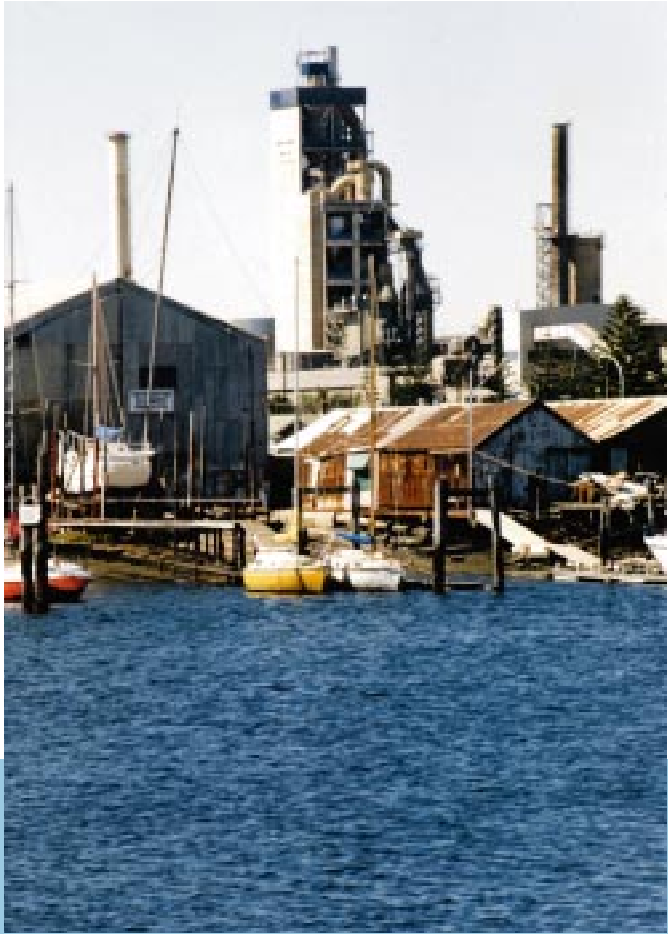
Water Monitoring Report

September 1995 - December 1996



Ambient Water Quality Monitoring of the Port River Estuary

Report No 1

Environment Protection Authority

Department for Environment, Heritage and Aboriginal Affairs

Cover Photograph: The Port River and local land uses at Port Adelaide

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SUMMARY

This report summarises the water quality of the Port Adelaide (Port) River estuary between September 1995 and December 1996.

Monthly samples are collected in the Port River, Barker Inlet, Inner Harbour and Outer Harbour and analysed for nutrients (total Kjeldahl nitrogen (TKN), total phosphorus, ammonia, and nitrate), chlorophyll (indicative of algae), heavy metals (lead, zinc, copper, mercury, cadmium, iron and aluminium), microbiological indicators of faecal contamination (faecal coliforms, faecal streptococci and Enterococci), water clarity or turbidity and salinity (total dissolved solids).

The report sets criteria for each characteristic such that water quality can be described broadly as good, moderate or poor.

Based on the preliminary findings of the ambient water quality monitoring programme the water quality of the Port River estuary would be described as poor for the following reasons:

1. Concentrations of nutrients (ammonia) are high at most sites. Moderate concentrations of total phosphorus and nitrogen occur at many of the sites.

2. Water clarity as determined by turbidity measurements is of moderate quality at most sites.

3. Chlorophyll concentrations are high or moderate at all sites.

4. Heavy metal (particularly copper and lead) concentrations often exceed guideline concentrations at all sites.

5. Microbiological quality is classified as good at all sites. However, some samples from some sites occassionally exceed the maximum number of indicator microorganisms in a sample (*ANZECC Australian Water Quality Guidelines for Fresh and Marine Waters*) for primary contact and have been classified as poor at times. Nevertheless, taken over the whole period, all sites meet the NHMRC Australian Guidelines for Recreational Use of Water.

A number of initiatives in the Port River estuary area should improve water quality over time. These include nutrient reduction and effluent reuse programmes for the sewage treatment works, environmental improvement programmes being established by industry in the area, and the development of extensive wetlands to treat stormwater. These initiatives should reduce nutrient concentrations over time and, as a result, also improve water clarity and chlorophyll levels. They should also help to reduce heavy metal concentrations by removing particulate matter which can adsorb some metals.

Updates of these results will be published annually.

CONTENTS

1 INTRODUCTION

The Environment Protection Authority is undertaking an ambient water quality monitoring programme designed to provide a long term assessment of water quality in the Port Adelaide (Port) River estuary. The programme began in September 1995 and each month samples are taken from nine key sites (figure 1) and analysed. The sites and characteristics chosen are based on environmental issues for the estuary, while sampling frequency is determined by system variability. This report summarises the preliminary results of the programme.

The objectives of the ambient monitoring programme are to:

- provide a qualitative and quantitative assessment of water quality in the Port River estuary
- determine statistically significant changes or trends in the key characteristics of water quality
- provide data to assess the long term ecologically sustainable development of the Port River estuary.

1.1 AMBIENT WATER QUALITY

Ambient water quality refers to the overall quality of waterbodies and indicates the quality of water when all the effects that may impact upon quality are considered as a whole rather than focussing on the effects of particular discharges. The results in this report are indicative of water quality from September 1995 to December 1996.

1.2 THE PORT RIVER ESTUARY

The area of the Port River estuary consists of West Lakes, the Port River, North Arm and the Angas and Barker inlets. All these areas are subject to a number of uses and environmental impacts. Recreational activities include boating, fishing and swimming. Industrial uses include loading and unloading ships and the use of the estuary water for cooling purposes by the power station on Torrens Island. The estuary contains extensive mangrove and seagrass beds and is an important feeding and nursery ground for fish, crustaceans, molluscs and migratory birds. The area also contains two aquatic reserves.

The environmental values for the estuary are therefore protection of water quality:

- to support the aquatic ecosystem
- for recreation and aesthetic uses
- for industrial uses of the water.

1.3 WHAT IS MONITORED

Characteristics monitored in the programme are:

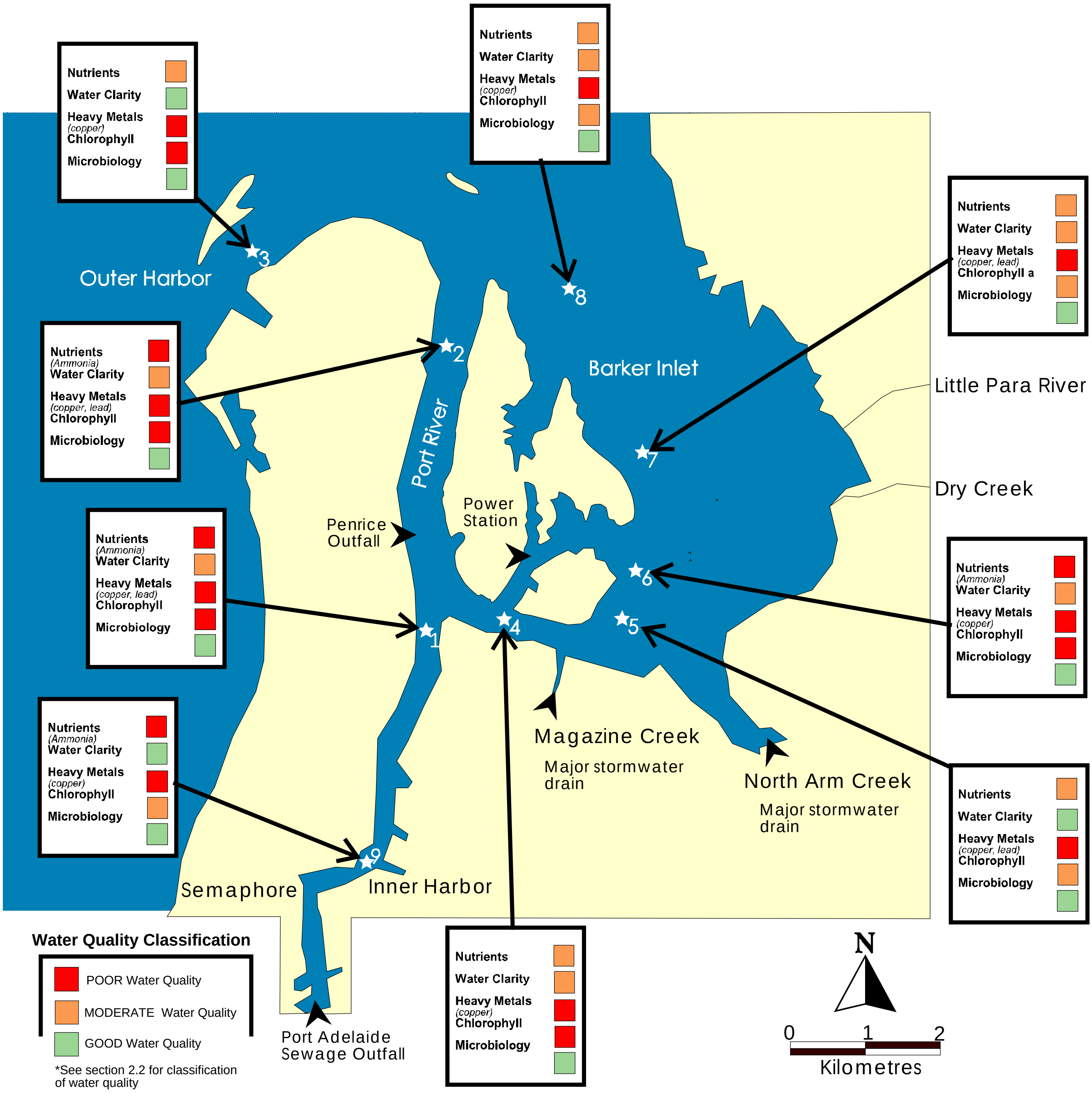
- nutrients (total Kjeldahl nitrogen (TKN), total phosphorus, ammonia, and nitrate)
- chlorophyll *a* which indicate the presence of algae
- metals (lead, zinc, copper, mercury, cadmium, iron and aluminium)

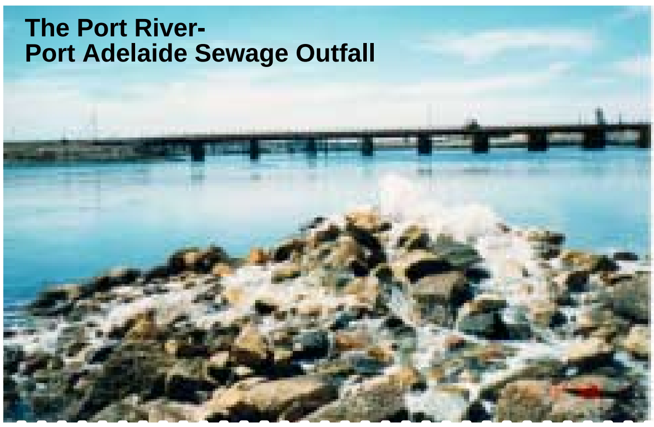
- indicators of faecal contamination (faecal coliforms, faecal streptococci and Enterococci)
- water clarity (turbidity) and salinity (total dissolved solids).

The characteristics measured are based on the water quality requirements to support the designated environmental values contained in the *Australian Guidelines for Fresh and Marine Waters* (ANZECC 1992).

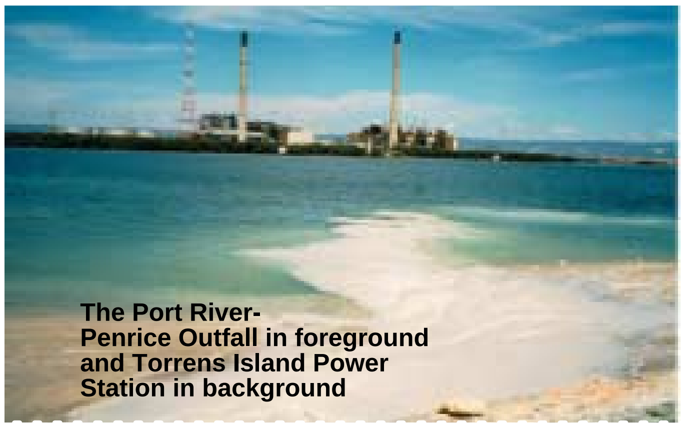
Figure 1

Ambient Water Quality Monitoring Sites - Port River





The Port River- Port Adelaide Sewage Outfall



The Port River- Penrice Outfall in foreground and Torrens Island Power Station in background

2 ASSESSMENT METHODS

2.1 STATISTICAL METHODS

The purpose of a monitoring programme is to assess the continuing water quality of the whole system by taking occasional, small and representative samples. It is clearly an uncertain process and if the data are to represent the true situation, the degree of uncertainty must be quantified. Some relatively simple statistical procedures can be used to assist in this understanding, including the use of confidence intervals (a known degree of confidence that the interval covers the true value) and control charts.

Tables of values listed in this report quote the mean, the 95% confidence intervals for the mean and the standard deviation. Other statistical parameters used are the median and the 90th and 10th percentiles. The percentiles are used in lieu of a maximum and minimum to indicate the range, whereas the standard deviation indicates the spread of the data from the mean. The 90^{th} percentile and the median (the 50^{th} percentile) are used to determine broad water quality classifications.

For microbiological data with pronounced skewed data sets (the mean and the median are substantially different) logarithmic transformations were used to derive the geometric mean. The 95% upper and lower confidence limits for the geometric mean is given in ranges $GM_L – GM_U$.

2.2 WATER QUALITY CLASSIFICATION

It is useful to broadly classify the water quality at each site as good, moderate or poor. As there are no accepted national criteria that can be used for such classifications the following criteria have been developed based on the percentage of time that the water quality conditions exceed the ANZECC Australian Water Quality Guidelines for Fresh and Marine Waters and other criteria. It is recognised that the classifications used are somewhat arbitrary but they do provide a useful and relatively simple means of broadly classifying the water quality.

A. Heavy metals

- GOOD: 90th percentile is less than or equal to the ANZECC guideline. (The water quality is less than the ANZECC guideline most of the time. This means that, for samples taken monthly, if more than one measurement in a year exceeds the guideline then the water quality would not be classified as good.)

- MODERATE: 90th percentile above the ANZECC guideline but median below the ANZECC guideline.

- POOR: Median is greater than or equal to the ANZECC guideline **OR** any single measurement is more than 10 times the ANZECC guideline. (The water quality exceeds the ANZECC guideline more than 50% of the time or a single measurement is at the concentration where acute toxic effects may be observed in some organisms).

B. Microbiology - Faecal coliforms, Faecal streptococci and Enterococci

- GOOD: 90th percentile is less than or equal to the *NHMRC Guidelines for Recreational Use of Water (*primary contact). Water quality is good provided the NHMRC guidelines are not exceeded, or are only exceeded on the odd occasion.

- MODERATE: 90th percentile is greater than the NHMRC guideline but the median is less than the guideline.

- POOR: Median is greater than the *NHMRC Australian Guidelines for Recreational Use of water (*primary contact). The water quality is poor if numbers of microbiological indicator organisms exceed the NHMRC guidelines more than 50% of the time

C. Nutrients, turbidity and chlorophyll

There are no specific ANZECC guidelines for nutrients in estuaries, only range concentrations indicative of estuaries and coastal waters (ANZECC 1992). Table 1 describes a broad classification for nutrients in the Port River estuary based on:

- detection levels
- background concentrations observed at Port Hughes, South Australia and the Southern Metropolitan Coastal Waters Study (WA Department of Environment Protection 1996)
- range criteria for marine and estuarine waters (ANZECC 1992)

The 90th percentile of the measurements is used to determine the appropriate classification.

Table 1 Criteria used to broadly classify water quality for nutrients, turbidity and chlorophyll.

	TKN-N (mg/L)	Nitrate (as N) (mg/L)	Total phosphorus (mg/L)	Ammonia (as N) (mg/L)	Turbidity (NTU)	Chlorophyll (ug/L)
• GOOD:	<1.0	<0.1	<0.1	<0.05	<5	<1
• MODERATE	1.0-10.0	0.1-1.0	0.1-1.0	0.05-0.5	5-25	1-10
• POOR:	>10.0	>1.0	>1.0	>0.5	>25	>10

2.3 DIFFERENCES BETWEEN SITES

It is important to determine whether there are statistically significant differences between monitoring sites. The variation in some data can be substantial but may not be significant from a statistical viewpoint. Paired t-tests were used to test for differences at the 5% level of significance (P=0.05). At this level there is a probability of only 1 in 20 that a difference in means could have arisen by chance.

3 ASSESSMENT OF THE DATA

Figure 1 shows the location of monitoring sites and summarises the water quality conditions at each location.

3.1 NUTRIENTS

TKN is a measure of organically bound nitrogen and includes both dissolved and particulate forms; nitrate and ammonia are dissolved forms of nitrogen. Total phosphorus includes both dissolved and particulate forms of phosphorus.

Sources

The major sources of nitrogen and phosphorus into the Port River are from the sewage treatment works, urban stormwater containing soil and fertilisers, industrial discharges and rainfall.

Impacts

Nutrients in excess (eutrophication) can lead to excessive algal growth. This in turn can lead to depletion of oxygen and cause fish deaths and other effects.

So called 'red tides' are frequently observed in the Port River and are due to algae known as dinoflagellates. The germination of the dinoflagellate cysts and 'red tide' blooms are principally caused by high nutrient levels and initiated by calm, stratified conditions in the estuary at optimal temperature and salinity ranges. A subsurface bloom occurs for 6–9 months each year at 3–4 metres depth. The red colouration of the water is seen when the subsurface bloom rises to near the surface.

On occassions there have been restrictions placed on the taking of shellfish from the Port River due to the presence of toxic dinoflagellates.

Ammonia is an important nutrient but can have direct toxic effects on marine organisms by reducing the ability of haemoglobin to combine with oxygen, causing death through suffocation.

Ammonia (Ammonia as nitrogen)

The results (table 2) indicate that four sites have poor water quality and five sites have a moderate water quality using the criteria described in section 2.2C. It is known that point source discharges from Penrice Soda Products (located between sites 1 and 2) and the Port Adelaide sewage treatment works (upstream from site 9) both contribute substantial loads of ammonia into the Port River.

Table 2 Ammonia in the Port River estuary.

Statistics (mg/L)	**Site number**								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Mean	0.50	0.26	0.10	0.32	0.30	0.32	0.24	0.12	0.99
± Confidence interval	0.20	0.13	0.05	0.14	0.12	0.13	0.09	0.08	0.29
Median	0.50	0.18	0.10	0.33	0.31	0.30	0.24	0.10	0.82
Number of samples	14	14	14	14	14	14	14	14	6
Standard deviation	0.32	0.21	0.07	0.22	0.19	0.20	0.15	0.12	0.46
10th percentile	0.10	0.08	0.04	0.10	0.10	0.10	0.10	0.03	0.59
90th percentile	0.87	0.54	0.17	0.45	0.50	0.57	0.39	0.18	1.58
water quality classification	poor	poor	mod	mod	mod	poor	mod	mod	poor

Classification based on 90th percentile as follows: good: <0.05 mg/L; moderate: 0.05-0.5 mg/L; poor: >0.5 mg/L

Note: Site 1 is significantly different to sites 2,3,4,5,6,7 and 8, $P<0.05$
Site 2 is significantly different to sites 3 and 8, $P<0.05$
Site 3 is significantly different to sites 4,5,6 and 7, $P<0.05$
Site 8 is significantly different to sites 4,5,6 and 7, $P<0.05$
Site 9 is significantly different to sites 2,3,4,5,6,7 and 8, $P<0.05$

Nitrate (Nitrate as nitrogen)

The results (table 3) indicate that all sites have moderate water quality using the criteria described in section 2.2C. Elevated nitrate concentrations can lead to excessive algal growth and poor water clarity.

As shown in table 3, the confidence intervals for the mean nitrate concentrations are generally large and the mean and the median are substantially different indicating a skewed data set.

Table 3 Nitrate in the Port River estuary.

Statistics (mg/L)	**Site number**								
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Mean	0.58	0.38	0.31	0.53	0.49	0.44	0.40	0.05	0.26
± Confidence interval	0.57	0.47	0.48	0.60	0.50	0.39	0.30	0.04	0.10
Median	0.26	0.20	0.07	0.24	0.22	0.22	0.22	0.02	0.21
Number of samples	14	14	14	14	14	14	14	14	6
Standard deviation	0.91	0.74	0.75	0.95	0.79	0.61	0.50	0.06	0.15
10th percentile	0.06	0.05	0.01	0.12	0.09	0.10	0.05	0.01	0.15
90th percentile	0.89	0.50	0.38	0.63	0.79	0.73	0.79	0.13	0.41
Water quality classification	mod	mod	mod	mod	mod	mod	mod	mod	mod

Classification based on 90th percentile as follows: good: <0.1 mg/L; moderate: 0.1-1 mg/L; poor >1 mg/L

Note: Site 3 is significantly different to sites 1,2 and 9, $P<0.05$
Site 2 and 3 is significantly different to sites 4 and 5, $P<0.05$

Site 8 is significantly different to sites 1,6,7 and 9, $P<0.05$

Total Kjeldahl Nitrogen (TKN as nitrogen)

The results (table 5) indicate that most sites have moderate water quality using the criteria described in section 2.2C. This is a similar pattern to that observed for total phosphorus.

Table 5 TKN in the Port River estuary.

	Site number								
Statistics (mg/L)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Mean	0.99	0.77	0.88	1.03	0.87	0.74	0.78	0.53	1.50
± Confidence interval	0.40	0.47	1.12	0.74	0.41	0.34	0.40	0.31	0.31
Median	1.0	0.51	0.50	0.70	0.77	0.71	0.68	0.46	1.30
Number of samples	14	14	14	14	14	14	14	14	6
Standard deviation	0.64	0.75	1.77	1.17	0.64	0.53	0.63	0.48	0.49
10th percentile	0.22	0.10	0.13	0.22	0.22	0.10	0.10	0.10	1.10
90th percentile	1.47	1.96	0.75	1.82	1.76	1.31	1.47	0.82	2.10
Water quality classification	mod	mod	good	mod	mod	mod	mod	good	mod

Classification based on 90th percentile as follows: good: <1 mg/L; moderate: 1-10 mg/L; poor: >10 mg/L

Note: Site 9 is significantly different to all other sites, P<0.05
Site 8 is significantly different to sites 1,6 and 7, P<0.05

Phosphorus (Total Phosphorus)

The results (table 4) indicate that all sites have moderate water using the criteria described in section 2.2C.

Table 4 Total phosphorus in the Port River estuary.

	Site number								
Statistics (mg/L)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Mean	0.15	0.11	0.11	0.16	0.17	0.14	0.16	0.11	0.16
± Confidence interval	0.08	0.07	0.09	0.09	0.11	0.08	0.09	0.08	0.05
Median	0.10	0.06	0.05	0.09	0.08	0.10	0.10	0.06	0.12
Number of samples	14	14	14	14	14	14	14	14	6
Standard deviation	0.13	0.11	0.14	0.14	0.18	0.12	0.15	0.12	0.08
10th percentile	0.06	0.03	0.01	0.05	0.04	0.05	0.05	0.03	0.10
90th percentile	0.36	0.25	0.29	0.41	0.40	0.34	0.37	0.31	0.26
Water quality classification	mod	mod	mod	mod	mod	mod	mod	mod	mod

Classification based on 90th percentile as follows: good: <0.1 mg/L; moderate: 0.1-1 mg/L; poor: >1 mg/L

Note: Site 2 is significantly different to sites 1,4,6 and 7, P<0.05
Site 7 is significantly different to site 8, p<0.05
Site 9 is significantly different to sites 1,4,5,6 and 8, p<0.05

3.2 Water Clarity

The penetration of light through the water column can be limited by particulate and dissolved matter, such as clay, silt, colloidal particles, and algae. Turbidity (measured in Nephelometric Turbidity Units or NTU) is a measure of the amount of scattering of light and can be approximately related to visibility as follows:

2NTU	10 metres depth
5 NTU	4 metres depth
10 NTU	2 metres depth
25 NTU	0.9 metres depth
100 NTU	0.2 metres depth

Sources

Particulate and dissolved matter originates from stormwater runoff (principally from soil and stream bank erosion) and industrial discharges.

Impacts

Water clarity is important to the ecological health of the Port River estuary because a reduction in light penetration reduces the ability of plants to photosynthesise. The resulting reduction in primary production may have deleterious effects on phytoplankton, macrophytes and benthic plants such as seagrasses. Particulate matter can also smother sessile benthic organisms and provide habitat for harmful bacteria and viruses. Poor water clarity can also affect the visual or aesthetic appearance of a waterbody.

Turbidity

The results (table 6) indicate that most sites are classified as having moderate water quality using the criteria described in section 2.2C. Site 7 opposite the Dry creek and Little Para river discharges has a high mean with high variability. This is to be expected.

Table 6 Turbidity in the Port River estuary.

	Site number								
Statistics (mg/L)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Mean	3.9	3.5	1.7	2.3	2.3	2.5	5.2	1.8	1.5
± Confidence interval	3.0	2.8	1.4	1.7	1.7	1.8	5.3	1.4	0.7
Median	1.9	1.9	0.8	1.3	1.2	1.2	1.7	1.0	1.1
Number of samples	14	14	14	14	14	14	14	14	6
Standard deviation	4.7	4.4	2.2	2.7	2.7	2.8	8.5	2.2	1.1
10th percentile	0.5	0.6	0.4	0.5	0.5	0.5	0.5	0.4	0.75
90th percentile	9.8	6.8	4.7	5.0	4.7	5.4	12.8	5.1	2.65
Water quality classification	mod	mod	good	mod	good	mod	mod	mod	good

Classification based on 90th percentile as follows: good: <5 NTU; moderate: 5-25 NTU; poor: >25 NTU

Note: Site 1 is significantly different to site 3 and 8, P<0.05
Site 3 is significantly different to site 4 and 6, P<0.05

3.3 ALGAE

Chlorophyll a

Chlorophyll is a measure of the amount of algae in the water.

Impacts

Algae can reduce water clarity and cause shading of seagrass leaves, thereby reducing normal photosynthetic activity. Algae can also cause aesthetic problems and, occassionally, public health concerns associated with the release of toxins.

As shown in table 7, the confidence intervals for the mean are generally large and the mean and the median are often substantially different indicating a skewed data set.

The water quality is poor at most sites using the criteria described in Section 2.2C. It is known that the estuary frequently experiences "red tides" at various times during the year due to algal blooms and the high chlorophyll concentrations support this observation.

Table 7 Chlorophyll *a* in the Port River estuary.

	Site number								
Statistics (µg/L)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Mean	10.91	7.49	5.40	6.25	1.93	1.61	0.88	2.70	1.83
Confidence interval	6.87	6.90	5.75	3.85	3.09	2.65	1.26	1.85	1.29
Median	6.50	2.85	2.20	4.20	2.25	1.25	1.55	1.40	1.0
Number of samples	14	14	14	14	14	14	14	14	6
Standard deviation	10.86	10.91	9.09	6.09	4.94	5.04	5.15	2.93	2.04
10th percentile	1.60	1.0	1.0	1.0	1.0	0.80	1.0	1.0	1.0
90th percentile	24.0	16.10	12.90	15.80	7.91	10.40	6.88	7.47	3.50
Water quality classification	poor	poor	poor	poor	mod	poor	mod	mod	mod

Classification based on 90th percentile as follows: good: <1 µg/L; moderate: 1-10 µg/L; poor: >10 µg/L

Note: Site 1 is significantly different to sites 2, 5, 6, 7 and 8, P<0.05
Site 4 is significantly different to site 8, P<0.05

3.4 HEAVY METALS

The Port River estuary is relatively shallow and protected making dispersion and dilution processes less effective. Heavy metals accumulate in this estuary in higher concentrations than in deeper waters. They also tend to accumulate readily in sediments, therefore, their presence in the water column is usually the result of recent inputs. Heavy metals are found in particulate and dissolved forms and although some are essential biological elements, such as iron, all have the potential to be toxic to organisms above certain concentrations.

Sources

Heavy metal contamination in the Port River can be directly linked to industrial sources and urban runoff. Industrial sources include smelters, power stations, port facilities, sewage treatment works, and chemical and manufacturing plants.

Aluminium may be present in water from natural leaching from rock and soil or from industrial sources and sewage effluent.

Cadmium may enter the environment from wastewater, fertilisers and metallurgical industries.

Copper derives from human activities, copper water pipes and antifouling paints. It is readily accumulated in plants and animals.

Iron occurs commonly in soil and rocks as oxide, sulfide and carbonate minerals but will also enter the environment from ships and industrial activities.

Lead reaches the Port River estuary through rain, fall-out of lead dust, stormwater runoff, and municipal and industrial wastewater discharges. A significant contributor is runoff from roads coupled with burning of leaded petrol.

Mercury enters the environment from industrial emissions or spills.

Zinc enters the environment through zinc production, waste incineration, and runoff from roads.

Impacts

Heavy metals have an effect on biota through their ability to bio-accumulate, move up the food chain and ultimately be consumed by humans.

Aluminium (Total Al)

Results for total aluminium are given in table 8. It is not possible to classify aluminium concentrations at this stage as there are no guidelines for marine or estuarine waters. Aluminium is known to be toxic to some freshwater organisms and the mechanism of toxicity would indicate that similar effects may occur in some marine species.

Table 8 Aluminium in the Port River estuary.

Statistics (mg/L)	Site number 1	2	3	4	5	6	7	8	9
Mean	0.182	2.716	0.229	0.243	0.293	0.348	0.444	0.223	0.073
± Confidence interval	0.226	5.882	0.341	0.385	0.468	0.529	0.524	0.344	0.045
Median	0.063	0.085	0.045	0.039	0.036	0.076	0.071	0.058	0.049
Number of samples	14	14	14	14	14	14	14	14	6
Standard deviation	0.357	9.300	0.539	0.609	0.740	0.837	0.828	0.544	0.072
10th percentile	0.036	0.024	0.010	0.022	0.017	0.028	0.018	0.016	0.011
90th percentile	0.233	1.196	0.527	0.431	0.496	0.434	1.738	0.201	0.160

No guideline for total aluminium in estuaries and marine waters.

Note: Sites not significantly different, P>0.05

Soluble Aluminium

Results for soluble aluminium are given in table 9. There are no specific guidelines for aluminium in marine or estuarine waters but in freshwater systems soluble forms of aluminium are more toxic than particulate forms. The mechanism of toxicity is such that problems may also occur in marine species. The guideline for freshwater aquatic ecosystems (0.1mg/L if pH>6.5) has therefore been used to classify marine waters.

Table 9 Soluble aluminium in the Port River estuary.

Statistics (mg/L)	Site number 1	2	3	4	5	6	7	8	9
Mean	0.106	0.082	0.060	0.094	0.114	0.120	0.145	0.115	0.014
± Confidence interval	0.200	0.160	0.111	0.152	0.234	0.198	0.284	0.217	0.003
Median	0.014	0.010	0.010	0.015	0.010	0.023	0.010	0.013	0.014
Number of samples	14	14	14	14	14	14	14	14	6
Standard deviation	0.315	0.253	0.176	0.240	0.370	0.313	0.449	0.343	0.004
10th percentile	0.010	0.010	0.010	0.010	0.009	0.008	0.006	0.007	0.010
90th percentile	0.066	0.032	0.028	0.091	0.043	0.100	0.105	0.108	0.018
Water quality classification	good	good	good	good	good	good	mod	mod	good

Classification : good: 90th percentile ≤0.1 mg/L
moderate: 90th percentile >0.1 mg/L but median <0.1 mg/L
poor: median ≥0.1 mg/L

Note: Sites not significantly different, P>0.05

Cadmium (Total Cadmium)

Water quality for cadmium is classified as good at all sites (table 10) based on the criteria described in Section 2.2A.

Table 10 Cadmium in the Port River estuary.

Statistics (mg/L)	Site number 1	2	3	4	5	6	7	8	9
Mean	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
± Confidence interval	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0
Median	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Number of samples	14	14	14	14	14	14	14	14	6
Standard deviation	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0.0008	0
10th percentile	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.001
90th percentile	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Water quality classification	good	good	good	good	good	good	good	good	good

Classification : good: 90^{th} percentile ≤0.002 mg/L
moderate: 90^{th} percentile >0.002 mg/L but median <0.002 mg/L
poor: median ≥0.002 mg/L

Note: Sites not significantly different, P>0.05

Copper (Total Copper)

The results (table 11) indicate that water quality is poor at all sites based on the criteria described in Section 2.2A. Copper is a significant toxicant to marine organisms and the relatively high concentrations in the Port River estuary are of concern.

Table 11 Copper in the Port River estuary.

Statistics (mg/L)	Site number 1	2	3	4	5	6	7	8	9
Mean	0.016	0.019	0.017	0.016	0.017	0.020	0.018	0.019	0.015
± Confidence interval	0.007	0.010	0.009	0.007	0.007	0.009	0.008	0.018	0.006
Median	0.016	0.012	0.012	0.013	0.013	0.017	0.014	0.011	0.012
Number of samples	14	14	14	14	14	14	14	14	6
Standard deviation	0.011	0.016	0.014	0.011	0.011	0.014	0.012	0.028	0.010
10th percentile	0.005	0.006	0.003	0.003	0.006	0.008	0.005	0.002	0.009
90th percentile	0.033	0.036	0.036	0.030	0.034	0.040	0.034	0.033	0.024
Water quality classification	poor	poor	poor	poor	poor	poor	poor	poor	poor

Classification : good: 90^{th} percentile ≤0.005 mg/L
moderate: 90^{th} percentile >0.005 mg/L but median <0.005 mg/L
poor: median ≥0.005 mg/L

Note: Site 2 is significantly different to site 9, P<0.05

Iron (Total iron)

No guidelines are available for the classification of iron in estuarine or marine waters. It was included in the program because of the number of rusting hulks in the area.

Table 12 Iron in the Port River estuary.

	Site number								
Statistics (mg/L)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Mean	0.123	0.171	0.080	0.101	0.107	0.242	0.421	0.096	0.095
± Confidence interval	0.073	0.146	0.033	0.069	0.069	0.247	0.498	0.059	0.070
Median	0.080	0.088	0.073	0.050	0.065	0.120	0.130	0.050	0.050
Number of samples	14	14	14	14	14	14	14	14	6
Standard deviation	0.115	0.230	0.053	0.109	0.108	0.247	0.788	0.093	0.110
10th percentile	0.050	0.050	0.022	0.016	0.036	0.050	0.050	0.030	0.050
90th percentile	0.215	0.319	0.124	0.230	0.202	0.322	0.856	0.205	0.185

No guideline for total iron in estuaries or marine waters.

Note: Sites not significantly different, P>0.05

Lead (Total lead)

Although water quality at some sites is classified as poor (table 13) using the criteria described in Section 2.2A, the concentrations are only mariginally above the ANZECC guideline. Nevertheless elevated lead concentrations are of concern because of the potential for bioaccumulation. This is particularly important in an area known to be a nursery ground for many species of fish and other marine animals.

Table 13 Lead in the Port River estuary.

	Site number								
Statistics (mg/L)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Mean	0.0039	0.0046	0.0033	0.0036	0.0056	0.0035	0.0041	0.0041	0.0050
± Confidence interval	0.0014	0.0019	0.0015	0.0013	0.0045	0.0013	0.0019	0.0009	0
Median	0.0050	0.0050	0.0035	0.0050	0.0050	0.0045	0.0050	0.0050	0.0050
Number of samples	14	14	14	14	14	14	14	14	6
Standard deviation	0.0022	0.0030	0.0024	0.0020	0.0073	0.0020	0.0030	0.0014	0
10th percentile	0.0007	0.0013	0.0005	0.0007	0.0010	0.0007	0.0007	0.0023	0.0050
90th percentile	0.0057	0.0078	0.0050	0.0050	0.0060	0.0050	0.0057	0.0050	0.0050
Water quality classification	poor	poor	good	good	poor	good	poor	good	good

Classification : good: 90th percentile ≤0.005 mg/L
moderate: 90th percentile >0.005 mg/L but median <0.005 mg/L
poor: median ≥0.005 mg/L

Note: Sites not significantly different, P>0.05

Mercury (Total mercury)

Water quality is classified as good at all sites (table 14) using the criteria described in Section 2.2A.

Table 14 Mercury in the Port River estuary.

Statistics (mg/L)	Site number 1	2	3	4	5	6	7	8	9
Mean	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0005
± Confidence interval	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0
Median	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0005
Number of samples	14	14	14	14	14	14	14	14	6
Standard deviation	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0
10th percentile	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0005
90th percentile	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
Water quality classification	good	good	good	good	good	good	good	good	good

Classification : good: 90th percentile ≤0.001 mg/L
moderate: 90th percentile >0.001 mg/L but median <0.001 mg/L
poor: median ≥0.001 mg/L

Note: Sites not significantly different, P>0.05

Zinc (Total zinc)

Water quality is moderate at seven sites and good at two sites (table 15) based on the criteria described in Section 2.2A.

Table 15 Zinc in the Port River estuary.

Statistics (mg/L)	Site number 1	2	3	4	5	6	7	8	9
Mean	0.053	0.038	0.040	0.038	0.034	0.035	0.035	0.038	0.026
± Confidence interval	0.031	0.016	0.016	0.020	0.010	0.011	0.011	0.015	0.006
Median	0.040	0.034	0.034	0.032	0.032	0.038	0.039	0.039	0.028
Number of samples	14	14	14	14	14	14	14	14	6
Standard deviation	0.049	0.026	0.026	0.031	0.016	0.017	0.018	0.023	0.009
10th percentile	0.011	0.011	0.011	0.011	0.014	0.010	0.010	0.010	0.017
90th percentile	0.104	0.070	0.077	0.059	0.050	0.055	0.055	0.060	0.033
Water quality classification	mod	mod	mod	mod	good	mod	mod	mod	good

Classification : good: 90th percentile ≤0.05 mg/L
moderate: 90th percentile >0.05 mg/L but median <0.05 mg/L
poor: median ≥0.05 mg/L

Note: Site 2 is significantly different to site 9, P<0.05

Soluble Zinc

Results of zinc monitoring are given in table 16. It is not possible to classify water quality at this stage as there are no guidelines for zinc in marine or estuarine waters. Soluble zinc concentrations were included because it is likely that soluble forms are more toxic than particulate forms.

Table 16 Soluble zinc in the Port River estuary.

	Site number								
Statistics (mg/L)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Mean	0.022	0.024	0.024	0.023	0.021	0.022	0.023	0.026	0.011
± Confidence interval	0.011	0.010	0.011	0.010	0.011	0.009	0.010	0.011	0.003
Median	0.021	0.023	0.022	0.020	0.013	0.017	0.016	0.031	0.010
Number of samples	14	14	14	14	14	14	14	14	6
Standard deviation	0.018	0.015	0.017	0.016	0.017	0.015	0.017	0.017	0.004
10th percentile	0.007	0.006	0.008	0.007	0.006	0.008	0.006	0.007	0.008
90th percentile	0.047	0.041	0.044	0.040	0.037	0.036	0.040	0.042	0.015

No guideline for soluble zinc in estuaries.
Note: Sites not significantly different, P>0.05

3.5 MICROBIOLOGICAL

The presence of micro-organisms in water is important primarily from a human health perspective. There are two significant microbial groups in marine waters: microbes from animal and human wastes; and environmental micro-organisms. Faecal coliforms and faecal streptococci are used as indicators of faecal contamination.

Source

Pathogens from faecal material find their way into the Port River from sewage, boats, septic tank leaks, stormwater and runoff from within the estuary, creeks, drains and the harbour. They may enter the environment freely suspended but are highly associated with particulate matter.

Impact

The route of pathogen uptake is through ingestion, inhalation or breaks of the skin. Water used for primary contact activities (such as swimming) and for secondary contact (such as boating or fishing) should meet the requirements for recreational use of waters.

In tables 17, 18 and 19 for microbiological characteristics, the confidence intervals for the mean are generally large, and the mean and the median are often substantially different indicating a skewed data set. The geometric mean is considered to be a better statistical parameter than the arithmetic mean to compare trends over time and differences between sites.

Faecal coliforms

Faecal coliforms are found in large numbers in the intestinal tract of humans and other warm blooded animals. Whilst occassionally some faecal coliforms may be of environmental origin, they are nevertheless regarded as a sensitive indicator of recent faecal contamination. Faecal coliforms die off more rapidly in marine waters than some other microorganisms such as viruses and protozoa.

Results (table 17) indicate that all sites meet the NHMRC requirements for primary contact recreation.

Table 17 Faecal coliforms in the Port River estuary.

	Site number								
Statistics (organisms/100ml))	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Geometric Mean	1.59	2.67	4.79	3.83	1.92	4.07	2.83	2.03	6.14
Confidence interval - GM_L	1.04	1.13	2.93	2.27	1.51	2.70	1.33	0.90	5.28
Confidence interval - GM_U	2.42	6.33	7.81	6.45	2.43	6.14	6.05	4.54	7.13
Median	1.0	1.0	4.0	2.5	1.0	3.5	2.0	1.0	8.0
Number of samples	14	14	14	14	14	14	14	14	6
No. samples that exceed 600 organisms per 100ml	0	0	1	1	1	1	0	0	0
10th percentile	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
90th percentile	4.7	32.5	13.1	12.4	3.0	7.4	26.9	19.2	43.5
Water quality classification	good	good	good*	good*	good*	good*	good	good	good

Classification: good: 90^{th} percentile =150/100mL
moderate: 90^{th} percentile >150/100mL but median =150/100mL
poor: median ≥150/ 100mL
* can be poor at times (maximum number in a sample exceeds 600/100 mL)

Note : Site 5 is significantly different to sites 3, 4 and 6 $P<0.05$

Faecal streptococci

Faecal streptococci are found in the faeces of humans and other animals. In humans numbers of faecal streptococci are less than faecal coliforms but in other animals numbers can exceed those of faecal coliforms.

Not all faecal streptococci can be reliably associated with the gut, thus, while the presence of faecal streptococci is suggestive of faecal contamination they are regarded as a less sensitive indicator than faecal coliforms. Faecal streptococci are however more persistent in water than faecal coliforms and so may be a better indicator of the presence of certain pathogens which also die off slowly (for example, viruses).

Table 18 Faecal streptococci in the Port River estuary.

	Site number								
Statistics (organisms/100ml))	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Geometric Mean	2.33	2.47	3.05	3.39	2.50	4.96	3.53	1.96	3.80
Confidence interval - GM_L	1.41	1.61	1.73	1.85	1.61	2.81	1.61	1.34	1.43
Confidence interval - GM_U	3.84	3.79	5.37	6.22	3.87	8.77	7.78	2.85	10.12
Median	2.0	1.50	2.0	3.50	1.50	5.0	2.50	1.50	4.50
Number of samples	14	14	14	14	14	14	14	14	6
No. samples that exceed 60 organisms per 100ml	0	0	0	0	0	1	1	0	0
10th percentile	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
90th percentile	7.4	8.0	17.1	12.1	9.0	19.1	19.8	6.7	20.0

Classification: No specific guidelines for Faecal streptococci. see Enterococci
Note: Sites not significantly different, $P>0.05$

Enterococci

Enterococci are a more specific indicator of faecal contamination than faecal streptococci. They have longer survival times in the environment than faecal coliforms and are a useful indicator in marine waters where faecal pollution is suspected but faecal coliforms are either absent or present in low numbers.

Enterococci are more persistent in marine waters than faecal coliforms and consequently are regarded as a better indicator of the presence of certain pathogens (eg viruses).

All sites (table 19) meet the NHMRC criteria for primary contact recreational use using the criteria given in Section 2.2B. One sample at site 7 exceeded the maximum number of Enterococci permitted in any one sample under the ANZECC Australian Water Quality Guidelines for Fresh and Marine Waters (60 organisms per 100 ml) and is classified as "poor at times".

Table 19 Enterococci in the Port River estuary.

	Site Number							
Statistics (organisms/100ml))	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Geometric Mean	2.78	1.77	2.58	3.19	1.86	2.90	3.93	1.57
Confidence interval - GM_L	1.44	1.04	1.12	1.52	0.9	1.29	1.32	1.09
Confidence interval - GM_U	5.39	3.0	5.95	6.73	3.50	6.52	11.72	2.23
Median	3.5	1.5	1.5	3.5	1.0	4.0	3.0	1.5
Number of samples	8	8	8	8	8	8	8	8
No. samples exceeding 60 organisms /100 mL	0	0	0	0	0	0	1	0
10th percentile	1.7	1.0	1.0	1.0	1.0	1.0	1.0	1.0
90th percentile	7.1	4.5	13.6	10.0	5.5	9.3	32.9	3.0
Water quality classification	good	good	good	good	good	good	good*	good

Classification: good: 90th percentile =33/100mL
moderate: 90th percentile >33/100mL but median =33/100mL
poor: median ≥33/ 100ml.
* can be poor at times (maximum number in a sample exceeds 60/100 mL)

Note: Sites not significantly different, P>0.05

3.6 SALINITY

Salinity is expressed in units of conductivity (µS/cm). Low salinity indicates freshwater input during storm events, whereas high salinity may indicate intrusion from nearby salt fields or the effects of thermal discharges.

Results of salinity monitoring are shown in table 20.

In July 1996, a conductivity reading at site 6 fell to 970 µS/cm. This was due to large volumes of fresh water entering the estuary from Dry Creek, Little Para River and numerous stormwater drains. (Over 100 mm of rainfall for each month was recorded during June, July and August 1996 in Adelaide). A low tide recorded at Inner Harbor during the time of sampling in July contributed to the freshwater reading. Similar, but less dramatic, drops in salinity were recorded at a number of other sites.

Table 20 Salinity in the Port River estuary.

	Site number								
Statistics (µS/cm)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Mean	57129	55936	55500	57707	58421	52648	57907	58614	58350
± Confidence interval	4055	6876	6758	4009	3991	11559	5724	3870	3274
Median	57550	57600	57250	58550	5890	58450	59700	59600	59050
Number of samples	14	14	14	14	14	14	14	14	6
Standard deviation	6412	10872	10685	6338	6310	18276	9050	6118	5176
10th percentile	51910	51590	51230	51530	51670	31170	51340	51820	52600
90th percentile	65800	64390	62180	63830	64910	63900	65020	63760	63400

Note: Sites not significantly different, P>0.05

4 CONCLUDING REMARKS

Based on the preliminary findings of the ambient water quality monitoring programme the water quality of the Port River estuary would be described as poor for the following reasons:

1. Concentrations of ammonia are high at most sites. Moderate concentrations of total phosphorus, nitrate and TKN occur at many of the sites.

2. Water clarity as determined by turbidity measurements is of moderate quality at most sites.

3. Chlorophyll concentrations are high or moderate at all sites.

4. Copper concentrations often exceed guideline concentrations at all sites, and concentrations of other heavy metals (particularly lead and zinc) exceed guideline concentrations at a number of sites regularly.

5. Microbiological quality is classified as good at all sites. However, some samples from some sites occassionally exceed the maximum number of indicator microorganisms in a sample (*ANZECC Australian Water Quality Guidelines for Fresh and Marine Waters*) for primary contact and have been classified as poor at times. Nevertheless, taken over the whole period, all sites meet the NHMRC Australian Guidelines for Recreational Use of Water.

A number of initiatives in the Port River estuary area should improve water quality over time. These include nutrient reduction and effluent reuse programmes for the sewage treatment works, environmental improvement programmes being established by industry in the area, and the development of extensive wetlands to treat stormwater. These initiatives should reduce nutrient concentrations over time and, as a result, also improve water clarity and chlorophyll levels. They should also help to reduce heavy metal concentrations by removing particulate matter which can adsorb some metals.

5 FURTHER READING

Ashbolt, NJ. 1995. Human health risk from microorganisms in the Australian marine environment. In Zann and Sutton, *State of the marine environment report for Australia: Technical Annex: 2 - Pollution*, pp 31–40.

ANZECC. 1992. *National Water Quality Management Strategy—Australian Water Quality Guidelines for Fresh and Marine Waters*. Australian and New Zealand Environment and Conservation Council.

Batley, GE. 1995. Heavy metals and tributyltin in Australian coastal and estuarine waters. In Zann and Sutton, *State of the marine environment report for Australia: Technical Annex: 2 - Pollution*, pp 63–72.

Brodie, J. 1985. The problems of nutrients and eutrophication in the marine environment. In Zann and Sutton, *State of the marine environment report for Australia: Technical Annex: 2 - Pollution*, pp 1–29.

Cabelli, VJ, Dufour, AP, McCabe, LJ and Levin, MA. 1983. A marine recreational water quality criterion consistent with indicator concepts and risk analysis. Journal WPCF. 55(10): 1306 - 1314.

Cugley, J. 1994. Ambient water quality monitoring for SA—Issues and requirements. EPA Draft Report.

Department of Environment Protection. 1996. Southern metropolitan coastal waters study (1991–1994): Report 17. Perth, Western Australia.

EPA. 1997. Ambient water quality monitoring of Gulf St Vincent metropolitan bathing waters. Report no. 1. Environment Protection Authority, Department of Environment, Heritage and Aboriginal Affairs. South Australia.

Favero, MS. 1985. Microbiologic indicators of health risks associated with swimming. *American Journal of Public Health*. 75(9): 1051 - 1054.

Fleisher, JM. 1992. US federal bacteriological water quality standards: A re-analysis. In: Kay, D (ed). 1992. Recreational water quality management. Volume 1: Coastal waters. Ellis Horwood. Chapter 9, pp: 113 - 127.

Seyfried, PL, Tobin, RS, Brown, NE and Ness, PF. 1985a. A prospective study of swimming-related illness. 1. Swimming associated health risk. *American Journal of Public Health*. 75(9): 1068 - 1070.

Seyfried, PL, Tobin, RS, Brown, NE and Ness, PF. 1985b. A prospective study of swimming-related illness. 2. Morbidity and the microbiological quality of water. *American Journal of Public Health*. 75(9): 1071 - 1075.

Taylor, JK. 1987. *Quality assurance of chemical measurements*. Lewis Publishers, pp. 129–146.

Ward, JT, Warren, LJ and Swaine, DJ. 1982. *Effects of heavy metals on aquatic life*. CSIRO.

Zann, LP and Sutton, D. (Eds). 1995. *State of the marine environment report for Australia: Technical Annex: 2 - Pollution*. Great Barrier Reef Marine Park Authority, for the Department of the Environment, Sport and Territories, Ocean Rescue 2000 Programme: Townsville.