HORNSBY
SHIRE COUNCIL

Water Quality Companion Technical Report

Water quality report card

Acknowledgements:

Data used in this Companion Technical Report was organised and collected by both specialist consultants and numerous members of Hornsby Shire Council's Water Catchments team (now part of the Natural Resources team).

The rationale and methodology used to determine the waterway health grades was researched and developed by Paul Fredrickson under the direction of Dr Ross McPherson, Chief Environmental Scientist, Hornsby Shire Council.

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List of Acronymns

ANZECC	Australian and New Zealand Environment Conservation Council
ARMCAN	Agriculture and Resource Management Council of Australia and New Zealand
CRR	Catchments Remediation Rate
DO	dissolved oxygen
EHV	environmental health value
EPT	ephemeroptera, plecoptera and trichoptera abundance
FC	Faecal coliforms
NHMRC	National Health and Medical Research Council
NOx - N	oxidised nitrogen
NH_3 - N	ammonium nitrogen
REHV	regional environmental health value
SIGNAL2	stream invertebrate grade number average level
SoJI	Statement of Joint Intent
SS	suspended solids
StSc	standardised score
STP	sewage treatment plant
TDI	trophic diatom index
TN	total nitrogen
TP	total phosphorous
WCS	worst case scenario
WQRC	Water Quality Report Card

Cover image courtesy of Kaye Menner, Normanhurst - *Hidden Beauty*

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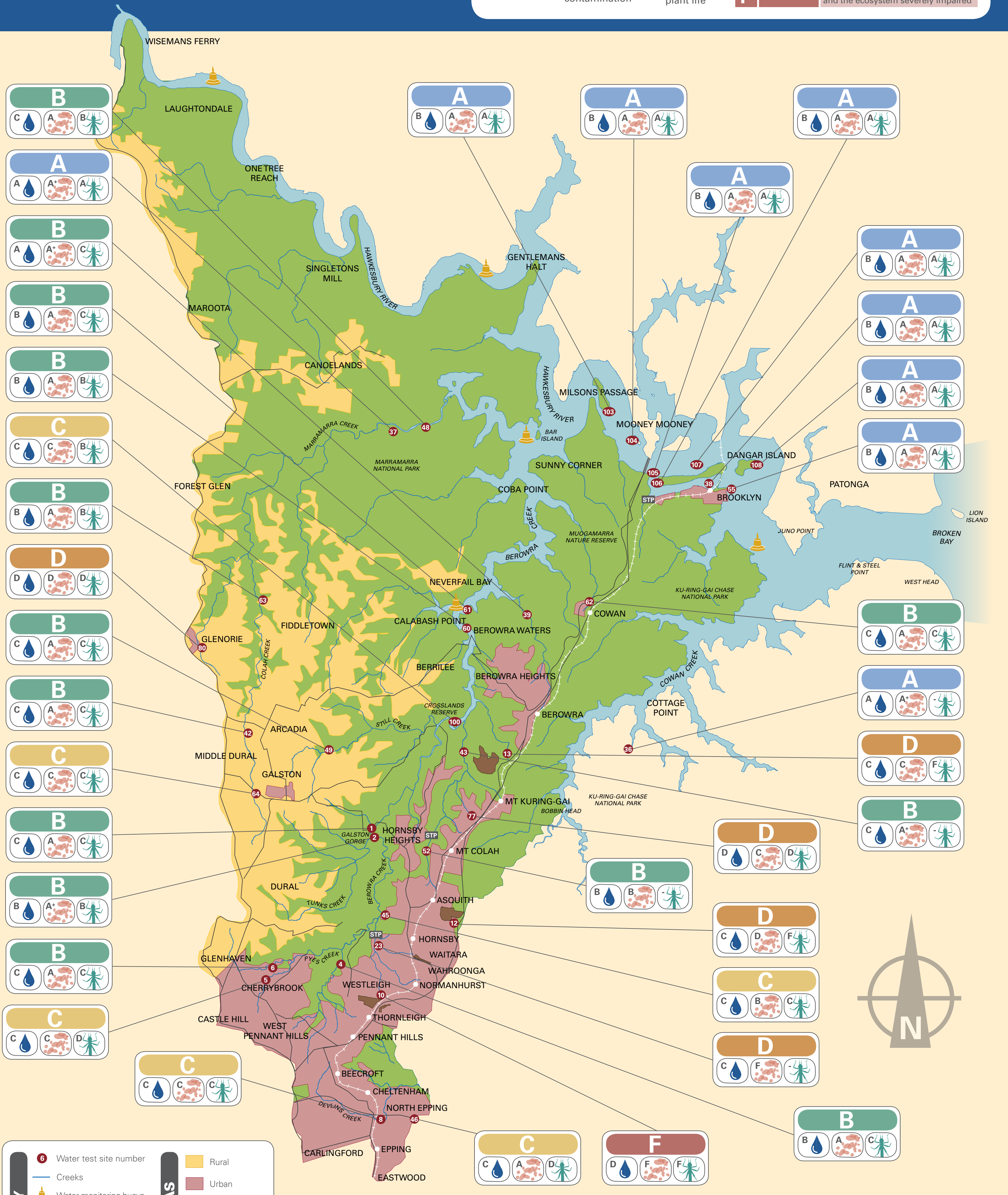
1.0 Your water quality report card

Summary Waterway Health Grading

- Physical & chemical condition
- Bacterial contamination
- Water bugs & microscopic plant life

What do the grades mean?

A	Excellent	Indicates clean water and a healthy ecosystem
B	Good	Increasingly degraded water quality and ecosystems
C	Fair	
D	Poor	
F	Fail	Implies water quality is always poor and the ecosystem severely impaired



KEY

- Water test site number
- Creeks
- Water monitoring buoys
- Main roads
- Train stations
- STP Sewage Treatment Plant

AREAS

- Rural
- Urban
- Industrial
- Bushland
- Estuarine

Grades are based on data collected by Hornsby Shire Council's water quality monitoring program

For more information, including test site locations, see the Companion Technical Report and Annual Water Quality Reports

hornsby.nsw.gov.au/waterquality

2.0 Introduction

The importance of understanding the condition of our local environment has never been more critical, more than ever before, it is impacting on our health and wellbeing and thus our quality of life. Increasing population growth in the Shire continues to apply additional stress to our local environment.

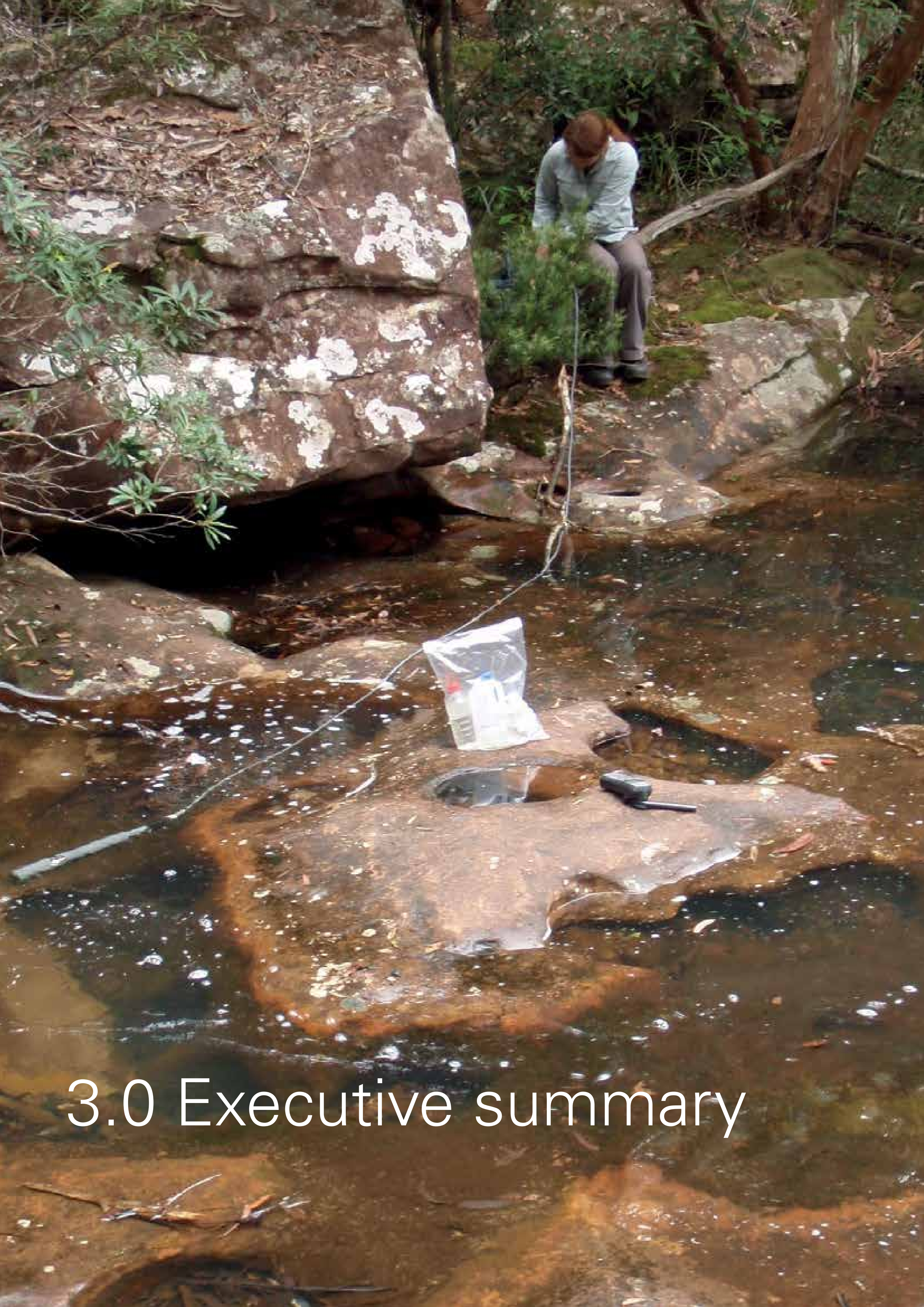
Water quality is one of the prime indicators of environmental health. The continuing collection and interpretation of water quality data through time is essential to our understanding of both climate variability and the impact of development on the Shire's natural environment.

Hornsby Shire Council's water quality monitoring program commenced in October 1994 after the signing of the Statement of Joint Intent (SoJI) by the then Berowra Creek Catchment Committee and Hornsby Shire Council in response to increasing concern about algal blooms in the Berowra estuary. Council scientific staff continue to carry out inspection, on-site water testing and water sampling at all sites, data from which has been published in Council's annual water quality reports since 1996.

To make Council's water quality monitoring program more accessible to the community, Council has produced a water quality report card, rather than an annual report, for 2012. This is available in a summary brochure which provides a snapshot of waterway health in the Shire through a grading system shown on a fold-out map. This companion technical report explains the grading process in more detail and gives the actual water quality readings which form the basis of the grades.

I hope you enjoy reading about the health of our creeks and estuarine areas. As this is a new initiative for the Natural Resources Branch we would appreciate any comments about our new approach.

Dr Ross McPherson
Chief Environmental Scientist
Hornsby Shire Council



3.0 Executive summary

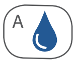
3.0 Executive summary

This companion report to Hornsby Shire Council's Water Quality Report Card (WQRC) 2012 documents the background context, rationale and methods used to determine waterway health grades of creek and estuarine areas within the Shire (refer to the Water Quality Report Card - page 4). It is anticipated that it will be used by those in the community interested in finding out more about how the health grades have been determined and also about the actual water quality data in their locality. The WQRC replaces Council's annual water quality report for 2012.

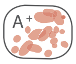
Council's water quality monitoring program, upon which the WQRC 2012 is based, has been used to assess, through time, the impact of land use on waterways within the Shire and to monitor the performance of Council's Catchments Remediation Rate (CRR) program. The data is used by Council to prioritise catchment remediation works, and to support environmental assessments, catchment modelling and education programs.

The new approach of disseminating the water quality monitoring program data through the WQRC 2012 in an easily accessible form will hopefully encourage a heightened interest in water quality in the Shire. Similar to school grades, the report card awards waterway health grades (A, B, C, D and F) to 36 water test and sampling sites (24 creek and 12 estuarine locations) within the Hornsby Shire local government area (LGA).

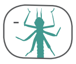
Grades were determined using three types of indicators:



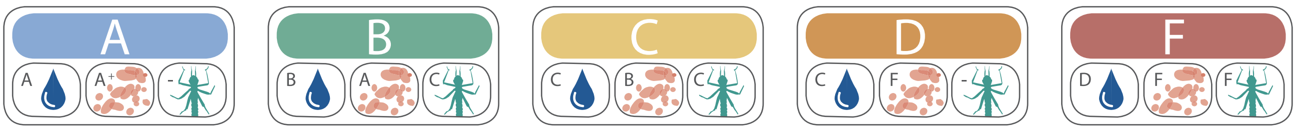
physical and chemical condition



bacterial contamination



water bugs and microscopic plant life.



4.0 Council’s water quality monitoring program

4.0 Council's water quality monitoring program

4.1 Purpose of the monitoring program

Council's current water monitoring program was set up in its present form soon after the Statement of Joint Intent (SoJI), an agreement between the NSW Department of Planning, Environment Protection Authority, Hawkesbury-Nepean Catchment Management Trust, Hornsby Shire Council and the Water Board, was agreed to in 1994 (see Appendix 1 and Culture Shift, 1998).

The SoJI was established in response to a number of issues:

- The regular occurrence of algal blooms in the estuarine section of Berowra Creek in the late 1980s and early 1990s
- Increasing pressures of urban development and sewage discharge issues
- Tighter pollution regulations coming into force at that time (eg. the Protection of the Environment Operations Act 1997)
- Publication of Australian environmental water quality guidelines (ANZECC, 1992)
- Detrimental impacts on water quality of catchment activities identified by water sampling programs carried out by Council, Sydney Water, the NSW Environment Protection Authority (EPA) and community groups (see, for example, Coad et al (1998); HSC (1995); AWT (1993); AWT (1996); TCMS (1997); Culture Shift (1998).
- Details of reported findings can be found in annual water quality reports available at hornsby.nsw.gov.au/waterquality. The water monitoring program has been used to assess, through time, the impact of land use on waterways within the Shire and to monitor the performance of Council's Catchments Remediation Rate (CRR) program. The data is used by Council to prioritise catchment remediation works, and to support environmental assessments, catchment modelling and education programs. The objectives of the water quality monitoring program are further described in Appendix 2.

4.2 Water quality test and sampling sites

The water quality test sites, relevant to the WQRC 2012, are listed and described in Appendix 3. A test site is a geographic location where a probe can be used to measure the physical conditions of a water body and/or where a sample of water can be taken for analysis of the water body's chemical characteristics. Thus, a test site may not include taking a water sample and vice versa, hence the use of the two terms. The physical and chemical water quality data used to compile the WQRC 2012 was collected over the period 2005 to 2010.

4.3 Physical characteristics of water bodies

Water quality tests using a multi-sensor water quality monitoring probe are undertaken monthly/fortnightly on-site to measure the water's:

- temperature
- electrical conductivity
- turbidity
- dissolved oxygen
- pH

4.4 Chemical characteristics of water bodies

Water samples are collected monthly/fortnightly and sent for laboratory analysis for:

- suspended solids
- nutrients – ie. total nitrogen, oxidised nitrogen, ammonium nitrogen and total phosphorus
- bacteria – ie. enterococci (in estuarine waters) and faecal coliforms

Note that the above two sets of results translate into waterway health grades for **physical and chemical condition and bacterial contamination.**

4.5 Abundance and diversity characteristics of water animal and plant life

At freshwater sites test for animal and plant life were carried out during spring and autumn from 2002 to 2007. This involved collecting and sorting on-site, and sending away from expert indentifications.

- freshwater macroinvertebrates (animals able to be caught in a net)
- freshwater diatoms (microscopic benthic plant life)

At estuarine sites the biological indicator chosen for assessing aquatic biota was chlorophyll-a. Water samples were collected monthly between 2005 and 2010 and sent for laboratory testing.

Note that the above set of results, a measure of the health of the water body ecosystem, translates into waterway health grades for **water bugs and microscopic plant life.**

These test results can be interpreted to give an indicator of the health of the ecosystem and the relative risk to recreational users involved in water contact.

A glossary of terms, found after the reference list at the end of this report, provides more information on the above water quality characteristics.

5.0 Waterway health grading terminology

5.0 Waterway health grading terminology

Table 1 shows the proposed terminology and rankings for the grading system used for reporting the health of creeks and estuaries in Hornsby Shire. This table shows the waterway health grading system for physical and chemical characteristics only, that is, for the first grade shown on the WQRC 2012. For these stressors, the water quality data collected for each was compared to regional environmental health values (REHVs) as determined by the *ANZECC Guidelines* (2000) and explained in the following sections of the report.

The health grades are A to F, similar to school grades: Grade A is the top score, which indicates clean water and a healthy ecosystem, whereas grades B, C and D indicate increasingly degraded water bodies. Grade F stands for a 'fail' implying that water quality is always poor and the ecosystem severely impaired.

Calculation of the extent of bacterial contamination, the second waterway health grade shown on the WQRC 2012, is explained in section 8.3. Similarly, calculation of the abundance and diversity of water bugs and microscopic plant life, the third waterway health grade shown in the WQRC, is explained in section 8.4.

Table 1: Grading system used to categorise water quality for physical and chemical stressors

Health grade and colour	Percent of time physical-chemical stressors satisfy Guideline REHVs*	Health description	Cleanliness categories	Probable impact on the natural aquatic biota
A	Over 80%	Excellent	Clean	Healthy
B	50% to 80%	Good	Slightly degraded	Mild impairment
C	20 to 50%	Poor	Moderately degraded	Moderate impairment
D	Less than 20%	Very Poor	Severely degraded	Serious impairment
F	Never passes	Fail	Always bad	Severe impairment

REHVs stand for regional environmental health values. For an explanation of how REHVs have been calculated see sections 6.0 and 7.0.

6.0 Freshwater sites: environmental health values (EHVs)

6.0 Freshwater sites: (EHVs)

6.1 Australian water quality guidelines: freshwaters

The *ANZECC/ARMCANZ Guidelines* (2000)[1] list default trigger values for numerous water quality indicators for different uses of water, such as the protection of aquatic ecosystems. The *Guidelines* (2000) recommend the use of the published default trigger values for initial water quality assessments.

Council's previous annual water quality reports compared test results with the *Guidelines* (2000) for the level of **aquatic ecosystem protection** provided by the tested water. In particular, Council used **the default trigger values for aquatic ecosystem protection in SE Australian lowland east flowing rivers** (refer table 3.3.2, footnote (d) *Guidelines 2000*).

These trigger values, used by Council in the past for freshwaters in the Shire, are given below in Table 2 [Row 1].

Triggers for suspended solids and turbidity are not precisely defined in the *Guidelines* (2000) so the 'NSW State Authority' recommendations for turbidity and suspended solids in coastal rivers, as listed in the *Guidelines* (see volume 2 section 8.2.2), have also been included in Table 2 [Row 1].

However, the *Guidelines* (2000) suggest that more appropriate guideline trigger values for selected indicators should be developed based on local or regional information obtained from long-term monitoring of local reference sites. Since 1996 Council has tested two local reference sites (one in Marramarra National Park, the other in Ku-ring-gai Chase National Park) sites 36 and 37 (see Appendix 3). These sites are considered to represent the highest quality of water health against which the water quality in other water bodies in less pristine locations can be compared.

6.2 Developing regional environmental health trigger values (REHVs) for water quality indicators in freshwater creeks in Hornsby Shire

As mentioned above, the *Guidelines* (2000) strongly suggest that site-specific triggers, developed on a local or regional scale, are more appropriate than using the 'default' values listed in the *Guidelines*. Site-specific triggers developed in this report will be referred to as regional environmental health (trigger) values (REHVs).

To this end, testing water quality indicators at a number of **local reference sites** has been an important part of Council's ongoing monitoring program and therefore, historic data from these sites has been used in the development of REHVs. Measurements of physical, chemical and biological indicators at suitable reference sites provide benchmarks for assessing and maintaining biological diversity in waterways in the local region.

The *Guidelines* (2000) suggest that relevant EHVs can be developed after long-term testing at suitable reference sites, by using, for example, the statistical '80th percentile value' ($80^{th\%ile}$) for each of the important water quality indicators.

Council has tested two unimpacted reference sites monthly for over 15 years and has found that the $80^{th\%ile}$ values for the 15 years of data (as shown in Table 2 [Row 2]) comply consistently with the *Guidelines* (2000).

As suggested and argued by Storey *et al* (2007) the use of $80^{th\%ile}$ values at pristine/unimpacted reference sites may, in our case, be unrealistic in the development of REHVs for physical-chemical indicators. The use of the $80^{th\%ile}$ implies that 20% of the water quality data at the reference sites themselves would then be above (ie. fail) the resulting determined REHV, and in addition it would be 'forcing' a much higher standard of quality on all other creeks in the region.

Thus, as Storey *et al* (2007) suggest, it was considered reasonable and more realistic to base Hornsby's REHVs on the $95^{th\%ile}$ values at our unimpacted reference sites.

The calculated $95^{th\%ile}$ values for each indicator at the two reference sites are shown in Table 2 [Rows 3 and 4]. The $5^{th\%ile}$ value is also given for the lower end of the range for dissolved oxygen and pH values.

1 *The ANZECC/ARMCANZ Guidelines (2000) is referred to elsewhere in this report as the Guidelines (2000).*

2 *Footnote: An Inquiry was carried out by the Healthy Rivers Commission of NSW (HRC) into the Hawkesbury Nepean River System and was published in 1998 (HRC, 1998). The HRC recommended water quality objectives for nutrients and chlorophyll in different parts of the Hawkesbury River catchment. The recommended values for nutrients were somewhat higher than the Guidelines (2000) values. The Inquiry was carried out prior to the publication of the ANZECC/ARMCANZ Guidelines. Consequently, in the next section of this report, site-specific environmental health trigger values, called regional environmental health trigger values (REHVs), have been developed as part of the waterway health grading process.*

Table 2: ANZECC/ARMCANZ Freshwater Guidelines triggers and the calculated 95th%ile values at two freshwater reference sites in Hornsby[2]

	Indicator ->	number N	Turbidity (ntu)	SS (mg/L)	Total P (mg/L)	Total N (mg/L)	NH3-N (mg/L)	NOx-N (mg/L)	pH	EC (ms/cm)	DO (%sat)	Faecal Coliforms (CFU?100ml)
1	**ANZECC/ ARMCANZ Guideline/ Trigger**	-	6[a]	6[a]	0.025	0.350	0.020	0.040	6.5 - 8	<0.30	85 - 110	**Median < 150 80th% < 600**
2	**Reference Sites 36 and 37. 80th%**	390	2	2	0.010	0.170	0.010	0.010	5.1[b] - 6.4	0.27	94[b] - 105	Median = 6 80th% = 46
3	**Reference Sites 36. 95th%**	200	5.6	3	0.010	0.21	0.020	0.020	**4.8[c] - 7**	0.30	76[c] - 112	Median = 4 95th% = 130
4	**Reference Sites 37. 95th%**	190	**8.1**	**7**	**0.010**	**0.32**	**0.020**	**0.050**	4.8[c] - 6.4	**0.32**	**75[c] - 118**	Median = 8 95th% = 320

Site 36 and 37 data for monthly testing over the years 1995 to 2011.
Site 36 = Murray Anderson Ck (nr Mt Murray Anderson) flowing into Smiths Ck, Ku-ring-gai Chase NP
Site 37 = Smugglers Ck (nr Smugglers Ridge) flowing to Marramarra Ck near Orange Orchard in Marramarra NP
b = 20th% used for lower range of DO and pH
*c = 5th% used for lower range of DO and pH. *Guidelines (2000) - Primary Contact Recreational Use*
a - NSW State trigger for Turbidity and Suspended Soilds for NSW coastal rivers (Guideline (2000) Vol 2S. 8.2)
Values highlighted were the chosen REHV triggers

Table 2 [Rows 3 and 4] shows that there are slight differences in the calculated 95th%ile for each indicator at the two reference sites, 36 and 37. Dissolved oxygen (DO) levels at both reference sites have a broader range and pH is lower (more acidic) than the *Guidelines* (2000) values. The calculated 95th%ile triggers, shown for turbidity and suspended solids at the reference sites, are reasonable values for the predominantly sandstone geology in Hornsby Shire.

In choosing appropriate REHVs, and to allow for the difference between *Guidelines* (2000) triggers and the calculated 95th%ile values at reference sites, it was decided to use the highlighted values in Table 2. The values chosen are the highest values for the two reference sites (ie. least strict/least conservative) for each of the parameters.

It was decided that the *Guidelines* (2000) value for primary recreation trigger for faecal coliforms would be retained as this value is based on health risk to humans, not on aquatic ecosystem protection. The two reference sites easily satisfied this bacterial level of the recreational guideline more than 95% of the time.

The values shown in Table 3 were subsequently selected as Hornsby's interim REHVs and used to determine the waterway health grades for freshwater sites.

Table 3: Chosen regional environmental health trigger values for physical-chemical stressors and faecal bacteria for freshwater sites

Turbidity	Suspended Soilds	Total Phosphorus	Total Nitrogen	Oxidised Nitrogen	Ammonium Nitrogen	pH	Electrical Conductivity	Dissolved Oxygen	Faecal Coliforms
NTU	mg/L	mg/L	mg/L	mg/L	mg/L		mS/cm	%sat	cfu/100mL
<8	**<7**	**<0.01**	**<0.32**	**<0.05**	**<0.02**	**4.8 to 7**	**<0.32**	**75 to 118**	**Median<150 and 80th%<600**

6.3 Developing regional environmental health values (REHVs) for aquatic biota in freshwater creeks in Hornsby Shire

The *Guidelines* (2000) explain that biological assessment is a vital part of assessing changes in aquatic ecosystems. Biological indicators continually monitor water quality, integrating the effects of past and present exposure to contaminants or pressures. In addition, comparing biological indicators at the site(s) of interest with the same indicators from relatively natural or unimpacted sites provides a basis for detecting and assessing important changes in ecological health.

Thus part of Council's water quality monitoring program also measured the impacts of changing water quality on the health of selected aquatic biota. Macroinvertebrate and diatom groups were chosen as biological indicators of water quality in freshwater creeks impacted by stormwater runoff from developed industrial, urban and rural areas. A number of unimpacted reference sites within national park bushland areas in Hornsby Shire were also studied to obtain information about the same aquatic biota in natural areas.

Macroinvertebrates and diatoms were sampled for several reasons:

- They are a major component of biological diversity in freshwater streams.
- They are easy to collect using standardised methods.
- Their species diversity and abundance can be related to water quality with some species being very sensitive to contaminants, while others are very hardy and pollution-tolerant.

In addition, they provide an indication of past stream conditions as well as present conditions, and provide an assessment of the combined impacts of upstream land uses on stream health. In contrast, spot checks of water quality alone provide information on conditions only at the time of sampling (Chessman, 2003).

The sampling program was carried out for Council at 20 freshwater sites in Hornsby Shire by consultants during the years 2002 to 2007. Collections were carried out 10 times at six monthly intervals in spring and autumn. The results of these surveys were reported by AMBS (2005) and GHD (2008); and reviewed by Wright (2011).

Three biotic indices were calculated for use in the Report Card from the results of the surveys, as follows:

(a) **The stream invertebrate grade number average level: the SIGNAL2 score** is the most commonly used biotic index for measuring ecosystem health in Australia (Chessman, 1995; 2005). Macroinvertebrates are collected using a net and are identified by experts. Each macroinvertebrate species is assigned a grade number between 1 and 10; with 10 being highly sensitive to pollution and 1 indicating those organisms with a high tolerance to a range of environmental conditions. The original version of SIGNAL required all macroinvertebrates to be identified to the taxonomic (classification) level of family. SIGNAL2 has versions to suit both family and order-class-phylum identification.

The index provides several categories of likely pollution levels, from 'clean', with high abundance and richness of pollution-sensitive macroinvertebrates, to increasingly polluted, indicated by an increasing scarcity or absence of pollution-sensitive species and greater abundance of pollution-tolerant animals. Thus a 'high' SIGNAL score implies clean water and good aquatic habitat whereas a 'low' SIGNAL score implies poor ecosystem health, poor water quality and/or poor habitat condition.

(b) **The ephemeroptera, plecoptera and trichoptera abundance or EPT% score** is a widely used biotic index, particularly in the Northern Hemisphere, based on the abundance of three common macroinvertebrate families (containing species of) ephemeroptera (mayflies), plecoptera (stoneflies) and trichoptera (caddisflies). These families have been identified as being intolerant to pollution. Clean waters have high numbers of EPT animals with 'high' EPT scores, while polluted waters have few or no EPT animals and a 'low' EPT score (Wright, 2011).

(c) **The trophic diatom index or TDI** measures the response of a particular suite of diatom species that are known to be affected by elevated nutrient levels (Kelly, 2002). The index value is based on the diatom species identified, with values for TDI as low as 0 in waters with very low nutrient levels, up to 100 in waters with high nutrient concentrations. The TDI calculation was carried out by Jason Sonneman of Ecological in Victoria (who identified the species) using the software program Omnidia (Lecointe et al, 1993) based on a scoring system developed by Kelly and Whitton, 1995.

The methodology of grading developed for the South East Queensland Freshwater Report Card (EHMP, 2010) was applied to Hornsby Council's data for SIGNAL, EPT and TDI scores.

The REHV was calculated from the reference site data: for SIGNAL and EPT the REHVs are equal to the $20^{th\%ile}$ value and for TDI the REHV is the $80^{th\%ile}$ value. The 'worst case scenario' (WCS) was determined from all data at all sites: the WCS is equal to the $90^{th\%ile}$ of all data for TDI or equal to the $10^{th\%ile}$ for all SIGNAL2 and EPT data.

Table 4 shows the determined REHV and WCS values for the three freshwater indicators. REHV was calculated for ten samplings over the years 2002-2007 at one reference site (site 37). The WCS was calculated using ten sets of measured data at each of twenty sites over the same period.

Table 4: Chosen regional environmental health trigger values and worst case scenarios for aquatic biota for freshwater sites

Biota indicator	REHV	WCS
TDI	1.8	91
SIGNAL2	4.65	2.1
EPT	55.8	0

7.0 Estuarine-tidal sites: environmental health values (EHVs)

7.0 Estuarine-tidal sites: (EHVs)

7.1 Australian water quality guidelines – marine and estuarine waters

The *Guidelines* (2000) discussed in section 6.1 with reference to freshwaters, also include default trigger values for numerous water quality indicators for the protection of marine and estuarine aquatic ecosystems.

The *Guidelines* (2000) recommend using the published default trigger values for the initial water quality assessments, but suggest that specific local trigger values can be developed based on long-term monitoring of local reference sites in marine and estuarine areas.

Council's previous annual water quality reports have compared test results for estuarine areas with the *Guidelines* (2000) for the water use of aquatic ecosystem protection and recreational water quality. In particular, Council has used the default trigger values for aquatic ecosystem protection in SE Australian estuaries and faecal coliform values for the primary contact category in recreational waters (refer tables 3.3.2 and 3.3.3, and section 5.2.3.1 in the *Guidelines (2000)*).

These trigger values, used by Council in the past for estuarine-tidal water in the Shire, are given in Table 5 below. The trigger value for suspended solids is not precisely defined in the *Guidelines* (2000) so the 'NSW State Authority' recommendations for suspended solids of 6 mg/L in estuaries, as reported in the *Guidelines* (2000) (volume 2 and section 8.2.2), have also been included in Table 5. The triggers for microbial contamination by enterococci derived from the *Guidelines* in the section called *Managing Risk in Recreational Waters* (NRMRC, 2008) were also used.

Council's water quality monitoring program does not include a reference estuarine site because all estuarine areas in or near the Shire (Hawkesbury River, Berowra and Cowan Creeks) are in some way impacted by stormwater or treated sewage discharge from developed areas.

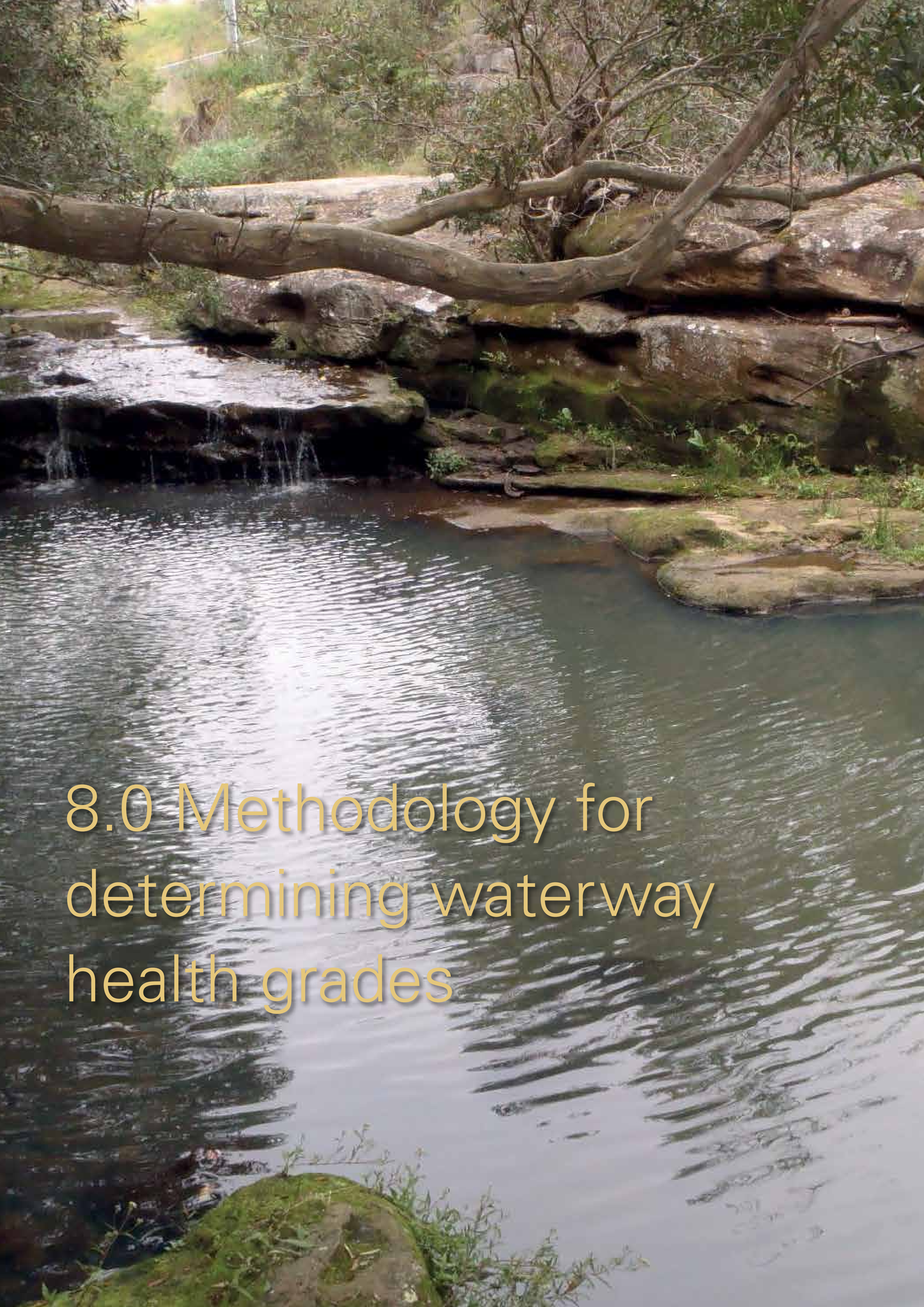
Therefore, it was not possible to develop our own REHVs for estuaries based on long-term reference site data. In the absence of available data for local estuarine reference sites it was decided to use the *ANZECC/ARMCANZ* and *NHMRC Guidelines* values as our chosen REHVs – these are shown in Table 5 below.

Table 5: Regional environmental health trigger values for physical-chemical, microbial and aquatic biota indicators for estuarine-tidal sites

	Turbidity	Suspended Soilds	Total Phosphorus	Total Nitrogen	Oxidised Nitrogen
Units	NTU	mg/L	mg/L	mg/L	mg/L
REHV Triggers	**10**	**6**	**0.03**	**0.3**	**0.015**

	Ammonium Nitrogen	pH	Dissolved Oxygen	Faecal Coliforms#	Enterococci@	Chlorophyll-a
Units	mg/L		%sat	cfu/100mL	cfu/100mL	ug/L
REHV Triggers	**0.015**	**7 - 8.5**	**80-110**	**Median<150 and 80th%ile<600**	**95th%ile<40 (200,500)**	**4**

Triggers based on Guidelines (2000) for Aquatic Ecosystems South-East Australian Estuaries, except the following:
 # Faecal Coliforms - based on Guidelines (2000) Recreational Water Primary Contact.
@ Enterococci based on NHMRC (2008), See section 8.3 for interpretation and calculations.



8.0 Methodology for determining waterway health grades

8.0 Methodology for determining waterway health grades

This section explains how the water monitoring data were analysed and how the health grades were determined for each water quality indicator and for each water test site. Appendix 4 provides a summary of the grading methodology described below and Appendix 5 provides a summary of the results.

8.1 Indicator health grades at a site

The three steps below were undertaken in sequence to determine the waterway health grades at each test site:

- Step 1: Determine the **regional environmental health trigger values (REHVs).** This process is described for the physical-chemical stressors, microbial indicators and estuarine biota in sections 6 and 7 of this report. Section 6.3 describes the process for determining REHVs for aquatic (freshwater) biota.
- Step 2: Determine an **indicator health grade for each individual water quality indicator at each water test site:**

  (i) The method for *physical-chemical stressors (physical and chemical condition in the WQRC 2012)*, involved comparing the water quality test results using box-plots for each parameter with the relevant REHV as listed in Table 3 for freshwater sites or Table 5 for estuarine sites (see section 8.2).

  (ii) For *microbial indicators (bacterial contamination in the WQRC 2012)*, the box-plot method was used to compare the data with the REHVs (see section 8.3).

  (iii) For freshwater *biota macroinvertebrates and diatoms (water bugs and microscopic plant life in the WQRC 2012)*, the biota health grades were determined using a ranking method based on a standardised scoring and worst case scenario system (see section 8.4).
- Step 3: Combine the various indicator grades at each site to obtain the **summary waterway health grade** (see section 9).

  To maximise the use of available water monitoring data, it was decided to determine water test site health grades for the following three group categories:

(I) Site health grade for physical-chemical stressors:

(a) For **freshwater sites** this was the combined ranking (see section 9) of the indicator health grades for: pH, electrical conductivity, dissolved oxygen, turbidity, suspended solids, total nitrogen, total phosphorus, oxidised nitrogen (NOx - N) and ammonium nitrogen (NH_3 - N).

(b) For **estuarine/tidal sites** this was the combined ranking of the indicator health grades for: pH, dissolved oxygen, turbidity, suspended solids, total nitrogen, total phosphorus, oxidised nitrogen (NOx - N) and ammonium nitrogen (NH_3 - N).

(II) Site health grade for microbial indicators:

The indicator health grades were determined at freshwater sites using faecal coliforms, and at the estuarine tidal sites using faecal coliformas <u>and</u> enterococci.

The gradings are based on relative risk to users of the waterways for recreational activities involving contact with the water.

(III) Site health grade for aquatic biota indicators:

(a) For freshwater sites, this was the combined indicator health grades determined for the three biota indices: SIGNAL2 score, EPT score and TDI score (see sections 6.3 and 8.4).

(b) For estuarine-tidal sites, this was the indicator health grade for chlorophyll-a.

8.2 Indicator health grades of physical-chemical stressors

A way of presenting and summarising the large amount of water quality data obtained during Council's water monitoring program has been to use **box-plots** (eg. HSC, 2010).

This graphical method was used to present statistical data including the median, maximum and minimum $20^{th\%ile}$ and $80^{th\%ile}$ values for each indicator at each water test site for the reporting period.

The box-plot enables ready comparison of water quality data between sites and over time. It is also a convenient method to illustrate how often (% of time or % of tests) a site satisfies the relevant water quality trigger values. The box-plots are readily graphed using Statistica software.

The health grading method developed in this report for water quality of fresh and estuarine waters is based on the percentile distribution of five years of monitoring results using box-plots.

This method requires a regular (eg. monthly) testing regime in all seasons and weather conditions to ensure that the full range of seasons, climatic conditions and indicator concentrations are represented and measured.

The method of calculating the indicator health grades is shown in two ways in Figures 1 and 2.

Figure 1: A presentation of the method for indicator health grading at water sampling sites using percentiles and REHVs

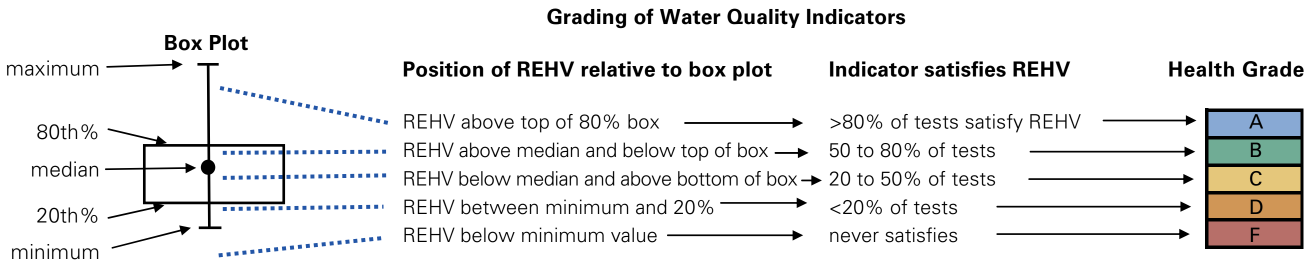
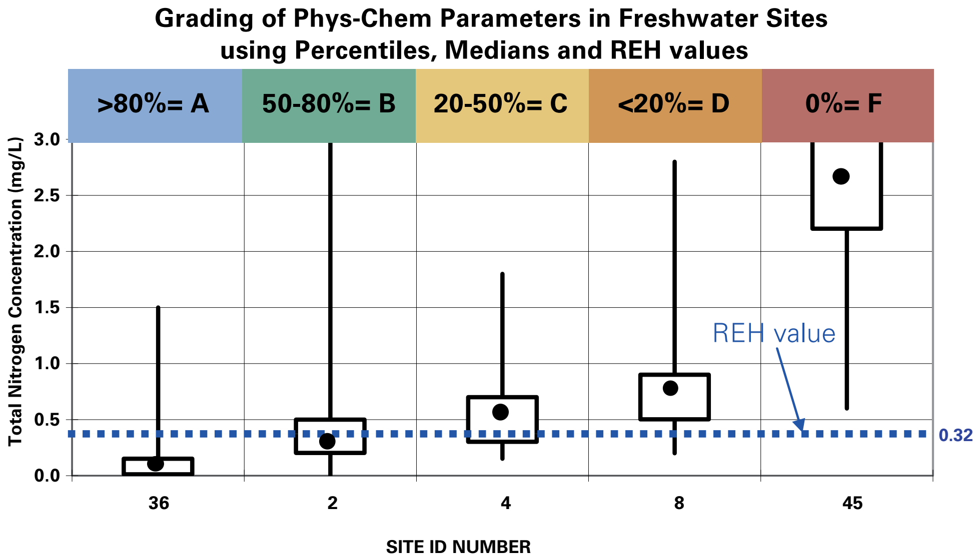


Figure 2: Another presentation of the method of indicator health grading at sampling sites using the relative position of REHVs and box-whisker plots



For example, if the REHV for a particular indicator is satisfied at a sample site for more than 80% of tests then the site receives an 'A' grade for that indicator.

If the same indicator at another site never satisfies the REHV then that site receives an 'F' grade. Grades B, C and D are intermediate between these extremes.

Figure 2 shows examples of box-plots for five selected sites for total nitrogen (TN) with a REHV equal to 0.32 mg/L. At reference site 36, the $80^{th\%ile}$ (top of box) for TN is lower than the REHV, therefore site 36 complies with the REHV more than 80% of the time, so it receives an 'A' grade for TN.

However, the box-plot for TN at site 45 at Fishponds in Berowra Creek, downstream of West Hornsby Sewage Treatment Plant, shows that every test result for TN carried out monthly for five years was greater than 0.32 mg/L. Site 45 therefore never satisfied the REHV; so it receives an 'F' grade for TN.

In Figure 2, sites 2, 4 and 8 received grades B, C and D for TN respectively, based on the relative position of the REHV and the median or the top and bottom of the box (ie. $80^{th\%ile}$ and $20^{th\%ile}$ values respectively).

The box-plot graphs of Hornsby Council's data for all physical-chemical stressor indicators for all sites for the period January 2005 to June 2010 are presented in Appendix 6.1.

This procedure for ranking the physical-chemical indicators, based on percentile values, is similar to that used by Krogh *et al* (2008) in their compilation of data from the Hawkesbury-Nepean River environmental monitoring program (although that program used maximum, $75^{th\%ile}$,$50^{th\%ile}$, $25^{th\%ile}$, and minimum values as cut-offs).

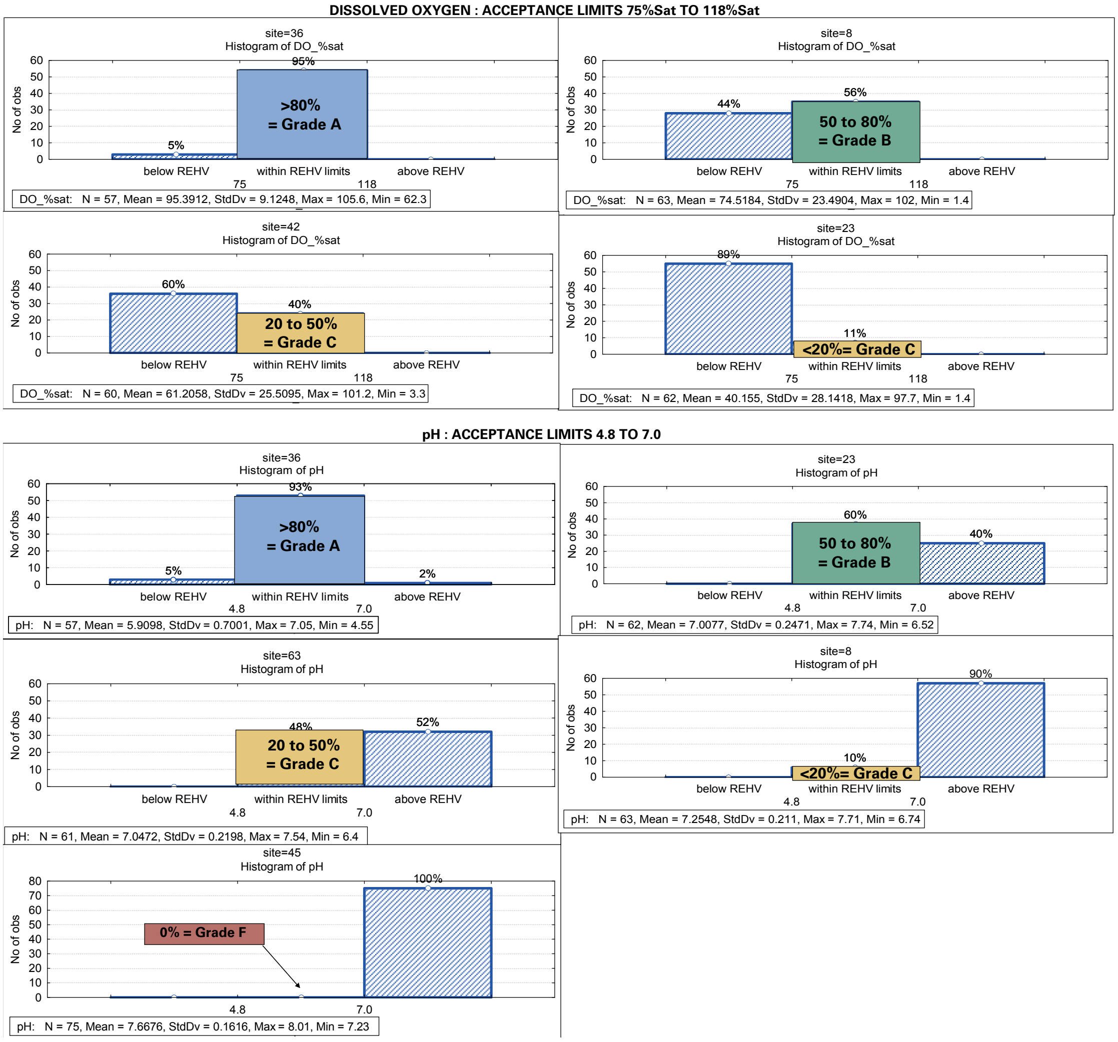
In the case of the indicators pH and dissolved oxygen, which have upper and lower REHVs, it is possible, but less precise, to use box-plots to determine the percentage of results that lie within the preferred range.

An alternative, more precise, method using a statistical package is to prepare histograms of the type shown in Figure 3. This shows the pH and dissolved oxygen data for sites giving the percentage of data that is within the REHV limits (pH 4.8-7 and DO 75-118 %sat).

The indicator health grades are derived using the same satisfaction cut-off points as shown in Figure 1 - that is: >80% of tests satisfy REHV = A; 50 to 80% = B; 20 to 50% = C; <20% = D; never satisfies = F.

The resulting indicator health grades for physical-chemical stressors are shown in section 9 Table 10.

Figure 3: Method using histograms to obtain the percentage of tests that satisfy the REHV for pH and DO



Note: Consideration was given to alternative methods of grading physical-chemical stressors using standardised scores and worst case scenarios as recently used by the Georges River Combined Council's Committee (GRCCC, 2010), South East Queensland Healthy Waterways (ENMP, 2010), Port Curtis Integrated Monitoring Program (Storey et al, 2007) and Cobaki and Terranora Ecosystem Health Monitoring Program (IWC, 2009).

*This grading methodology is generally based on the development of ecosystem health guideline values (EHVs) derived from the 80th percentile (and, for pH and DO, the 80th%ile and 20th%ile) values at minimally-disturbed reference sites, together with the development of worst case scenarios (WCS) derived from 90th%ile (and 10th%ile) of data for **all** sites.*

These EHVs are considered to indicate the expected values of each indicator for streams in 'healthy' condition. The WCS values indicate the expected value of each indicator for streams in the 'unhealthiest' condition. Based on the EHVs, WCS and indicator values a standardised score (StSc) calculation produces a value between 0 and 1 (0=worst, 1=best) for each parameter for each sampling occasion at each site.

This method, however, did not adapt well to Hornsby's physical-chemical stressor data. The reason is that there were few reference sites and the choice of other sites, for historic reasons, was biased to heavily impacted sites (eg. freshwater sites downstream of intense urban development STP effluent points, industrial areas, or landfill seepages).

Nevertheless, however, it should be noted that this standardised score methodology was used for Council's freshwater aquatic biota monitoring as discussed in section 8.4.

8.3 Indicator health grades for microbial indicators

(i) Freshwater sites

Table 3 sets out the chosen REHV trigger values for faecal coliforms in freshwater sites ie. median<150 cfu/100mL and 80th percentile <600.

This means that for a site to obtain an 'A' grading the results for the bacterial counts for more than half the tests should be less than 150 cfu/100mL and, at the same time, more than 80% of tests should be less than 600 cfu/100mL.

This REHV is based on the section called *Primary Contact Recreational Use in the Guidelines* (2000).

An additional grade, A+, has been added here to highlight those few sites that had very low levels of bacterial contamination, that is, where >80% of tests were less than 150 cfu/100mL.

Note that although continuous regular monthly monitoring by Council over a five year period provides a good indication of the full potential range of bacterial test results, the frequency of sampling recommended in the *Guidelines* is for at least five samples per month.

The grading for faecal coliforms was done using the box-plot percentile method similar to that used for physical-chemical stressors parameters as described in section 8.2.

Table 6 and Figure 4 set out how the indicator health grades were determined based on the median and 80$^{th\%ile}$ values for faecal coliforms at each freshwater site.

Table 6: Criteria for indicator grading of faecal coliforms at freshwater and estuarine-tidal sites using median and percentile values.

Faecal Coliforms	Median	80th Percentile
A+	<150	<150
A	<150	<600
B	<150	>600 and <1000
B	>150	<600
C	>150 and <600	<1000
D	>600	<1000
F	<1000	

Figure 4: Examples of grading for faecal coliforms at selected sites using median and 80th percentile values (based on criteria shown in Table 1)

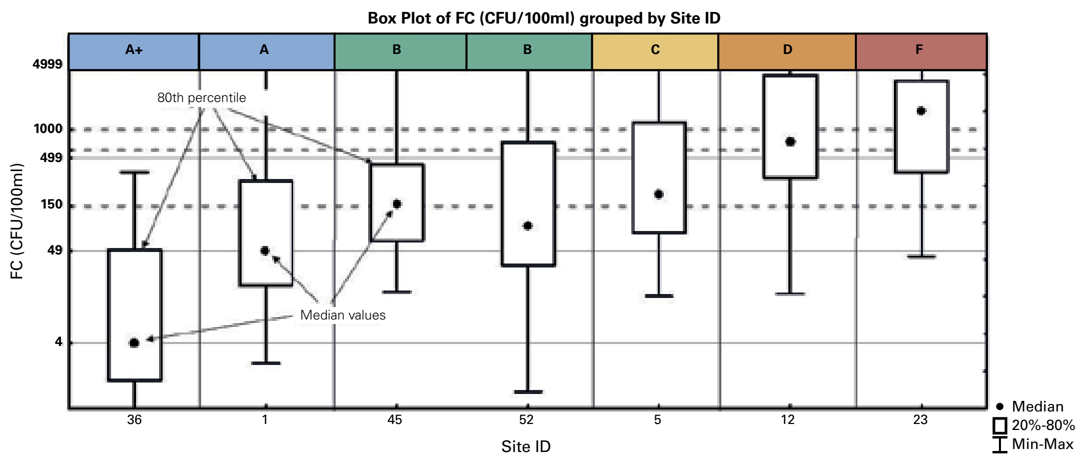
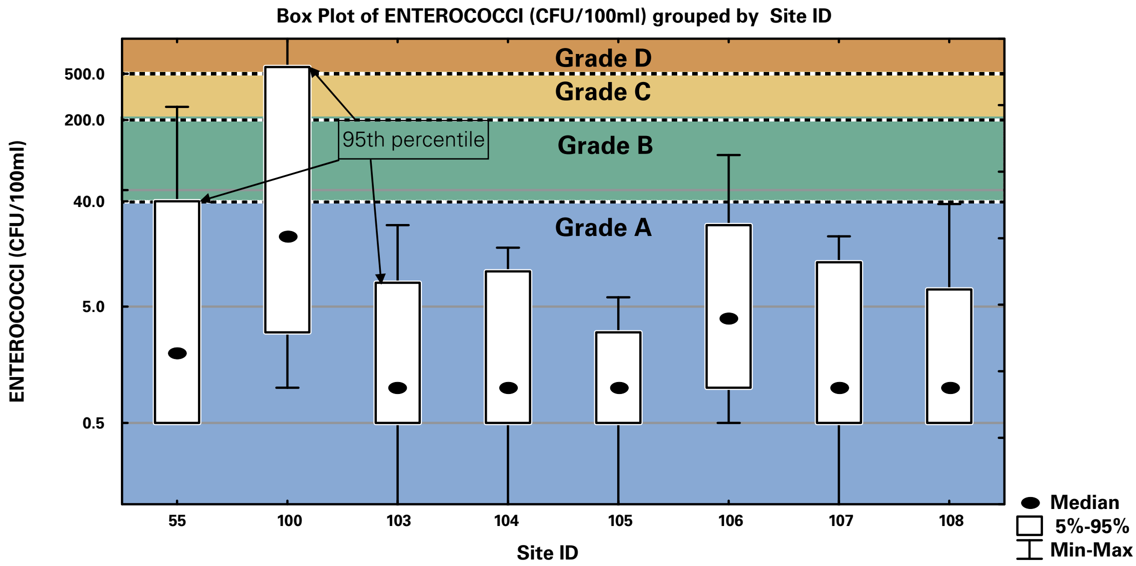


Figure 5: Grading of enterococci results of estuarine-tidal sites (grade is determined by the site's 95th percentile value ie. top of box)



(ii) Estuarine-tidal sites

Table 5 sets out the chosen REHV triggers used for grading the water quality indicators at estuarine-tidal sites.

Faecal coliform grading was done in the same way as for freshwaters (section 8.3(i)) using box-plots with median values and the 80th%ile. Table 6 sets out cut-off values for grading of faecal coliforms in estuarine waters. Examples of box-plots used for grading of faecal coliforms at selected sites is shown in Figure 4.

Site grading for enterococci however, used 95th percentile values as recommended in Table 5.7 of the *NHMRC Guidelines for Managing Risks in Recreational Waters* (2008) and shown in Table 7 below. The grades for enterococci results for estuarine samples, using box-plots, are shown in Figure 5. Enterococci tests were not done at all estuarine-tidal sites during the reporting period.

Appendix 6.3 contains box-plots of the faecal coliform tests for fresh and estuarine waters, with 80th%ile levels shown, and of enterococci in estuarine waters with the 95th%ile shown.

The results of grading of microbial indicators at each estuarine-tidal site are shown in Table 12.

Table 7: Criteria for indicator grading of enterococci at estuarine sites using 95th percentile cut-off values recommended by NHMRC (2008) for recreational waters.

Enterococci Grade	95th Percentile
A	<40
B	40 to 200
C	200 to 500
D	>500

8.4 Indicator health grades for aquatic biota indicators

(i) Freshwater sites

During 2002-2007 Council commissioned biannual (spring and autumn) sampling for macroinvertebrates and diatoms. The results of these surveys were reported by AMBS (2005) and GHD (2008) and included statistical analysis and grouping of species data into a number of indices.

Three of the indices of stream health determined from the biota indicators were:

(a) the stream invertebrate grade number average level or SIGNAL2 score

(b) the ephemeroptera, plecoptera, and trichoptera abundance or EPT% scores

(c) the trophic diatom index or TDI index.

These three biotic indices were available for 10 sampling events at most of the 20 freshwater sites.

More recently, Wright (2011) reviewed the 2002-2007 survey data and summarised the data as shown in Appendix 6.4.

The methodology of grading developed for the South East Queensland Freshwater Report Card (EHMP, 2010) was applied to Hornsby Council's data for SIGNAL2, EPT and TDI scores.

The REHVs for SIGNAL2, EPT and TDI scores were calculated from the reference data (site 37): for SIGNAL and EPT the REHVs equal the 80th%ile value and for TDI the REHV is the 20th%ile value.

The WCS was determined from all data at all sites. The WCS is equal to the 90th%ile of all data for TDI or equal to the 10th%ile for all SIGNAL2 and EPT data.

Table 8 shows the determined REHV and WCS values for the three freshwater biota indicators.

Based on the REHV, WCS and indicator values a standardised score (StSc) for each indicator was calculated for each test at each site using the following formula:

- Where EHV<WCS (ie. where lower scores are healthier, such as TDI scores):
  standardised score (StSc) = 1 – (indicator value - REHV)/(WCS - REHV); or
- Where EHV>WCS (ie. where higher scores are healthier, such as SIGNAL and EPT scores):
  standardised score (StSc) = 1 – (REHV - indicator value)/(REHV - WCS).

(Any StSc values <0 are rounded to = 0, while values >1 are rounded to = 1).

The above produced StSc values between 0 and 1 (0=worst, 1=best).

A standard score close to 1 for an indicator reflects that the indicator met or exceeded the ecosystem health guideline, whereas an StSc value lower than 1 means a departure from ideal. Values of StSc close to zero indicate the unhealthiest conditions.

Table 8 above shows how grades for each biota indicator were derived from the average standardised scores. Higher StSc values gave better grades. All results and standardised scoring for freshwater aquatic biota indicators are set out in Appendix 6.4.

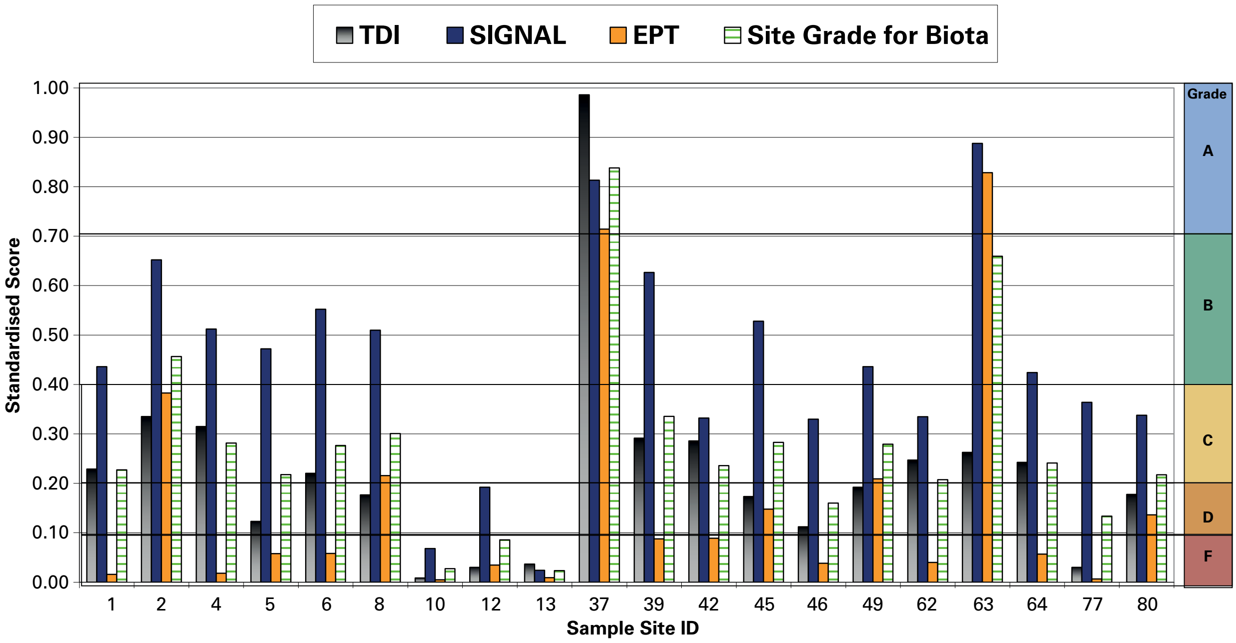
Indicator grades are summarised in Table 13 and graphed in Figure 6.

Table 8: Scoring system used to grade the freshwater aquatic biota indicators using the REHV, WCS and standardised score(StSc) method

Biota indicator	REHV	WCS
TDI	1.8	91
SIGNAL2	4.65	2.1
EPT	55.8	0

Site Grade	Average StSc
A	>0.7
B	>0.4 - 0.7
C	>0.2 - 0.4
D	>0.1 - 0.2
F	<0.1

Figure 6: Graph showing average standardised scores and health grades for five years of data for the freshwater biota health indicators TDI, SIGNAL2 and EPT and site health grades obtained by averaging the three biota indicator scores.



ii) Estuarine-tidal sites

Chlorophyll-a concentration is the aquatic biota indicator Council used for estuarine-tidal sites because it is directly related to phytoplankton abundance and biomass in waters. Chlorophyll-a is also an effective measure of trophic status, a potential indicator of the maximum photosynthetic rate (P-max) and is a commonly used measure of water quality (ANZECC/ARMCANZ, 2000).

Occasional elevated chlorophyll-a concentrations do not necessarily indicate poor estuarine health. The long-term persistence of elevated levels, however, indicates the potential problem of increased incidence of algal blooms resulting in potential fish kills or shellfish toxicity.

The *Guidelines* (2000) trigger level for chlorophyll-a of 4 ug/L was chosen by Council as the REHV (see Table 5).

The water quality health grade based on the chlorophyll-a concentrations has been determined for the monthly data collected between 2005 and 2010 using the method of box-plots and percentiles as described in section 8.2.

The results for grading of the estuarine aquatic biota indicator at each site are shown in Table 14.

9.0 Combining indicator health grades into site health grades

9.0 Combining indicator health grades into site health grades

9.1 The process

Various methods have been reported for combining indicator values into site gradings.

An early application was applied to water quality data obtained in the NSW north-east rivers (NSW EPA, 1996). In that study, water quality indicators were compared with selected *ANZECC Guidelines* (1992) for various environmental values and water uses.

If any of the chosen indicators failed the relevant EHV then the site itself failed that environmental value on that occasion, thus a pass or a fail depended directly on the 'worst' indicator.

More recent studies, however, generally involve combining the grades or standardised scores of the various indicators at a site by averaging (EHMP, 2010; GRCCC, 2010).

In this report averaging methods have been used to develop the site grades.

9.2 Results of site grading for physical-chemical stressors for 2005-2010

(i) Freshwater sites

The health grading of each physical-chemical **indicator** is described in section 8.2.

Table 10 shows the calculated median values and determined grading of each indicator at each site for the monthly sampling conducted from 2005-2010.

The final site grade for physical-chemical stressors is calculated using an averaging process as follows:

- Each indicator grade is given a score as shown in the first two columns of Table 9.
- The scores for the nine physical-chemical indicators are then averaged.
- The average score is then compared with the site score shown in column 3 in Table 9 to give the corresponding site grade shown in column 4 of Table 9.

Table 9: How indicator grades are scored and averaged to produce a site grade for physical-chemical stressors

1		2		3		4
Indicator Grade		**Indicator Score**		**Average Indicator Score**		**Site Grade**
A	⇨	9	}	>8	⇨	A
B	⇨	7		>6 to 8	⇨	B
C	⇨	5		>4 to 6	⇨	C
D	⇨	3		>2 to 4	⇨	D
F	⇨	1		0 to 2	⇨	F

The indicator health grades for physical-chemical stressors for each freshwater site are shown in Table 10. The final column of Table 10 shows the site health grades derived from the averaged indicator scores.

Table 10: Results of indicator health grades and site health grades for physical-chemical stressors Freshwater sites for 2005-2010 – showing median values for each indicator and grading results at each site

Parameter ->		**Turbidity (NTU)**	**SS (mg/L)**	**Total P (mg/L)**	**Total N (mg/L)**	**NH3-N (mg/L)**	**NOx-N (mg/L)**	**pH**	**EC (mS/cm)**	**DO (%sat)**	**Worst parameters**	**Average Indicator Score**	**Site**
REHTrigger ->		**8**	**7**	**0.01**	**0.32**	**0.02**	**0.05**	**4.8 to 7**	**0.32**	**75 to 118**	**>50% of tests failed**		**Grade**
Site	**No. of tests**												
Reference Sites													
36	65	0.2	1	0.003	0.11	0.005	0.005	5.9	0.16	99		9	A
37	70	0.4	1	0.003	0.12	0.005	0.050	5.7	0.2	100		9	A
Urban and STP Sites													
1	70	1.3	0	0.04	2.2	0.015	1.7	7.6	0.56	94	TN, TP, NOx, pH, EC	5.2	C
4	70	2.9	1	0.02	0.4	0.01	0.16	7.2	0.3	90	NOx, pH, TP, TN	6.6	B
5	70	3.5	2	0.025	0.7	0.015	0.44	7.2	0.5	86	NOx, pH, TP, TN, EC	5.7	C
6	70	4.6	2	0.026	0.5	0.01	0.18	7.4	0.4	92	NOx, pH, TP, TN, EC	5.7	C
8	70	4.1	2	0.027	0.6	0.03	0.28	7.3	0.46	83	NOx, pH, TP, TN, EC, NH3	5	C
23	70	7.1	4	0.05	0.61	0.09	0.1	7	0.3	37	NOx, DO, TP, TN, EC, Ph	4.8	C
39	70	0.9	1	0.005	0.23	0.005	0.04	7	0.2	92		8.6	A
43	70	0.9	1	0.03	2.45	0.005	1.9	7.9	0.65	97	TN, TP, NOx, pH, EC	5.7	C
45	70	1.2	1	0.04	2.7	0.02	2	7.6	0.64	97	TN, TP, NOx, pH, EC	4.8	C
46	70	3.5	1	0.011	0.33	0.02	0.14	7.3	0.48	104	TN, TP, NOx, pH, EC	5.8	C
52	70	3.5	1	0.012	0.29	0.016	0.04	7.2	0.3	80	pH, TP	6.6	B

Table 10 continued

Parameter ->		Turbidity (NTU)	SS (mg/L)	Total P (mg/L)	Total N (mg/L)	NH3-N (mg/L)	NOx-N (mg/L)	pH	EC (mS/cm)	DO (%sat)	Worst parameters	Average Indicator Score	Site
REHTrigger ->		8	7	0.01	0.32	0.02	0.05	4.8 to 7	0.32	75 to 118	>50% of tests failed		Grade
Site	No. of tests												Based on average Indicator Score
Industrial Sites													
10	140	12	6	0.075	1.5	0.22	0.74	7.5	0.7	75	TN, TP, NOx, NH3, pH, EC, Turb, DO	3.6	D
12	140	5.8	3	0.04	1.05	0.04	0.68	7.7	0.4	101	TN, TP, NOx, pH, EC, NH3	4.6	C
13	140	7.3	4	0.047	0.54	0.05	0.15	7.2	0.3	78	TN, TP, NOx, pH, EC, NH3, DO	5.2	C
77	70	6	2	0.016	22	12	7	7.4	0.99	58	TN,NOx, NH3, pH, EC, DO, TP	3.7	D
Rural Sites													
2	70	1.5	1	0.007	0.31	0.005	0.05	7.1	0.35	98	pH, EC	7.5	B
42	70	9	5	0.024	0.53	0.02	0.11	6.9	0.4	75	TP, TN, Turb, NOx, EC, DO	5.2	C
49	70	4	2	0.015	0.55	0.005	0.12	7.3	0.52	97	TN, pH, EC, TP, NOx	5.9	C
62	55	3	1	0.029	0.62	0.02	0.25	7.4	0.38	88	TN, pH, TP, NOx, EC	5.9	C
63	70	3.9	2	0.019	0.45	0.01	0.09	7	0.44	86	TP, TN, NOx, pH, EC	6.3	B
64	70	5.4	2	0.062	0.84	0.03	0.45	7.2	0.5	88	TP, TN, NOx, EC, NH#, pH	5	C
80	60	5.3	4	0.19	1.6	0.14	0.78	7.2	0.5	91	TP, TN, NH3, Nox, pH, EC	3.9	D

(ii) Estuarine-tidal sites

Table 11 sets out the corresponding grading results for physical-chemical indicators for estuarine sites using the same criteria (see section 8.2).

The final site grade is given in the last column using the calculation used to average the site indicator scores as described in Table 9.

Table 11: Results of indicator health grades and site health grades for physical-chemical stressors Estuarine/tidal sites for 2005-2010 – showing median values for each indicator and grade results at each site

Parameter ->		Turbidity	SS	Total P	Total N	NH3-N (mg/L)	NOx-N (mg/L)	pH	DO	Worst parameters	Average Indicator Score	Site Grade
REHTrigger ->		<10	<6	<0.03	<0.3	<0.015	<0.015	4.8 to 7	75 to 118	>50% of test failed		
Site	No. of tests	NTU	mg/L	mg/L	mg/L	mg/L	mg/L		%sat			
38	65	8.8	12	0.01	0.22	0.007	0.014	7.7	96	SS	6.6	B
48	65	10.4	11	0.011	0.29	0.02	0.02	7.2	80	SS, Turb, NOx, NH3, DO	6	C
55	70	6.5	10	0.009	0.2	0.01	0.019	7.9	93	SS, NOx	7.3	B
60	70	1.4	6	0.012	0.32	0.01	0.05	7.4	81	TN, NH3,DO	7	B
61	80	1.1	4	0.019	0.32	0.01	0.02	7.6	82	TN, NH3,DO	6.8	B
100	60	4.5	5	0.037	0.56	0.06	0.06	7.1	70	NOx, NH3, DO, TP	4.8	C
103	50	11.5	16	0.008	0.2	0.01	0.024	7.7	89	SS, Turb, NOx	7.3	B
104	50	8.7	13	0.007	0.2	0.01	0.02	7.7	91	SS, NOx	7.3	B
105	50	9.4	13	0.008	0.2	0.01	0.02	7.8	91	SS, NOx	7.3	B
106	50	8	11	0.007	0.2	0.008	0.019	7.7	91	SS, NOx	7.5	B
107	50	6.9	10	0.008	0.2	0.01	0.02	7.8	92	SS, NOx	7.3	B
108	50	6	12	0.007	0.17	0.01	0.015	7.8	94	SS	7.5	B

9.3 Results of site grading for microbial water quality for 2005-2010

Table 12 sets out the results for calculated health grades for bacterial quality at all water test sites for the period 2005-2010.

In the case of some estuarine-tidal sites, results for both faecal coliforms and enterococci were available.

Thus two bacterial grades - for faecal coliforms and enterococci - are shown respectively in the last column, with the average grade coloured for site 100.

Table 12: Results of grading bacterial indicators at freshwater and estuarine-tidal sites for 2005-2010 – median values and grading results

Freshwater Sites

Site	Faecal Coliforms	Grade
Reference Sites		
36	4	A+
37	8	A+
Urban and STP Sites		
1	48	A
4	71	A
5	200	C
6	52	A
8	225	C
23	1600	F
39	16	A+
43	18	A+
45	158	B
46	80	A
52	91	B
Industrial Sites		
10	1000	F
12	740	D
13	320	C
77	220	C
Rural Sites		
2	8	A+
42	76	A
49	48	A
62	74	A
63	51	A
64	280	C
80	975	D

Estuarine/Tidal Sites

Site	Faecal Coliforms	Enterococci	Grade
38	2	*	A+
48	20	*	A+
55	2	2	A+/A
60	4	*	A+
61	2	*	A+
100	43	20	A- D
103	1	1	A+/A
104	1	1	A+/A
105	1	1	A+/A
106	4	4	A+/A
107	1	2	A+/A
108	1	1	A+/A

**Enterococci testing commenced in 2010 at these sites. SInce then site 38 has been grade A, while sites 48, 60 and 61 are grade C*

9.4 Results of site health grading for aquatic biota for 2002-2007

(i) Freshwater sites

Table 13 sets out the average scores and the grades obtained for the three biotic indices for each freshwater site (see section 8.4).

The final site health grades at each sample site comprise the average of the three indicator grades shown in the last column. The averaging method described in Table 9 was used.

Table 13: Freshwater sites - biota indicator grades at each site for the period 2002-2007 with corresponding site grades

Indicator Grades				
Site	**TDI**	**Signal 2**	**EPT**	**Grade**
Reference Sites				
36	-	-	-	-
37	A	A	A	A
Urban and STP Sites				
1	C	B	F	C
4	C	B	F	C
5	D	B	F	D
6	C	B	F	C
8	D	B	C	C
23	-	-	-	-
39	C	B	F	C
43	-	-	-	-
45	D	B	D	C
46	D	C	F	D
52	-	-	-	-
Industrial Sites				
10	F	F	F	F
12	F	D	F	F
13	F	F	F	F
77	F	C	F	D
Rural Sites				
2	C	B	C	B
42	C	C	F	C
49	D	B	C	C
62	C	C	F	C
63	C	A	A	B
64	C	B	F	C
80	D	C	D	C

(ii) Estuarine-tidal sites

Table 14 sets out the resulting health grades obtained for aquatic biota at each of the estuarine-tidal sample sites.

As there is only one aquatic biota indicator grade for these sites, the site grade is the same as the indicator grade in this case.

Table 14: Estuarine-tidal aquatic biota health grade Median Chlorophyll-a concentrations and corresponding grade for each site

Site Guideline ->	Chlorophyll-a 4ug/L	Site Grade
38	2.5	A
48	2.5	B
55	2	A
60	3.3	B
61	5	C
100	2.4	B
103	2.2	A
104	2	A
105	2	A
106	2.5	A
107	2.5	A
108	2	A

10.0 Summary of water quality health gradings

10.0 Summary of water quality health gradings

Table 15 below provides a breakdown of the three separate indicator gradings (ie. physical-chemical condition, bacterial quality and aquatic biota quality) at each water test site and the overall summary waterway health grading, determined by combining the three indicator grades using the procedure set out in Table 9.

Table 15: Final water quality health grades for the 36 water test sites

Site	Ecosystem Health		Pathogen Risk	Final
Freshwater	Phys-Chem	Biota	Bacteria	Grade
Reference Sites				
36	A	-	A+	**A**
37	A	A	A+	A
Urban and STP Sites				
1	C	C	A	B
4	B	C	A	B
5	C	D	C	C
6	C	C	A	B
8	C	C	C	C
23	C	-	F	D
39	A	C	A+	B
43	C	-	A+	B
45	C	C	B	C
46	C	D	A	C
52	B	-	B	B
Industrial Sites				
10	D	F	F	F
12	C	F	D	D
13	C	F	C	D
77	D	D	C	D
Rural Sites				
2	B	B	A+	B
42	C	C	A	B
49	C	C	A	B
62	C	C	A	B
63	B	B	A	B
64	C	C	C	C
80	D	D	D	D
Estuarine-Tidal				
38	B	A	A+	A
48	C	B	A+	B
55	B	A	A+	A
60	B	B	A+/A	B
61	B	C	A+	B
100	C	B	(A/D) C	C
103	B	A	A+/A	A
104	B	A	A+/A	A
105	B	A	A+/A	A
106	B	A	A+/A	A
107	B	A	A+/A	A
108	B	A	A+/A	A

11.0 Conclusion

11.0 Conclusion

In the Water Quality Report Card 2012, the three water quality health grades described above and the summary waterway health grading (ie. the final grade) for each of Council's 36 water test sites are presented on a map of Hornsby Shire.

The average of these three indicator grades was then awarded a summary waterway health grading for each of the water test sites. Grades in the 2012 report card are based on water quality data collected between 2002 and 2010 under Council's water quality monitoring program and on how that data compares to environmental health values for freshwater and estuarine bodies set out in the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ 20000) and in the Guidelines for Managing Risks in Recreational Water (NHMRC 2008).*

The results show that the water quality of freshwater, estuarine and marine waterways in Hornsby Shire has not deteriorated significantly since the water quality monitoring program was established. Water test sites in the north of the Shire exhibit excellent water quality, whilst B and C grades predominate in the rest of the Shire, with D grades found close to rural and industrial areas. The only F grade is found downstream of Industry at Thornleigh.

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13.0 Glossary

Algae: Simple chlorophyll-bearing plants which are capable of photosynthesis. They may occur in all aquatic environments, and may be microscopic in size. Algal monitoring in The Berowra Estuary refers to the collection and identification of 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 a change in water colour and smell, by surface froths, or even fish kills. Blooms of certain algal species at times produce toxic chemicals which are accumulated by aquatic organisms and may kill them or render them unfit to eat.

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 often an indicator of contamination by raw sewage. (See nitrogen)

Catchment: The area of land above a chosen stream site from which rainfall and water discharges all drain to that site.

Chlorophyll-a: This is a biological pigment which enables plants, including algae, to photosynthesise. The pigment concentration is measured in a water samples to provide an indication of the biomass of phytoplankton (microscopic, suspended plants) in the water; high concentrations may identify undesirable growth of phytoplankton.

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

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. Diatoms are an important part of estuarine phytoplankton and benthic 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 maximum amount of DO that will dissolve in water (ie. when the water is saturated with DO) is 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 00C equates to 14.63 mg oxygen per litre of water. The value percent saturation is the relative amount of DO in water compared with the theoretical maximum that can be dissolved. Low DO % saturation in rivers may indicate eutrophication problems where DO is being consumed be chemical and biological reactions. Supersaturated conditions, when DO is greater than 100%, may occur in waters when oxygen input, due to algal or plant photosynthesis, exceeds that lost by respiration of via the water-air interface by 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. They are able to survive longer in saline waters than faecal coliforms. Although they are not particularly harmful themselves to humans, high enterococci counts in water indicates increased likelihood for the presence of more harmful micro-organisms and higher risk of infection.

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

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 starting at the tidal limit of Berowra Creek and reaching to its mouth at the Hawkesbury River near Bar Island.

Eutrophication or eutrophic conditions: Abundance of nutrients in waterways resulting in high rates of phytoplankton productivity frequently resulting in oxygen depletion below the surface layer of the water body.

Faecal coliforms: Faecal coliforms are bacteria that inhabit the intestines of humans and other mammals and are present in faeces. Direct detection of many serious pathogens in waterways is not feasible because they occur intermittently in the water column, there are many possible species, they are difficult to detect and the analysis costs are prohibitive. For this reason, Faecal coliforms 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.

Leachate: Water which has passed through the soil and contains soluble substances from it. At landfill sites the leachate that collects may contain high concentrations of ammonia and organic compounds.

Macroinvertebrates: A group name given to a wide range of small animal 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. Monitoring of water quality may take the form of: visual appearance (eg. clarity, colour, scums, oily films), suspended particles (eg. clays, algae, bacteria), dissolved chemicals (eg. Nutrients, salts), microorganisms (eg. Bacteria), or plant and animal life (eg. Algae, macroinvertebrates)

Nitrogen: The dissolved forms of nitrogen include ammonia (NH3 and NH4) and oxidised nitrogen (NO2 and NO3). 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 the eutrophication of waters. 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.

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 (PO4).

Reference site: A monitoring site against which other sites are compared. In Councils' studies the sites are chosen in catchments unimpacted by man's land development activities. Ideally, in environmental studies of waterways, the reference creek is chosen, if possible, to have a similar catchment type and geology.

Stormwater: Flows off land and washes litter, loose dirt and dust from the surface of land, carrying it into storm drains and creeks.

Suspended solids: The concentration of material suspended in the water; usually measured in units of milligrams of suspended solids per litre of water. Water clarity will decrease with increasing concentrations of suspended solids. High levels of suspended solids have the potential to reduce the amount of light available to benthic and planktonic aquatic organisms for their metabolism and photosynthesis.

Temperature: Temperature is the basic physical characteristic of the water body. 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.

14.0 Appendices

Appendix 1: Statement of joint intent

STATEMENT OF JOINT INTENT

COMMUNITY CONTRACT FOR BEROWRA CREEK

Endorsed,
Robert Webster
27/4/94.

It is hereby agreed that

Department of Planning
Environment Protection Authority
Hawkesbury-Nepean Catchment Management Trust
Hornsby Council
Water Board

will henceforth work together to achieve, within the framework of the current Urban Development Program, the ecologically sustainable development of the Berowra Creek catchment and the recovery of the environmental health of the Creek.

To this end it is agreed that the initial goal for Berowra Creek at Fishponds Waterhole and downstream shall be consistent with the pursuit of recreational activities such as swimming, canoeing and boating. Furthermore, it is agreed that fishing with confidence and safety and the protection of the shellfish industry are longer term goals. The values to be protected are defined by the Australian Water Quality Guidelines for Fresh and Marine Waters and are characterised as Primary Contact Recreation and Protection of Modified Aquatic Ecosystems for Fish, Crustacea and Shellfish.

It is also agreed that a Water Quality Management Strategy and a Plan of Management to achieve this initial goal will be jointly prepared and progressively implemented. All parties to this agreement will cooperate to ensure that a draft Water Quality Management Strategy for Berowra Creek is prepared and placed on exhibition by end of September 1994.

It is acknowledged that Berowra Creek contains excessive levels of nitrogen and high levels of phosphorus. Accordingly appropriate nutrient reduction measures will be implemented forthwith.

To this end the Water Board will install by end July 1994 measures at West Hornsby Sewage Treatment Plant to endeavour to achieve an arithmetic mean of 20 to 25mg/L Total Nitrogen concentration in the discharged effluent. Also the Water Board will make immediate operational changes to reduce phosphorus and faecal coliform concentrations in discharged effluent from West Hornsby Sewage Treatment Plant and Hornsby Heights Sewage Treatment Plant. Furthermore the Water Board will prepare and exhibit by end September 1994 an options study for Hornsby Heights Sewage Treatment Plant and West Hornsby Sewage Treatment Plant. The options study will propose technically feasible measures for further nitrogen reduction. The options of 15mg/L, 10mg/L and 5mg/L Total Nitrogen (90 percentile) in discharged effluent and pumping effluent out of the catchment are to be specifically considered. The Water Board will prepare and publicly exhibit by end June 1995 an EIS for each of those options which the Technical Working Party established by the Minister for Planning considers feasible and warranting such examination. The Board undertakes that the option approved by the Minister for Planning will be put in operation expeditiously.

Hornsby Council undertakes that it will impose and enforce controls on construction sites so as to significantly reduce the sediment and other pollutants reaching the Creek from these sources. To this end Hornsby Council will prepare and exhibit by end September 1994 a draft Erosion and Sediment Control Code. Hornsby Council will prepare and exhibit by end September 1994 a revised Stormwater Management Code, a revised Stormwater Design Manual and an Issues Report on the remediation of the existing stormwater system. As part of implementing the Water Quality Management Strategy, Hornsby Council will also expeditiously prepare an options study, environmental assessment and an implementation strategy for reducing storm water nutrient ingress to Berowra Creek. Hornsby Council will utilise the principle of water sensitive urban design in its consideration of future developments.

The Hawkesbury-Nepean Catchment Management Trust will prepare and exhibit by end September 1994 a draft public education strategy.

The Water Board, Environmental Protection Authority and Hornsby Council shall forthwith commence a catchment survey to identify and quantify sources of pollution so that appropriate remediation and enforcement action can be taken.

The Water Board, Environmental Protection Authority and Hornsby Council shall forthwith establish a cooperative monitoring program for the waterways of Berowra Creek so that the effectiveness of changes can be measured and assessed.

The Department of Planning undertakes that it will not introduce any planning measures that are incompatible with the ecological sustainability of Berowra Creek.

Department of Urban Affairs and Planning	EPA NSW	Hawkesbury Nepean	Sydney WATER	HORNSBY SHIRE COUNCIL
G. Kibble Director of Planning	N. Sheperd Director-General Environment Protection Authority	R. Crawford Chairman Hawkesbury-Nepean Catment Management Trust	P. Broad Managing Director Water Board	C. Meany Mayor Hornsby Council

Appendix 2: Hornsby Shire Council's water quality monitoring program

Excerpt from Water Quality Monitoring Report - 2009-2010 Annual Report

The objectives of this program are to:

- Undertake long term monitoring of water catchments within Hornsby Shire to assess trends in water quality from both point and diffuse pollution sources, with an emphasis on understanding causes and effects of algal blooms in Berowra Estuary.
- Compare the observed water quality data with undisturbed catchments in nearby national parks, and with nationally accepted Guidelines for fresh and marine waters; specifically for the water values associated with the *protection of aquatic ecosystems,* with *recreational water uses,* and for *stormwater reuse projects*.
- Use biological monitoring at representative sites to complement the water quality program. (Indicator species utilised are macroinvertebrates, diatoms and planktonic algae).
- Determine the effectiveness of Catchments Remediation assets in removing pollutants from the waterways.
- Support water savings programs, including water treatment and reuse projects at swimming pools and old landfill sites, and stormwater harvesting and reuse projects at sports ovals.
- Use water quality data to calibrate and support catchment/pollutant modelling and assist with environmental education programs.

The Hornsby Shire Council water quality monitoring program commenced in October 1994 in response to increasing concern about algal blooms in Berowra Estuary and tightening of water pollution regulations. Council scientific staff have carried out inspection, on-site water testing and water sample collection at all sites since the program's inception. Collected waters are sent for more detailed analysis at specialist industry accredited laboratories.

Sampling site locations have generally remained unchanged since the program began. Additional sites have been progressively added in order to monitor the effectiveness of devices installed by Council to improve the quality of stormwater and landfill leachate entering local creeks, and to assess water quality in the Hawkesbury River prior to and after commissioning of the new sewage treatment plant at Brooklyn.

Annual water quality monitoring reports have been produced since 1996. Reports are available in printed format in local libraries. Reports for recent years can also be accessed on Council's website at www.hornsby.nsw.gov.au/environment/ (choose subcategories 'water catchments' then 'water quality').

During the years 2002 to 2007, at selected representative sites, biological monitoring and reporting (using macroinvertebrate and diatoms as indicator organisms) was carried out under contract for Council. A brief description of those programs has been included in earlier annual reports, but more detailed data can be accessed via the consultant reports. The macroinvertebrate and diatom monitoring data was reviewed by an independent consultant during this reporting period and the findings reported in the subsequent annual report.

An important project, initiated as part of the Estuary Management Program, was the installation of a number of chlorophyll monitoring probes which report real-time data and provide an indication of any change in algal activity and salinity in estuarine waters. One probe has been operating since 2002 in the upper Berowra estuary near Calabash Bay. Over the last two years, additional probes with temperature, salinity and chlorophyll sensors have been installed in the lower Berowra estuary near Bar Island and in the Hawkesbury River between Wisemans Ferry and Broken Bay (HSC, 2010a). If high chlorophyll-a readings occur Council officers respond by taking additional samples for algal identification. If harmful species are identified in high numbers Council then works in collaboration with the Regional Algal Co-ordinating Committee to monitor the bloom and inform the community of possible risks or estuary closures.

14.0 Appendices continued

Appendix 3: Location of freshwater and estuarine sampling sites

Figure A3.1: Location of freshwater sample sites

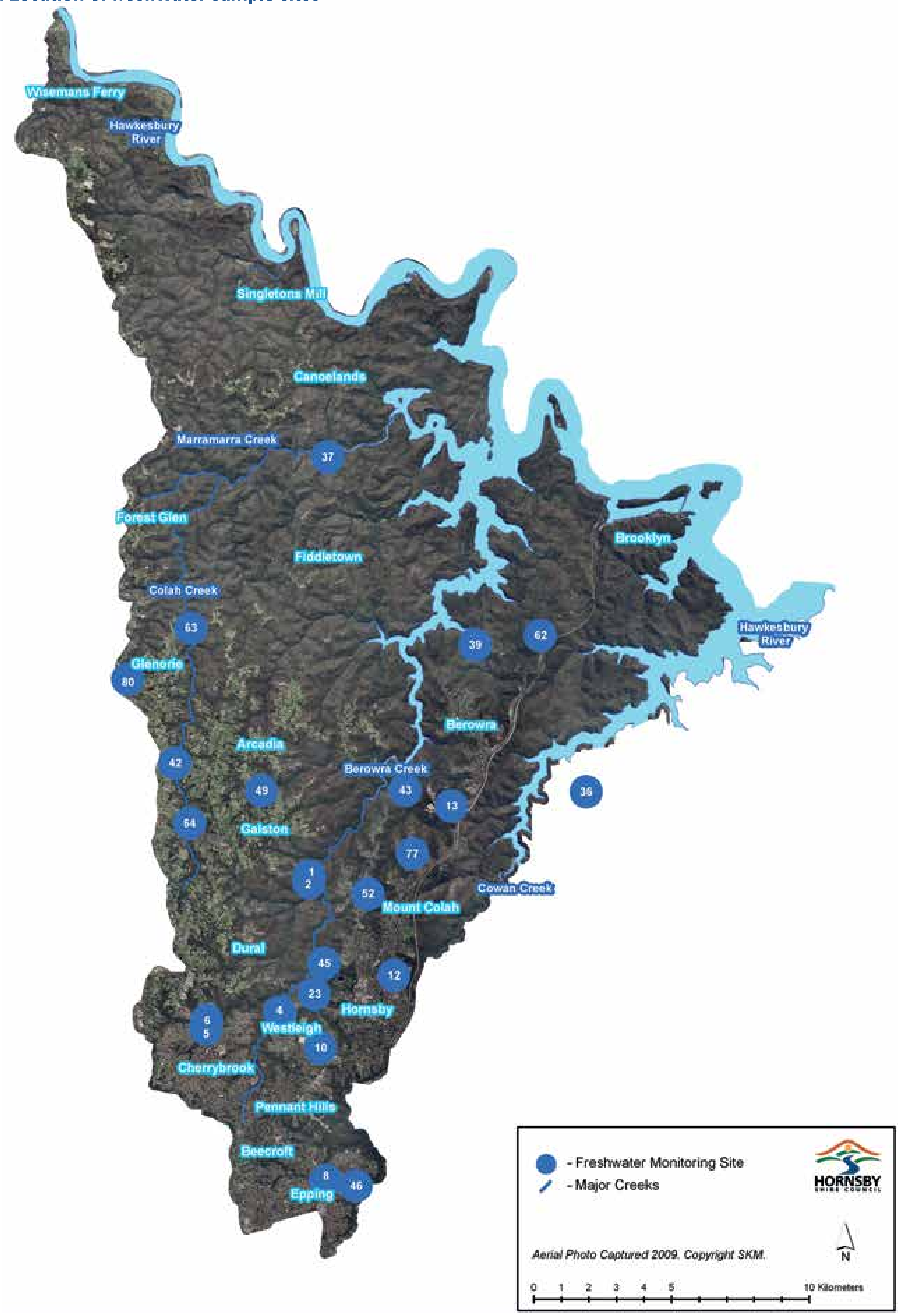

Table A3.1: Descriptions of freshwater sampling sites

Site	Location	Major Land Use/Impact	Samples per month	Catchment	Site Catchment Area (Ha)	Major influences on flow or quality
1	Berowra Creek, 200m downstream of concrete road bridge at Galston Gorge	Urban, STP	1	B	5550	STP upstream
2	Tunks Creek, Galston Gorge under wooden truss bridge	Urban/Rural	1	B	1690	
4	Berowra Creek, Westleigh 500m down track from Barkala Pl, near Great Nth Walk	Urban	1	B	1230	
5	Pyes Creek, Cherrybrook, end of Christine Place	Urban	1	B	380	
6	Georges Creek, Dural, off Falon Drive	Urban	1	B	440	
8	Devlins Creek, Sutherland Road, Cheltenham	Urban	1	LC	823	
10	Larool Creek, Sefton Road, Thornleigh	Industrial	2	B	38	
12	Hornsby Creek, upstream of Leighton Pl road bridge, Hornsby	Industrial	2	C	305	
13	Sams Creek, Hamley Road, Mt Kuring-gai	Industrial	2	B	18	
23	Waitara Creek, 100m upstream from WHSTP outfall, Hornsby	Urban/Industrial	1	B	650	
36	Murray Anderson Creek, by boat of Smiths Creek	National Park Ref	1	C	250	
37	Smugglers Creek, by boat/walk off Marramarra Creek	National Park Ref	1	B	530	
39	Joe Rafts Creek, above cofluence with Berowra Creek	Urban	1	B	688	
42	Colah Creek, upstream of Wylds Road Bridge, Glenorie	Rural	1	B	990	
43	Calna Creek, above confluence with Berowra Creek	Urban, STP	1	B	1060	STP upstream
45	Berowra Creek, at upper end Fishponds Waterhole, Hornsby	Urban, STP	1	B	3320	STP upstream
46	Unnamed tributary of Terrys Creek, Somerset St, Nth Epping	Urban	1	LC	82	
49	Still Creek, end of Mansfield Road behind tennis court	Rural	1	B	440	
52	Calna Creek, 300m upstream of HHSTP outfall	Urban	1	B	280	
62	Cowan Township, accessed by bush track from Alberta Ave	Rural	1	B	11	
63	Colah Creek, via Ben Bullen Road	Urban	1	B	2290	
64	Galston Village, tributary of Colah Creek near Salaway Place	Rural	1	B	145	
77	Gleeson Creek, end of Oxley Dr, Mt Colah	Industrial/Landfill	1	B		Urban landfill
80	Glenorie Creek, Tekopa Ave, Glenorie upstream of GPT	Rural	1	B	100	
Key:	**B - Berowra Creek LC - Lane Cove Catchment C - Cowan Catchment**					

TableA3.2: Catchment characteristics of freshwater sampling sites

Site	Creek	Type - Aerial	Sewered	Drainage	Suburb	Catchment (Has)	Large Pervious (Has)	Residential (Has)	Indust/Comm (Has)	Rural area (Has)	Res Imperv (%)	Ind/Comm Imperv (%)	Rural Imperv (%)	TI	EI
2	Tunks	Rural/NP	Partially	No	Galston	1688	947.2	14.1	3.8	722.9	40%	80%	5%	2.7%	0.5%
4	Berowra	Res/Np	Yes	No	Cherry/Thorn	1235	331.5	891.8	11.7	0	45%	95%	5%	33.4%	33.4%
5	Pyes	Residential	Yes	Yes	Dural	377.9	41.6	336.3	0	0	50%	0%	0%	44.5%	44.5%
6	Georges	Rural/Res	Yes	Res - Yes	Dural/Glenhaven	443.1	137.2	86.45	46.6	172.85	50%	90%	5%	21.2%	19.2%
8	Devlins	Res	Yes	Yes	Various	825	74.4	744.6	6	0	45%	95%	0%	41.3%	41.3%
10	Larool	Res	Yes	Yes	Thornleigh	38.1	0.75	17.65	19.7	0	35%	90%	0%	62.7%	62.7%
12	Hornsby	Res	Yes	Yes	Various	305.6	5.9	227.15	72.55	0	60%	95%	0%	67.2%	67.2%
13	Sams	Ind	Yes	Yes	Mt KRG	18.6	2.8	0	15.8	0	0%	95%	0%	80.7%	80.7%
23	Waitara (US STP)	Res/NP	Yes	Yes	Various	912.2	140.5	751.1	20.6	0	50%	95%	0%	43.3%	43.3%
37	Smugglers	NP	No	No	-	532.8	532.8	0	0	0	0%	0%	0%	0.0%	0.0%
39	Joes Craft	Res/NP	Yes	Yes	Berowra Hts	688	484.4	203.6	0	0	35%	0%	0%	10.4%	10.4%
42	Colah	Rural	No	Res - Yes	Galston Village	1537	662.6	203.6	0	670.8	35%	0%	0%	4.6%	4.6%
49	Still	Rural	No	No	Galston	439.4	76.1	0	0	363.3	0%	0%	0%	0.0%	0.0%
52	Calna	Res/NP	Yes	Yes	Various	281.4	81	200.4	0	0	45%	95%	0%	32.0%	32.0%
62	Cowan/Kimmerikong	Res/NP	No	Yes	Cowan	11	4.3	6.7	0	0	40%	0%	0%	24.4%	24.4%
63	Colah	Rural	No	Res - Yes	Galston Village	1310	612.9	6.7	0	690.4	40%	0%	0%	0.2%	0.2%
64	Trib Colah	Rural/Res	No	Res - Yes	Galston Village	145	15.1	*37.7*	*1.6*	90.6	45%	100%	5%	15.9%	12.8%
77	Gleeson	Res/NP	Yes	Yes	Mt Colah	45.9	10.6	35.3	0	0	35%	0%	0%	26.9%	26.9%
80	Glenorie	Rural/Res	No	Res - Yes	Glenorie	105.1	0	7	0	98.1	35%	0%	0%	2.3%	2.3%
113	Dog Pound	Res/Np	Yes	Yes	Westleigh	24.8	14.8	10	0	0	40%	0%	0%	16.1%	16.1%
117	Byles	Res/NP	Yes	Yes	Beecroft	316.1	86.6	229.5	0	0	40%	0%	0%	29.0%	29.0%
118	Still	Rural/NP	No	No	Galston	1553.1	965.2	0	0	587.9	0%	0%	0%	0.0%	0.0%

Reference: This table taken from Equatica, 2010.

14.0 Appendices continued

Figure A3.2: Location of estuarine/tidal sampling sites

Table A3.3: Descriptions of estuarine sampling sites

Site	Location	Monitoring Status	Freq
38	Sandbrook Inlet, Brooklyn, Hawkesbury River	EH	M
48	Marramarra Creek at orange orchard	EH	M
55	Hawkesbury River at Brooklyn Baths	REC	W
60	Berowra Creek, 50m downstream of Berowra Waters Ferry	EH	M
61	Berowra Creek, mid stream at Calabash Point	EH	M
100	Berowra Creek at Crosslands Reserve (north beach)	REC, EH	W, M
103	Mouth of Milsons Passage (Eastern end)	Brooklyn STP	M
104	Middle of Hawkesbury River off Peat Island	Brooklyn STP	M
105	Under old Hawkesbury River Bridge; 2nd pylon Southern end	Brooklyn STP	M
106	Middle Sandbrook Inlet, off Fenwick's Marina	Brooklyn STP	M
107	Middle Hawkesbury north off Long Island	Brooklyn STP	M
108	Hawkesbury off Bradleys Beach Dangar Island	Brooklyn STP	M

M = monthly throughout the year
EH = long-term environmental health
STP = Brooklyn STP monitoring program

W = weekly over summer for recreational monitoring
REC = summer recreational monitoring

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Appendix 4: Summary of grading methodology

SUMMARY OF METHOD	
Chose time frame:	**Phys-Chem, Bacto and Chlorophyll** - 5 years data 2005-2010. samples taken monthly or bimonthly **Aquatic Biota**: freshwater macroinvertebrates and diatoms - 5 years 2002-2007 - samples taken Spring and Autumn each year
Chose categories of water quality:	Phys-chem, Microbial and Aquatic biota
Parameters- Freshwaters	**Phys-Chem**: Turbidity, SS, TP, TN, NOx-N, NH3-N ,pH, EC, DO **Microbial**: faecal coliforms **Aquatic Biota**: (1) Stream Invertebrate Grade Number Average Level= 'SIGNAL 2 (2) Ephemeroptera, Plecoptera and Trichoptera = EPT Index (3) Trophic Diatom Index = TDI
Parameters - Estuarine	**Phys-Chem**: pH, turb, SS, DO, TP, TN, NOx, NH3 **Microbial**: Faecal coliforms and/or Enterococci **Aquatic Biota** : Phytoplanktonic Algae = chlorophyll
Choose Freshwater REH trigger values	**Phys-Chem** : Devloped using the higher of the 95th% values for reference site 36 and 37. **Bacteria**: Faecal coli = Median<150 and 80th%<600 **Freshwater Biota:** REHV = 80th% value for SIGNAL, EPT and TDI for reference site 37. (Worst Case Scenarios: 10th% or 90th% for SIGNAL, EPT and TDI at all sites.)
Choosing Estuarine REH Triggers	**Phys-Chem and Biota:** use ANZECC/ARMCANZ Guidelines for NSW estuaries **Bacteria**: Faecal coli = Median<150 and 80th%<600: Enterococci 95th% < 40, 200, 500
Data Presentation	Draw **box-plots** of each parameter for all sites (show max, min, 20th and 80th percentiles, median; **OR** for Enterococci use 95th percentile OR, use **histogram graphs** to determine % of tests within the limits for Indicators pH and DO (which have upper and lower limits).
Scoring and Grading	Overlay relevant REHV across the boxplots, OR, for freshwater biota use Standardised Score method with REHV and WCS values.
Physical-Chem -Freshwater and Estuary	Grade each Phys-Chem parameter at each site: A(green) if>80% pass; B(yellow) if<80% and >50% pass; C(red) if<50% and >20%; D(purple) if<20% pass; F(black) if all fail Determine Site Grade for Physical-Chem based on the average Indicator Grade/Colour
Bacto	Faecal coli: A+(green) if Median<150 and 80th%<150; A(green) if Median<150 and 80th%< 600; B(yellow) if Median <150 and 600<80th%<1000 OR Median >150 and 80th%<600; C(red) if Med>150 and 80th%<600; D(purple) if Med>150 and 80th%>600; F(black) if Med>1000 Enterococci: NHMRC guideline. A(green) if 95th%<40; B(yellow) if 95th%<200; C(red) if 95th%<500; D(purple) if 95th%>500
Aquatic Biota	Estuary Chlorophyll: based on ANZECC Guideline and percentile distribution using box-plots (as per Freshwater phys-chem scores). Site Biota Grade = Indicator Grade : Freshwater biota: for Indicator Grade use average standardised score. Grade A if ASS>0.7 ; Grade B if 0.7>ASS>0.4; Grade C if 0.4>ASS>0.2; Grade D if 0.2>ASS>0.1; Grade F if ASS<0.1 Freshwater Biota: Site Grade use average of the 3 Indicator Grades

Appendix 5: Summary of regional environmental health values and grading methodologies

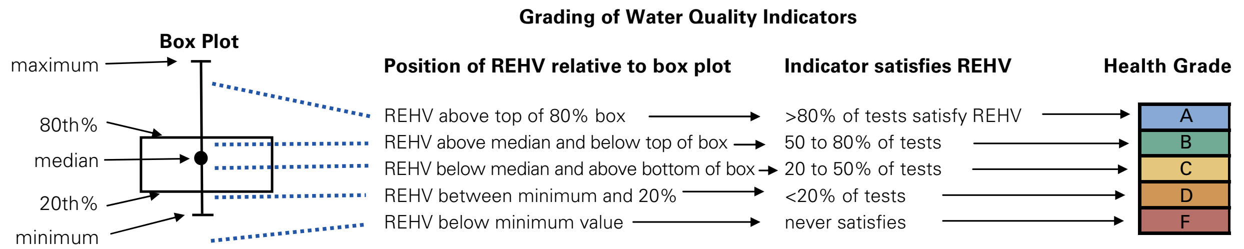
Regional environmental health trigger values for physical-chemical stressors and faecal bacteria for freshwater sites

Turbidity	Suspended Soilds	Total Phosphorus	Total Nitrogen	Oxidised Nitrogen	Ammonium Nitrogen	pH	Electrical Conductivity	Dissolved Oxygen	Faecal Coliforms
NTU	mg/L	mg/L	mg/L	mg/L	mg/L		mS/cm	%sat	cfu/100mL
<8	**<7**	**<0.01**	**<0.32**	**<0.05**	**<0.02**	**4.8 to 7**	**<0.32**	**75 to 118**	**Median<150 and 80th%<600**

Regional environmental health trigger values for physical-chemical, bacteria and aquatic biota indicators used for estuarine-tidal sites

Turbidity	Suspended Soilds	Dissolved Oxygen	pH	Total Phosphorus	Oxidised Nitrogen	Ammonium Nitrogen	Faecal Coliforms	Enterococci	Chlorophyll
NTU	mg/L	%sat		mg/L	mg/L	mg/L	cfu/100mL	cfu/100ml	ug/L
10	**6**	**80-110**	**7-8.5**	**0.03**	**0.015**	**4.8 to 7**	**Median<150 and 80th% <600**	**95th% <40 (200, 500)**	**4**

Method for indicator health grading at sampling sites for physical-chemical indicators and estuarine biota indicator using box-plots of percentiles and REHVs



The method for indicator health grading at sampling sites for bacterial indicators using box-plots of percentiles and REHVs

Faecal Coliforms	Median	80th Percentile
A+	<150	<150
A	<150	<600
B	<150	>600 and <1000
B	>150	<600
C	>150 and <600	>1000
D	>600	>1000
F	>1000	

Enterococci Grade	95th Percentile
A	<40
B	40 to 200
C	200 to 500
D	>500

Regional environmental health triggers and worst case scenario values and grading standardised scores for freshwater aquatic biota indicators

Biota indicator	REHV	WCS
TDI	1.8	91
SIGNAL2	4.65	2.1
EPT	55.8	0

Site Grade	Average StSc
A	>0.7
B	>0.4 to 0.7
C	>0.2 to 0.4
D	>0.1 to 0.2
F	<0.1

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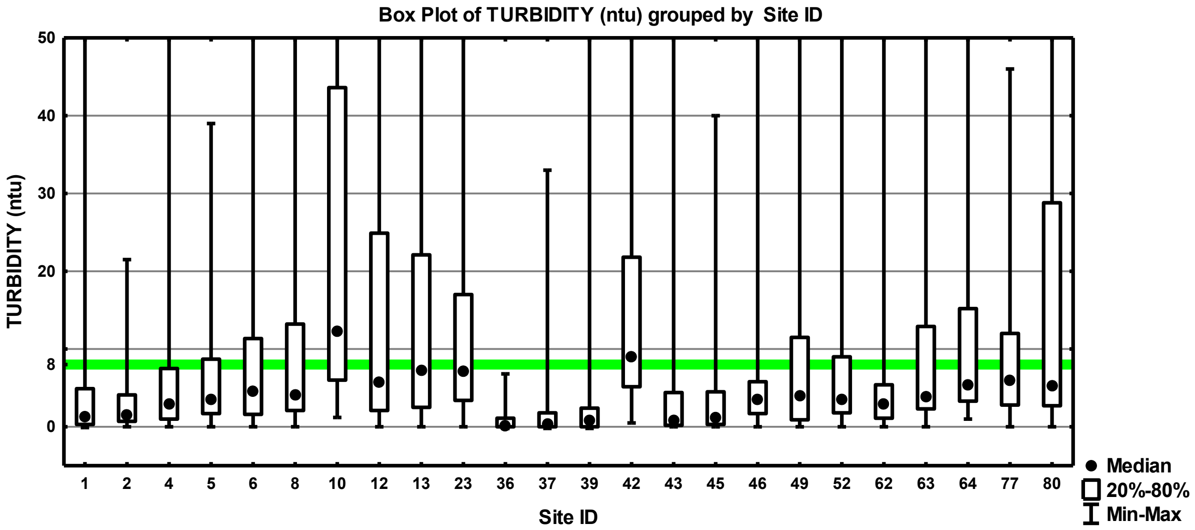
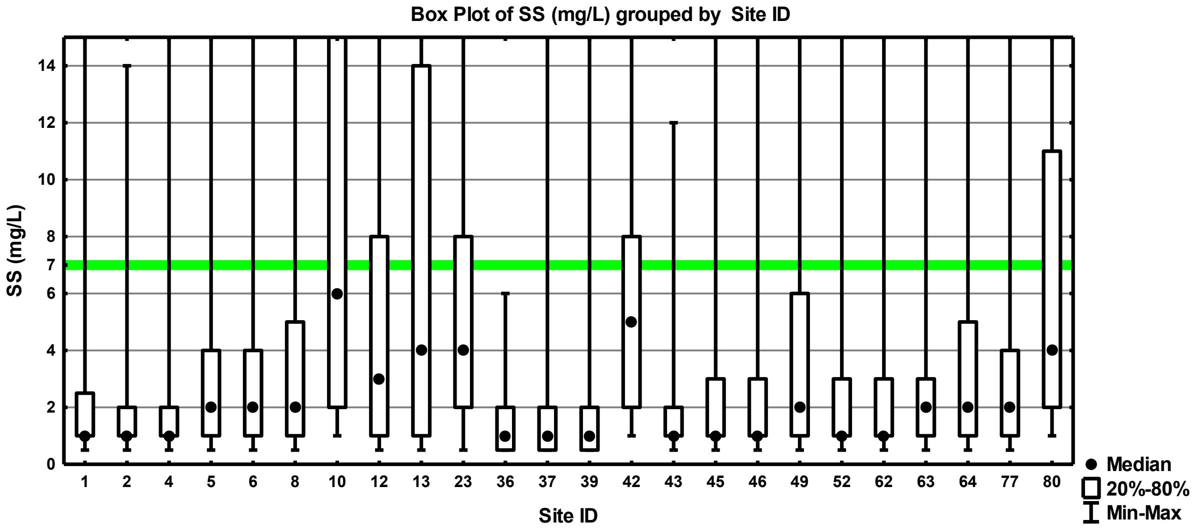
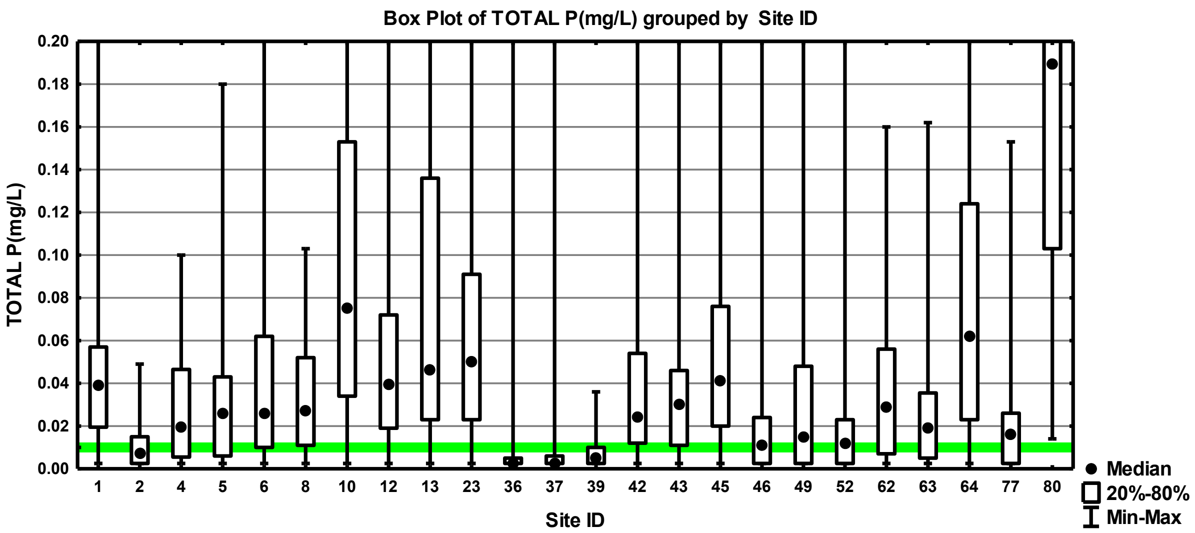
Appendix 6: Water quality data used for waterway health grading

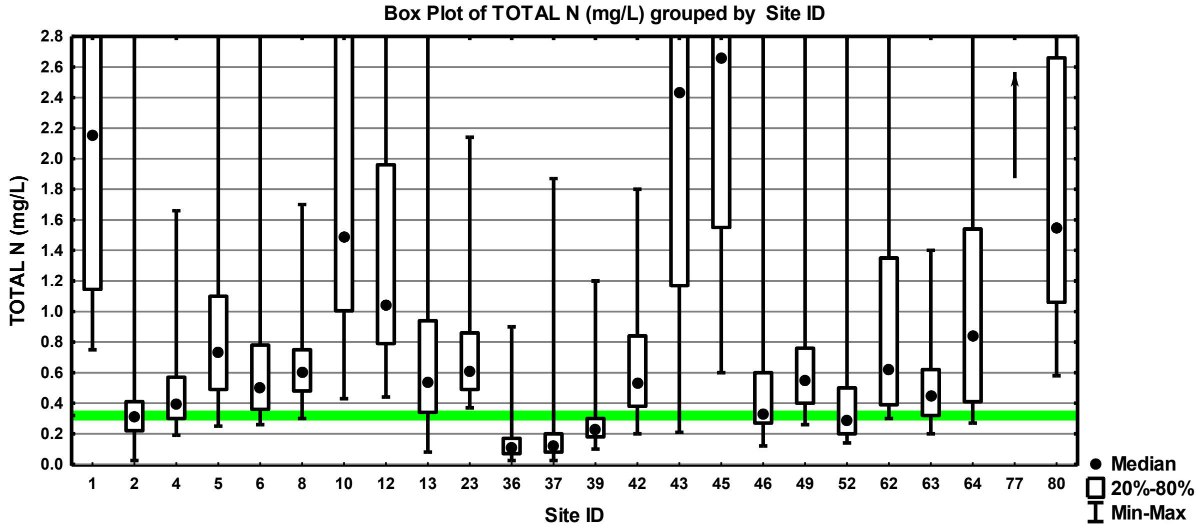
Appendix 6.1: Freshwater sites: physical-chemical stressors

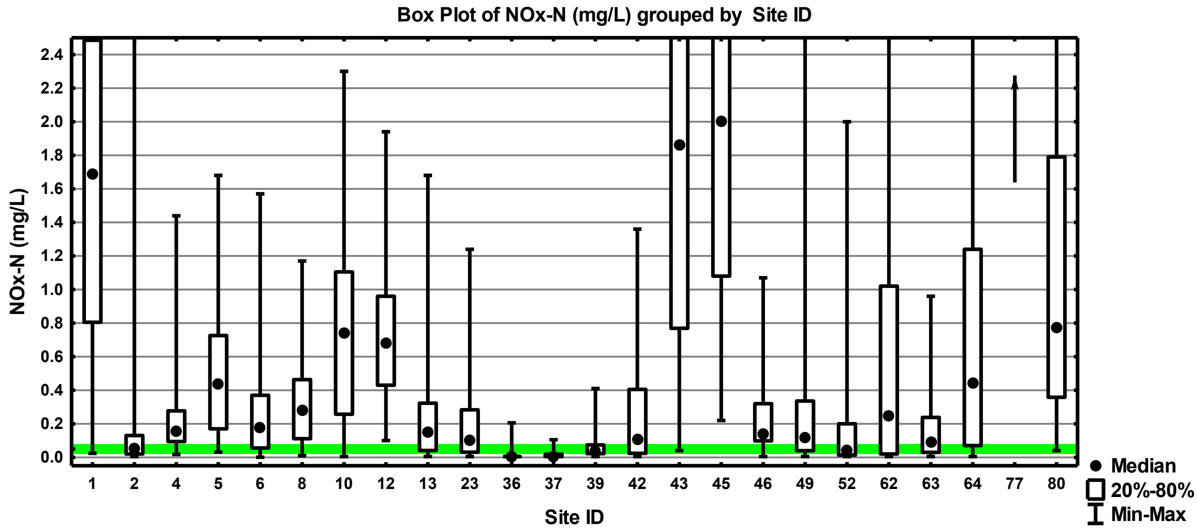
Box-plot graphs for all physical-chemical parameters for **freshwater sites**. Graphs show maximum, minimum, 20th percentile, 80th percentile and median for the 2005-2010 period. The overlayed dotted line is the REHV.

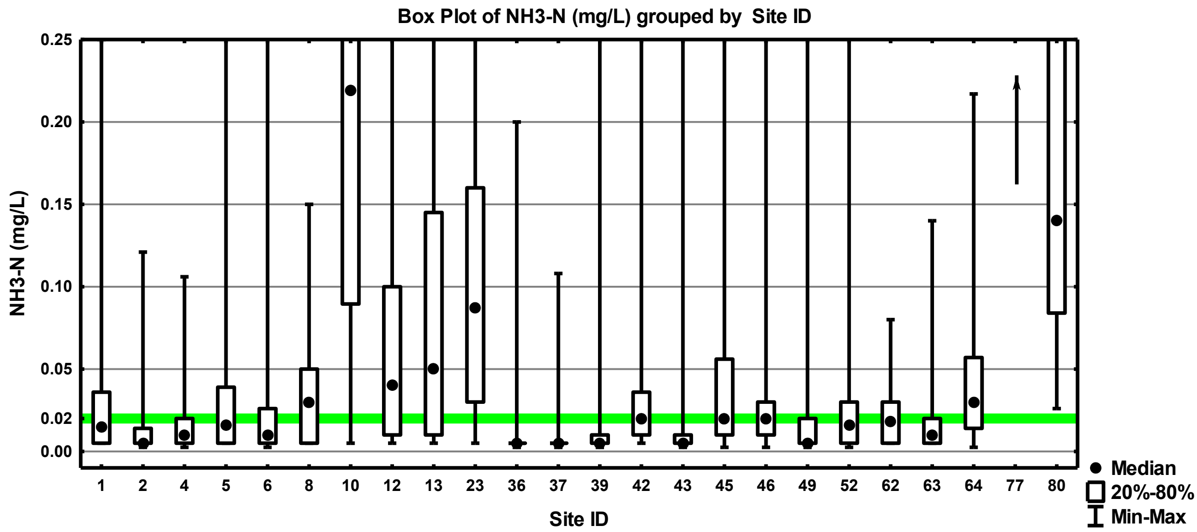




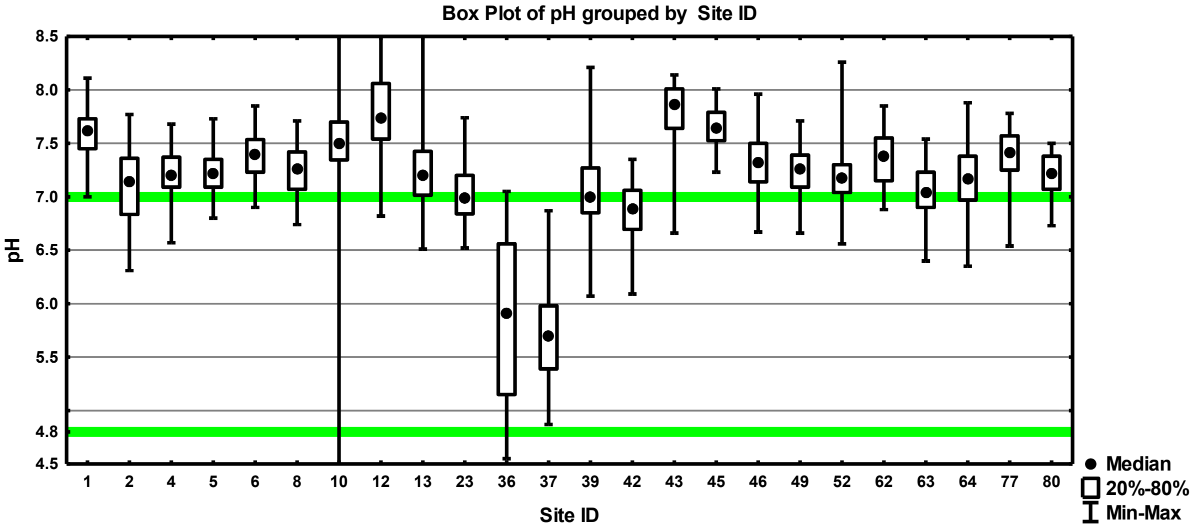


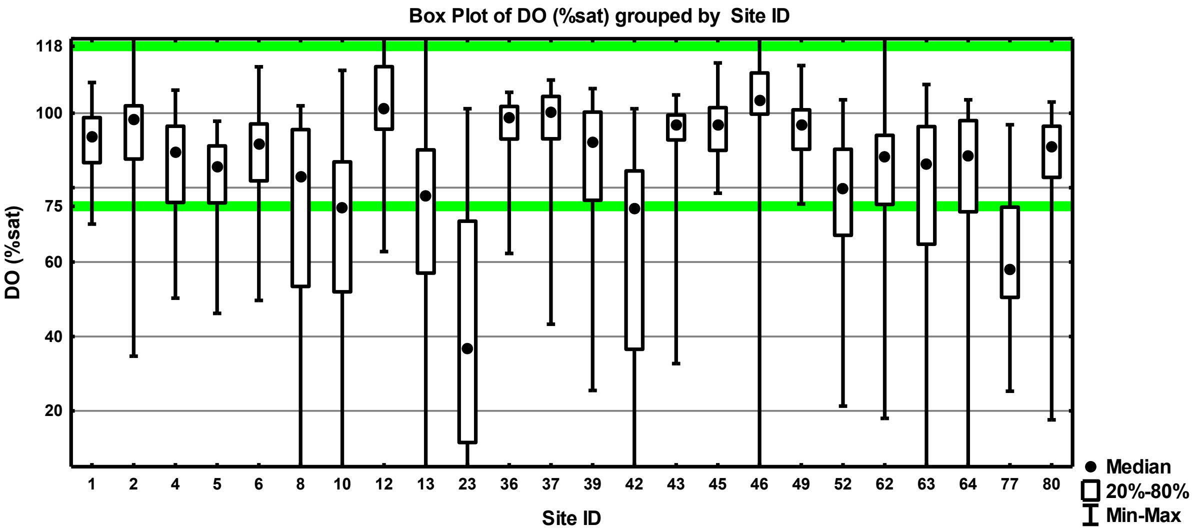

Box Plot of TOTAL N (mg/L) grouped by Site ID
TOTAL N (mg/L)
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1 2 4 5 6 8 10 12 13 23 36 37 39 42 43 45 46 49 52 62 63 64 77 80
Site ID
Median
20%-80%
Min-Max

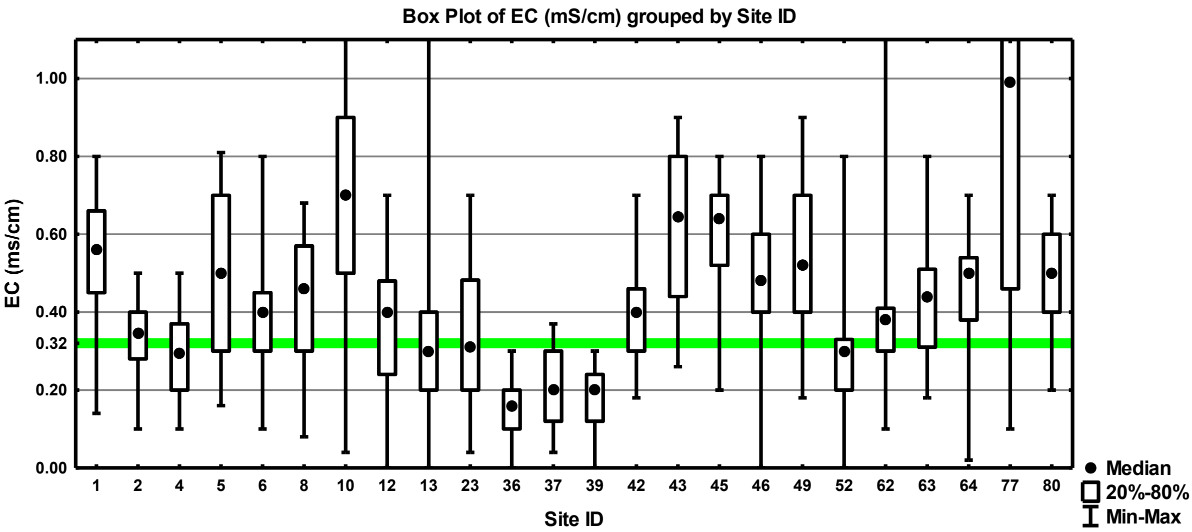

Box Plot of NOx-N (mg/L) grouped by Site ID
NOx-N (mg/L)
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1 2 4 5 6 8 10 12 13 23 36 37 39 42 43 45 46 49 52 62 63 64 77 80
Site ID
Median
20%-80%
Min-Max


Box Plot of NH3-N (mg/L) grouped by Site ID
NH3-N (mg/L)
0.25
0.20
0.15
0.10
0.05
0.02
0.00
1 2 4 5 6 8 10 12 13 23 36 37 39 42 43 45 46 49 52 62 63 64 77 80
Site ID
Median
20%-80%
Min-Max

14.0 Appendices continued

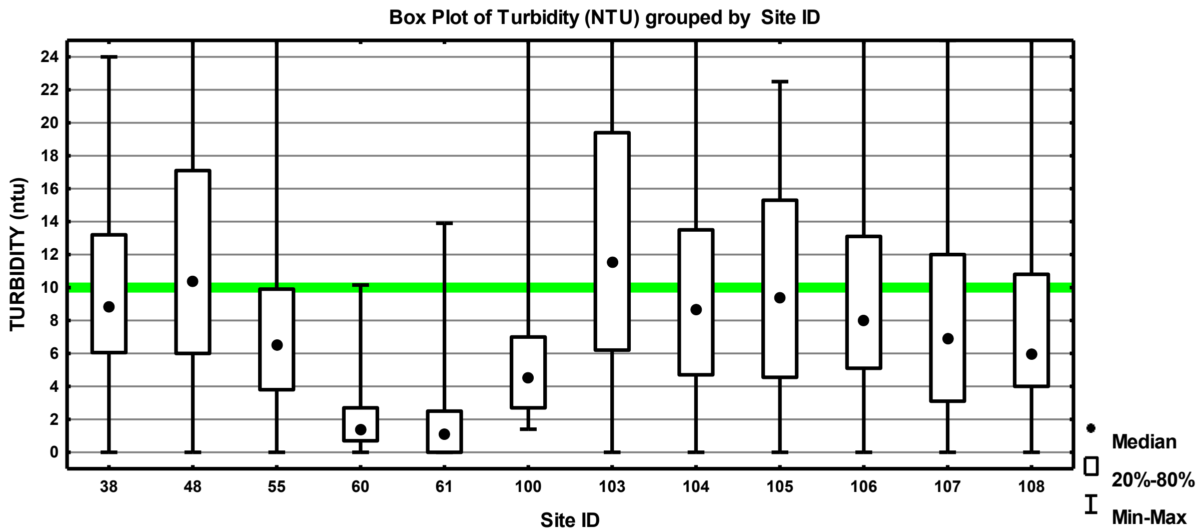


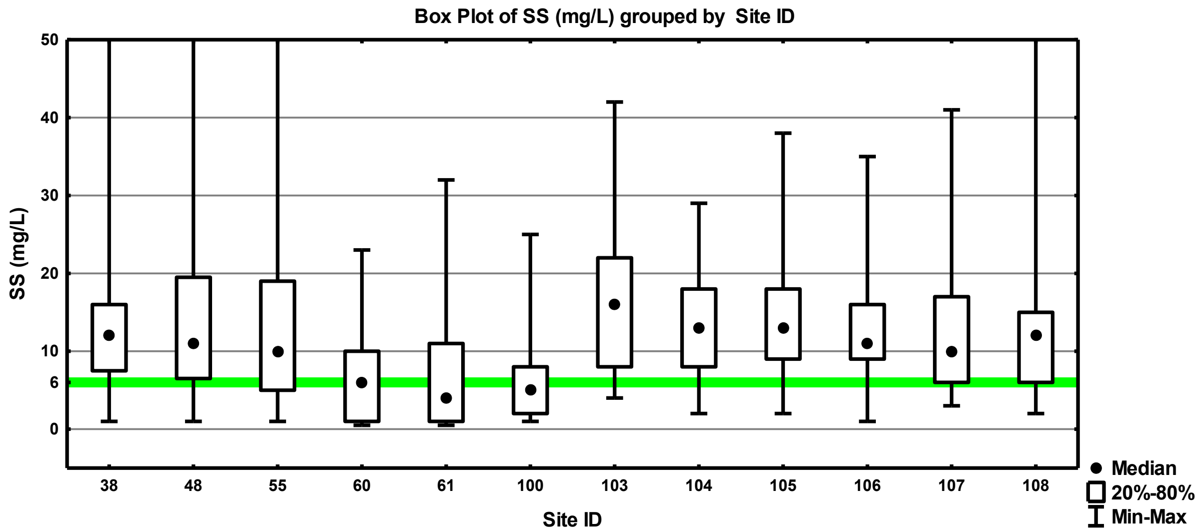


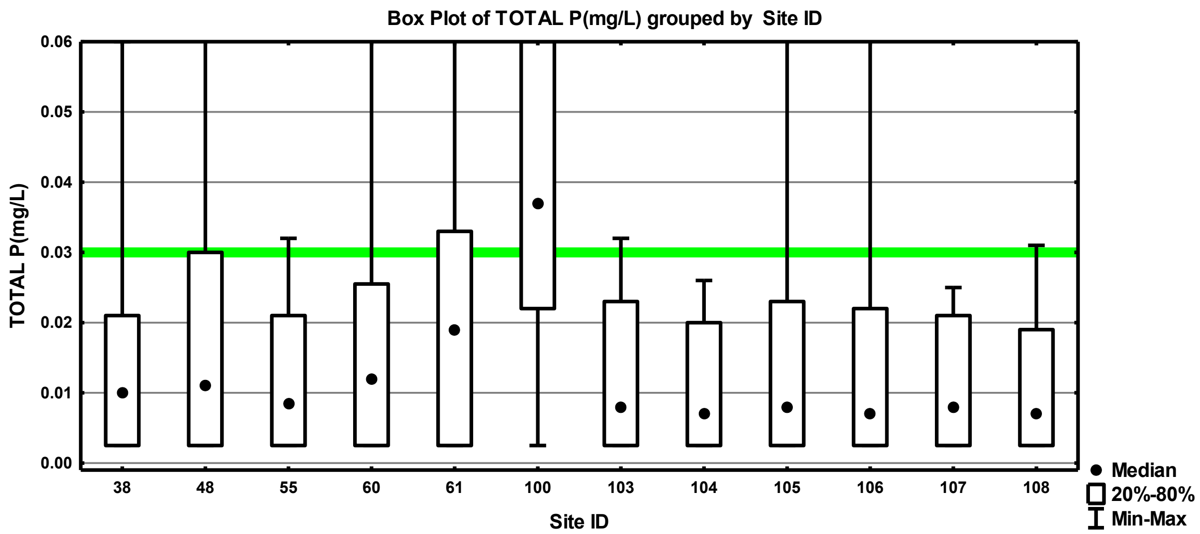


Appendix 6.2: Estuarine/tidal sites: physical-chemical stressors and aquatic biota

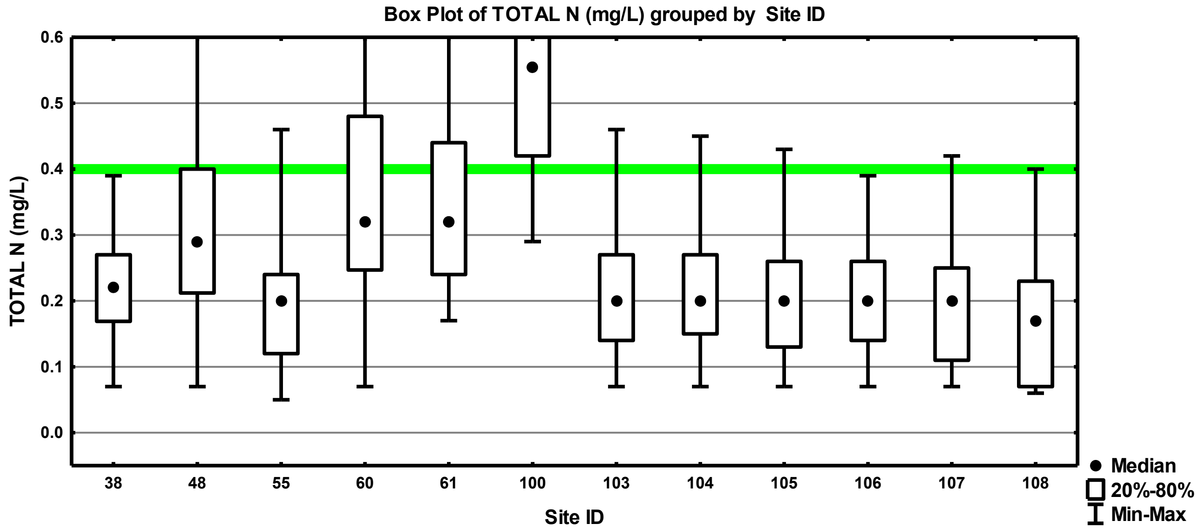
Box-plot graphs for all **physical-chemical and aquatic biota** (chlorophyll-a) parameters for **estuarine/tidal sites**. Graphs show maximum, minimum, 20th percentile, 80th percentile and median for the 2005-2010 period. The overlayed dotted line is the REHV.

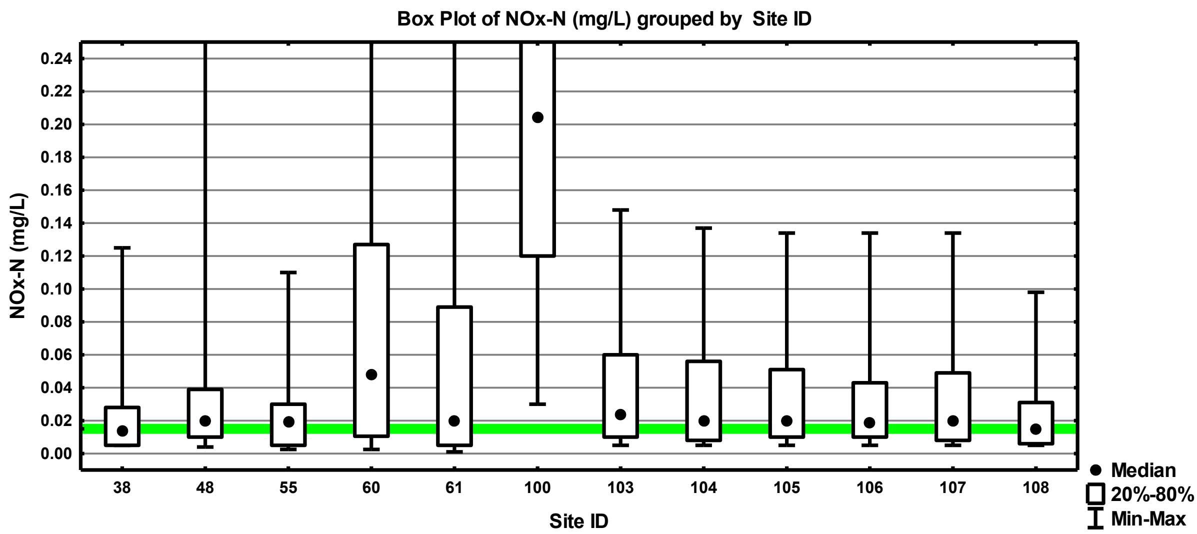


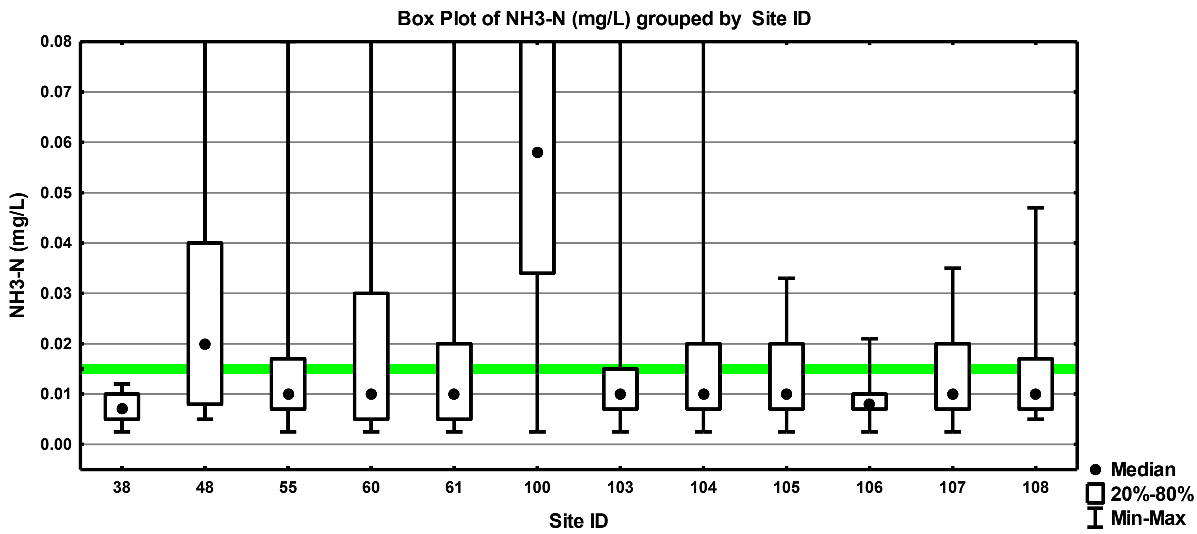


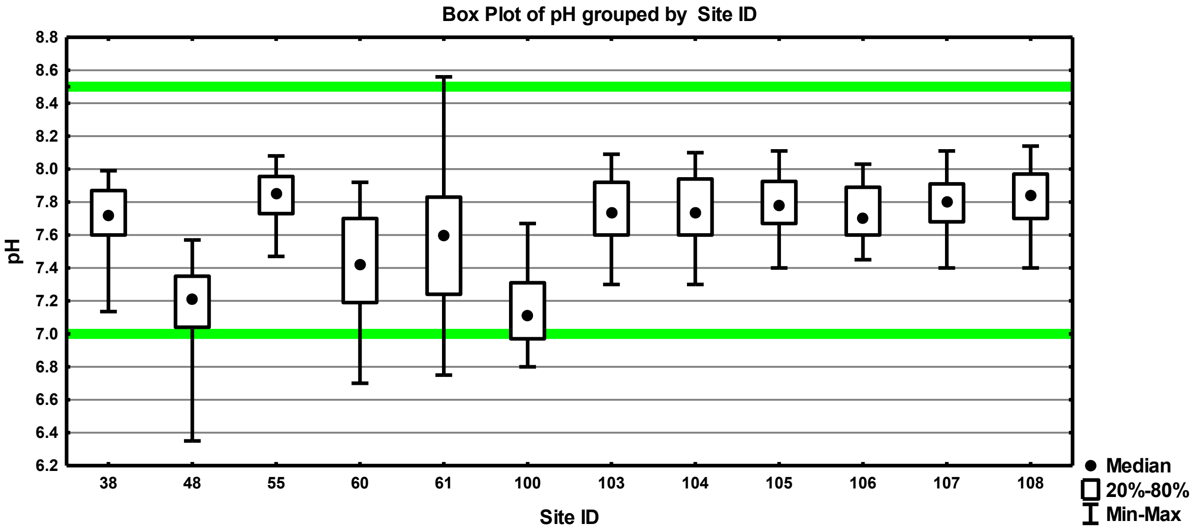


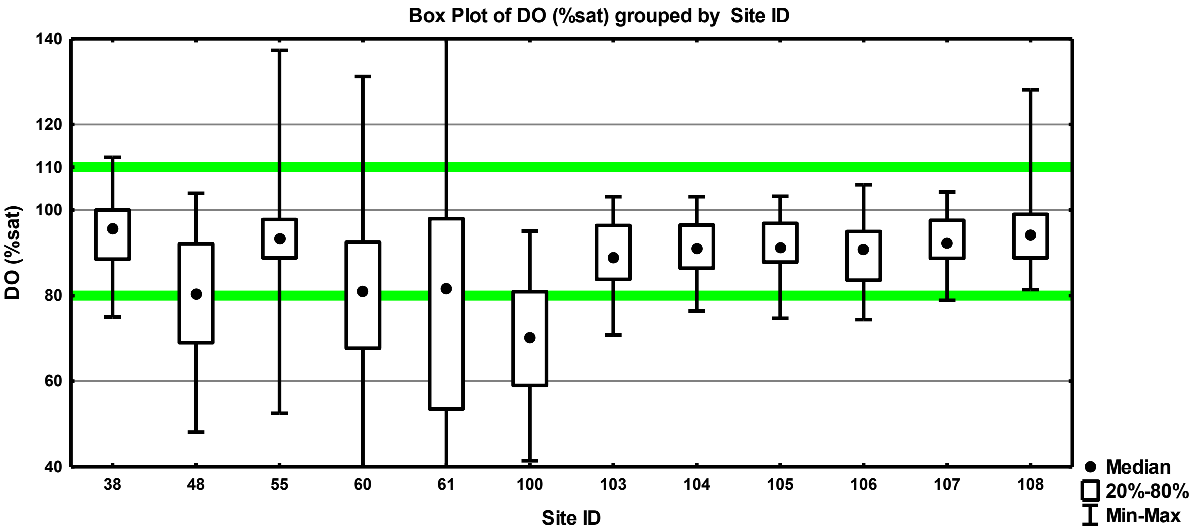
14.0 Appendices continued

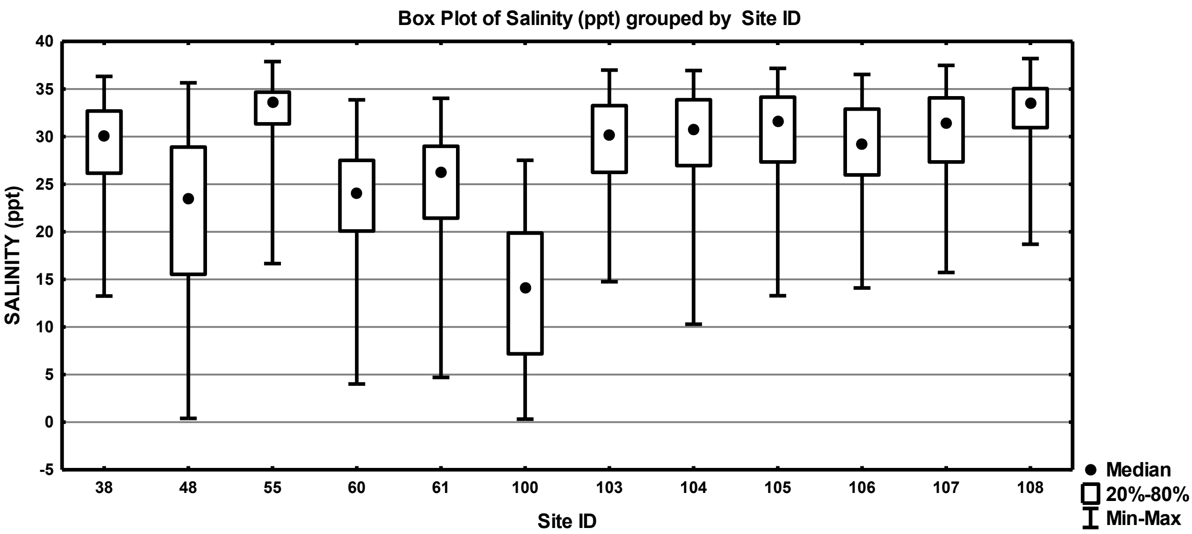




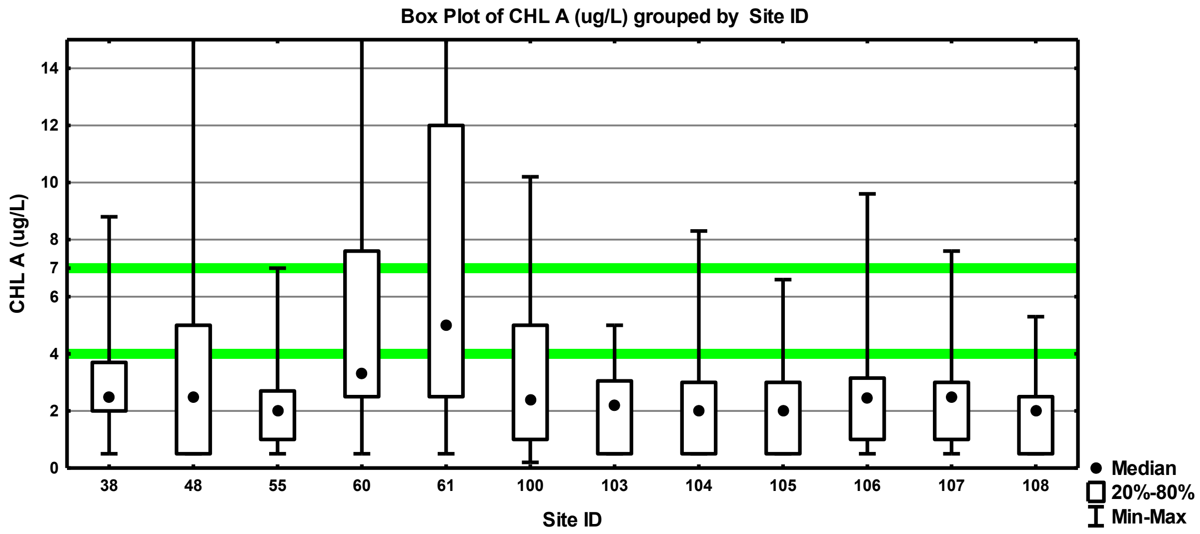



Box Plot of pH grouped by Site ID
pH
8.8
8.6
8.4
8.2
8.0
7.8
7.6
7.4
7.2
7.0
6.8
6.6
6.4
6.2
38
48
55
60
61
100
103
104
105
106
107
108
Site ID
Median
20%-80%
Min-Max


Box Plot of DO (%sat) grouped by Site ID
DO (%sat)
140
120
110
100
80
60
40
38
48
55
60
61
100
103
104
105
106
107
108
Site ID
Median
20%-80%
Min-Max


Box Plot of Salinity (ppt) grouped by Site ID
SALINITY (ppt)
40
35
30
25
20
15
10
5
0
-5
38
48
55
60
61
100
103
104
105
106
107
108
Site ID
Median
20%-80%
Min-Max

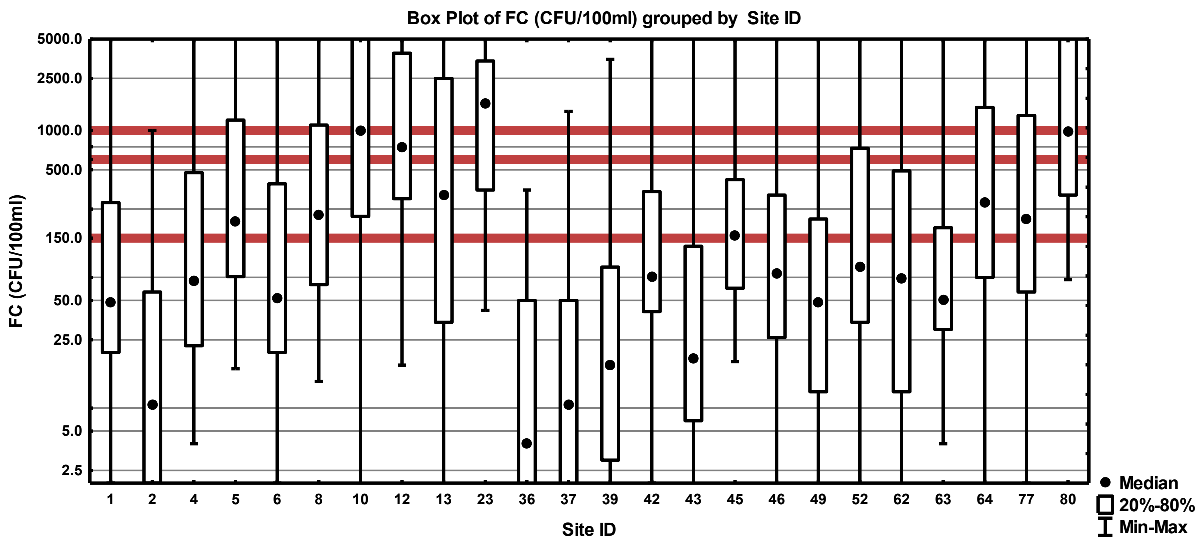
14.0 Appendices continued

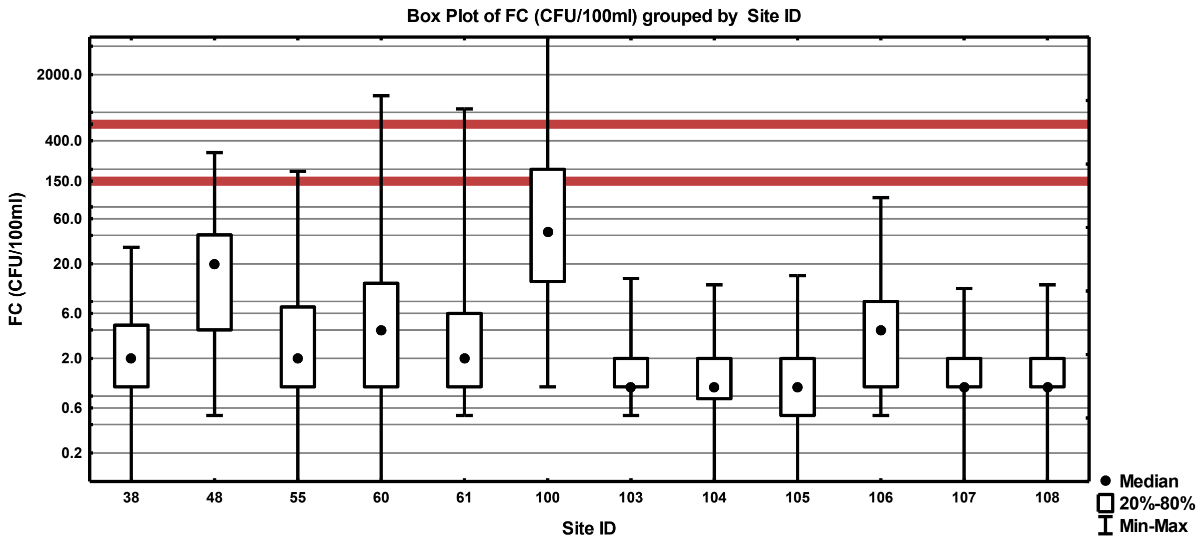


Appendix 6.3: Freshwater and estuarine/tidal sites: bacterial indicators

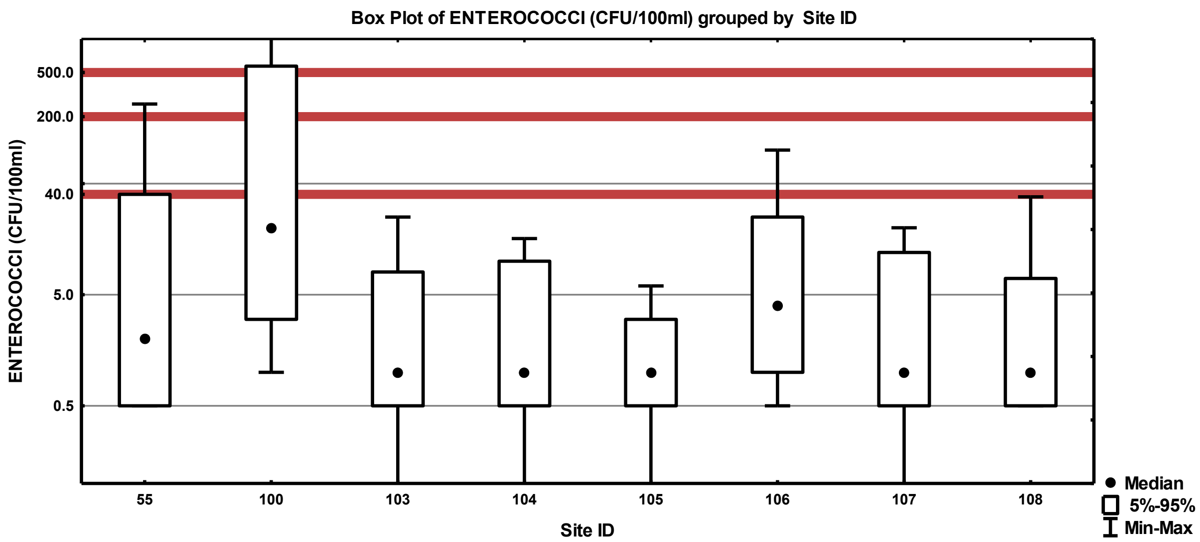
Box-plot graphs for microbial indicators for freshwater and estuarine sites.

Graphs of faecal coliform (FC) results show maximum, minimum, 20th percentile, 80th percentile and median for the 2005-2010 period. The overlayed lines are the REHVs.





Below are box-plots for enterococci at estuarine sites, showing maximum, minimum, 5th percentile, 95th percentile and medians for the 2005-2010 period. The dotted lines correspond to NHMRC classification.



14.0 Appendices continued

Appendix 6.4: Freshwater aquatic biota (includes tables of seasonal data) and calculation of grades

Appendix 6.4.1: SIGNAL2 score

SIGNAL 2 Score

Year ->	2002	2003	2003	2004	2004	2005	2005	2006	2006	2007	Years 2002 to 2007				
Season ->	S	A	S	A	S	A	S	A	S	A	mean	max	min	20th %	80th %
Site No.															
1	3.6	3.2	2.6	3.2	4	4	2.6	3.2	2.9	2.6	3.2	4.0	2.6	2.6	3.7
2	4	4	3.2	3.6	3.3	4.3	3.8	3.9	3.3	3.9	3.7	4.3	3.2	3.3	4.0
4	1.6	2.7	4	4	3	3.2	4	3.3	3.5	4	3.3	4.0	1.6	2.9	4.0
5	2.3	3.4	3.8	2.9	3.8	3.1	3.1	3.3	4.2	2.9	3.3	4.2	2.3	2.9	3.8
6	3.2	3.4	2.6	3.4	4.1	3.7	2.5	3.6	4.4	3.9	3.5	4.4	2.5	3.1	3.9
8						4		3	3.7	2.8	3.4	4.0	2.8	2.9	3.8
10	1.3	1.8	1.8	2.5	2.1	1.5	1.5	2	3.4	1.8	2.0	3.4	1.3	1.5	2.2
12	1.9	2.7	2	2.2	2.5	2.8	3.3	2.6	2.3	3.2	2.6	3.3	1.9	2.2	2.9
13	1.5	2.2	2.3	1.8	1.8	2.4	1.9	1.8	1.5	2.1	1.9	2.4	1.5	1.7	2.2
37	4.6	4.6	4.1	6	4.1	3.3		4.3	3.3	4.3	4.3	6.0	3.3	3.8	4.6
39	3.5	4.2	3.4		3.7	3.7	3.6	3.9	3.3	3.7	3.7	4.2	3.3	3.5	3.8
42	2.9	2.7	3.7	3	2.6	3.2	2.7	2.8	3.1	2.6	2.9	3.7	2.6	2.7	3.1
45	2.5	2.9	3.2	3.5	4.6	3.7	3	4.1	3	3.7	3.4	4.6	2.5	3.0	3.8
46						3.6		2.9	2	3.1	2.9	3.6	2.0	2.5	3.3
49	3	3.8	3.2	3.9	2.3	3	3	2.9	3.1	3.7	3.2	3.9	2.3	3.0	3.7
62		3.1	3.6	3.4	2.3	3	2.5	2.7		2.9	2.9	3.6	2.3	2.6	3.3
63	2.1	5.2	4.4	6.8	4.5	5.6	4.7	5.2	4.6	4.9	4.8	6.8	2.1	4.5	5.3
64	4.4	2.7	3.6	2.8	2.3	2.6	4.3	2.7	2.7	3.5	3.2	4.4	2.3	2.7	3.7
77	2.7	3.4	2.8	3	2.8	3.1	2.9	3.3	2.7	3.4	3.0	3.4	2.7	2.8	3.3
80	2.4	2.5		2.9	2.5	3.6	4	3.4	2.4	2.8	2.9	4.0	2.4	2.5	3.5

Standard Scores for SIGNAL 2 values for samples collected from edge habitats from Hornsby Shire Council waterways 2002-2007											
	2002	2003	2003	2004	2004	2005	2005	2006	2006	2007	SIGNAL
Site no.	S	A	S	A	S	A	S	A	S	A	AVERAGE StSc
1	0.60	0.44	0.20	0.44	0.76	0.76	0.20	0.44	0.32	0.20	**0.44**
2	0.76	0.76	0.44	0.60	0.48	0.88	0.68	0.72	0.48	0.72	**0.65**
4	0.00	0.24	0.76	0.76	0.36	0.44	0.76	0.48	0.56	0.76	**0.51**
5	0.08	0.52	0.68	0.32	0.68	0.40	0.40	0.48	0.84	0.32	**0.47**
6	0.44	0.52	0.20	0.52	0.80	0.64	0.16	0.60	0.92	0.72	**0.55**
8						0.76		0.36	0.64	0.28	**0.51**
10	0.00	0.00	0.00	0.16	0.00	0.00	0.00	0.00	0.52	0.00	**0.07**
12	0.00	0.24	0.00	0.04	0.16	0.28	0.48	0.20	0.08	0.44	**0.19**
13	0.00	0.04	0.08	0.00	0.00	0.12	0.00	0.00	0.00	0.00	**0.02**
37	1.00	1.00	0.80	1.00	0.80	0.48		0.88	0.48	0.88	**0.81**
39	0.56	0.84	0.52		0.64	0.64	0.60	0.72	0.48	0.64	**0.63**
42	0.32	0.24	0.64	0.36	0.20	0.44	0.24	0.28	0.40	0.20	**0.33**
45	0.16	0.32	0.44	0.56	1.00	0.64	0.36	0.80	0.36	0.64	**0.53**
46						0.60		0.32	0.00	0.40	**0.33**
49	0.36	0.68	0.44	0.72	0.08	0.36	0.36	0.32	0.40	0.64	**0.44**
62		0.40	0.60	0.52	0.08	0.36	0.16	0.24		0.32	**0.34**
63	0.00	1.00	0.92	1.00	0.96	1.00	1.00	1.00	1.00	1.00	**0.89**
64	0.92	0.24	0.60	0.28	0.08	0.20	0.88	0.24	0.24	0.56	**0.42**
77	0.24	0.52	0.28	0.36	0.28	0.40	0.32	0.48	0.24	0.52	**0.36**
80	0.12	0.16		0.32	0.16	0.60	0.76	0.52	0.12	0.28	**0.34**

Appendix 6.4.2: EPT% abundance

SIGNAL 2 Score

Year ->	2002	2003	2003	2004	2004	2005	2005	2006	2006	2007	Years 2002 to 2007				
Season ->	S	A	S	A	S	A	S	A	S	A	mean	max	min	20th %	80th %
Site No.															
1	3.6	3.2	2.6	3.2	4	4	2.6	3.2	2.9	2.6	3.2	4.0	2.6	2.6	3.7
2	4	4	3.2	3.6	3.3	4.3	3.8	3.9	3.3	3.9	3.7	4.3	3.2	3.3	4.0
4	1.6	2.7	4	4	3	3.2	4	3.3	3.5	4	3.3	4.0	1.6	2.9	4.0
5	2.3	3.4	3.8	2.9	3.8	3.1	3.1	3.3	4.2	2.9	3.3	4.2	2.3	2.9	3.8
6	3.2	3.4	2.6	3.4	4.1	3.7	2.5	3.6	4.4	3.9	3.5	4.4	2.5	3.1	3.9
8						4		3	3.7	2.8	3.4	4.0	2.8	2.9	3.8
10	1.3	1.8	1.8	2.5	2.1	1.5	1.5	2	3.4	1.8	2.0	3.4	1.3	1.5	2.2
12	1.9	2.7	2	2.2	2.5	2.8	3.3	2.6	2.3	3.2	2.6	3.3	1.9	2.2	2.9
13	1.5	2.2	2.3	1.8	1.8	2.4	1.9	1.8	1.5	2.1	1.9	2.4	1.5	1.7	2.2
37	4.6	4.6	4.1	6	4.1	3.3		4.3	3.3	4.3	4.3	6.0	3.3	3.8	4.6
39	3.5	4.2	3.4		3.7	3.7	3.6	3.9	3.3	3.7	3.7	4.2	3.3	3.5	3.8
42	2.9	2.7	3.7	3	2.6	3.2	2.7	2.8	3.1	2.6	2.9	3.7	2.6	2.7	3.1
45	2.5	2.9	3.2	3.5	4.6	3.7	3	4.1	3	3.7	3.4	4.6	2.5	3.0	3.8
46						3.6		2.9	2	3.1	2.9	3.6	2.0	2.5	3.3
49	3	3.8	3.2	3.9	2.3	3	3	2.9	3.1	3.7	3.2	3.9	2.3	3.0	3.7
62		3.1	3.6	3.4	2.3	3	2.5	2.7		2.9	2.9	3.6	2.3	2.6	3.3
63	2.1	5.2	4.4	6.8	4.5	5.6	4.7	5.2	4.6	4.9	4.8	6.8	2.1	4.5	5.3
64	4.4	2.7	3.6	2.8	2.3	2.6	4.3	2.7	2.7	3.5	3.2	4.4	2.3	2.7	3.7
77	2.7	3.4	2.8	3	2.8	3.1	2.9	3.3	2.7	3.4	3.0	3.4	2.7	2.8	3.3
80	2.4	2.5		2.9	2.5	3.6	4	3.4	2.4	2.8	2.9	4.0	2.4	2.5	3.5

Standard Scores for SIGNAL 2 values for samples collected from edge habitats from Hornsby Shire Council waterways 2002-2007

	2002	2003	2003	2004	2004	2005	2005	2006	2006	2007	SIGNAL
Site no.	S	A	S	A	S	A	S	A	S	A	AVERAGE StSc
1	0.60	0.44	0.20	0.44	0.76	0.76	0.20	0.44	0.32	0.20	**0.44**
2	0.76	0.76	0.44	0.60	0.48	0.88	0.68	0.72	0.48	0.72	**0.65**
4	0.00	0.24	0.76	0.76	0.36	0.44	0.76	0.48	0.56	0.76	**0.51**
5	0.08	0.52	0.68	0.32	0.68	0.40	0.40	0.48	0.84	0.32	**0.47**
6	0.44	0.52	0.20	0.52	0.80	0.64	0.16	0.60	0.92	0.72	**0.55**
8						0.76		0.36	0.64	0.28	**0.51**
10	0.00	0.00	0.00	0.16	0.00	0.00	0.00	0.00	0.52	0.00	**0.07**
12	0.00	0.24	0.00	0.04	0.16	0.28	0.48	0.20	0.08	0.44	**0.19**
13	0.00	0.04	0.08	0.00	0.00	0.12	0.00	0.00	0.00	0.00	**0.02**
37	1.00	1.00	0.80	1.00	0.80	0.48		0.88	0.48	0.88	**0.81**
39	0.56	0.84	0.52		0.64	0.64	0.60	0.72	0.48	0.64	**0.63**
42	0.32	0.24	0.64	0.36	0.20	0.44	0.24	0.28	0.40	0.20	**0.33**
45	0.16	0.32	0.44	0.56	1.00	0.64	0.36	0.80	0.36	0.64	**0.53**
46						0.60		0.32	0.00	0.40	**0.33**
49	0.36	0.68	0.44	0.72	0.08	0.36	0.36	0.32	0.40	0.64	**0.44**
62		0.40	0.60	0.52	0.08	0.36	0.16	0.24		0.32	**0.34**
63	0.00	1.00	0.92	1.00	0.96	1.00	1.00	1.00	1.00	1.00	**0.89**
64	0.92	0.24	0.60	0.28	0.08	0.20	0.88	0.24	0.24	0.56	**0.42**
77	0.24	0.52	0.28	0.36	0.28	0.40	0.32	0.48	0.24	0.52	**0.36**
80	0.12	0.16		0.32	0.16	0.60	0.76	0.52	0.12	0.28	**0.34**

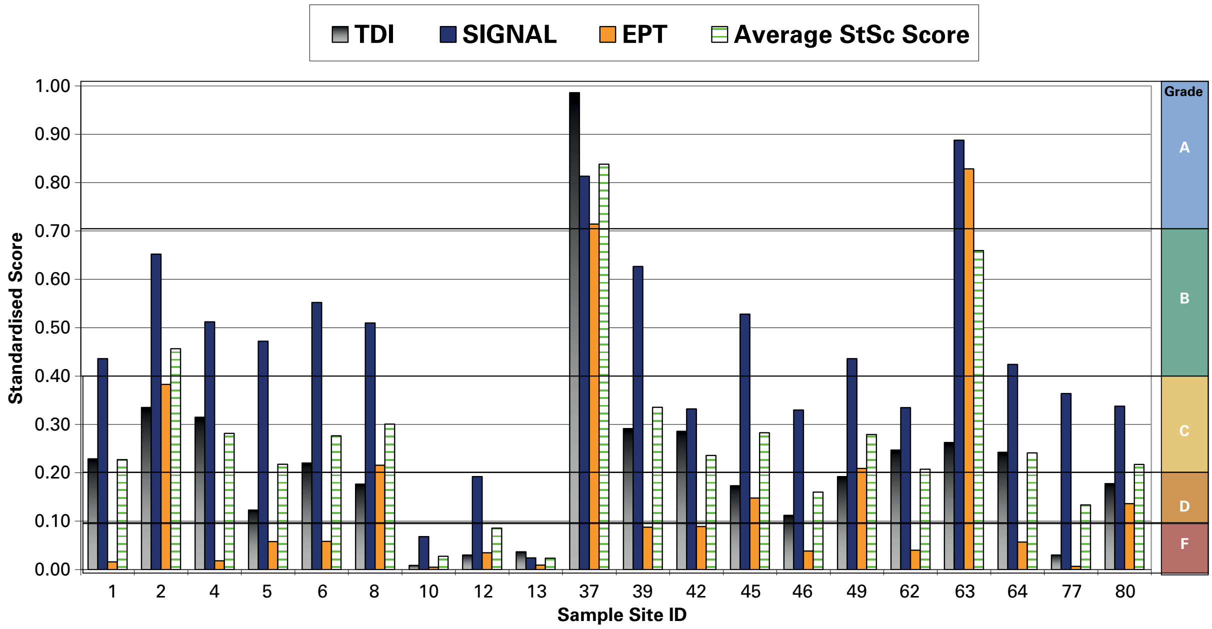
14.0 Appendices continued

Appendix 6.4.3: TDI biotic index

TDI Biotic index															
Year ->	2002	2003	2003	2004	2004	2005	2005	2006	2006	2007	Years 2002 to 2007				
Season ->	S	A	S	A	S	A	S	A	S	A	mean	max	min	20th %	80th %
Site No.											Mean				
1	65	67	75	69	59	75	73	74	78	73	70.8	78.0	59.0	66.6	75.0
2	68	76	73	56	54	50	73	51	56	56	61.3	76.0	50.0	53.4	73.0
4	69	68	78	62	57	60	72	60	53	52	63.1	78.0	52.0	56.2	69.6
5	80	81	80	81	81	77	82	79	83	79	80.3	83.0	77.0	79.0	81.2
6	70	72	69	61	82	78	62	65	87	70	71.6	87.0	61.0	64.4	78.8
8					81	64			78	79	75.5	81.0	64.0	72.4	79.8
10	100	96	96	99	96	97	96	92	90	85	94.7	100.0	85.0	91.6	97.4
12	96	97	98	95	92	77	93	92	91	79	91.0	98.0	77.0	88.6	96.2
13	90	89	95	96	90	97	91	98	67	88	90.1	98.0	67.0	88.8	96.2
37	3	2	3	3	0	4	1	4	4	4	2.8	4.0	0.0	1.8	4.0
39	71	72	71	77	60	50	65	61	64	61	65.2	77.0	50.0	60.8	71.2
42	57	68	70	70	65	59	75	58	63	72	65.7	75.0	57.0	58.8	70.4
45	80	75	79	78	70	78	71	78	76	73	75.8	80.0	70.0	72.6	78.2
46					82	81			73	89	81.3	89.0	73.0	77.8	84.8
49	64	75	76	76	73	74	82	74	74	73	74.1	82.0	64.0	73.0	76.0
62	70	70	79	80	66	66	65	66	66	64	69.2	80.0	64.0	65.8	71.8
63	58	60	69	68	77	67	77	66	65	71	67.8	77.0	58.0	64.0	72.2
64	41	85	73	74	73	67	73	69	72	69	69.6	85.0	41.0	68.6	73.2
77	91	91	88	91	88	86	90	86	88	87	88.6	91.0	86.0	86.8	91.0
80	80	77	78	78	79	56	77	82	67	80	75.4	82.0	56.0	75.0	80.0

Standardised Scores for TDI for samples collected from Hornsby Shire Council waterways for 2002-2007											
	2002	2003	2003	2004	2004	2005	2005	2006	2006	2007	TDI
Site no.	S	A	S	A	S	A	S	A	S	A	Average StSc
1	0.29	0.27	0.18	0.25	0.36	0.18	0.20	0.19	0.15	0.20	**0.23**
2	0.26	0.17	0.20	0.39	0.42	0.46	0.20	0.45	0.39	0.39	**0.34**
4	0.25	0.26	0.15	0.33	0.38	0.35	0.22	0.35	0.43	0.44	**0.32**
5	0.13	0.12	0.13	0.12	0.12	0.16	0.10	0.14	0.09	0.14	**0.12**
6	0.24	0.22	0.25	0.34	0.10	0.15	0.33	0.29	0.05	0.24	**0.22**
8					0.12	0.31			0.15	0.14	**0.18**
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.07	**0.01**
12	0.00	0.00	0.00	0.00	0.00	0.16	0.00	0.00	0.00	0.14	**0.03**
13	0.01	0.03	0.00	0.00	0.01	0.00	0.00	0.00	0.27	0.04	**0.04**
37	0.99	1.00	0.99	0.99	1.00	0.98	1.00	0.98	0.98	0.98	**0.99**
39	0.23	0.22	0.23	0.16	0.35	0.46	0.29	0.34	0.31	0.34	**0.29**
42	0.38	0.26	0.24	0.24	0.29	0.36	0.18	0.37	0.32	0.22	**0.29**
45	0.13	0.18	0.14	0.15	0.24	0.15	0.23	0.15	0.17	0.20	**0.17**
46					0.10	0.12			0.20	0.03	**0.11**
49	0.31	0.18	0.17	0.17	0.20	0.19	0.10	0.19	0.19	0.20	**0.19**
62	0.24	0.24	0.14	0.13	0.28	0.28	0.29	0.28	0.28	0.31	**0.25**
63	0.37	0.35	0.25	0.26	0.16	0.27	0.16	0.28	0.29	0.23	**0.26**
64	0.56	0.07	0.20	0.19	0.20	0.27	0.20	0.25	0.22	0.25	**0.24**
77	0.00	0.00	0.04	0.00	0.04	0.06	0.01	0.06	0.04	0.05	**0.03**
80	0.13	0.16	0.15	0.15	0.14	0.39	0.16	0.10	0.27	0.13	**0.18**

Appendix 6.4.4: Summary and gradings for freshwater aquatic biota



Grading results

Site	Average Standardised Scores			Site Grade
	TDI	SIGNAL	EPT	Av StSc Scores
1	0.23	0.44	0.02	0.23
2	0.34	0.65	0.38	0.46
4	0.32	0.51	0.02	0.28
5	0.12	0.47	0.06	0.22
6	0.22	0.55	0.06	0.28
8	0.18	0.51	0.22	0.30
10	0.01	0.07	0.00	0.03
12	0.03	0.19	0.03	0.09
13	0.04	0.02	0.01	0.02
37	0.99	0.81	0.71	0.84
39	0.29	0.63	0.09	0.34
42	0.29	0.33	0.09	0.24
45	0.17	0.53	0.15	0.28
46	0.11	0.33	0.04	0.16
49	0.19	0.44	0.21	0.28
62	0.25	0.34	0.04	0.21
63	0.26	0.89	0.83	0.66
64	0.24	0.42	0.06	0.24
77	0.03	0.36	0.01	0.13
80	0.18	0.34	0.14	0.22

Biota indicator	REHV	WCS
TDI	1.8	91
SIGNAL2	4.65	2.1
EPT	55.8	0

Site Grade	Average StSc
A	<0.7
B	<0.4 - 0.7
C	<0.2 - 0.4
D	<0.1 - 0.2
F	<0.1