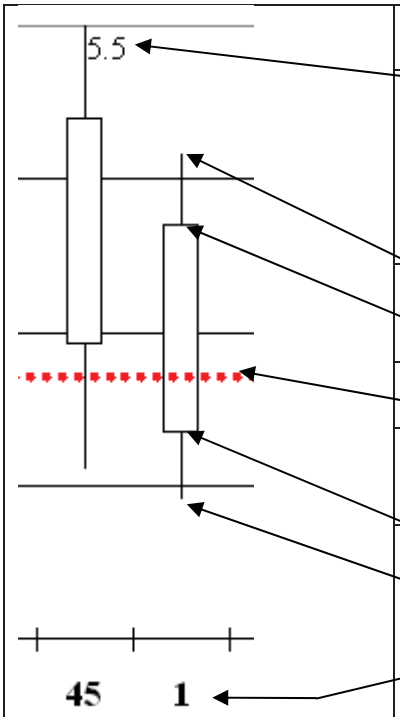
The monitoring has occurred at many sites at numerous times throughout the year for many parameters, generating a large database. Presentation of such large amounts of data is not the role of this annual report. Rather, the aim of this report is to provide summaries and trends. To do this the data is presented here in graphs and summary tables which show the averages and distribution of each parameter using basic statistical terms as described in Table 10 and Figure 3.

Table 10. Terminology for water quality data presentation

Term	Meaning
Valid N	The number of water samples taken or tests conducted at the site during the reporting period for each parameter
Mean	The numerical average of the values for a parameter for the samples taken or tested during the reporting period. The 'mean' value often appears high as it is easily biased high by one or two extreme values.
Minimum	The lowest value of the parameter at a site for all the samples taken or tested during the reporting period. The numerical difference between the 'minimum' and 'maximum' value for the parameter is the 'range' of values for that parameter during the reporting period.
Maximum	The highest value of the parameter at a site for all the samples taken or tested during the reporting period
20th% or 20th Percentile	The statistically calculated value of the parameter above which 80% of all test results lie. Values below the 20th% might be considered significantly lower than the average.
80th% or 80th Percentile	The statistically calculated value of the parameter below which 80% of all tests lie. Values above the 80th% might be considered significantly higher than the average.
Std Dev.	The statistical standard deviation of the values for a parameter for the samples taken or tested during the reporting period. If the Std Dev is high relative to the mean (eg. Temperature, turbidity, Faecal coliforms) it means the parameter varies a lot throughout the year. If the Std Dev is low relative to the mean (eg. pH) it means there is little variability of that parameter over the year.

Graphical presentation of data using a 'whisker-box-plot' enables ready comparison of water quality at any site with other sites including with the reference sites. The graphs present the minimum, maximum, 20th% and 80th% data for a parameter at a site and so give an visual idea of the magnitude, scatter and most usual range of a parameter, and can also readily present a comparison with existing Guideline values. Below in Figure 3 is shown how to interpret the graphs used in the report.

Figure 3. Interpretation of water quality using Whisker-Box Plots



Interpretation of the Whisker-Box Plots

- Sometimes the maximum concentration value of some parameters is so high it is necessary to draw the whisker-box 'off scale'. In this case the value of the maximum concentration of '5.5' is typed here for the 2006/7 year for this site.
- Maximum value for the test data at this site in 2006/2007year
- 80th percentile value for test data in 2006/07year
- Guideline concentration (eg. ANZECC/AMCANZ - for ecosystem protection)
- 20th percentile value for test data in 2006/07year
- Minimum value for test data in 2006/07year
- Sampling Site Number. The whisker-box symbol directly above the site number shows the distribution of data for a selected parameter in 2006/7 year

1.18 Wet Weather Event Sampling

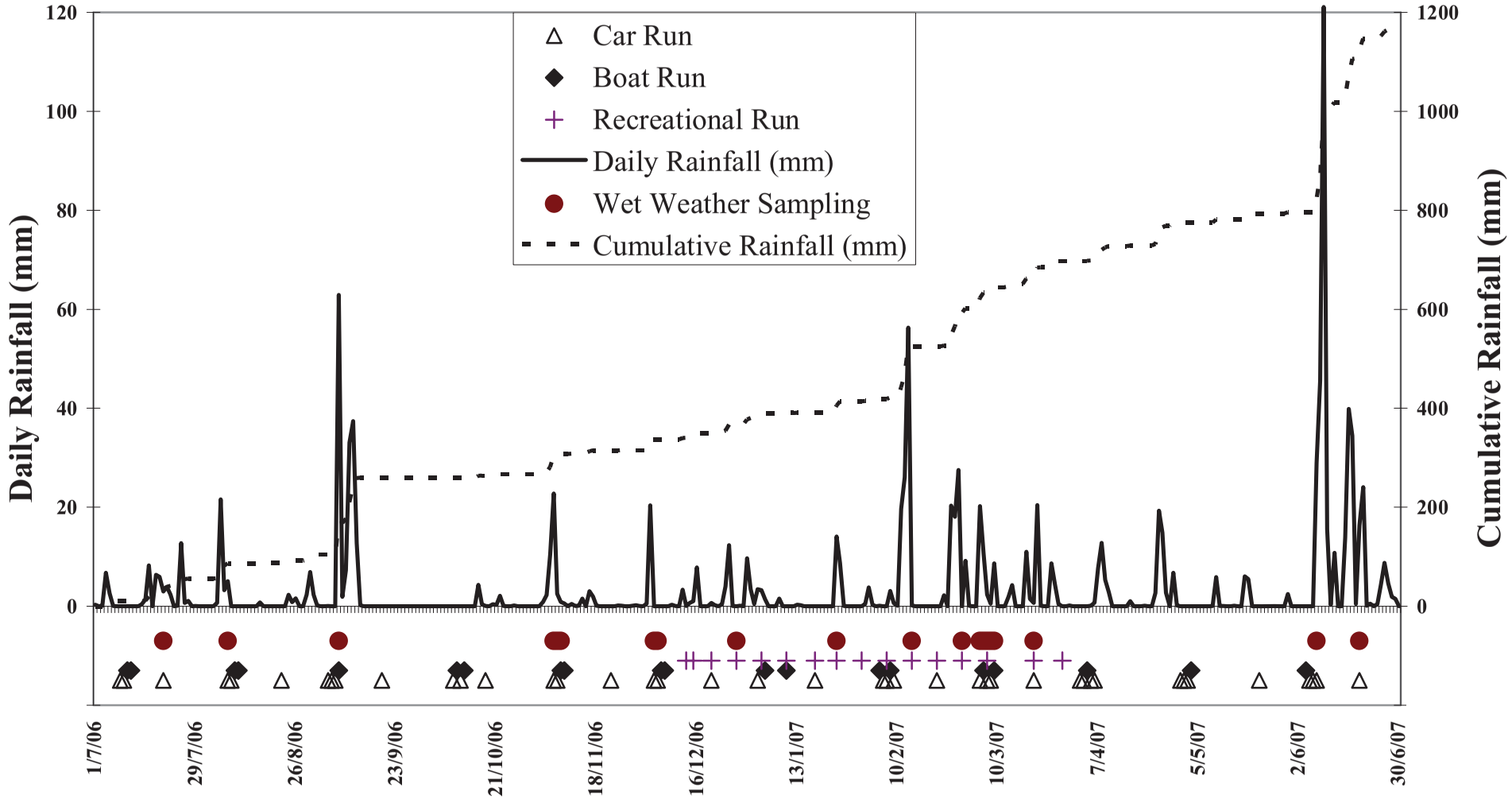
Rainfall events have a major effect on water quality in creeks and estuary, but increasing turbidity and suspended solids in stormwaters, and increasing the likelihood of overflows of sewage systems into waterways. The magnitude of the effect is related to the amount and intensity of the rainfall.

The water monitoring program involves sampling to a set monthly schedule which over the year will usually include representative dry and wet times. For the purposes of this program a wet weather sampling event is considered to be one for which a total of over 10mm of rain fell on the sampling day and the previous day. Figure 4 shows the daily rainfall records obtained from the Bureau of Meteorology; the average daily rainfall of 9 gauging stations throughout the Shire. Overlaid is the annual program for the year 2006-2007 showing the days routine sampling by car or boat was undertaken, and also the times of the summer recreational sampling.

The wet weather sampling events are highlighted on Figure 4. During the reporting year a total of 77 sampling days included 16 wet weather days.

Figure 4. Water Sampling and Rainfall

Graph showing dates of sampling events overlayed on daily rainfall. Wet weather sampling events are highlighted.



1.19 Reference Creeks. Sites 37 and 36

Data from these sites show natural variation of water parameters at sites with minimal human impact. Thus the sites provide 'control' or 'reference' data to compare against sites downstream of areas of development. Water quality at the reference sites are within ANZECC/ARMCANZ Guideline values for the majority of the time. Monitoring through time suggests that the water quality at these sites has remained constant, with relatively few fluctuations except in very wet weather.

The pH values at the reference sites are more acidic (ie. lower pH) than the pH range generally recommended by ANZECC/ARMCANZ Guidelines. However these pH levels are not unusual for unbuffered waters in wholly sandstone catchments and are not considered to indicate poor water quality at these reference sites.

Smugglers creek (site 37) normally contained low bacteria and suspended solids, but on one occasion in Sept 2006, soon after heavy rain, faecal coliform levels (1400 org/100ml) and suspended solids (30 mg/L) were high. In June 2006 at Smugglers concentrations of organic nitrogen (1.87mg/L) and phosphorus (0.3mg/L) were relatively very high when stream flow was considered normal and the water was very clear.

On one occasion at Murray Anderson Creek (site 36) in January 2007 total phosphorus concentration was unusually high (0.2mg/L) when flow was very low and water very clear.

1.19.1 Site 37: Smugglers Creek, Marramarra National Park

Site 37 is located in Smugglers Creek, a tributary of Marramarra Creek. The site is defined as a reference creek within this program as the catchment is located wholly within the boundary of Marramarra National Park. There is no development within the upper catchment of this site. The catchment area above this site is approximately 43 hectares all of which is undisturbed bushland.

Table 11: Summary Statistics for Site 37 for July 06 to June 07

Parameters	Valid N	Mean	Min	Max	20th%	80th%	Std Dev
Temperature ^{o}C	11	16.73	7.90	23.65	11.55	21.06	5.56
Conductivity (mS/cm)	11	0.27	0.2	0.3	0.2	0.3	0.05
Turbidity (NTU)	11	4.0	0.0	33.0	0.0	2.8	9.69
Dissolved Oxygen (mg/L)	11	9.0	3.7	12.1	6.9	11.2	2.56
Dissolved Oxygen (% sat)	11	90.6	43.3	107.3	79.6	102.7	19.35
pH	11	5.74	4.93	6.87	5.70	5.83	0.48
Faecal Coliforms (CFU/100 mL)	12	248	1	1400	2	122	517
Ammonium-N (mg/L)	12	0.015	<0.010	0.108	<0.010	0.011	0.029
Oxidised-N (NOx)(mg/L)	12	0.02	<0.01	0.09	<0.01	0.02	0.028
Total Nitrogen (mg/L)	12	0.36	0.07	1.87	0.15	0.34	0.486
Total Phosphorus (mg/L)	12	0.031	<0.005	0.307	<0.005	0.005	0.0875
Suspended Solids (mg/L)	12	4.7	<1	30	<1	5.4	8.4

1.19.2 Site 36: Murray Anderson Creek, tributary off Smiths Creek

Site 36 is located in Murray Anderson Creek, which is a tributary draining to Smiths Creek within the Cowan Creek catchment. The catchment above this site is approximately 20 hectares in size all within Ku-ring-gai Chase National Park. As such, this site is used as a reference site and has been sampled since January 1995. As with Site 37 this site has had minimal changes in water quality both through time and between wet and dry weather periods.

Table 12: Summary Statistics for Site 36 for July 06 to June 07

Parameters	Valid N	Mean	Min	Max	20th%	80th%	Std Dev
Temperature ^{o}C	11	14.86	8.54	22.73	10.93	17.82	4.55
Conductivity (mS/cm)	11	0.17	0.1	0.3	0.1	0.2	0.08
Turbidity (NTU)	11	0.9	0.0	4.9	0.1	1.1	1.41
Dissolved Oxygen (mg/L)	11	9.8	5.4	11.7	9.1	11.2	1.84
Dissolved Oxygen (% sat)	11	95.2	62.3	103.0	95.6	101.4	12.00
pH	11	6.36	4.91	7.05	6.00	6.72	0.61
Faecal Coliforms (CFU/100 mL)	13	58	1	300	3	41	108
Ammonium-N (mg/L)	13	0.040	<0.010	0.200	0.005	0.080	0.063
Oxidised-N (NOx)(mg/L)	13	0.01	<0.01	0.02	<0.01	0.01	0.004
Total Nitrogen (mg/L)	13	0.17	0.08	0.30	0.11	0.20	0.070
Total Phosphorus (mg/L)	13	0.018	0.003	0.203	0.003	0.003	0.0556
Suspended Solids (mg/L)	13	1.7	<1	6	0.5	3.2	1.8

1.20 Urban Areas. Sites 39, 4, 5, 6, 46, 8

Urban catchments consist of representative residential and commercial areas throughout the Shire. They are characterised by reticulated water and sewerage systems. The areas have large areas of impervious surfaces (eg roads, driveways, roofs) and a complex stormwater collection infrastructure; together these result in stormwater running quickly into local streams. Six streams are currently monitored downstream of urban areas.

Figure 5 gives a graphical comparison of selected water quality parameters in 2006/07 at the six sites on creeks draining the urban areas and, for comparison, at the two reference sites.

The levels of turbidity and suspended solids were generally low in 2006/07. These low results are indicative of the prevailing drought conditions in which the sediments and other particles have not been transported to the creeks via stormwater. High suspended solids (SS) and turbidity levels were recorded within the urban creeks on a few occasions during periods of high flow following short episodes of heavy rain (egs. SS = 40 mg/L at Site 39 in Sept 06, and SS = 67 mg/L at Site 46 in Feb 07)

Faecal Coliform results within the urban areas were similar to previous years; being moderate most of the time. However, several peak events did occur specifically at Terrys Creek (site 46) in February 2007 and Pyes Creek (site 5) in January 2007.

Concentrations of Total Nitrogen and Oxidised (NOx) Nitrogen were mostly higher than the guideline levels in all urban creeks, except at Joe Crafts Creek (site 39). These high levels of bioavailable nitrogen would explain observations of algal growths usually being present on stream bedrock at the sample sites. High Oxidised Nitrogen levels could be sourced from fertilisers, detergents, eroding soils, decomposing lawn clippings, pet faeces or sewage overflows. Site 39 on Joe Crafts Creek is much further downstream (4km) from nutrient sources from an urban area (Berowra), as compared to other urban downstream sites 4,5,6,8,and 46. It is likely that reduction of nutrient concentrations (by natural assimilation) occurs over the stream length of Joe Crafts Ck above site 39.

Ammonium Nitrogen concentrations are generally within guideline levels (ie. <0.02 mg/L) at most sites; exceptions being at Georges Creek (Site 6) on most occasions, at Joe Crafts Creek (Site 39) in

September 2006 during a wet period with high stream flow, and at Terrys Creek tributary (site 46) when an extremely high value of 25 mg/L of ammonium nitrogen was recorded in February 2007 coincident with high Suspended Solids and Faecal Coliforms.

Phosphorus concentrations in streams below urban areas are mostly within Guidelines (ie. <0.025mg/L) at sites 4, 5, 8,and 39 but not at sites 6 and 46 which exceeded the guideline on more than half the sampling times. Unfortunately all sites, except Joe Crafts Creek (site 39), did show occasional very high levels, particularly site 6 and 46 which showed above average Suspended Solids concentrations. Sources of phosphorus contributing to elevated levels of nutrients within urban areas are similar to those of nitrogen.

Levels of pH within urban areas are consistently within Guidelines. Conductivity levels are similar to previous years and are typical of creeks in sandstone areas.

Dissolved oxygen levels within the urban areas in 2006/07 were usually within Guideline levels except for occasional low levels when some streams stopped flowing. However, all urban sites tested on 9 January 2007 (sites 4, 5, 6, 8, 46) showed extremely low oxygen, indicating probable DO probe calibration error on that day.

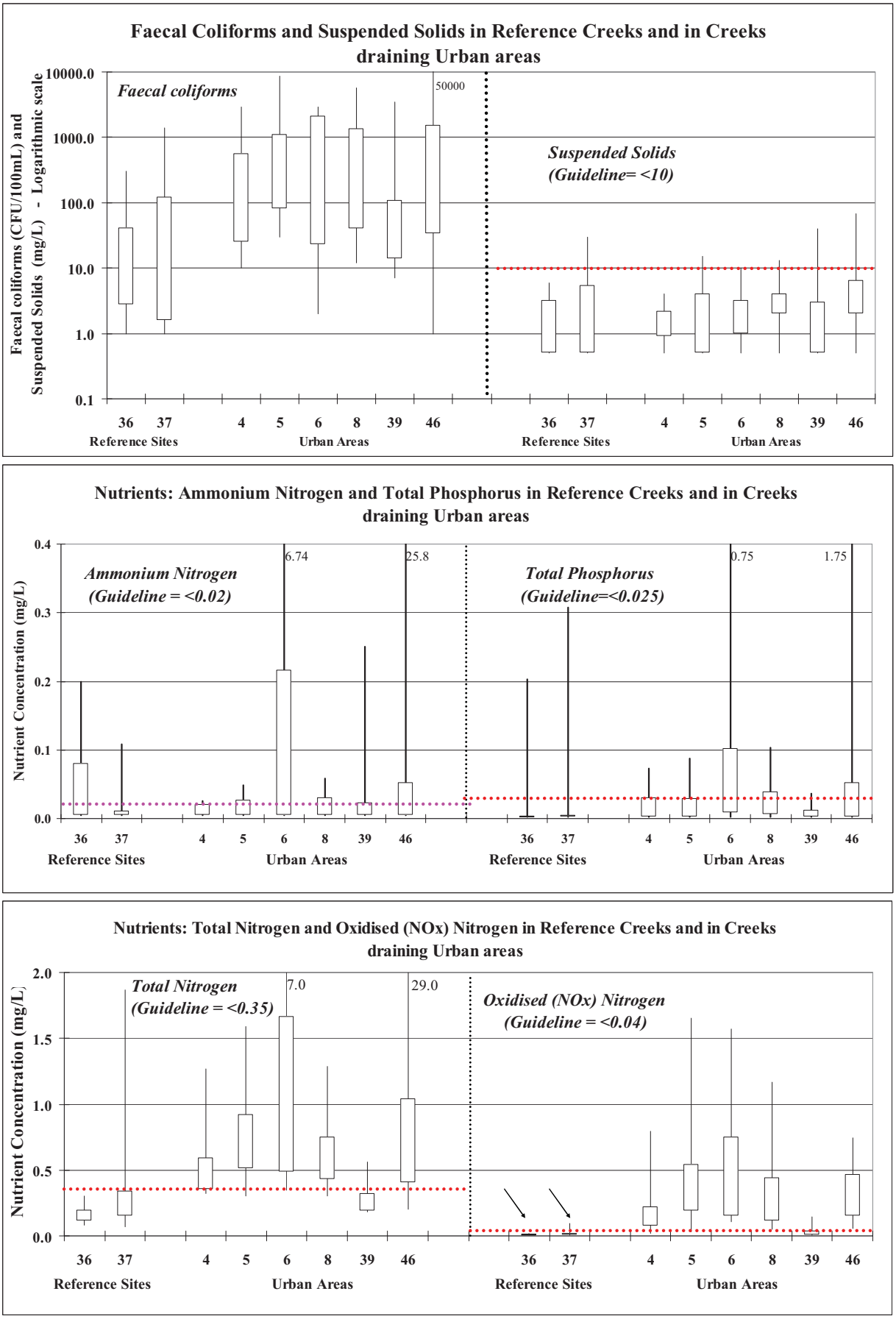
1.20.1 Site 39: Joe Crafts Creek, Berowra.

Site 39 is located 100 metres above the confluence with Berowra Creek estuary in the freshwater section of the creek and is characterised by a rocky substrate. Sampling commenced at this site in October 1994. The site receives runoff predominantly from the Berowra urban area and a large area of bushland. The site differs from other urban area monitoring sites in that it is much further (4km) downstream from the associated urban development. The site, however, provides a good indication of water quality for the Joe Crafts Creek catchment as a whole as it is close to its confluence with Berowra Creek.

Table 13: Summary Statistics for Site 39 for July 06 to June 07

Parameters	Valid N	Mean	Min	Max	20th%	80th%	Std Dev
Temperature ^{o}C	10	15.14	7.61	21.17	10.29	19.92	4.99
Conductivity (mS/cm)	10	0.2	0.0	0.3	0.18	0.2	0.08
Turbidity (NTU)	10	8.3	0.0	65.0	0.9	3.7	20.02
Dissolved Oxygen (mg/L)	10	9.1	6.3	11.4	7.5	10.7	1.80
Dissolved Oxygen (% sat)	10	88.6	71.0	103.0	79.2	95.7	10.47
pH	10	7.208	6.67	8.21	6.84	7.58	0.51
Faecal Coliforms (CFU/100 mL)	13	365	7	3500	14	110	963
Ammonium-N (mg/L)	13	0.030	<0.010	0.251	<0.010	0.023	0.067
Oxidised-N (NOx)(mg/L)	13	0.03	<0.10	0.15	<0.01	0.04	0.037
Total Nitrogen (mg/L)	13	0.29	0.18	0.56	0.19	0.32	0.119
Total Phosphorus (mg/L)	13	0.010	<0.005	0.036	<0.005	0.012	0.0113
Suspended Solids (mg/L)	13	4.5	<1	40	<1	3	10.7

Figure 5: Water Quality in Urban Creeks; Annual distribution of parameters compared with Reference Creeks



1.20.2 Site 4: Berowra Creek, Westleigh.

Site 4 is located in the Berowra Valley Regional Park with access being gained through Barkala Close, Westleigh. This site is upstream of the two sewage treatment plants and is influenced by a mixture of landuses from predominantly residential and bushland areas.

Table 18: Summary Statistics for Site 4 for July 06 to June 07

Parameters	Valid N	Mean	Min	Max	20th%	80th%	Std Dev
Temperature °C	8	13.54	6.56	20.09	9.79	17.92	4.82
Conductivity (mS/cm)	8	0.23	0.1	0.4	0.2	0.03	0.09
Turbidity (NTU)	8	5.1	1.5	20.8	1.7	5.2	6.53
Dissolved Oxygen (mg/L)	8	8.8	4.6	12.0	7.4	10.4	2.32
Dissolved Oxygen (% sat)	8	82.4	51.0	106.2	77.0	88.4	15.70
pH	8	7.14	6.79	7.41	7.04	7.32	0.20
Faecal Coliforms (CFU/100 mL)	10	473	10	2900	25	570	887
Ammonium-N (mg/L)	10	0.013	<0.010	0.025	<0.010	0.021	0.009
Oxidised-N (NOx)(mg/L)	10	0.20	0.02	0.80	0.07	0.22	0.223
Total Nitrogen (mg/L)	10	0.55	0.32	1.27	0.35	0.59	0.316
Total Phosphorus (mg/L)	10	0.022	<0.005	0.073	<0.005	0.031	0.0219
Suspended Solids (mg/L)	10	1.7	<1	4	0.9	2.2	1.1

1.20.3 Site 5: Pyes Creek, Cherrybrook.

Site 5 is located in Pyes Creek at Cherrybrook and drains a catchment of approximately 380 hectares of which 79% is zoned residential. The site is located in a section of creek that has extensive patches of exposed bedrock and which illustrates the influence of higher scouring flows from an catchment with a large proportion of impervious surfaces.

Table 15: Summary Statistics for Site 5 for July 06 to June 07

Parameters	Valid N	Mean	Min	Max	20th%	80th%	Std Dev
Temperature °C	10	15.36	7.84	22.42	9.96	19.43	4.94
Conductivity (mS/cm)	10	0.44	0.2	0.8	0.2	0.64	0.24
Turbidity (NTU)	10	8.7	0.4	24.9	2.3	12.1	8.80
Dissolved Oxygen (mg/L)	10	8.6	5.6	11.1	7.6	9.6	1.67
Dissolved Oxygen (% sat)	10	84.9	62.0	96.9	81.3	93.9	10.21
pH	10	7.20	6.94	7.41	7.05	7.35	0.17
Faecal Coliforms (CFU/100 mL)	11	1508	30	8600	80	1100	2937
Ammonium-N (mg/L)	11	0.017	<0.010	0.049	<0.010	0.027	0.015
Oxidised-N (NOx)(mg/L)	11	0.46	0.03	1.65	0.19	0.54	0.461
Total Nitrogen (mg/L)	11	0.74	0.30	1.59	0.51	0.92	0.380
Total Phosphorus (mg/L)	11	0.019	<0.005	0.088	<0.005	0.029	0.0250
Suspended Solids (mg/L)	11	3.4	<1	15	<1	4	4.2

1.20.4 Site 6: Georges Creek, Dural.

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

Table 16: Summary Statistics for Site 6 for July 06 to June 07

Parameters	Valid N	Mean	Min	Max	20th%	80th%	Std Dev
Temperature °C	9	14.47	7.62	22.05	9.82	17.69	4.89
Conductivity (mS/cm)	9	0.33	0.2	0.5	0.2	0.4	0.11
Turbidity (NTU)	9	12.9	1.3	39.5	2.6	20.4	12.90
Dissolved Oxygen (mg/L)	9	8.76	5.3	11.1	8.0	10.1	1.78
Dissolved Oxygen (% sat)	9	85.4	49.7	98.0	82.4	95.2	14.52
pH	9	7.38	7.13	7.55	7.23	7.52	0.16
Faecal Coliforms (CFU/100 mL)	10	1043	2	2900	23	2080	1163
Ammonium-N (mg/L)	10	0.772	<0.010	6.740	0.005	0.216	2.113
Oxidised-N (NOx)(mg/L)	10	0.51	0.11	1.57	0.15	0.75	0.532
Total Nitrogen (mg/L)	10	1.46	0.35	7.00	0.49	1.67	2.018
Total Phosphorus (mg/L)	10	0.112	<0.005	0.750	0.008	0.102	0.2278
Suspended Solids (mg/L)	10	2.9	<1	10	1	3.2	2.7

1.20.5 Site 46: Terrys Creek tributary, Epping

Site 46 is located in a tributary of Terrys Creek at Epping. Part of the creek is piped under the M2 Motorway. The catchment above this site is approximately 90 hectares, 87% of which is zoned residential.

Table 17: Summary Statistics for Site 46 for July 06 to June 07

Parameters	Valid N	Mean	Min	Max	20th%	80th%	Std Dev
Temperature °C	10	15.70	7.22	22.69	10.34	20.13	5.41
Conductivity (mS/cm)	10	0.48	0.2	0.7	0.2	0.6	0.20
Turbidity (NTU)	10	13.3	1.0	96.5	2.8	5.9	29.29
Dissolved Oxygen (mg/L)	10	9.8	2.2	12.2	9.4	11.4	2.85
Dissolved Oxygen (% sat)	10	96.2	25.7	114.3	100.2	106.9	25.18
pH	10	7.31	7.02	7.84	7.09	7.47	0.26
Faecal Coliforms (CFU/100 mL)	12	4942	1	50000	33	1520	14269
Ammonium-N (mg/L)	12	2.311	<0.010	25.800	<0.010	0.052	7.414
Oxidised-N (NOx)(mg/L)	12	0.31	0.05	0.74	0.15	0.47	0.223
Total Nitrogen (mg/L)	12	3.07	0.20	29.00	0.40	1.04	8.185
Total Phosphorus (mg/L)	12	0.190	<0.005	1.750	<0.005	0.053	0.5015
Suspended Solids (mg/L)	12	8.7	<1	67	2	6.4	18.5

1.20.6 Site 8: Devlins Creek, Cheltenham

Site 8 is located in Devlins Creek, adjacent to Sutherland Road at Cheltenham. The catchment above this site is approximately 965 hectares with 8% falling outside Hornsby Shire in the Parramatta City

Council area. Almost 77% of this catchment is zoned residential with the remaining 23% consisting of special uses (9%), commercial/industrial and business (1%) and open space (13%).

Table 18: Summary Statistics for Site 8 for July 06 to June 07

Parameters	Valid N	Mean	Min	Max	20th%	80th%	Std Dev
Temperature ^{o}C	10	15.28	7.44	21.17	10.18	20.04	4.92
Conductivity (mS/cm)	10	0.38	0.2	0.6	0.2	0.5	0.15
Turbidity (NTU)	10	14.0	1.4	66.0	1.7	16.5	20.19
Dissolved Oxygen (mg/L)	10	7.68	4.3	10.8	6.6	9.0	1.86
Dissolved Oxygen (% sat)	10	75.6	48.5	100.2	67.6	89.5	15.66
pH	10	7.20	7.00	7.41	7.06	7.32	0.15
Faecal Coliforms (CFU/100 mL)	12	1392	12	5800	40	1360	2094
Ammonium-N (mg/L)	12	0.020	<0.010	0.058	<0.01	0.031	0.018
Oxidised-N (NOx)(mg/L)	12	0.30	0.05	1.17	0.11	0.44	0.315
Total Nitrogen (mg/L)	12	0.65	0.30	1.29	0.43	0.75	0.294
Total Phosphorus (mg/L)	12	0.027	<0.005	0.103	0.006	0.039	0.0289
Suspended Solids (mg/L)	12	4.0	<1	13	2	4	3.7

1.21 Hornsby Heights Sewage Treatment Plant. Sites 52 and 43

Hornsby Heights Sewage Treatment Plant (HHSTP) discharges approximately 5.3 megalitres of tertiary treated effluent per day to Calna Creek four kilometres upstream of the confluence with Berowra Creek.

This plant has completed a major upgrade as part of Sydney Water's commitment to the Statement of Joint Intent for Berowra Creek and WaterPlan 21. The main goal of this upgrade was to reduce total nitrogen/nitrate levels in order to reduce the frequency of algal blooms in the Berowra estuary.

In 2004, Hornsby Shire Council ceased monitoring sites at the outfall (site 19) and immediately downstream of the outfall (site 21). Monitoring is still undertaken 300 m upstream of the outfall (site 52) and 4 km downstream of the STP (site 43).

Figure 6 gives graphical comparison of water quality in 2006-2007 between selected parameters at the two reference sites and the sites on creeks near the two STPs.

Apart from a few occasions, suspended solids and turbidity readings were within or close to the Guidelines for both sites. Higher readings were recorded at Calna Creek, 300 m upstream of the STP outlet (Site 52) than Site 43 (downstream of the STP).

Levels of faecal coliforms downstream of HHSTP at Site 43 were lower than the upstream site (site 43) when the plant was operating within its designed capacity (i.e. not on bypass operation).

Concentrations of total nitrogen, comprising mostly oxidised nitrogen, is consistently higher downstream at site 43 and demonstrates an influence by the treated effluent from HHSTP. Although the STP discharge has significantly lower oxidised nitrogen contents than before the STP upgrades a few years ago, the levels are still well above the Guideline values and continue to dominate the nutrient load into Berowra Creek.

The concentrations of Ammonium Nitrogen were generally higher upstream of HHSTP than further downstream. This indicates that the upgraded STP was successfully targeting and removing ammonia and not generally adding significant concentrations to Calna Creek.

Site 43 (4 km downstream of HHSTP) has generally higher total phosphorus concentrations than upstream of HHSTP (site 53). The concentrations are only slightly elevated due to assimilation over 4 km of creekline prior to confluence with the estuary.

Levels of pH were consistently within Guidelines and similar to trends observed in urban areas.

Conductivity is typically greater at sites influenced by effluent. The conductivity at the downstream site 43 was significantly greater than site 52 which is located upstream of the outfall. This difference is due to the influence of effluent which is contributing greater concentrations of total dissolved solids and other major ions. This pattern is consistent with previous years reporting.

The dissolved oxygen was considerably higher downstream of the outfall (site 43) due to the turbulence of creek flow providing good contact with air.

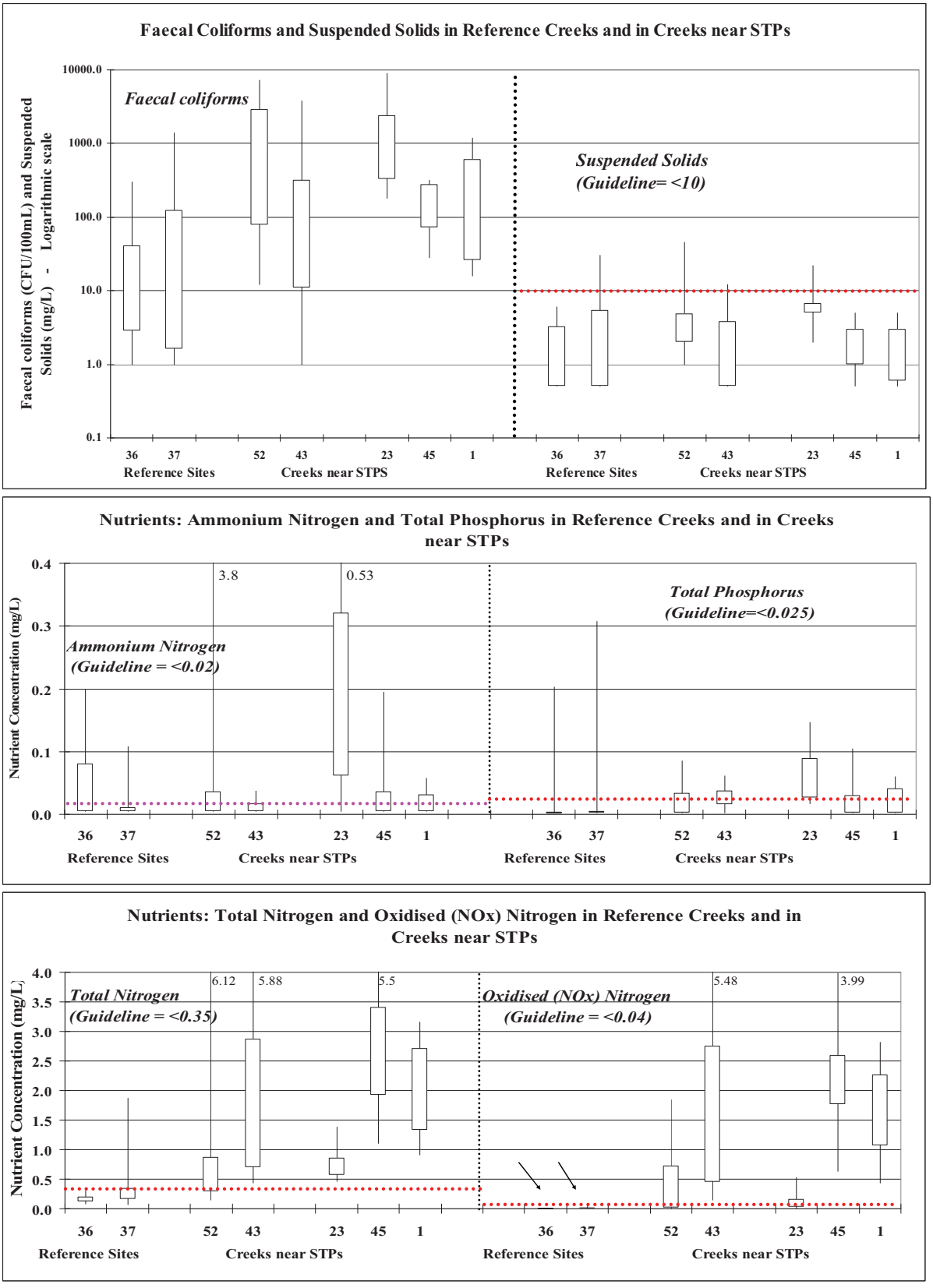
1.21.1 Site 52: 300 metres upstream of HHSTP outfall, Calna Creek

This site is located in Calna Creek upstream of Site 20, 300m above the HHSTP outfall. The water quality at this site provides a direct indication of the influence of the urban catchment on water quality compared to HHSTP. The catchment area above this site is approximately 263 hectares with 59% zoned residential.

Table 19: Summary Statistics for Site 52 for July 06 to June 07

Parameters	Valid N	Mean	Min	Max	20th%	80th%	Std Dev
Temperature ^{o}C	12	15.13	5.63	21.27	12.36	18.92	4.32
Conductivity (mS/cm)	12	0.26	0.0	0.4	0.2	0.38	0.12
Turbidity (NTU)	12	11.4	1.2	46.5	2.4	16.0	14.79
Dissolved Oxygen (mg/L)	12	8.2	3.4	10.4	7.6	10.0	1.93
Dissolved Oxygen (% sat)	12	80.8	37.4	97.4	75.0	92.3	16.32
pH	12	7.27	6.87	7.67	7.22	7.33	0.22
Faecal Coliforms (CFU/100 mL)	17	1809	12	7200	77	2880	2499
Ammonium-N (mg/L)	17	0.238	<0.010	3.770	0.005	0.036	0.910
Oxidised-N (NOx)(mg/L)	17	0.34	<0.01	1.84	0.02	0.72	0.486
Total Nitrogen (mg/L)	17	0.87	0.15	6.12	0.28	0.87	1.395
Total Phosphorus (mg/L)	17	0.018	<0.005	0.085	<0.005	0.033	0.0218
Suspended Solids (mg/L)	17	6.9	1	46	2	4.8	11.9

Figure 6: Water Quality in Creeks near STPs; Annual distribution of parameters compared with Reference Creeks



Note 1: Sites 52 and 43 help monitor effects of Hornsby Heights STP discharge. The sites are on Calna Creek immediately upstream of Hornsby Heights STP discharge point and 4km downstream of the STP, respectively.

Note 2: Sites 23, 45 and 1 help monitor effects of West Hornsby STP discharge. Site 23 is on Waitara Ck 100m upstream of the discharge point. Sites 45 and 1 are both freshwater sample sites downstream of West Hornsby STP on Berowra Creek, at Fishponds and at Galston Gorge respectively.

1.21.2 Site 43: 50 m upstream of the confluence with Berowra Creek, Calna Creek

Site 43 is located in Calna Creek, which is 4km downstream of the STP, and approximately 50 metres upstream of the confluence with the Berowra Creek estuary and not influenced by tidal flushing. This section of creek is shaded and the substrate consists of large sandstone boulders. Sampling at this site gives a good indication of water entering Berowra Creek from the Calna Creek catchment. Dry weather flows are dominated by STP input. Runoff from urban and bushland areas may dominate during wet weather flows.

Table 20: Summary Statistics for Site 43 for July 06 to June 07

Parameters	Valid N	Mean	Min	Max	20th%	80th%	Std Dev
Temperature ^{o}C	13	15.63	8.91	21.17	12.63	19.14	3.93
Conductivity (mS/cm)	13	0.68	0.4	0.9	0.54	0.8	0.17
Turbidity (NTU)	13	21.0	0.0	208.0	0.6	11.2	56.89
Dissolved Oxygen (mg/L)	13	9.1	3.8	11.7	8.3	10.5	1.90
Dissolved Oxygen (% sat)	13	91.7	32.7	102.2	92.8	99.1	18.03
pH	13	7.78	6.66	8.24	7.57	8.09	0.42
Faecal Coliforms (CFU/100 mL)	12	436	1	3800	11	318	1077
Ammonium-N (mg/L)	12	0.011	<0.010	0.037	<0.010	0.017	0.012
Oxidised-N (NOx)(mg/L)	12	1.74	0.15	5.48	0.45	2.75	1.743
Total Nitrogen (mg/L)	12	2.25	0.44	5.88	0.70	2.87	1.753
Total Phosphorus (mg/L)	12	0.029	<0.005	0.061	0.016	0.038	0.0170
Suspended Solids (mg/L)	12	2.9	<1	12	<1	3.8	3.2

1.22 West Hornsby Sewage Treatment Plant. Sites 23, 45 and 1.

West Hornsby Sewage Treatment Plant (WHSTP) discharges approximately 13.8 megalitres per day of tertiary treated effluent to Waitara Creek, 700 metres upstream of its confluence with Berowra Creek and approximately 12 km upstream of the tidal reach of Berowra Waters.

Both this STP and Hornsby Heights Sewage Treatment Plant, have undergone major upgrades as part of Sydney Water's commitment to the Statement of Joint Intent for Berowra Creek and WaterPlan 21. A major goal of this upgrade was to reduce total nitrogen levels which influence the occurrence of algal blooms in the estuary.

In 2004, Hornsby Shire Council ceased monitoring sites at the outfall (site 22) and immediately downstream of the outfall (site 24). Monitoring is still undertaken 100 m upstream of the outfall (site 23) and 1 km downstream of the STP at Fishponds on Berowra Creek (site 45) and at Berowra Creek at Galston Gorge a further 5km downstream.

Figure 6 gives graphical comparison of water quality in 2006/07 of selected parameters at the two reference sites with the sites on creeks near the two STPs.

The water temperature was significantly greater downstream of the outfall (usually about 3^{o}C higher at site 45 than site 23) due to the elevated temperatures of the STP effluent. This is due to biological techniques used within the plant to treat effluent. The storage of effluent water within maturation ponds exposes the effluent to high amounts of sunlight, warming the effluent with ambient heat and exposing the effluent to UV light for sterilisation. This trend is particularly noticeable in summer when temperatures are at their highest. The impact of higher temperatures extends downstream a number of kilometres downstream, but does not extend as far as site 1 where temperature is similar to other urban sites.

Suspended solids and Turbidity levels are higher at site 23 located upstream of the sewage treatment plant outfall. Ducks regularly found at this site may be disturbing the sediment, contributing to the

elevated turbidity levels found here. Turbidity levels decrease with the influence of the effluent diluting upstream turbid waters. Nevertheless, the 3 sites were consistently below the chosen Guidelines for turbidity and suspended solids.

Site 23 located upstream of WHSTP had the highest levels of faecal coliforms. The site also receives run-off from a large and diverse urban catchment. Contributing to this faecal contamination could be sewage from leaking sewer pipes and pet/animal faeces. The process of disinfection within WHSTP and dilution of upstream waters with sterilised SPT effluent during dry weather maintains the lower faecal coliform levels.

Total Nitrogen and Oxidised Nitrogen concentration values are higher downstream of the sewage treatment plant. In comparison with the reference creeks these concentrations are considered very high and, at Fishponds Site 45 and Berowra Ck Site 1, always exceeded the Guidelines.

Trends in the concentration values of Ammonia were similar to those of faecal coliforms for site 23, i.e. consistently high. This suggests sewerage infrastructure upstream from this site is failing or there are numerous sewer overflows in the Waitara Creek catchment which includes Larool Creek where ammonia and faecal values are consistently high. Confounding this conclusion, is the residual excrement at site 23 from a local population of ducks (on average 5 individuals are present during sampling) which may be masking the effect of sewage intrusions into the creek.

Concentration values of Total Phosphorus were mostly within the Guidelines at the downstream site 45, but this increased further downstream at Site 1 where about half the samples exceeded the Guidelines.

Levels of pH were consistently within Guidelines and are not considered to be problematic. Conductivity at site 45 (Fishponds) is greater than the upstream site, with the greater conductivity levels being directly attributed to the presence of effluent with associated dissolved salts from residential use of chemicals (eg. detergent powder)which are not removed by the STP process.

Levels of dissolved oxygen below the STP were consistently within Guidelines but not at the upstream site (site 23). This site has low dissolved oxygen levels due to the low flow conditions often creating ponding water under stagnant conditions.

1.22.1 Site 23: 100 metres upstream of WHSTP outfall, Waitara Creek

Site 23 is located approximately 100 metres upstream of WHSTP outfall and is situated in the pool above the fire trail crossing. This site drains the Waitara Creek catchment which contains residential, commercial, small areas of open space as well as Larool Creek which drains the Thornleigh industrial area. The total catchment area above this site is 542 hectares. Of this total 58% is zoned residential, 19% is zoned special uses, 18% is zoned open space and 5% is zoned commercial.

Table 21: Summary Statistics for Site 23 for July 06 to June 07

Parameters	Valid N	Mean	Min	Max	20th%	80th%	Std Dev
Temperature °C	12	16.35	8.51	22.61	11.76	20.63	4.71
Conductivity (mS/cm)	12	0.33	0.2	0.6	0.3	0.4	0.11
Turbidity (NTU)	12	10.2	5.0	23.3	5.3	13.4	5.68
Dissolved Oxygen (mg/L)	12	2.8	0.4	8.0	1.0	3.9	2.34
Dissolved Oxygen (% sat)	12	28.1	4.7	70.1	10.2	41.0	21.54
pH	12	6.88	6.55	7.28	6.78	7.03	0.20
Faecal Coliforms (CFU/100 mL)	12	2074	180	8900	326	2380	2557
Ammonium-N (mg/L)	12	0.186	<0.010	0.534	0.061	0.320	0.162
Oxidised-N (NOx)(mg/L)	12	0.11	<0.01	0.52	0.02	0.16	0.146
Total Nitrogen (mg/L)	12	0.76	0.46	1.38	0.57	0.85	0.249
Total Phosphorus (mg/L)	12	0.061	0.017	0.146	0.026	0.089	0.0382
Suspended Solids (mg/L)	12	7.2	2	22	5	6.8	5.9

1.22.2 Site 45: Berowra Creek at Fishponds Waterhole

This site is located in the Berowra Valley Regional Park and is influenced by the Pyes/Georges Creek catchments as well as WHSTP and the Waitara Creek catchment. However, the higher concentrations of nitrogen species can mainly be attributed to the WHSTP. Notwithstanding the current effect of the STP on nitrogen concentrations downstream of the discharge point, it should be noted that the concentration values at Fishponds are now about 10-20% of those routinely recorded before the STP upgrade works. Nevertheless further nutrient removal is required to achieve Guideline values for nitrogen.

The catchment area above this site is approximately 3173 hectares of which 12% is zoned rural, 46% is zoned residential, 3% is zoned industrial/commercial/business, 10% is special uses, 9% is open space, 3% is environmental protection and 17% is national parks and reserves.

Table 22: Summary Statistics for Site 45 for July 06 to June 07

Parameters	Valid N	Mean	Min	Max	20th%	80th%	Std Dev
Temperature °C	10	19.21	13.87	24.00	15.92	22.07	3.64
Conductivity (mS/cm)	10	0.69	0.6	0.8	0.68	0.7	0.06
Turbidity (NTU)	10	2.7	0.6	13.0	0.9	2.4	3.70
Dissolved Oxygen (mg/L)	10	9.2	7.6	10.8	8.5	9.6	0.92
Dissolved Oxygen (% sat)	10	98.8	90.0	107.2	95.7	103.5	5.17
pH	10	7.57	7.39	7.84	7.51	7.61	0.12
Faecal Coliforms (CFU/100 mL)	12	172	28	320	73	276	105
Ammonium-N (mg/L)	12	0.035	<0.010	0.195	<0.010	0.036	0.052
Oxidised-N (NOx)(mg/L)	12	2.22	0.64	3.99	1.77	2.59	0.946
Total Nitrogen (mg/L)	12	2.89	1.10	5.50	1.92	3.40	1.320
Total Phosphorus (mg/L)	12	0.026	<0.005	0.104	<0.005	0.030	0.0274
Suspended Solids (mg/L)	11	2.2	<1	5	1	3	1.5
Chlorophyll-a (ug/L)	12	1.5	<1	2.5	<1	2.5	1.04

1.22.3 Site 1: Berowra Creek, Galston Gorge.

Site 1 is located on Berowra Creek at Galston Gorge and is included in the sites associated with WHSTP because of the sustained influence of the WHSTP on water quality. The catchment above this site is approximately 5200 hectares with 30% zoned rural, 33% residential and 19% national parks and reserves. Other landuses in the catchment include special uses, open space, industrial/commercial/business and environmental protection.

Table 23: Summary Statistics for Site 1 for July 06 to June 07

Parameters	Valid N	Mean	Min	Max	20th %	80th %	Std Dev
Temperature ^{o}C	10	16.94	10.17	23.07	11.67	21.04	4.78
Conductivity (mS/cm)	10	0.53	0.3	0.7	0.4	0.6	0.15
Turbidity (NTU)	10	4.4	0.2	12.0	0.9	8.0	4.49
Dissolved Oxygen (mg/L)	10	9.2	7.0	11.5	7.9	10.7	1.59
Dissolved Oxygen (% sat)	10	94.1	80.8	105.7	88.8	101.5	8.63
pH	10	7.63	7.20	7.95	7.45	7.75	0.22
Faecal Coliforms (CFU/100 mL)	12	328	16	1200	26	602	396
Ammonium-N (mg/L)	12	0.021	<0.010	0.058	<0.010	0.031	0.017
Oxidised-N (NOx)(mg/L)	12	1.51	0.43	2.81	1.06	2.26	0.730
Total Nitrogen (mg/L)	12	1.91	0.91	3.16	1.33	2.71	0.753
Total Phosphorus (mg/L)	12	0.024	<0.005	0.060	<0.005	0.041	0.0208
Suspended Solids (mg/L)	12	2.1	<1	5	0.6	3	1.4

1.23 Industrial Areas. Sites 10, 12 and 13

Council has three major industrial areas located at Sefton Rd, Thornleigh; Leighton Pl, Hornsby; and Beaumont Rd, Mt Kuring-gai. These three areas drain into Larool Ck (site 10), Hornsby Ck (site 12) and Sams Creek (site 13), respectively.

Figure 7 gives graphical comparison of water quality in 2006/07 of selected parameters at the sites on creeks draining the industrial areas and also the two reference creeks.

Suspended solids and Turbidity levels were consistently the highest within the Shire below the Thornleigh industrial area (site 10) with high values even in dry times and with a mean for the year for turbidity of 44 NTU. Hornsby Council's Environment Protection Officers have an ongoing program to investigate sources within this area.

Levels of faecal coliforms were generally very high downstream of the industrial areas. These sites consistently receive faecal contamination from failing sewerage infrastructure or other unidentified sources.

Concentration values of Total Nitrogen, Ammonium Nitrogen, Oxidised Nitrogen and Total Phosphorus were all above Guidelines at all 3 industrial areas on almost all sampling days. The highest levels were found below the Thornleigh (site-10) and Mt Kuring-gai (site 13) industrial sites. The source of these nutrients is unknown, however, illegal discharges and failing sewerage infrastructure are likely major sources.

Generally, levels of pH were within ANZECC 2000 Guidelines and were indicative of catchments where there is a large percentage of impervious surface in the upper catchment. A pH reading of 2 occurred in February 2007 at site 10 below Thornleigh industrial area, which indicates a possibility of illegal discharge of strong acid some time prior to that sampling event. Conductivity levels were consistently high below the Thornleigh industrial area, especially on the occasion when the water was pH 2. The source of this contamination was not able to be identified at the time. Conductivity levels were moderate below Hornsby and Mt Kuring-gai industrial areas.

Similar to last year, dissolved oxygen levels were low on a significant number of occasions in the creeks below the three industrial areas, particularly Leighton Place (site 12)

1.23.1 Site 10: Larool Creek, Thornleigh.

The headwaters of Larool Creek originate within the Thornleigh industrial area and flow in a northerly direction until it intersects Waitara Creek west of Hornsby. Site 10 is about 100m downstream of Sefton Road. The catchment above this site is small, approximately 36 hectares of which 34% is zoned residential, 51% is zoned commercial/business/industrial, 13% is open space and 2% is special uses. As indicated by the water quality results, this creek has received a consistent level of pollution which has resulted in poor water quality for many years. It is considered that this creek is one of the most polluted within Hornsby Shire.

Table 24: Summary Statistics for Site 10 for July 06 to June 07

Parameters	Valid N	Mean	Min	Max	20th%	80th%	Std Dev
Temperature ^{o}C	21	16.96	9.68	22.26	13.37	20.50	4.02
Conductivity (mS/cm)	21	0.82	0.3	3.1	0.6	0.9	0.56
Turbidity (NTU)	21	44.4	6.9	191.0	11.5	72.0	49.25
Dissolved Oxygen (mg/L)	21	5.29	0.1	10.4	3.1	8.3	2.96
Dissolved Oxygen (% sat)	21	53.7	1.0	98.5	33.6	83.0	28.97
pH	21	7.20	2.00	8.04	7.20	7.57	1.21
Faecal Coliforms (CFU/100 mL)	24	37929	1	510000	192	12840	110343
Ammonium-N (mg/L)	24	0.643	<0.010	4.850	0.146	0.797	1.005
Oxidised-N (NOx)(mg/L)	24	0.87	0.10	2.01	0.49	1.46	0.559
Total Nitrogen (mg/L)	24	3.50	0.90	31.60	1.42	3.24	6.090
Total Phosphorus (mg/L)	24	0.080	<0.005	0.437	0.013	0.104	0.1029
Suspended Solids (mg/L)	24	16.7	2	81	6	21.8	19.6

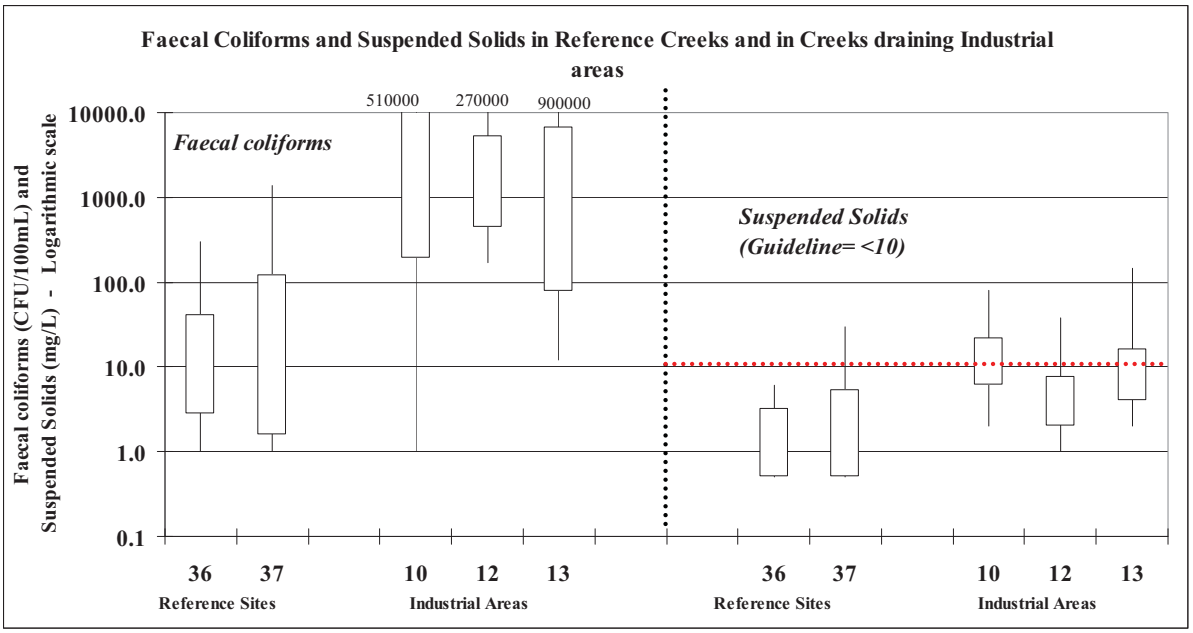
1.23.2 Site 13: Sams Creek, Mt Kuring-gai.

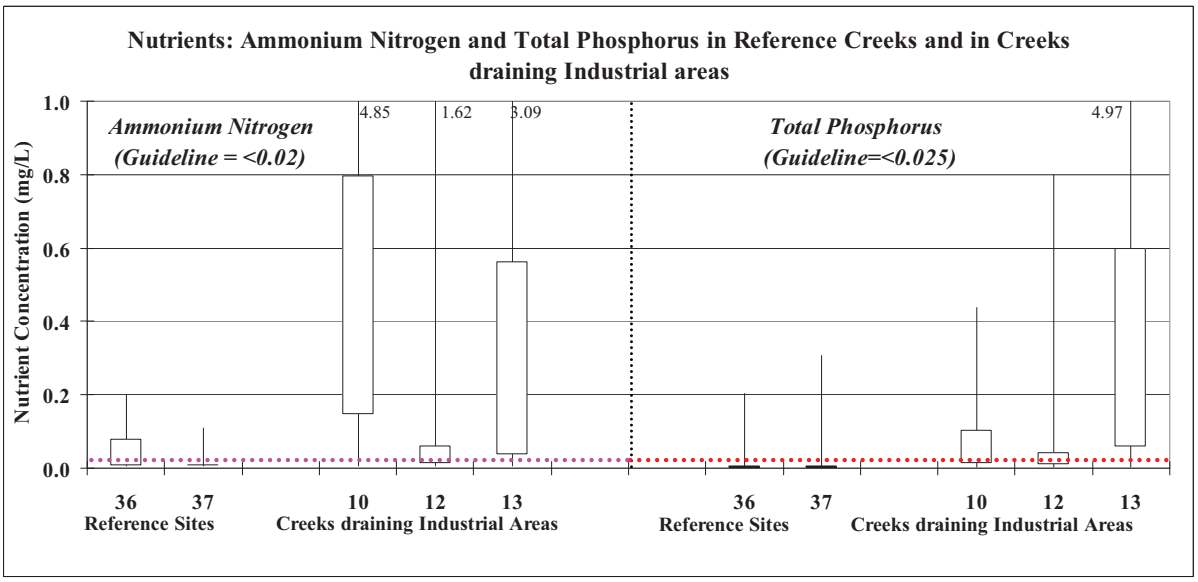
This site is located in the headwaters of Sams Creek within Berowra Valley Regional Park, at the end of Hamley Road, Mt Kuring-gai. Industry dominates the landuse upstream of this site with numerous premises still relying on the pump out off effluent. The catchment above this site is approximately 12.1 hectares with 86% zoned industrial and 14% zoned open space. This creek flows in a north westerly direction for 3km before its junction with Berowra Creek.

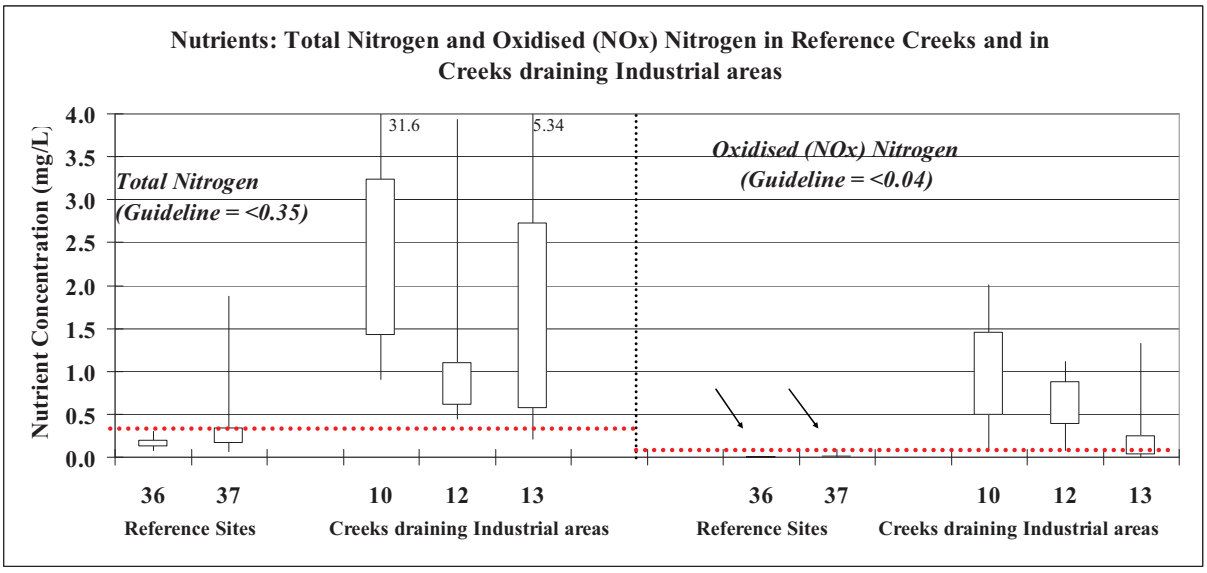
Table 21: Summary Statistics for Site-13 for July 06 to June 07

Parameters	Valid N	Mean	Min	Max	20th%	80th%	Std Dev
Temperature ^{o}C	23	17.20	7.56	23.20	12.69	21.26	4.42
Conductivity (mS/cm)	23	0.33	0.0	0.6	0.2	0.46	0.15
Turbidity (NTU)	23	15.3	2.6	46.7	6.7	21.1	11.06
Dissolved Oxygen (mg/L)	23	6.39	0.2	11.1	4.3	9.6	3.09
Dissolved Oxygen (% sat)	23	66.5	2.0	125.5	40.1	95.6	32.36
pH	23	7.36	6.75	8.88	7.15	7.53	0.40
Faecal Coliforms (CFU/100 mL)	23	44895	12	900000	78	6800	187008
Ammonium-N (mg/L)	23	0.424	<0.010	3.090	0.037	0.563	0.730
Oxidised-N (NOx)(mg/L)	23	0.19	<0.01	1.33	0.03	0.25	0.278
Total Nitrogen (mg/L)	23	1.54	0.21	5.34	0.56	2.72	1.398
Total Phosphorus (mg/L)	23	0.501	<0.005	4.970	0.058	0.600	1.0164
Suspended Solids (mg/L)	23	16.7	2	144	4	16.4	29.9

Figure 7: Water Quality in Creeks draining Industrial/Commercial areas; Annual distribution of parameters compared with Reference Creeks







1.23.3 Site 12: Leighton Place, Hornsby Creek.

Site 12 is located in Hornsby Creek, upstream of the road bridge at Leighton Place and flows into Kuring-gai Chase National Park. The catchment above this site is approximately 300 hectares in size and 60% of the landuse is residential comprising high, medium and low density residential zonings. Commercial/Industrial/Business makes up 17%, 10% is Special use A (roads, rail etc), 10% is Special use B (Community purposes) and 2% is open space. This highly urbanised catchment contains large areas of impervious surfaces which can contribute to higher flow volumes during rain and rapidly transport pollutants to the creek.

Table 26: Summary Statistics for Site 12 for July 06 to June 07

Parameters	Valid N	Mean	Min	Max	20th%	80th%	Std Dev
Temperature °C	20	17.31	9.22	23.61	13.51	20.99	4.17
Conductivity (mS/cm)	20	0.37	0.0	0.6	0.3	0.5	0.14
Turbidity (NTU)	20	16.7	0.2	62.0	2.1	31.0	18.85
Dissolved Oxygen (mg/L)	20	10.90	9.2	13.0	10.2	11.7	0.93
Dissolved Oxygen (% sat)	20	113.0	101.3	135.6	103.3	119.9	9.76
pH	20	8.10	7.50	8.93	7.79	8.45	0.41
Faecal Coliforms (CFU/100 mL)	25	14042	170	270000	444	5340	53598
Ammonium-N (mg/L)	25	0.096	<0.010	1.620	0.014	0.059	0.319
Oxidised-N (NOx)(mg/L)	25	0.60	0.07	1.12	0.38	0.88	0.279
Total Nitrogen (mg/L)	25	0.98	0.44	3.93	0.61	1.10	0.671
Total Phosphorus (mg/L)	25	0.058	<0.005	0.798	0.009	0.042	0.1567
Suspended Solids (mg/L)	25	7.3	1	38	2	7.8	10.4

1.24 Rural Areas. Sites 2, 42, 49, 62, 64 and 80

Rural areas have been classified as those areas with a majority of their catchment area under rural zoning or townships which still rely on onsite or pump out disposal of their effluent. Seven sites were monitored in 2006/07.

Figure 8 shows a summary of selected results at the rural sites.

Turbidity levels and suspended solids at the rural sites were generally low and satisfied the Guidelines on almost all occasions. The exception was Site 80 on Glenorie Creek where the Guidelines were exceeded about half the time.

As with last year, consistently elevated levels of faecal coliforms were recorded at most sites, particularly often at Glenorie (site 80), and often below Cowan Village (site 62) and Galston Village (site 64) indicating that run-off from septic systems and/or illegal discharges continue to occur within this area.

Monitoring sites (sites 64, 42, 49, 80 and 62) in close proximity to onsite sewage treatment systems had the highest total nitrogen results. Concentration values exceeded Guidelines on all occasions.

Levels of Oxidised Nitrogen were high at all sites and exceeded Guideline on most occasions, especially site 64 Galston Village.

Elevated levels of Ammonia were present at all sites except at Tunks Creek Site 2. Concentrations of ammonia were highest at Glenorie (site 80) which is also indicative of sewage pollution. All samples from Site 64 and 80 exceeded Guideline levels on all occasions..

Levels of total phosphorus were highest at Glenorie Creek (site 80). Sources of this phosphorus are most probably from fertiliser and domestic uses (detergents, illegal dumping of greywater, etc) in the upper catchment. Levels of pH were consistently within Guidelines at all sites within the rural areas.

1.24.1 Site 62: Cowan Township.

This site is located in the headwaters of Kimmerkong Creek and receives run-off from the Cowan township. The monitoring site is located upstream of the former quarry. Sampling commenced at this site in July 2002.

Table 27: Summary Statistics for Site 62 for July 06 to June 07

Parameters	Valid N	Mean	Min	Max	20th%	80th%	Std Dev
Temperature °C	6	16.19	8.38	20.48	13.65	20.21	4.78
Conductivity (mS/cm)	6	0.37	0.1	0.5	0.2	0.5	0.18
Turbidity (NTU)	6	22.3	0.3	124.0	0.4	5.7	49.87
Dissolved Oxygen (mg/L)	6	8.6	7.5	9.6	7.6	9.6	1.02
Dissolved Oxygen (% sat)	6	86.5	74.8	101.0	81.3	92.6	9.27
pH	6	7.14	7.04	7.28	7.04	7.22	0.10
Faecal Coliforms (CFU/100 mL)	10	13018	6	120000	402	2130	37610
Ammonium-N (mg/L)	10	0.017	<0.010	0.042	<0.010	0.024	0.012
Oxidised-N (NOx)(mg/L)	10	0.29	<0.01	1.51	<0.01	0.43	0.479
Total Nitrogen (mg/L)	10	0.71	0.31	1.77	0.38	0.97	0.495
Total Phosphorus (mg/L)	10	0.035	<0.005	0.144	<0.005	0.053	0.043
Suspended Solids (mg/L)	10	5.2	1	26	2	4.8	7.6

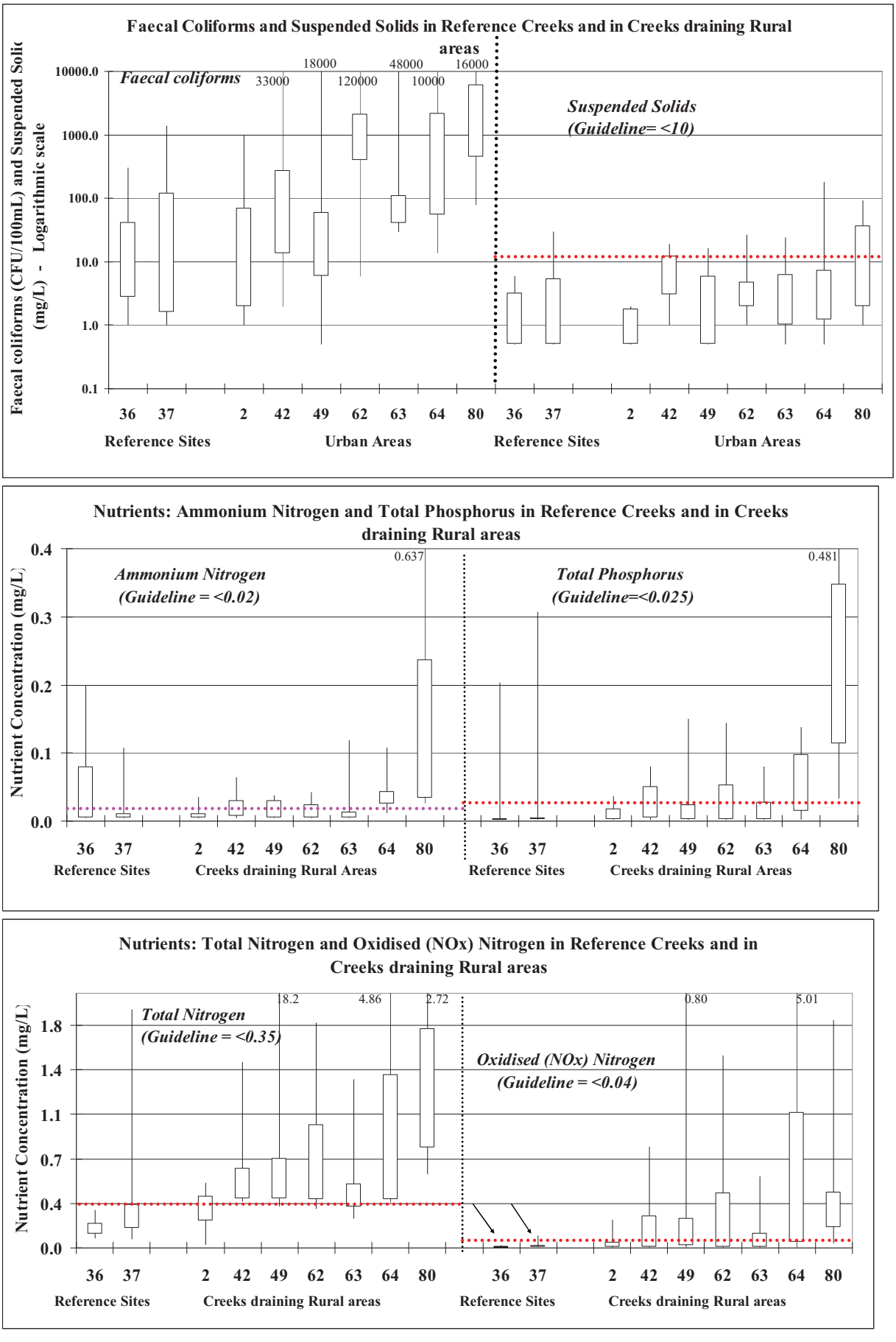
1.24.2 Site 64: Colah Creek, Galston Village.

Site 64 is located off Salaway Road, Galston. The monitoring location is on a tributary of Colah Creek, which receives run-off from the Galston township. Sampling commenced at this site in July 2002.

Table 24: Summary Statistics for Site-64 for July 06 to June 07

Parameters	Valid N	Mean	Min	Max	20th%	80th%	Std Dev
Temperature °C	10	15.06	7.49	21.98	11.32	18.86	4.55
Conductivity (mS/cm)	10	0.49	0.2	0.7	0.4	0.6	0.14
Turbidity (NTU)	10	11.4	2.0	40.8	3.9	18.6	11.97
Dissolved Oxygen (mg/L)	10	7.2	0.0	11.3	6.3	8.9	3.13
Dissolved Oxygen (% sat)	10	70.4	0.0	103.6	62.5	90.2	29.79
pH	10	7.15	6.81	7.57	6.92	7.43	0.27
Faecal Coliforms (CFU/100 mL)	12	1445	14	10000	55	2164	2861
Ammonium-N (mg/L)	12	0.037	0.012	0.108	0.025	0.043	0.025
Oxidised-N (NOx)(mg/L)	12	0.78	<0.01	5.01	0.04	1.06	1.475
Total Nitrogen (mg/L)	12	1.12	0.36	4.86	0.38	1.36	1.334
Total Phosphorus (mg/L)	12	0.055	<0.005	0.138	0.014	0.098	0.049
Suspended Solids (mg/L)	12	18.0	<1	179	1.2	7.4	50.8

Figure 8: Water Quality in Creeks draining Rural areas; Annual distribution of parameters compared with Reference Creeks



1.24.3 Site 2: Tunks Creek, Galston Gorge.

Site 2 is located at the bottom of Tunks Creek catchment, 100 metres upstream of the confluence with Berowra Creek. The site is approximately 5 km downstream of rural and urban sources. The catchment area is approximately 1700 hectares with 65% being zoned rural and approximately 30% consisting of open space and environmental protection zones. Sampling commenced at this site in October 1994.

Table 29: Summary Statistics for Site 2 for July 06 to June 07

Parameters	Valid N	Mean	Min	Max	20th%	80th%	Std Dev
Temperature °C	10	15.50	7.27	24.46	9.76	20.92	5.74
Conductivity (mS/cm)	10	0.43	0.4	0.5	0.4	0.5	0.05
Turbidity (NTU)	10	2.1	0.4	9.0	0.7	2.1	2.52
Dissolved Oxygen (mg/L)	10	9.4	3.1	12.8	7.5	11.6	2.91
Dissolved Oxygen (% sat)	10	92.3	34.7	138.9	82.8	103.7	26.62
pH	10	7.32	6.75	7.73	6.88	7.61	0.37
Faecal Coliforms (CFU/100 mL)	12	119	1	1000	2	69	284
Ammonium-N (mg/L)	12	0.010	<0.010	0.035	<0.010	0.011	0.010
Oxidised-N (NOx)(mg/L)	12	0.04	<0.01	0.22	0.01	0.05	0.060
Total Nitrogen (mg/L)	12	0.31	<0.05	0.51	0.22	0.40	0.137
Total Phosphorus (mg/L)	12	0.011	<0.005	0.036	<0.005	0.018	0.0123
Suspended Solids (mg/L)	12	1.0	<1	2	<1	1.8	0.6

1.24.4 Site 42: Colah Creek , Upstream of Wylds Road bridge, Glenorie.

Site 42 is located in Colah Creek, upstream of the Wylds Road Bridge, Glenorie. The catchment above this site is approximately 1010 hectares, 83% zoned as rural with the remaining areas being a mix of residential, main roads, commercial and open space. Sampling commenced at this site in October 1994.

Table 30: Summary Statistics for Site-42 for July 06 to June 07

Parameters	Valid N	Mean	Min	Max	20th%	80th%	Std Dev
Temperature °C	9	15.82	6.38	22.12	11.74	20.16	5.18
Conductivity (mS/cm)	9	0.41	0.3	0.5	0.3	0.5	0.09
Turbidity (NTU)	9	23.7	5.3	58.0	7.8	38.6	18.5
Dissolved Oxygen (mg/L)	9	4.4	0.8	8.3	2.7	6.5	2.40
Dissolved Oxygen (% sat)	9	43.3	7.9	81.0	29.5	64.5	23.81
pH	9	6.92	6.65	7.33	6.76	7.05	0.21
Faecal Coliforms (CFU/100 mL)	12	2867	2	33000	14	276	9491
Ammonium-N (mg/L)	12	0.022	<0.010	0.064	0.007	0.030	0.017
Oxidised-N (NOx)(mg/L)	12	0.16	<0.10	0.80	<0.01	0.25	0.261
Total Nitrogen (mg/L)	12	0.60	0.37	1.46	0.39	0.62	0.303
Total Phosphorus (mg/L)	12	0.025	<0.005	0.080	0.005	0.051	0.0259
Suspended Solids (mg/L)	12	6.6	1	19	3	12.4	5.8

1.24.5 Site 63: Colah Creek , end of Ben Bullen Road, Glenorie.

Site 63 is located in Colah Creek, prior to it flowing into Marramarra National Park. Sampling commenced at this site in July 2002.

Table 31: Summary Statistics for Site 63 for July 06 to June 07

Parameters	Valid N	Mean	Min	Max	20th%	80th%	Std Dev
Temperature °C	11	14.48	6.22	21.61	8.80	18.17	5.03
Conductivity (mS/cm)	11	0.55	0.3	0.8	0.4	0.7	0.18
Turbidity (NTU)	11	15.5	0.0	83.5	2.3	23.0	25.50
Dissolved Oxygen (mg/L)	11	7.4	0.0	12.8	6.1	9.5	3.58
Dissolved Oxygen (% sat)	11	70.4	0.0	107.7	64.8	85.9	31.05
pH	10	7.16	6.82	7.54	6.97	7.33	0.22
Faecal Coliforms (CFU/100 mL)	12	4064	30	48000	40	109	13836
Ammonium-N (mg/L)	12	0.018	<0.010	0.119	<0.010	0.013	0.032
Oxidised-N (NOx)(mg/L)	12	0.09	<0.01	0.56	<0.01	0.12	0.155
Total Nitrogen (mg/L)	12	0.49	0.23	1.32	0.32	0.51	0.294
Total Phosphorus (mg/L)	12	0.020	<0.005	0.080	<0.005	0.028	0.026
Suspended Solids (mg/L)	12	4.6	<1	24	1	6.2	6.7

1.24.6 Site 49: Still Creek, Mansfield Road, Arcadia.

Site 49 is located in the upper reaches of Still Creek draining a catchment of approximately 330 hectares, 80% of which is zoned rural and 17% is open space.

Table 32: Summary Statistics for Site 49 for July 06 to June 07

Parameters	Valid N	Mean	Min	Max	20th%	80th%	Std Dev
Temperature °C	10	15.83	8.13	22.16	10.76	19.70	4.87
Conductivity (mS/cm)	10	0.69	0.4	0.9	0.6	0.8	0.14
Turbidity (NTU)	10	8.8	0.0	74.6	0.3	4.1	23.17
Dissolved Oxygen (mg/L)	10	9.7	7.8	13.2	8.1	11.0	1.91
Dissolved Oxygen (% sat)	10	96.7	85.5	112.8	90.3	105.7	9.79
pH	10	7.40	6.90	7.92	7.27	7.60	0.29
Faecal Coliforms (CFU/100 mL)	12	1582	1	18000	6	60	5173
Ammonium-N (mg/L)	12	0.015	<0.010	0.038	<0.010	0.030	0.014
Oxidised-N (NOx)(mg/L)	12	1.62	<0.01	17.70	0.02	0.23	5.073
Total Nitrogen (mg/L)	12	2.12	0.33	18.20	0.38	0.70	5.098
Total Phosphorus (mg/L)	12	0.022	<0.005	0.150	<0.005	0.024	0.0420
Suspended Solids (mg/L)	12	3.5	<1	16	<1	6	4.8

1.24.7 Site 80: Glenorie Creek, Tekopa Ave, Glenorie, upstream of gross pollutant device

Site 80 is located in Glenorie Creek at the corner of Tekopa Ave and Tecoma Drive Glenorie. Sampling commenced at this site in August 1999 to assess the impact of the Glenorie township on water quality. This site is also impacted by a small area of market gardens

Table 33: Summary Statistics for Site 80 for July 06 to June 07

Parameters	Valid N	Mean	Min	Max	20th%	80th%	Std Dev
Temperature ^{o}C	9	16.07	7.35	22.32	11.85	19.41	4.79
Conductivity (mS/cm)	9	0.50	0.3	0.7	0.4	0.6	0.12
Turbidity (NTU)	9	8.6	2.2	23.3	4.0	12.4	6.89
Dissolved Oxygen (mg/L)	9	6.7	1.6	10.4	5.3	8.9	2.67
Dissolved Oxygen (% sat)	9	68.2	17.6	97.8	53.1	87.1	26.34
pH	9	7.05	6.80	7.36	6.93	7.13	0.16
Faecal Coliforms (CFU/100 mL)	11	4199	80	16000	450	6100	5657
Ammonium-N (mg/L)	11	0.175	0.026	0.637	0.034	0.237	0.185
Oxidised-N (NOx)(mg/L)	11	0.46	0.04	1.79	0.16	0.44	0.502
Total Nitrogen (mg/L)	11	1.24	0.58	2.72	0.79	1.72	0.624
Total Phosphorus (mg/L)	11	0.202	0.034	0.481	0.114	0.348	0.142
Suspended Solids (mg/L)	11	22.4	1	93	2	37	32.9

1.25 Estuarine Sites. Sites 60, 61, 48 and 38

Monitoring of water quality has occurred regularly at four estuarine sites since the mid 1990s. In 2006 six new sites in the Hawkesbury River were added to the sampling program to obtain baseline data upstream and downstream of the discharge site of the proposed Brooklyn STP outlet (see section 6.11).

Selected results of water testing are shown for the estuarine sites in Figure 9.

Turbidity within estuary sites results from soluble coloured organic compounds and from suspended particulate matter (which may include clay and silt, detritus and planktonic organisms) in the water column. Turbidity levels were highest at those sites located in downstream sections of the Estuary, close to the Hawkesbury River (sites 48 and 38). These two sites are generally shallow and narrow channels, with a bedload of predominately fine sediment, and in or adjacent to areas of strong tidal flow. These turbidity levels are considered to be indicative of a tidal dominated estuary as the sediment is easily resuspended from the turbulence created by tidal fluctuations.

Suspended solids were slightly elevated at those sites located in the downstream sections of the Estuary (site 48 and 38). However these levels are not considered excessive and are indicative of tidal dominated estuaries. Suspended sediments can provide food, shelter and transport for microbes.

During 2006-2007 faecal coliforms were consistently low at the estuarine sites 60, 61, 38, 48 and 55, but relatively high at Crosslands Site 90 (see section 6.12 Recreational Sites)

Levels of oxidised nitrogen were above the Guidelines on most occasions at site 60 and site 61 in the upper reaches of Berowra Estuary. Site 48 in Marramarra Ck was also above Guidelines more than half the time tested, with a single very high NOx concentration in March 2007. Berowra Creek at Crosslands Site 90 was tested only during the summer recreational season; it contained high NOx on all occasions, arising predominantly from residual nitrogen in discharge from West Hornsby and Hornsby Heights STPs.

Dissolved phosphorus measured within the estuary was consistently below detection limits with only a few occurrences where minor concentrations were detected, except at Crosslands where phosphorus was above the Guidelines on one occasion.

Levels of pH were consistently within Guidelines recommended for southeastern Australia.

Dissolved oxygen levels were generally within estuarine Guidelines. Low DO levels (70-80% DO saturation) were however recorded at site 60 and site 48 on a number of occasions during late spring and again in April. Slightly elevated DO was recorded at site 61 in February 2007 as a result of algal activity producing additional oxygen during daylight via the process of photosynthesis in organisms.

Chlorophyll-a levels were highest within the upper estuary sites 60 and 61 during late summer and early autumn. One extremely high chlorophyll-a (23 ug/L) at site 60 was recorded in July 2006 when suspended solids and DO were also high.

Elevated chlorophyll-a levels indicate high numbers of phytoplankton and free floating macroalgae. These chlorophyll-a concentrations are indicative of phytoplankton abundance and biomass within the estuary. Currently, a chlorophyll-a probe has been deployed within the estuary to monitor levels continuously. High levels of chlorophyll-a are not always indicative of poor estuarine health, it is the long term persistence of elevated levels that is of concern. As such, the upper percentile values provide a useful indicator of estuarine health. Generally, within the estuary chlorophyll-a levels fluctuate over time and depending on current climatic conditions. Phytoplankton numbers are greatest after rainfall, usually when nutrients are flushed into the estuary or during summer months when water temperatures are highest.

In addition to temperature and nutrients, the tidal regime is also important in controlling algal biomass. Tidal mixing can lower chlorophyll-a concentrations because the residence time of algae in the photic zone is reduced (Ozestuaries, 2007). Alternately, tidal mixing results in tidal sediments being re-suspended, creating an increase in turbidity which reduces light availability and subsequent photosynthetic activity.

High primary productivity within the water column, expressed by high chlorophyll-a concentrations, can contribute high amounts of easily decomposed (i.e. labile) organic matter to the sediments. Photosynthetic production and subsequent decomposition of algal biomass can increase the diurnal amplitude of the water column pH and dissolved oxygen fluctuations, and in some cases lead to anoxic and hypoxic events. All of these changes can translate into an overall reduction in animal and plant species diversity.

Dominant algal samples collected at estuarine sites 60 and 61 are shown in Figure 10. Phytoplankton types and numbers were similar at both sampling sites throughout the year. Bacillariophyceae was the most common class during summer months. Only in July did Dinophyceae dominate. Levels and dominant species were not considered problematic.

Figure 9. Water Quality at Estuarine and Recreational Sites. Annual distribution of Concentration Values

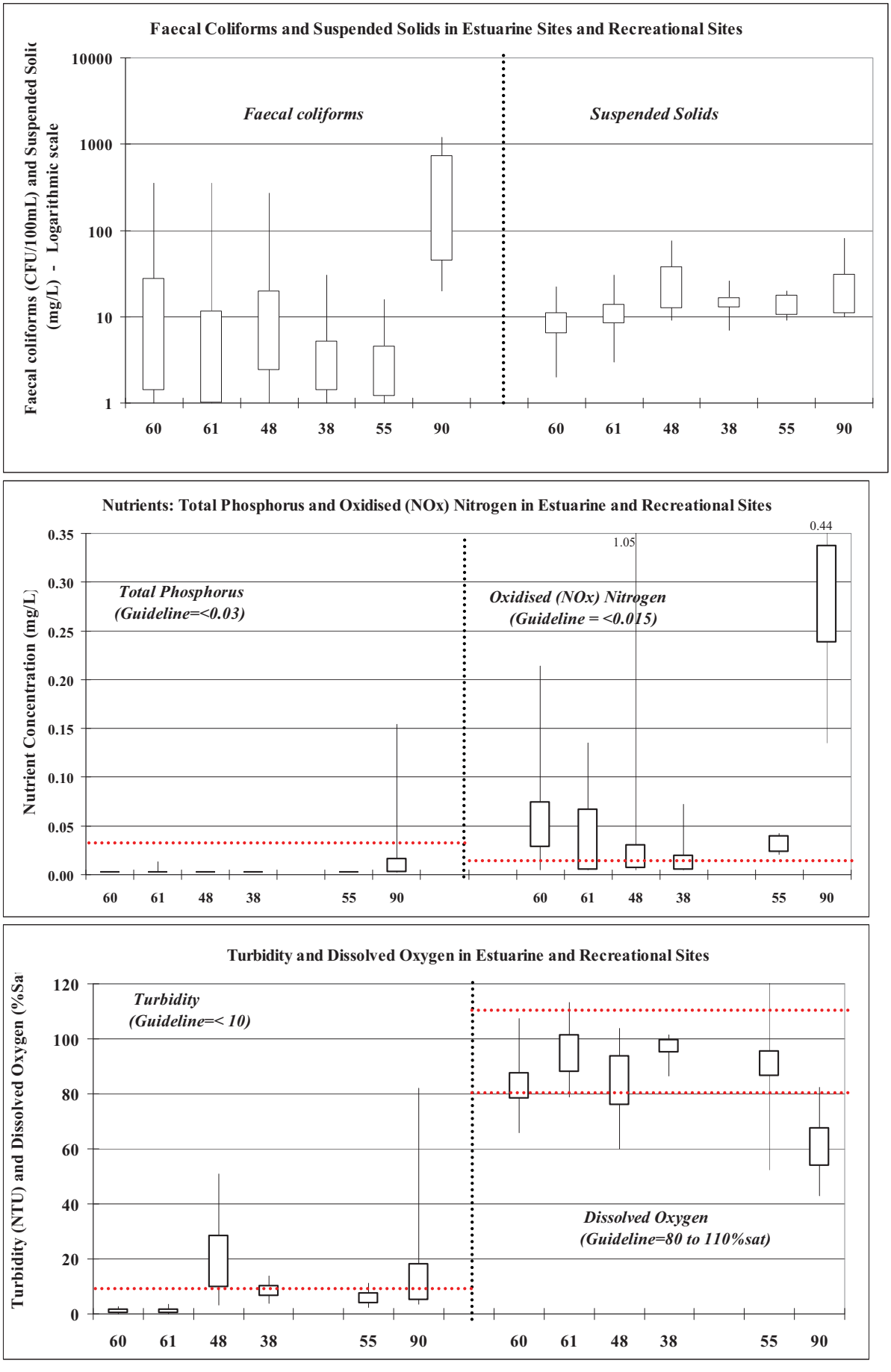
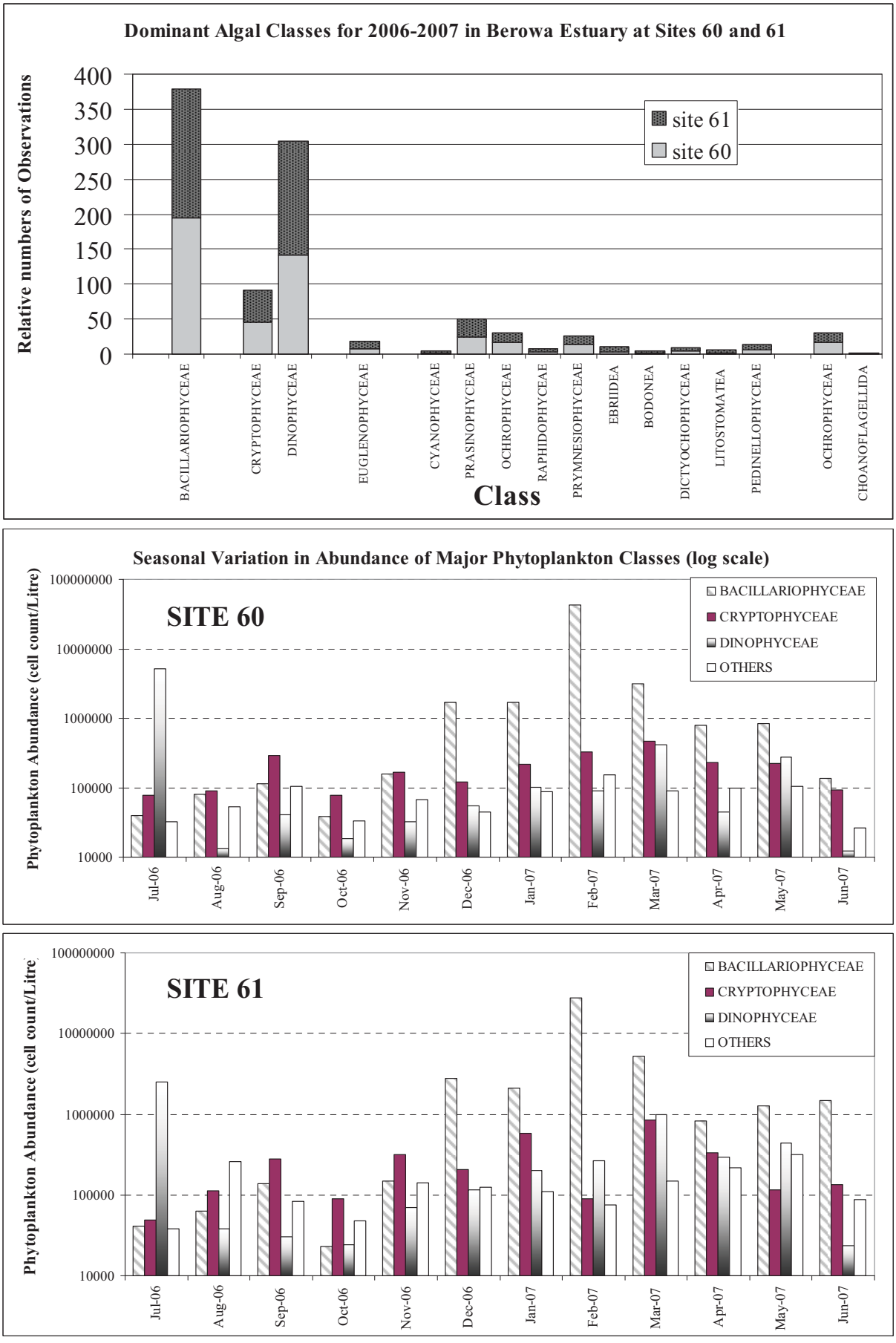


Figure 10: Dominant Algal classes for 2006/07 at sites 60 and 61



1.25.1 Site 60: Berowra Creek at Berowra Ferry crossing

Site 60 is located in the middle of Berowra Creek at Berowra Waters, 50 metres downstream of Berowra Ferry and has been sampled since 1997. Results of testing are summarised below.

Table 34: Summary Statistics for Site 60 for July 06 to June 07

Parameters	Valid N	Mean	Min	Max	20th%	80th%	Std Dev
Temperature °C	12	20.18	11.73	26.77	16.23	24.67	5.25
Turbidity (NTU)	12	1.1	0.0	2.7	0.3	1.6	0.86
Dissolved Oxygen (mg/L)	12	6.4	4.8	9.6	5.6	7.2	1.25
Dissolved Oxygen (% sat)	12	83.0	65.9	107.5	78.4	87.7	10.47
pH	12	7.38	7.05	7.78	7.19	7.54	0.22
Salinity (ppt)	12	28.08	22.9	33.86	25.59	30.51	3.00
Faecal Coliforms (CFU/100 mL)	13	56	1	350	1	28	120
Oxidised-N (NOx)(mg/L)	13	0.06	<0.01	0.21	0.03	0.07	0.053
Total Phosphorus (mg/L)	13	<0.005	<0.005	<0.005	<0.005	<0.005	0.000
Suspended Solids (mg/L)	13	8.9	2	22	6.4	11.2	4.8
Chlorophyll-a (ug/L)	13	4.8	<1	23	2.5	5.6	5.86
Soluble Reactive Phosphorus (mg/L)	13	0.004	<0.002	0.018	<0.002	0.005	0.0046

1.25.2 Site 61 - Berowra Estuary at Calabash Point

Site 61 is located in Berowra Creek at Calabash Point about 2 km downstream of the car ferry The results of multi probe testing and laboratory analysis of water samples is set out below

Table 35: Summary Statistics for Site- 61 for July 06 to June 07

Parameters	Valid N	Mean	Min	Max	20th%	80th%	Std Dev
Temperature °C	12	20.37	11.80	27.08	16.30	24.75	5.20
Turbidity (NTU)	12	1.3	0.0	3.5	0.3	1.8	1.09
Dissolved Oxygen (mg/L)	12	7.4	6.0	10.0	6.7	7.8	1.03
Dissolved Oxygen (% sat)	12	95.9	78.9	113.3	88.0	101.6	10.51
pH	12	7.54	7.17	7.84	7.38	7.67	0.18
Salinity (ppt)	12	28.43	23.08	34.02	25.49	31.06	3.14
Faecal Coliforms (CFU/100 mL)	13	31	1	350	1	12	96
Oxidised-N (NOx)(mg/L)	13	0.04	<0.01	0.14	<0.01	0.07	0.042
Total Phosphorus (mg/L)	13	<0.005	<0.005	0.013	<0.005	<0.005	0.003
Suspended Solids (mg/L)	13	11.8	3	30	8.4	13.8	6.3
Chlorophyll-a (ug/L)	13	3.7	2	7	2.5	5	1.7
Soluble Reactive Phosphorus (mg/L)	13	0.003	<0.002	0.018	<0.002	0.003	0.0050

Located near Site 61 is a “real-time” chlorophyll-a probe. This probe monitors chlorophyll a, conductivity and temperature. This probe provides an ‘early warning’ mechanism for detection of algal blooms. Discussion of that probe data is presented in the 2006-2007 Estuary Management Annual Report.

1.25.3 Site 48 – Marramarra Creek at the Orange Orchard

This site is located within the estuarine reaches of Marramarra Creek, adjacent to the old orange orchard. The results are compared to the Guidelines for marine waters and are influenced by shallow tidal movement.

Table 36: Summary Statistics for Site- 48 for July 06 to June 07

Parameters	Valid N	Mean	Min	Max	20th%	80th%	Std Dev
Temperature °C	12	18.85	9.70	25.67	13.94	23.17	5.19
Turbidity (NTU)	12	20.0	3.1	50.8	9.7	28.5	14.43
Dissolved Oxygen (mg/L)	12	6.9	4.8	9.5	5.4	8.5	1.55
Dissolved Oxygen (% sat)	12	86.0	60.0	103.9	75.8	93.9	12.31
pH	12	7.08	6.69	7.23	7.06	7.21	0.17
Salinity (ppt)	12	27.49	11.14	35.65	25.34	33.21	6.69
Faecal Coliforms (CFU/100 mL)	12	42	1	270	2	20	84
Oxidised-N (NOx)(mg/L)	12	0.10	<0.01	1.05	0.01	0.03	0.298
Total Phosphorus (mg/L)	12	<0.005	<0.005	<0.005	<0.005	<0.005	0.0000
Suspended Solids (mg/L)	12	27.0	9	76	12.4	37.6	21.4
Chlorophyll-a (ug/L)	12	2.7	<1	7	0.9	3	1.87

1.25.4 Site 38 - Hawkesbury River at Sandbrook Inlet, Brooklyn

Site 38 is located in the middle of Sandbrook Inlet, Brooklyn adjacent to a large number of swing moorings and marina operations.

Table 37: Summary Statistics for Site 38 for July 06 to June 07

Parameters	Valid N	Mean	Min	Max	20th%	80th%	Std Dev
Temperature °C	11	19.72	12.18	25.10	16.31	24.02	4.61
Conductivity (mS/cm)	11	49.45	44.1	53.1	47.1	51.2	2.79
Turbidity (NTU)	11	8.3	3.9	13.8	6.5	10.4	2.88
Dissolved Oxygen (mg/L)	11	7.3	6.1	8.7	6.9	8.0	0.78
Dissolved Oxygen (% sat)	11	96.4	86.5	101.4	95.1	99.6	3.96
pH	11	7.68	7.44	7.87	7.54	7.80	0.14
Salinity (ppt)	11	32.32	28.42	35.03	30.64	33.62	2.03
Faecal Coliforms (CFU/100 mL)	13	5	1	30	1	5	8
Oxidised-N (NOx)(mg/L)	13	0.02	<0.10	0.07	<0.01	0.02	0.018
Total Phosphorus (mg/L)	13	<0.005	<0.005	<0.005	<0.005	<0.005	0.0000
Suspended Solids (mg/L)	13	14.8	7	26	12.8	16.6	4.44
Chlorophyll-a (ug/L)	13	2.0	<1	3	0.7	2.5	1.0

1.26 Hawkesbury River STP Monitoring Sites: Sites 103, 104, 105, 106, 107 and 108

A Sewage Treatment Plant has been constructed at Brooklyn to treat waters from Brooklyn and Dangar Island residences before discharge from the Hawkesbury River bridge into the strong tidal flows of the Hawkesbury River.

A program was initiated by Council as part of the baseline monitoring of the environmental effects of the outfall. The STP is due to be commissioned in late 2007, so all data collected to date is pre-

discharge or baseline data. The summary tables below are presented here to give information on the current condition of the river.

Table 38. Summary Statistics for Site 103: Mouth of Milsons Passage for July 06 to June 07

Parameters	Valid N	Mean	Min	Max	20th%	80th%	Std Dev
Temperature °C	12	19.20	12.13	26.03	14.18	23.17	4.84
Turbidity (NTU)	12	8.9	0.0	24.3	3.6	16.5	7.57
Dissolved Oxygen (mg/L)	12	7.2	5.8	8.4	6.6	8.1	0.85
Dissolved Oxygen (% sat)	12	94.8	87.7	100.4	89.8	99.8	5.01
pH	12	7.78	7.47	8.09	7.55	7.94	0.21
Salinity (ppt)	12	33.48	26.93	36.99	31.30	35.66	2.95
Faecal Coliforms (CFU/100 mL)	12	1	1	4	1	2	1
Enterococci (CFU/100ml)	9	2	1	8	1	4	3
Oxidised-N (NOx)(mg/L)	12	0.03	<0.01	0.08	0.01	0.05	0.021
Total Phosphorus (mg/L)	12	<0.005	<0.005	<0.005	<0.005	<0.005	0.000
Suspended Solids (mg/L)	12	17.7	7	30	12	20	6.3
Chlorophyll-a (ug/L)	12	2.3	1	4	2	2.5	0.8

Table 39. Summary Statistics for Site 104: Middle of River off Peat Island for July 06 to June 07

Parameters	Valid N	Mean	Min	Max	20th%	80th%	Std Dev
Temperature °C	12	19.34	12.36	26.23	14.46	23.19	4.87
Turbidity (NTU)	12	5.5	0.0	27.1	3.0	5.8	7.09
Dissolved Oxygen (mg/L)	12	7.3	6.0	8.3	6.8	8.1	0.77
Dissolved Oxygen (% sat)	12	95.3	86.2	102.6	90.8	99.4	4.79
pH	12	7.79	7.53	8.10	7.59	7.95	0.20
Salinity (ppt)	12	34.06	27.2	36.94	31.83	36.20	2.97
Faecal Coliforms (CFU/100 mL)	12	2	1	6	1	2	2
Enterococci (CFU/100ml)	9	2	1	6	1	1	2
Oxidised-N (NOx)(mg/L)	12	0.02	<0.01	0.08	0.01	0.03	0.022
Total Phosphorus (mg/L)	12	<0.005	<0.005	0.006	<0.005	<0.005	0.001
Suspended Solids (mg/L)	12	15.5	8	24	13	18.8	4.3
Chlorophyll-a (ug/L)	12	1.7	0.5	2.5	0.6	2.5	0.9

Table 40. Summary Statistics for Site 105: Under Hawkesbury River Bridge for July 06 to June 07

Parameters	Valid N	Mean	Min	Max	20th%	80th%	Std Dev
Temperature °C	12	19.17	12.53	25.36	14.29	22.84	4.60
Turbidity (NTU)	12	5.1	0.0	20.9	2.5	6.2	5.43
Dissolved Oxygen (mg/L)	12	7.3	6.1	8.6	6.8	8.1	0.79
Dissolved Oxygen (% sat)	12	96.1	87.0	103.2	92.2	98.8	4.70
pH	12	7.83	7.58	8.11	7.65	7.96	0.18
Salinity (ppt)	12	34.39	27.51	37.17	32.12	36.58	2.87
Faecal Coliforms (CFU/100 mL)	12	1	1	2	1	1	0
Enterococci (CFU/100ml)	9	1	1	2	1	2	1
Oxidised-N (NOx)(mg/L)	12	0.02	<0.01	0.07	0.01	0.03	0.020
Total Phosphorus (mg/L)	12	0.008	<0.005	0.066	<0.005	<0.005	0.018
Suspended Solids (mg/L)	12	15.7	9	25	11.2	19.6	4.9
Chlorophyll-a (ug/L)	12	2.0	0.5	3	1.2	2.5	0.9

Table 41. Summary Statistics for Site 106: Middle inside mouth of Sandbrook Inlet off Marina for July 06 to June 07

Parameters	Valid N	Mean	Min	Max	20th%	80th%	Std Dev
Temperature °C	12	19.20	11.85	25.86	14.22	23.46	4.96
Turbidity (NTU)	12	9.9	0.0	27.9	2.8	23.4	10.98
Dissolved Oxygen (mg/L)	12	7.3	6.1	8.3	6.7	8.1	0.78
Dissolved Oxygen (% sat)	12	94.9	88.2	101.3	91.4	98.2	3.97
pH	12	7.79	7.53	8.03	7.62	7.93	0.18
Salinity (ppt)	12	33.53	27.3	36.53	31.26	35.67	2.84
Faecal Coliforms (CFU/100 mL)	12	5	1	40	1	2	11
Enterococci (CFU/100ml)	9	14	1	100	2	7	32
Oxidised-N (NOx)(mg/L)	12	0.02	<0.01	0.07	0.01	0.04	0.020
Total Phosphorus (mg/L)	12	<0.005	<0.005	<0.005	<0.005	<0.005	0.000
Suspended Solids (mg/L)	12	14.3	6	22	10.2	18	4.6
Chlorophyll-a (ug/L)	12	1.7	0.5	2.5	1	2.5	0.8

Table 42. Summary Statistics for Site 107: Middle Hawkesbury off Long Island for July 06 to June 07

Parameters	Valid N	Mean	Min	Max	20th%	80th%	Std Dev
Temperature °C	11	19.82	12.93	26.76	16.54	23.20	4.55
Turbidity (NTU)	11	4.1	0.0	17.2	1.4	5.5	4.75
Dissolved Oxygen (mg/L)	11	7.2	6.2	8.1	6.9	7.7	0.64
Dissolved Oxygen (% sat)	11	96.3	88.8	103.7	92.9	99.7	4.23
pH	11	7.84	7.60	8.11	7.69	7.99	0.18
Salinity (ppt)	11	34.67	29.05	37.48	32.11	36.93	2.79
Faecal Coliforms (CFU/100 mL)	12	2	1	10	1	1	3
Enterococci (CFU/100ml)	9	3	1	16	1	2	5
Oxidised-N (NOx)(mg/L)	12	0.02	<0.01	0.06	<0.01	0.03	0.018
Total Phosphorus (mg/L)	12	<0.005	<0.005	<0.005	<0.005	<0.005	0.000
Suspended Solids (mg/L)	12	14.3	8	32	9	15.8	7.6
Chlorophyll-a (ug/L)	12	2.3	0.5	4	2	2.5	0.9

Table 39. Summary Statistics for Site 108: Hawkesbury off Bradleys Beach Dangar Island for July 06 to June 07

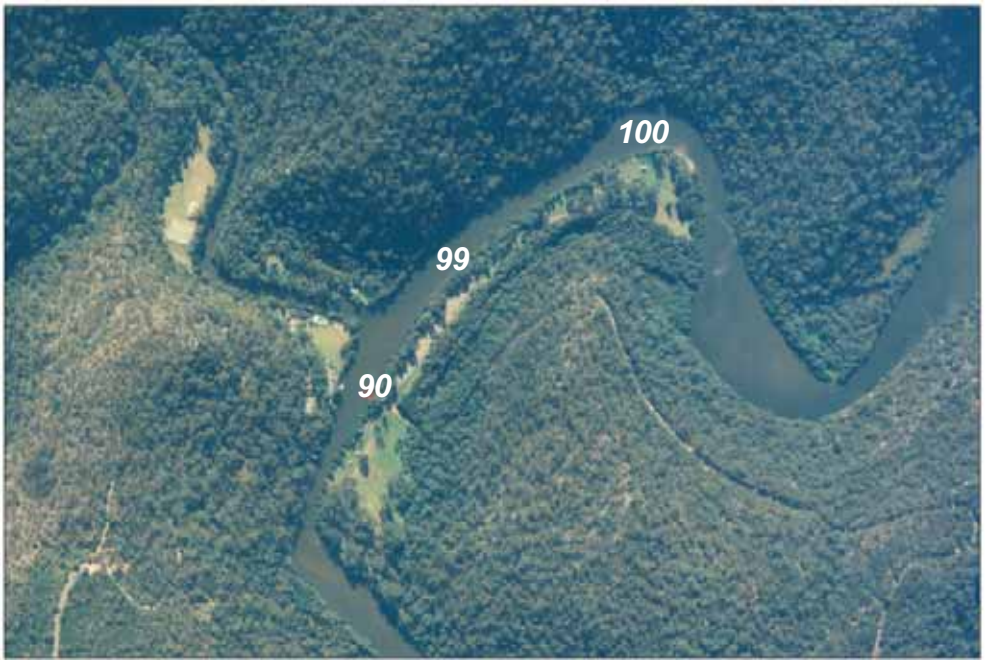
Parameters	Valid N	Mean	Min	Max	20th%	80th%	Std Dev
Temperature °C	11	19.64	13.30	24.34	16.88	22.95	3.97
Turbidity (NTU)	11	3.6	0.0	9.7	2.1	5.1	2.50
Dissolved Oxygen (mg/L)	11	7.3	6.4	7.9	7.0	7.6	0.51
Dissolved Oxygen (% sat)	11	97.8	91.5	108.5	94.4	103.3	5.38
pH	11	7.86	7.43	8.14	7.70	8.03	0.21
Salinity (ppt)	11	35.79	30.94	38.2	34.70	37.33	2.12
Faecal Coliforms (CFU/100 mL)	12	2	1	5	1	1	1
Enterococci (CFU/100ml)	9	9	1	38	1	16	14
Oxidised-N (NOx)(mg/L)	12	0.02	<0.01	0.04	0.01	0.02	0.011
Total Phosphorus (mg/L)	12	<0.005	<0.005	<0.005	<0.005	<0.005	0.000
Suspended Solids (mg/L)	12	16.6	3	64	10.2	15	15.5
Chlorophyll-a (ug/L)	12	1.9	0.5	3	1	2.5	0.9

1.27 Recreational Sites. Site 55: Hawkesbury River at Brooklyn Baths and Sites 90, 99 and 100 at Berowra Ck at Crosslands

Water-based recreational activities have always been popular in Australia and are highly valued by the community. Hornsby Shire Council undertakes water quality monitoring at two recreational sites during the months of December, January, February and March. Monitoring is carried out on a weekly basis at Brooklyn Baths (Figure 11) and Crosslands Reserve (Figure 12) based on recommendations in the National Health and Medical Research Council Guidelines for managing risks in recreational water (2006).

Figure 11: Brooklyn Baths sampling site 55

Figure 12: Crosslands Reserve sampling sites 90, 99 and 100



Assessments by Council in previous years of the two main recreational water sites led to the classification of the Brooklyn Baths site as "Low Risk" and Berowra Creek at Crosslands Reserve as "Moderate Risk" (Hornsby Shire Council, 2006a). This led to the monitoring schedule carried out over summer 2006-2007.

Results for on-site probe testing and laboratory analysis of samples taken over the 2006-2007 summer are summarised in Tables 44 and 45.

Table 44: Summary Data for Site 55: Hawkesbury River at Brooklyn Baths for December 2006 to March 2007

Parameters	Valid N	Mean	Min	Max	20th%	80th%	95th%	Std Dev
Temperature °C	17	23.89	21.76	26.19	22.96	24.71	25.40	1.14
Turbidity (NTU)	17	6.1	2.5	11.2	3.9	7.6	10.2	2.49
Dissolved Oxygen (mg/L)	17	6.4	5.8	9.5	5.9	6.6	7.3	0.85
Dissolved Oxygen (% sat)	17	91.4	52.5	137.3	86.5	95.7	104.5	15.63
pH	17	7.79	7.47	8.00	7.72	7.91	7.98	0.17
Salinity (ppt)	17	35.54	33.44	36.96	34.14	36.60	36.78	1.27
Faecal Coliforms (CFU/100 mL)	7	4	1	16	1	5	13	5
Enterococci (CFU/100ml)	7	7	1	40	1	2	29	15
Oxidised-N (NOx)(mg/L)	7	0.03	0.02	0.04	0.02	0.04	0.04	0.009
Total Phosphorus (mg/L)	7	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.000
Suspended Solids (mg/L)	7	14.6	9	20	10.4	17.8	19.4	4.2
Chlorophyll-a (ug/L)	7	1	<1	2	0.5	1.8	2	0.71

Table 45: Summary Data for Site 90, 99 and 100. Berowra Creek at Crosslands Reserve. December 2006 to March 2007

Parameters	Site 90	Valid N	Mean	Min	Max	20th%	80th%	95th%	Std Dev
Temperature °C		17	23.60	20.77	27.19	21.83	24.42	26.74	1.77
Turbidity (NTU)		17	14.3	3.6	82.0	4.9	18.2	33.8	18.43
Dissolved Oxygen (mg/L)		17	4.7	3.2	6.4	4.1	5.6	6.1	0.85
Dissolved Oxygen (% sat)		17	61.6	42.8	82.3	53.7	67.6	76.3	9.24
pH		17	7.26	6.85	7.45	7.15	7.42	7.45	0.16
Salinity (ppt)		17	17.75	1.39	27.45	9.37	25.45	27.38	8.20
Faecal Coliforms (CFU/100 mL)		7	406	20	1200	44	742	1077	457
Enterococci (CFU/100ml)		7	807	30	4700	48	448	3440	1725
Oxidised-N (NOx)(mg/L)		7	0.28	0.14	0.44	0.24	0.34	0.41	0.095
Total Phosphorus (mg/L)		7	0.027	<0.005	0.154	<0.005	0.017	0.114	0.057
Suspended Solids (mg/L)		7	28.0	10	81	10.8	30.8	66.3	24.8
Chlorophyll-a (ug/L)		7	1.8	<1	6	0.5	2.6	5.1	2.1
Parameters	Site 99	Valid N	Mean	Min	Max	20th%	80th%	95th%	Std Dev
Enterococci (CFU/100ml)		6	1009	60	5100	65	670	3990	2019
Parameters	Site 100	Valid N	Mean	Min	Max	20th%	80th%	95th%	Std Dev
Enterococci (CFU/100ml)		7	143	5	750	8	142	576	274

Results of the observations and testing are summarised in Tables 42 and 43 in terms of compliance with NHMCR Guidelines.

Selected results of analysis are also presented in Figure 9 together with other estuarine sites which are monitored for the whole year.

Table 46: Site 55: Hawkesbury River at Brooklyn Baths for December 2006 to March 2007 – Summary Compliance and Categories for Recreational Water use.

Month	Average Temp oC	Algae	pH	Dissolved Oxygen (%sat)	Oily Films or surface scums	Aesthetic aspects	Microbial Category	Aquatic Ecosystem Protection
NHMRC Recomm'n	***-***	***See table 2***	***6.5 – 8.5***	***>80 % sat***	***Free***	***Not Bothersome***	***See Table 3***	***See table 1 for TN, TP, turbidity***
December 2009	22 - 25	OK	7.8 OK	84 – 96 OK	OK	OK	A. Very good	OK
January 2007	23 - 24	OK	7.9 OK	53 – 137 Fair	OK	OK	A. Very good	OK
February 2007	24 - 26	OK	7.7 OK	86 – 94 OK	OK	OK	A. Very good	OK
March 2007	24	OK	7.8 OK	89 – 96 OK	OK	OK	A. Very good	OK

Table 47: Berowra Creek at Crosslands Reserve Sites 90, 99 and 100 for December 2006 to March 2007 – Summary Compliance and Categories for Recreational Water use.

Month	Average Temp oC	Algae	pH	Dissolved Oxygen (%sat)	Oily Films or surface scums	Aesthetic aspects	Microbial Category	Aquatic Ecosystem Protection parameters
NHMRC Recomm'n	***-***	***See table 2***	***6.5 – 8.5***	***>80 % sat***	***Free***	***Not Bothersome***	***See Table 3***	***See table 1 for TN, TP, turbidity***
December 2009	21 - 24	OK	7.1 – 7.4 OK	54 – 64 Poor	Fair	Nuisance organisms* and scum	D. Poor	Poor#
January 2007	22 – 27	OK	7.3 – 7.4 OK	43 – 82 Poor	OK	Nuisance organisms*	D. Poor	Poor#
February 2007	21 - 24	OK	7.0 – 7.3 OK	53 – 68 Poor	OK	Nuisance organisms*, turbid	D. Poor	Poor#
March 2007	23 - 24	OK	6.9 – 7.3 OK	52 – 75 Poor	OK	Nuisance organisms*, odour, turbidity	D. Poor	Poor#

* "Nuisance" organisms - Ducks and associated faeces noted. # Poor – excessive turbidity or nutrients

Based on the matrix in Tables 46 Brooklyn Baths is classified as VERY GOOD as it satisfies the Guidelines for the 2006-2007 summer swimming season.

Table 47 shows that Berowra Creek at Crosslands was classified as POOR for recreational swimming in summer. Crosslands no doubt receives contaminants (nutrients, bacteria) from further up the catchment, especially after heavy rainfall events in the upper catchment. The contaminants and their physical and biological, effects (high bacteria, low DO, high nutrients, scums and aesthetic problems) result in its Poor recreational classification. However, is it noted that sites 90 and 99 were more contaminated with enterococci than at site 100 which is further away from the developments at Crosslands. This indicates that localised souces of bacterial contamination should be further investigated at Crosslands.

It is noted that during the swimming season that 6 of the 16 sampling days were recorded as wet weather events (see Figure 4). This further confirms that the risk of water pollution affecting recreational water quality increases for a few days after rain. Authorities such as Beachwatch (http://www.environment.nsw.gov.au/beach/) and Hornsby Council do not recommend swimming at harbour and estuary sites (such as Crosslands) for 72 hours after heavy rain.

1.28 Biological Monitoring Results

1.28.1 Berowra Creek and Lane Cove River Catchments

The Macroinvertebrate and Diatom monitoring program was undertaken under contract initially by Australian Museum Business Services (from 2002 to 2005) and more recently by GHD (2005-2007). The project to date has developed robust and useful information relating to the health and composition of the aquatic communities within the Hornsby Shire.

The composition of the macroinvertebrate and diatom communities within the Berowra and Lane Cove River catchments are clearly influenced by catchment landuse types and seasonality (GHD, 2007). Land use continues to have the strongest impact, however the general trend toward seasonality continues with far fewer communities found during Spring than in Autumn. The macroinvertebrate and diatom communities recorded at most sampling sites were generally depauperate and characterised by species tolerant of disturbed conditions.

Historically the trend has been toward declining numbers and diversity of macroinvertebrate communites across the sites. This trend is not as obvious in the diatom data. The temporal decline may be due not only to contamination from developed areas but also to prevailing extended drought conditions.

1.29 Sewage overflows

Sydney Water's sewerage system includes pipes, pumping stations, overflow points and Sewage Treatment Plants (STPs) which are designed to transport and treat sewage flows. Information about sewage overflows can be sourced from www.sydneywater.com.au.

During dry weather, overflows or discharges of sewage can occur as a result of designed relief, blockage in a pipe or a pump failure. This blockage reduces the capacity of the pipe to carry its design flow and hence an untreated discharge occurs. During wet weather, stormwater flows may infiltrate aged piped systems thereby causing a further exceedance of the system capacity resulting in an overflow or bypass of the treatment system.

Sydney Water regularly notifies Hornsby Council of these overflows and how/when they are rectified. Within the Hornsby Shire a majority of these blockages are caused by tree roots or failing infrastructure. Sydney Water provides notification of overflows or bypasses on a weekly basis for the Greater Sydney Region including the Blue Mountains.

Sydney Water is committed to reducing overflows from sewerage systems through their SewerFix maintenance and improvement program. Property owners are responsible for maintaining the private sewer pipes on their property to ensure that plant roots, laundry and backwash water and stormwater runoff do not enter the trunk sewerage system.

Conclusions

Chemical, physical and biological water quality results for 2006-2007 show that the surrounding land-use, rainfall and seasons play a major role in aquatic health. The intensity and duration of rainfall contributes to the assimilation, transport and deposition into waterways of land based pollutants such as sediment, nutrients and general litter. At sites influenced by sewage and stormwater, the nutrients and suspended solids concentrations as well as turbidity and faecal coliforms are usually greater after wet weather than dry. Given the influence that stormwater plays in water quality degradation, it is noted that ANZECC/ARMCANZ (2000) Guideline values are regularly exceeded during wet and dry weather downstream of industrial sites. Water quality in creeks downstream of urban and rural areas is often good, but unfortunately these creeks are often flushed with contaminated stormwater containing

elevated nutrients, sediment and faecal bacteria. These episodes of contamination seriously damage stream ecology which then struggles to recover before the next episode.

Council's Catchments Remediation Rate Program aims to mitigate the influence of wet and dry weather contamination of creeks and bushland. This program involves the construction and maintenance of catchment remediation devices such as wetlands, sediment basins and gross pollutant traps, as well as pollution preventative strategies such as street sweeping, business environmental auditing and education.

The variations in water quality in the Shire's freshwater creeks is highlighted by comparison with water quality Guidelines as well as by comparison with the water quality results gathered from the two reference creeks located in catchments unimpacted by human developments and activities.

1.30 Suspended Sediment

Within developed areas rainfall runoff results in increased suspended solids and turbidity levels in creek waters arising from release of sediments from new development sites, roadways and hard surfaces, and illegal discharges. Given the prevailing drought conditions and current water restrictions, there were generally low levels of suspended solids and turbidity levels for 2006-2007 throughout the Shire. Turbidity and suspended solid levels were generally highest downstream of industrial and rural activities.

1.31 Faecal Coliforms

Faecal coliform results within the urban areas were considered to be moderate throughout the year. However peak events did occur specifically at Industrial sites (10, 12 and 13) and urban site 46 (Terrys Ck) and rural sites 62 and 80 below Glenorie. These problems are considered to result predominantly from failing sewerage infrastructure, from dry weather sewer overflows/chokes, poor on-site sewage treatment or animal excrement.

1.32 Nutrients

All urban site (excluding Joe Crafts Creek site-39) and industrial sites continued to have consistently high levels of nutrients. Sources of nutrients within urban areas include fertilisers, detergents, eroding soils, decomposing lawn clippings, pet faeces, sewage seepages or sewer overflows.

Within the rural areas nutrient concentrations were elevated at sites closest to onsite sewage treatment systems and rural activities (eg, agriculture and horticulture). Specifically, site 80 in Glenorie maintained high nutrient levels.

Hornsby Heights and West Hornsby Sewage Treatment Plants have undergone major upgrades as part of Sydney Waters' commitment to the Statement of Joint Intent for Berowra Creek and WaterPlan 21. The main goal of this upgrade was to reduce nutrients in treated effluent in order to protect the downstream Berowra Creek and Estuary from ongoing algal blooms. Initial results indicate that the upgrades have significantly reducing nutrient levels. Nevertheless oxidised nitrogen levels remained above the recommended Guidelines for freshwater sites and estuarine sites downstream of the STP discharges.

1.33 Temperature

Thermal pollution was only apparent downstream of the Sewage Treatment Plants. This is due to biological processing techniques used within the plant to treat effluent. The storage of effluent water within maturation ponds exposes the effluent to high amounts of sunlight and biological digestion, warming the effluent with ambient heat and exposure of the effluent to UV light for sterilisation. As such, the warmer water discharged from the outfall may be affecting stream biota for a few kilometres downstream of discharge points particularly during winter months.

1.34 Estuary

Within estuarine areas, levels of faecal coliforms were generally low. The action of tidal movement resuspending sediments and wet weather run-off from urban and rural areas contributes to periodic high levels of turbidity/suspended solids. Chlorophyll-a monitoring in the Berowra Creek estuary were elevated on a few occasions indicating high phytoplankton concentrations. This was confirmed by algal analysis which continued to identify a wide range of algal species. The algal composition is similar to previous years with no significant occurrences of harmful species at problematic concentrations. Nitrate concentration in Berowra Creek, sourced predominantly from the STPs, remained well above Guideline levels and was the likely nutrient source supporting the algal growths.

Recreational water monitoring over the summer season showed Brooklyn Baths continued to be classified as Very Good, while Berowra Creek at Crosslands Reserve had a “poor” classification.

1.35 Macroinvertebrates and Diatoms

The presence and abundance in freshwater creeks of diatom and macroinvertebrate species, some very sensitive to pollution and others more tolerant, provide a good indication of decline or improvement in water quality over a longer time frame than is possible by water quality testing alone. In this reporting period monitoring of freshwater sites showed a significant reduction in the diversity and abundance of macroinvertebrates in creeks downstream of urban, rural and industrial areas in the Shire over the last few years confirming the continued need for improvements in sewage and stormwater infrastructure, as well as ongoing community education and environmental auditing of industry operations and rural land use practices.

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Glossary

Algae: simple chlorophyll-bearing plants which are capable of photosynthesis. They may occur in all aquatic environments, and may be microscopic in size. Algal monitoring in Berowra Estuary refers to collection and identification of micro-algae or phytoplanktonic species and aims to help protect stakeholders by early detection of harmful species or algal blooms

Algal Bloom: An unusually large concentration of algal planktonic organisms made up of one or a few species. In the estuarine environment blooms may be noticed by change in water colour, by surface froths, or even fish kills.

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

Assimilation: The incorporation of absorbed substances into cellular material.

AUSRIVAS: Australian River Assessment Scheme. A rapid biological assessment method of collecting, processing and cataloguing of macroinvertebrates from freshwater streams.

Catchment: The area of land above a chosen stream site which all drains to that site.

Chlorophyll-a: This is a biological pigment which enables plants, including algae, to photosynthesize. The pigment concentration is measured in a 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 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 dissolve in solution conduct current very poorly.

Control Site. See Reference Site

Correlation: The linear relationship between two or more variables.

Diatoms: A large group of microscopic algae found as single celled or colonial organisms, characterised by a cell wall containing silica. Important part of estuarine phytoplankton and surface growths on rock and plant surfaces in both estuarine and freshwater streams. The diversity and richness of diatom species is used as an indicator of stream health.

Dissolved Oxygen: Oxygen in water is measured as dissolved oxygen (DO). The saturated concentration of DO in water being dependant 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 0^0C equates to 14.63 mg oxygen per litre of water. Supersaturated 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.

Ecology: Study of living organisms and their relationships to one another and the environment.

Ecosystem: A community composed of plants and animals which, together with its physical environment, functions as a unit.

Enterococci: A group of streptococcal bacteria, usually non-pathogenic, found in the human intestinal tract. Enterococci present in waters at recreational sites are considered indicators of human faecal contamination.

Erosion: The wearing away of the substrate as a result of factors including weathering and human use.

Escherichera:

Estuary: A partially enclosed coastal river mouth, characterised by tidal effects and mixing of fresh and sea water. The Berowra Creek estuary is the waterway between the Hawkesbury River up to the tidal limit of Berowra Creek.

Faecal coliforms: Faecal coliforms are bacteria that inhabit the intestines of humans and other mammals and are present in faeces. Direct detection of pathogens is not feasible because they occur intermittently in the water column, are difficult to detect and the costs are prohibitive. For this reason faecal coliform are measured as an indicator bacteria. Faecal coliforms are present in large numbers in human faeces but it is important to note that coliforms are not themselves pathogenic under normal conditions, although they can cause diarrhoea and sometimes urinary tract infections (Tortora *et al*, 1986). They are commonly used as an indicator of sewage pollution in water. (Sinden and Wainsbrough, 1996). The biggest impact of water-borne micro organisms is on human health. Micro-organism levels in urban waterways are generally highest after heavy storms due to contributions from unabated stormwater runoff, bypass at sewage treatment plants and leaks from sewage infrastructure.

Groundwater: Water below the surface of the earth, generally occurring in the pore spaces of rocks and soils.

Leachate: Water which has passed through the soil and contains soluble substances from it.

Macroinvertebrates: A group name given to a wide range of small animals species commonly found in freshwater streams and visible to the naked eye. Sometimes referred to as “Water Bugs”. Includes various species of insects, crustaceans, molluscs and worms including stoneflies, mayflies, shrimps, flatworms, blood worms, leeches, mosquito larvae and beetles. The diversity and richness of macroinvertebrate species, and the presence or absence of particular types, is used as an indicator of stream health.

Monitoring: The observation and assessment of a certain area over time.

Nitrogen: The principal 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 vegetation, leachate from landfill, animal faeces, industrial wastewater and fertilisers, 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 favouring exotic species or algal blooms) that can cause eutrophication of waters.

Nuisance organisms/plants: Plants and/or organisms that are usually introduced species which affect the health of an aquatic ecosystem.

pH: pH is the 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 7.0 is neutral. pH can affect the toxicity of pollutants such as ammonia, aluminium and cyanide and the rate at which pesticides break down in soil.

Phosphorus: Phosphorus is one of the main nutrients required for the growth of 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 river's 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 fertiliser application or attached to eroded soil particles. The dissolved form of phosphorus is mainly phosphate (PO_4).

Phytoplankton: Minute free-floating algal organisms that are the primary food source, directly or indirectly, of all sea organisms. Phytoplankton diversity and biomass varies seasonally in amount, depending on favourable light, temperature, and nutrients.

Reference Site: A monitoring site against which other sites are compared. Ideally, in environmental studies of waterways, the reference creek is chosen, if possible, to have a similar catchment type and geology, but to be unimpacted by human activities.

Sedimentation: Material of varying size, both mineral and organic, deposited away from its site of origin by the action of water, wind, gravity or ice.

Suspended solids: Suspended solids is 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 suspended solids have the potential to reduce the amount of light available to benthic organisms and aquatic organisms for their metabolism and photosynthesis.

Tidal flushing: The action by which an estuary or river exchanges water with the ocean due to the flow of water caused by the tides.

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 a measure of the light scattering properties of water. It indicates how much silt, algae and other material is 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.