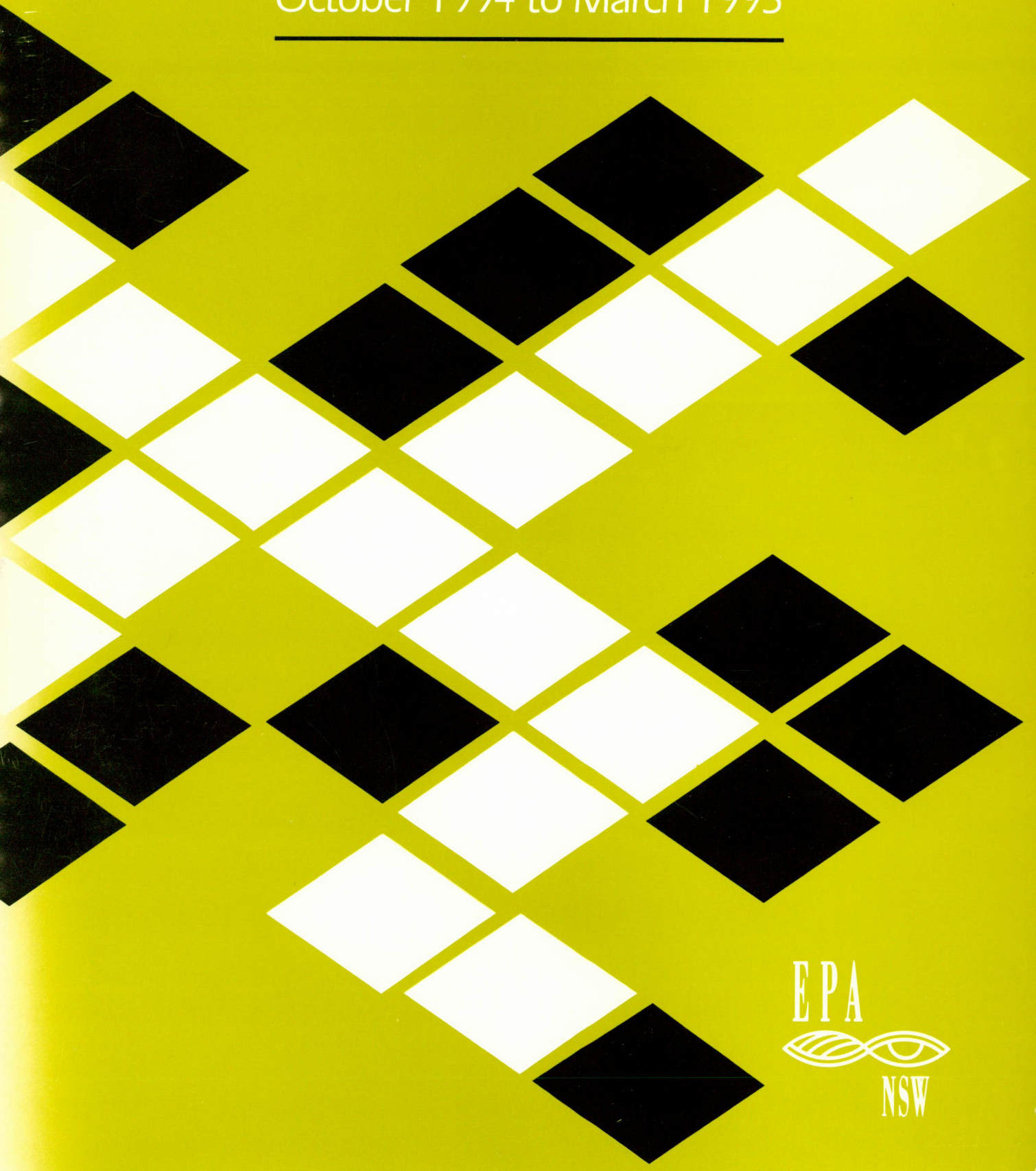
Recreational Water Quality

Hawkesbury–Nepean River System

October 1994 to March 1995



EPA NSW

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EPA
NSW

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SUMMARY

Between October 1994 and March 1995 (summer season), the NSW Environment Protection Authority (EPA) monitored recreational water quality at 12 recreation sites in the Hawkesbury-Nepean River system between Menangle and Berowra. In February 1995, sampling commenced at an additional site in the mainstream Hawkesbury River at Sackville ferry. This report summarises the findings of the monitoring of these thirteen sites.

The monitoring program was designed specifically to evaluate water quality at locations where the community chooses to use the river for recreation. The program uses national guidelines for sampling and data interpretation that are designed to provide information on the potential effect on human health of contact with the waters.

At each site on each sampling occasion, three water samples were collected for bacteriological analysis. At the same time, EPA staff measured pH, temperature, electrical conductivity and turbidity *in situ* and recorded the presence of any algae or surface films.

All sites except Macquarie Park (Windsor) complied with the national bacteriological guidelines for secondary contact recreation (boating, wading) during the months sampled. High faecal bacterial levels at Macquarie Park (Windsor) rendered this site unsuitable for secondary contact during February 1995. A bloom of cyanobacteria (blue-green algae) between Cattai and Wisemans Ferry also made some sites unsuitable for direct contact recreation during the study period.

All sites except Macquarie Park (Windsor) and South Creek (Windsor) complied with the national bacteriological guidelines for primary contact recreation during the entire study period. There was, however, evidence of residual bacterial contamination (as indicated by elevated enterococci densities) at Menangle, Tench Reserve, Macquarie Park, South Creek, Cattai and Berowra. Secchi distance was consistently below 1.6 m at Macquarie Park and South Creek, with the remaining sites showing variable visual clarity.

Regression analyses of rainfall and faecal bacterial densities was performed. In general, it was found that faecal bacterial densities and turbidity increased with increasing rainfall at the following sites: Menangle Bridge, South Creek and Berowra ferry.

Because high bacterial levels were found at South Creek and Macquarie Park in winter 1994 (EPA 1995) a special study of 21 sites in the South Creek, Eastern Creek and Cattai Creek subcatchments was conducted by the EPA from December 1994 to May 1995 with a view to identifying the sources of contamination. Each site was sampled fortnightly for faecal coliforms. The highest bacterial densities were measured in Eastern Creek at Level Crossing Road and in South Creek at Richmond Road Bridge. There was a general trend of decreasing water quality with increasing distance from the headwaters of the creeks. The high faecal bacterial densities found in South Creek and Eastern Creek confirm these creeks as the sources of the high densities experienced at the recreational site at Governor Phillip Park, South Creek. The study is continuing to establish the exact sources of contamination in South and Eastern Creeks and also to establish the source of the bacterial contamination at Macquarie Park, Windsor.

The EPA is continuing its monitoring of recreational water quality in the Hawkesbury-Nepean River during the 1995 winter season. In conjunction with the Hawkesbury-Nepean Catchment Management Trust, the Department of Health, Sydney Water and local councils the EPA is providing regular information to the community on trends in recreational water quality.

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1. THE AIM OF THIS REPORT

This report aims to help local councils and other organisations provide information on recreational water quality in the Hawkesbury-Nepean River system to assist individuals decide when and where they can boat, swim and generally use the river for recreation. It summarises the findings of the EPA's monitoring of recreational water quality at 13 sites in the Hawkesbury-Nepean River and its tributaries between October 1994 and March 1995 (the summer season), and provides an insight into the trends in water quality at those sites.

2. INTRODUCTION

The EPA began monitoring recreational water quality in the Hawkesbury-Nepean River in October 1993. The monitoring program was the first to specifically evaluate water quality at the locations where the community chooses to use the river for recreation. Reports on this program are produced every six months: for the summer (October to March) and winter (April to September) seasons.

The results of the October 1993 to March 1994 summer season and April to September 1994 winter season have been reported (EPA 1994; EPA 1995). During the summer 1993-94 season, eight recreational sites between Camden and Sackville were sampled. In April 1994, the number of sites was increased to 12, between Menangle and Berowra Creek. Sampling at Sackville ferry was discontinued in April 1994, but was recommenced in February 1995 in response to community interest.

The monitoring program targets popular recreational sites. It uses guidelines for sampling and data interpretation that are designed to provide information relevant to public health and aesthetic assessments.

There are two authoritative Australian guidelines for assessing recreational water quality: the National Health and Medical Research Council's *Australian Guidelines for Recreational Use of Water* (NHMRC 1990), and the chapter on 'Recreational Water Quality and Aesthetics' in the Australian and New Zealand Environment and Conservation Council's *Australian Water Quality Guidelines for Fresh and Marine Waters*

(ANZECC 1992). The two guidelines are very similar: both set out a range of parameters relevant to determining recreational water quality:

- an assessment of bacterial water quality using the indicator organisms, faecal coliforms and enterococci
- an assessment of the presence of nuisance organisms, such as algae
- an assessment of visual clarity and colour
- a measurement of pH
- a visual assessment of surface films
- a measurement of temperature.

On the advice of the NSW Department of Health, the NHMRC (1990) guidelines have been adopted as the guide for the collection and interpretation of data relevant to bacterial water quality. The ANZECC (1992) guidelines are used to assess algal and physico-chemical indicators of water quality.

The NHMRC (1990) and ANZECC (1992) guidelines both make the following distinction between primary and secondary contact recreation:

- *primary contact* recreation is characterised by bodily immersion or submersion where there is direct contact with the water, and includes activities such as swimming, diving, water skiing and surfing
- *secondary contact* recreation includes activities such as the paddling activities of children, wading, boating and fishing in which there is some direct contact with the water but where the probability of swallowing water is unlikely.

Following is a detailed discussion of the various water quality parameters.

2.1 Bacteriological indicators

Effective recreational water quality monitoring must include appropriate tests for the presence of faecal material that may transmit infectious diseases to humans or animals.

The disease-causing agents (pathogens) of greatest concern are those that infect the human gut, although the results of several Australian studies

have also suggested that people who swim in faecally-contaminated water may be at risk of skin, throat and eye infections. Pathogens may be bacterial, viral or protozoan, with viral and protozoan pathogens presenting the most frequent threat in Australian waters.

It is not practicable to test for viral or protozoan pathogens in recreational waters as part of a routine monitoring program for two reasons:

(1) Unlike bacterially contaminated water, the number of viral particles or protozoan cells needed for clinical infection may be very small thus requiring the collection of large volumes of water for testing.

(2) The laboratory tests for confirming the presence and identity of pathogenic viruses are currently complex, labour intensive and expensive. A number of Australian laboratories are progressively introducing molecular biology techniques as alternative tests, but tests relying, for example, on tissue culture and electron microscopy are still required for the identification of a number of common viral pathogens.

Therefore, bacterial indicators are used to test recreational waters for faecal contamination. Experience over the past 30 years in the UK, USA and Australia has shown that faecally-derived bacteria provide a suitable indicator system if the results are interpreted carefully. To date, research to link closely the levels of indicator bacteria in water with the incidence of disease has been limited, but there is still a strong *prima facie* case that there is an increased risk of bacterial, viral or protozoan diseases when indicator bacteria are elevated above established thresholds.

There has been extensive international debate about the most appropriate bacterial indicators for fresh and marine recreational waters, but attention has focused on the use of the faecal coliform and enterococcus groups of bacteria. These bacteria can indicate gross faecal contamination of a recreational site, and if they are monitored in a structured and regular way, they can indicate trends in water quality and allow basic risk-assessment procedures to be used.

NHMRC (1990) specifies the following bacteriological criteria for *primary* and *secondary* contact recreation:

- For *primary contact* recreation the median (or middle) value should not exceed 150 faecal coliforms per 100 mL for a minimum of five

samples taken at regular intervals not exceeding one month with four out of five samples containing less than 600 faecal coliforms per 100 mL.

- For *secondary contact* recreation the median value should not exceed 1,000 faecal coliforms per 100 mL for a minimum of five samples taken at regular intervals not exceeding one month with four out of five samples containing less than 4,000 faecal coliforms per 100 mL.

The NHMRC (1990) guidelines also state in a footnote that where pollution is suspected, but only low numbers of faecal coliforms can be detected, a geometric mean of 33 enterococci per 100 mL has been used as a bacterial indicator for marine waters and may be useful.

A major disadvantage in the use of bacterial indicators is that accurate results cannot be reported immediately. Confirmed results are not available until five working days after the samples have been collected. Samples for faecal coliform and enterococci analysis need to be incubated for 24 and 48 hours respectively, followed by a further 48 hours for verification. Thus, results can only be used in retrospect, i.e. a site cannot be assessed on the day on which the samples were collected. Because faecal bacterial densities are transient (i.e. faecal bacteria have short survival times in the environment), the results for any particular site are best interpreted on the basis of trends that are observed over the full recreational season (ANZECC 1992) (i.e. October to March in the present instance).

2.2 Algae

Algal blooms, particularly cyanobacterial (blue-green algae) blooms, also affect recreational use in the Hawkesbury River, especially between Windsor and Wisemans Ferry. Cyanobacterial blooms can be toxic at times and can restrict recreational and potable uses of the river.

The NSW Government has adopted recommendations of the Blue-Green Algae Task Force (1992) regarding alert levels for recreational use of waters which contain blue-green algae. Recommendation 10 of the Blue-Green Algae Task Force Final Report (1992) states that public health warnings for domestic use, recreation and stock watering should be issued when potentially toxic blue-green algae exceed 15,000 cells/mL. ANZECC (1992) also recommends that people should avoid direct contact activities if algal levels exceed 15,000 to 20,000 cells/mL.

2.3 Visual clarity and colour

To protect the aesthetic quality of a waterbody, ANZECC (1992) recommends that the waterbody's:

- natural visual clarity should not be reduced by more than 20%
- natural hue should not be changed by more than 10 points on the Munsell Scale
- natural reflectance should not be changed by more than 50%.

It can be unsafe to swim in waters where underwater objects, such as snags, cannot be seen. To protect the visual clarity of waters used for swimming, ANZECC (1992) recommends that 'the horizontal sighting of a 200 mm diameter black disc (Secchi disc) should exceed 1.6 m'.

2.4 pH

For primary contact recreation, ANZECC (1992) recommends that the pH of the water should be within the range 5.0-9.0, assuming that the buffering capacity of the water is low near the extremes of the pH limits. There is no pH criterion for secondary contact recreation.

2.5 Temperature

For primary contact recreation, ANZECC (1992) recommends that temperatures should be in the range of 15-35°C for prolonged exposure. There is no temperature criterion for secondary contact recreation.

2.6 Surface films

For primary and secondary contact recreation, there should not be a visible film of oil and/or petrochemicals on the water, nor should they be detectable by odour (ANZECC 1992).

The presence of oil or petrochemicals makes water aesthetically unattractive. They can form deposits on shorelines and bottom sediments that are detectable by sight and odour. Some organic compounds can be absorbed directly from the water through the skin, making these substances even more undesirable in recreational areas (ANZECC 1992).

3. METHODS

3.1 Site description

Twelve sites were sampled for the first four months of this study. An extra site at Sackville ferry was sampled for the remaining two months (Table 1 and Figure 1). Sites were selected on the basis of recreational use and to provide spatial coverage of the river between Menangle and Berowra Creek. The sites are described in Appendix A.

3.2 Sampling procedure and *in situ* measurements

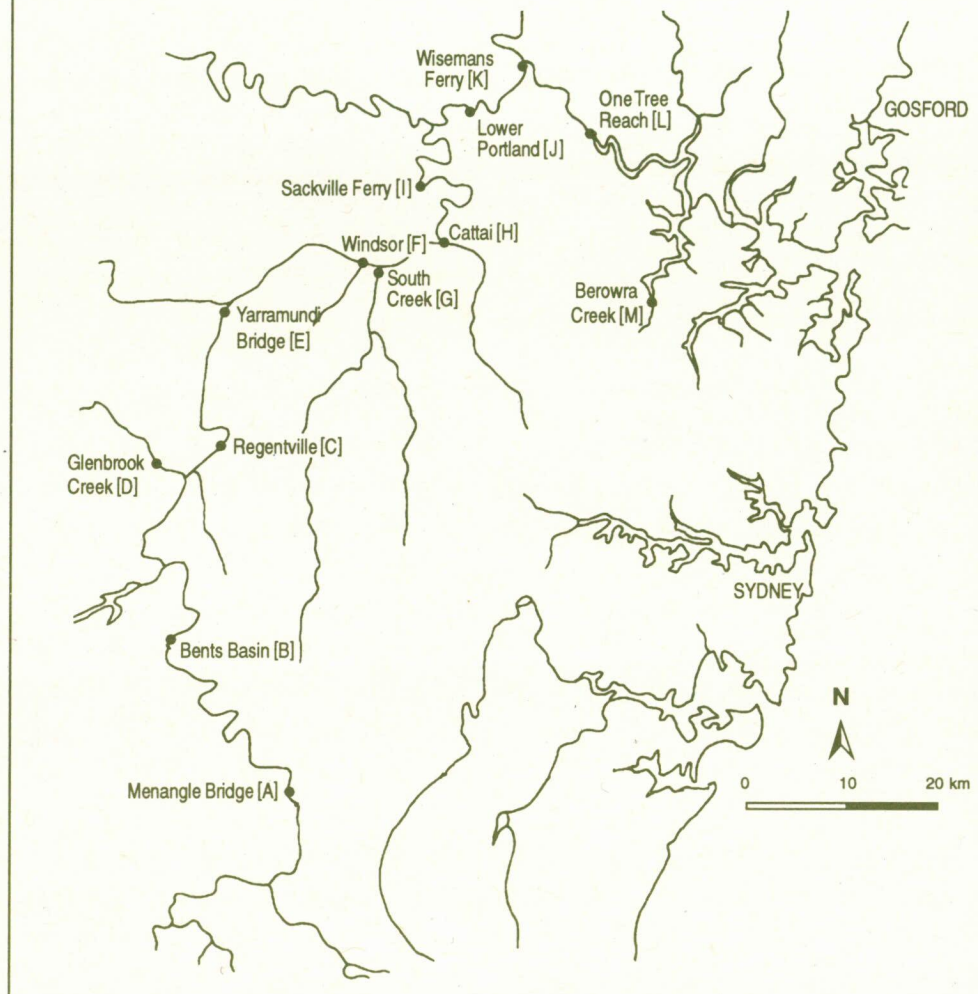
Water samples were collected in accordance with NHMRC (1990) and ANZECC (1992) guidelines, every six days from 6 October 1994 to 29 March 1995. The NHMRC (1990) guidelines recommend that sampling should be conducted where and when swimmers are present. In this study, sampling occurred between 6:30 am and 1 pm on a six-day cycle.

One team sampled eight sites from the shore while another team sampled five water-skiing sites from a boat (see Appendix A). Because of the spatial extent of recreational use, the water-skiing sites, sampled from a boat, were divided into sections. At each water-skiing site the river was divided

Table 1
Sampling site locations, site codes and number of months sampled.

Site code	Site location	No. of months sampled
A	Nepean River at Menangle Road Bridge	6
B	Nepean River at Bents Basin State Recreation Area	6
C	Nepean River at Tench Reserve ramp (Regentville)	6
D	Glenbrook Creek at Jellybean Pool	6
E	Nepean River at Yarramundi Bridge	6
F	Hawkesbury River at Macquarie Park (Windsor)	6
G	South Creek at Governor Phillip Park ramp (Windsor)	6
H	Hawkesbury River at Cattai National Park	6
I	Hawkesbury River at Sackville ferry	2
J	Hawkesbury River at Lower Portland	6
K	Hawkesbury River at Wisemans Ferry	6
L	Hawkesbury River at One Tree Reach	6
M	Berowra Creek at the ferry	6

Figure 1
Sampling sites on the Hawkesbury–Nepean River



lengthwise into four sections, each 150 m in length, with the total length for that site being 600 m. Prior to sampling, a single 150 m section was chosen randomly from within the site and was sampled on that day. Through time, each of the sections was equally represented. Samples collected within each 150 m section were collected randomly across the breadth of the river to accommodate any within-site cross-sectional spatial heterogeneity. The sites which were sampled from the shore were about 100 m in length and samples from these sites were collected randomly from the river bank. A 1.5 m extension pole was used to collect the sample away from the bank in an upstream movement.

In accordance with experience gained during summer 1993-94 (EPA 1994), three replicate water samples were collected for bacteriological analysis at each site from a depth of 50 cm (or as close as possible to that

depth). Samples were collected in sterile 500 mL plastic containers using aseptic techniques. The samples were stored on ice and transported in a portable ice chest ('esky') to the laboratory.

In addition, two algal samples were collected at each site. One sample was collected using a 20 µm mesh plankton net to provide a concentrated sample for species identification. The other, a surface grab sample (at sites upstream of Windsor) and a sample collected using an integrated vertical sampler (Venrick 1978) (at Windsor and downstream of Windsor) was collected in a 100 mL plastic bottle for species enumeration. Algal samples were stored and transported in the same manner as the bacteriological samples.

A single measurement of pH, temperature, electrical conductivity and turbidity was recorded *in situ* at each site at about 50 cm depth on each sampling occasion using a Grant YSI 3800 water quality logger or a Hydrolab H2O, which had been calibrated the previous day as per the manufacturer's instructions (Grant 1992, Hydrolab Corp. 1993). In addition, horizontal Secchi distance was measured at the sites sampled from the bank. Vertical Secchi depth was measured at the sites which were sampled from the boat, as it was not possible to measure horizontal Secchi distance.

A field sheet was completed at each site and included the following information: weather, presence of nuisance organisms, oily films on surface or shoreline, floating debris or grease, odour, frothing, colour/ appearance of water, and flow conditions. An example of the field sheet is provided in Appendix B.

3.3 Bacteriological analysis

All bacteriological samples were analysed for faecal coliforms and enterococci, and one sample from each site was analysed for *Escherichia coli*. From 6 October 1994 to 27 February 1995 samples were analysed by Microtech Laboratories (NSW) Pty Ltd, using methods described in *Standard Methods for the Examination of Water and Wastewater* (18th ed. 1992) sections 9222D, 9230Ca and 9225, respectively. Samples were analysed using the membrane filtration (MF) technique. The MF technique uses an enriched lactose (M-FC) medium and an incubation temperature of 44.5 ± 0.2°C for 24 ± 2 h for faecal coliforms and *E. coli*, and mE agar and incubation at 35.0 ± 0.5°C for 48 h for enterococci. This was followed by verification tests, which required up to a further 48 h of analysis.

Enterococci analysis involved two modifications in the confirmation step: the use of tryptone soya agar (TSA) instead of brain heart infusion agar (BHI) and a higher incubation temperature of 37°C instead of 35°C. Microtech Laboratories modified the faecal coliform and *E. coli* methods by overlaying the M-FC medium agar with resuscitation agar to improve recoveries.

From 5 March 1995, bacteriological samples were analysed by EML Consulting Services Pty. Ltd., using methods described in *Standard Methods for the Examination of Water and Wastewater* (18th ed. 1992) sections 9222D, 9230Ca and 9225. This laboratory does not modify the standard procedures.

The bacteriological analysis always started within eight hours of sample collection and the confirmed results were received from the laboratory within five working days of sample delivery.

The detection limit for bacteriological analysis is one colony-forming unit per 100 mL of sample (1 cfu/100 mL). Results reported as <1 cfu/100 mL were entered as half the detection limit (0.5 cfu/100 mL) for statistical analysis.

3.4 Algal counts

The concentrated samples collected by plankton net during this study were analysed for the presence of blue-green algae (*Microcystis* spp. and *Anabaena* spp.) cells. Where these species were detected, a full identification and count using the Lund cell technique (Lund *et al.* 1958) was carried out on the integrated vertical sample for that site.

3.5 Assessment of water quality data

The data were interpreted in three different ways. Firstly, on the advice of the Department of Health, the bacteriological data were assessed on a monthly basis in accordance with the NHMRC (1990) guidelines. Secondly, the bacteriological data were assessed on a seasonal basis as suggested by ANZECC (1992). Thirdly, the percentage compliance of the bacteriological, physico-chemical and algal data were assessed using the NHMRC (1990) and ANZECC (1992) criteria. A composite index for each site was also calculated using the NHMRC (1990) and ANZECC (1992) criteria.

Bacteriological data

As the NHMRC (1990) guidelines require five faecal coliform values per month, the geometric mean of the three replicate faecal coliform results for each site was calculated and used for further analysis. This geometric mean will be referred to as the *faecal coliform value.*

Monthly assessment: To assess the suitability of water for primary and secondary contact recreation on a monthly basis, the data were divided into six one-monthly periods. The median and the 80th percentile *faecal coliform values* were calculated for each monthly period. These values were compared to the NHMRC (1990) guidelines. To compare enterococci results with the NHMRC (1990) reference value, the enterococci data for each month were pooled (n=15) and the geometric mean was calculated for each site for each month. The number of months that each site complied with the guidelines was then determined.

Seasonal assessment: To assess the suitability of water for primary and secondary contact recreation on a seasonal basis (i.e. October 1994 to March 1995), the median and the 80th percentile for all *faecal coliform values* (n=30) for each site were calculated and compared to the guidelines. The enterococci data for the season were pooled (n=90) and the geometric mean was calculated for each site. The sites which complied with the guidelines on a seasonal basis were then determined.

Overall assessment

To gain an overview of recreational water quality using all relevant indicators, each parameter was assessed as follows:

For *secondary contact* recreation, the indicators faecal coliforms[1], algae and surface films were used. For *primary contact* recreation, the parameters faecal coliforms[2], pH, temperature, clarity, oily films and algae were used. The percentage of sampling days that each parameter complied with the relevant criteria was calculated. Not all parameters were measured on all sampling occasions, however, because of technical difficulties. Missing observations were not included in the following calculations.

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1 For this purpose a daily faecal coliform value (geometric mean) of 1000 cfu/100 mL (n=3) was used as the criterion.

2 For this purpose a daily faecal coliform value (geometric mean) of 200 cfu/100 mL (n=3) was used as the criterion.

A *composite index* was calculated for each site using the parameters mentioned above. This index represents the percentage of sampling occasions on which all parameters complied with the relevant criteria.

3.6 Rainfall data

Daily rainfall data were obtained for each of the 13 sites from gauging stations located in the vicinity of the sampling sites. Where possible, the total rainfall for the six days preceding each sampling day was calculated for each site.

The rainfall gauge station number and location used for each sampling site are listed in Appendix C.

3.7 Regression analyses

To examine potential relationships between faecal bacterial densities and other parameters, a simple linear regression analysis was performed for each site using:

- rainfall as the independent (X) variable and bacterial density as the dependent (Y) variable
- turbidity as the independent (X) variable and bacterial density as the dependent (Y) variable
- rainfall as the independent (X) variable and turbidity as the dependent (Y) variable
- faecal coliforms as the independent (X) variable and *E. coli* as the dependent (Y) variable (data from March 1995 were not used due to problems encountered in laboratory reporting).

The coefficient of determination (r^2) was calculated for each regression analysis.

To examine the relationship between turbidity and Secchi distance/depth, a simple linear regression analysis was performed using:

- turbidity was used as the independent (X) variable and (horizontal Secchi distance)$^{-1}$ as the dependent (Y) variable
- turbidity was used as the independent (X) variable and (vertical Secchi depth)$^{-1}$ as the dependent (Y) variable.

The proportion (or percentage) of the total variation in Y that is explained or accounted for by the fitted regression is termed the *coefficient of determination,* r^2 (Zar 1974). For example if there is a strong relationship between rainfall and faecal bacterial densities at a particular site, r^2 will approach or equal 1 (or 100 %); if the relationship is weak r^2 will approach or equal 0 (0 %).

3.8 South Creek, Eastern Creek and Cattai Creek study

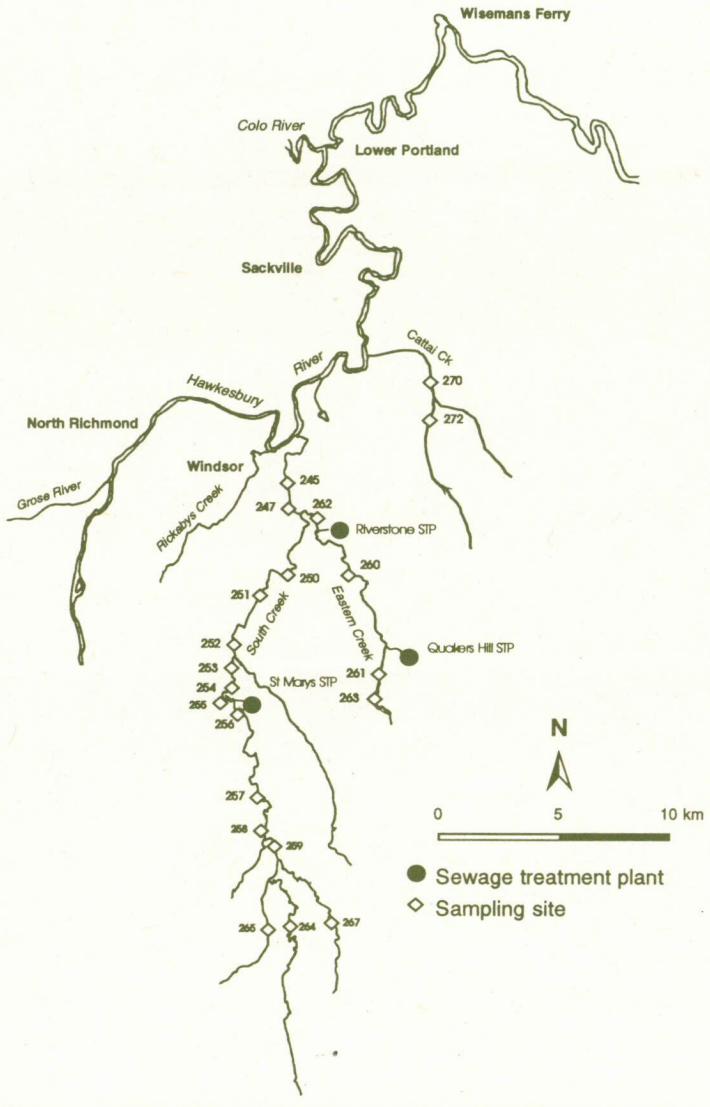
Because high bacterial densities were found at South Creek and Macquarie Park during April to September 1994 (EPA 1995), the EPA initiated a study of bacterial densities in South Creek, Eastern Creek and Cattai Creek subcatchments in December 1994 with a view to identifying the sources of faecal contamination.

Table 2
South Creek, Eastern Creek and Cattai Creek: Sampling site locations, site codes and number of samples collected

Site code	Sampling site location	Distance from confluence (km)	No. of samples
245	South Ck at Chisholm Place	5.3	10
247	South Ck at Sanctuary Drive	7.2	10
250	South Ck at Richmond Road Bridge	13.1	11
251	South Ck at Stoney Creek Road	17.7	11
252	South Ck at Sixth Avenue	21.1	10
253	South Ck at Ninth Avenue	22.6	11
254	South Ck at ADI* Crossing	24.5	8
255	South Ck at Hartog Drive	26.5	11
256	South Ck at Christie Street	28.9	11
257	South Ck at Luddenham Road Bridge	37.9	11
258	South Ck at Lot 815 Luddenham Road	40.8	10
259	South Ck at Water Supply Pipeline	42.1	10
260	Eastern Ck at Garfield Road	14.1	11
261	Eastern Ck at Richmond Road	24.3	8
262	Eastern Ck at Level Crossing Road	8.8	11
263	Eastern Ck at Power Street	26.1	8
264	South Ck at Elizabeth Drive	50.1	11
265	Badgerys Ck at Elizabeth Drive	49.7	11
267	Kemps Ck at Elizabeth Drive	51.1	11
270	Cattai Ck at Cattai Ridge Road	8.9	11
272	Cattai Ck at Pitt Town Road	12.3	11

* Australian Defence Industries

Figure 2
Sampling sites on South Creek, Eastern Creek and Cattai Creek



From 20 December 1994 to 9 May 1995 a total of 21 sites were sampled fortnightly: 13 sites in South Creek, 4 sites in Eastern Creek, 1 site in Badgery's Creek, 1 site in Kemps Creek and 2 sites in Cattai Creek (Figure 2, Table 2 and Appendix D). Sites were sampled fortnightly, rather than five times per month, as the purpose of sampling was to identify sources, rather than to assess suitability for recreation. Sites were selected on the basis of their location in relation to major point sources (e.g. sewage treatment plants) and diffuse sources (e.g. intensive agriculture) in each of the sub-catchments. Not all sites were sampled on all occasions.

Sampling procedure

One water sample was collected for bacteriological analysis at each site from a depth of approximately 15 cm. Samples were collected in sterile 150 mL plastic containers using aseptic techniques. The samples were stored on ice and transported in a portable ice chest ('esky'). Samples were stored overnight in a domestic refrigerator.

Bacteriological analysis

Samples were analysed for faecal coliforms by Microtech Laboratories (NSW) Pty Ltd, using the methods described in *Standard Methods for the Examination of Water and Wastewater* (18th ed. 1992) section 9222D. Samples were analysed using the membrane filtration (MF) technique. The MF technique uses an enriched lactose (M-FC) medium and an incubation temperature of 44.5 ± 0.2°C for 24 ± 2 h. This was followed by verification tests, which required up to a further 48 hours of analysis. Microtech Laboratories modified the faecal coliform method by overlaying the M-FC medium agar with resuscitation agar to improve recoveries.

It was not possible to deliver the samples to the laboratory on the same day as collection due to time constraints. Bacteriological analysis started, however, within 24 hours of sample collection. Confirmed results were received from the laboratory within seven days of sample delivery. The detection limit for the bacteriological analysis was 10 cfu/100 mL. Results reported as <10 cfu/100 mL were entered as half the reporting limit (5 cfu/100 mL) for statistical analysis.

Assessment of data

The minimum, 25th percentile, median, 75th percentile and maximum faecal coliform values for each site were calculated (the number of observations at each site varied from eight to 11). These values were plotted with distance from the confluence of South and Eastern Creeks with the mainstream Hawkesbury River.

4. QUALITY ASSURANCE/QUALITY CONTROL (QA/QC)

4.1 QA/QC procedures

All procedures were fully documented, including preparation for sampling, locations of sampling sites, sampling procedures, sample

storage and transport. All samples were submitted 'blind' to the laboratory, i.e. the laboratory was not advised of the locations from which the samples were taken. Sample codes were chosen randomly to prevent the laboratory from becoming confident of expected levels.

Transportation and field blanks

Each team submitted two samples to the laboratory for bacteriological analysis (faecal coliforms and enterococci) after each sampling occasion as part of the program's QA/QC component. Each team prepared:

- a *transportation blank* - i.e. a QA/QC sample used to determine whether there had been any contamination during storage and transport. The transportation blank was a 500 mL sample of heat-sterilised river water which was poured aseptically into a sterile sample bottle on the day of sampling but before leaving the base. The sample was taken into the field from the base and was stored and transported with the field samples.
- a *field blank* - i.e. a QA/QC sample used to determine whether there had been any contamination during sample collection, storage and transport. The field blank was a 500 mL sample of heat-sterilised river water which was poured aseptically into a sterile sample bottle at the first sampling site. The sample was then stored and transported with the field samples.

River water for the *transportation blanks* and *field blanks* was heat-sterilised (autoclaved) by the Division of Analytical Laboratories (Department of Health) prior to each sampling occasion.

Duplicate samples

To assess laboratory precision, each team collected two *duplicate* samples during each sampling day. For the duplicate samples, a one litre sample was collected using a pre-rinsed 1.5 litre container that was then shaken vigorously for one minute to homogenise the sample. This one litre sample was then decanted into two sterile 500 mL sample containers.

Laboratory comparison

To assess any differences between the two analytical laboratories used in this study (Microtech Laboratories and EML Consulting Services), an inter-laboratory comparison was performed on 5 March 1995. Twenty-six samples were collected randomly at the 13 sites. Each site was sampled

Figure 3
Faecal coliform data for duplicated samples
Data collected 6 October 1994 to 30 March 1995

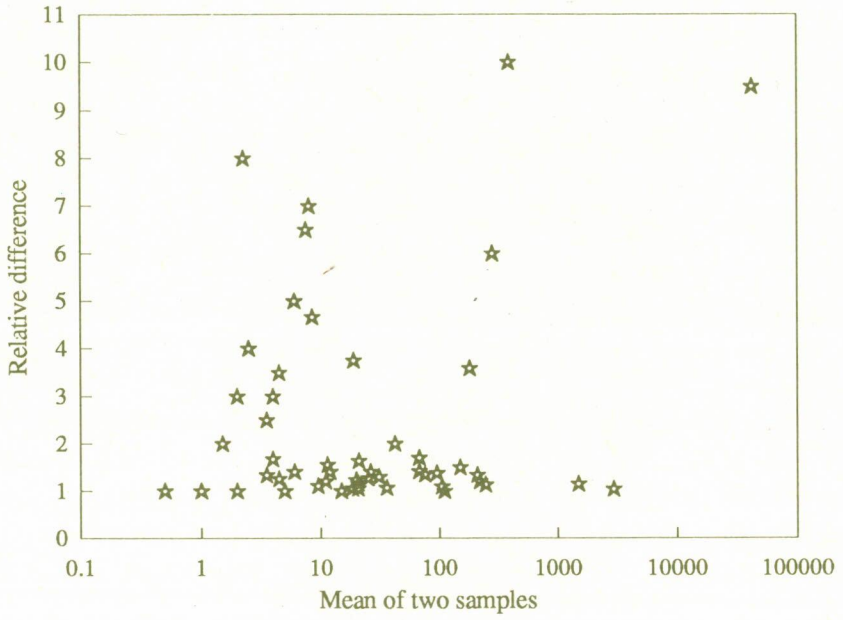
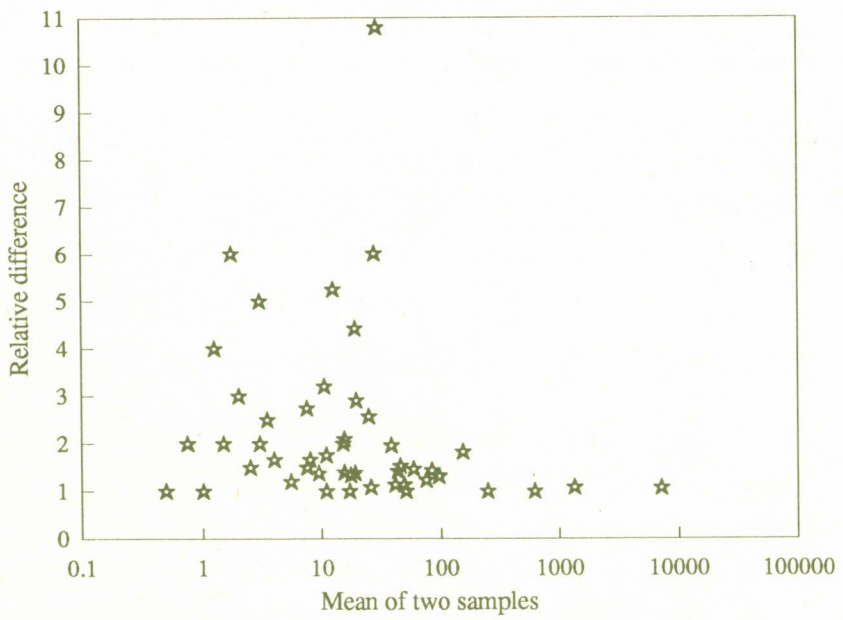


Figure 4
Enterococci data for duplicated samples
Data collected 6 October 1994 to 30 March 1995



at least once, with a few sites sampled three times. Each sample consisted of one litre of river water which was collected in a prerinsed 1.5 litre container. This was then shaken vigorously for one minute to homogenise the sample. Each sample was then aseptically divided into two sterile 500 mL sample containers, one of which was submitted to Microtech Laboratories and one to EML Consulting Services. A total of 52 samples were submitted — 26 to EML Consulting Services and 26 to Microtech Laboratories.

4.2 QA/QC results

Transportation and field blanks

A total of 112 blank samples were submitted to the laboratories during the study period. Of these, five samples were contaminated. One transport blank was contaminated with enterococci (20 cfu/100 mL) and two transport blanks were contaminated with faecal coliforms (18 cfu/100 mL and 100 cfu/100 mL respectively). Two field blanks were contaminated with enterococci and faecal coliforms (160 cfu/100 mL and 10 cfu/100 mL respectively). The contaminated transport and field blanks did not occur on the same occasions. It is not believed that this contamination affects the interpretation of the data in this report.

Duplicate samples

The mean faecal coliform density for each pair of duplicate samples was calculated. The relative difference between the faecal coliform densities for each pair of samples was calculated by dividing the higher value of the pair by the lower value. These values were plotted using the mean value on a $\log_{10}$ scale as the independent (X) variable and the relative difference value as the dependent (Y) variable (Figure 3). Two points were excluded from the graph as the relative differences were 40 (the two results were <1 cfu/100 mL and 20 cfu/100 mL) and 66 (<1 cfu/100 mL and 33 cfu/100 mL). This exercise was then repeated for the enterococci data (Figure 4). One point was excluded from the graph as the relative difference was 29 (the two results were 28 cfu/100 mL and 810 cfu/100 mL).

The results of this study demonstrate that variability in faecal bacterial densities was high. For example, where there is a relative difference of 2.0, one of the duplicates had faecal bacterial densities twice as high as the other sample.

This suggests that sites can comply or not comply with the guidelines because of sample heterogeneity and low analytical precision. The relative differences indicate a high degree of analytical variability and accordingly the results need to be interpreted with caution.

Laboratory comparison

The data from the inter-laboratory comparison for faecal coliforms and enterococci were natural log transformed and a two-tailed paired t-test was used to test the null hypothesis that there are no significant differences between the laboratory results (Zar 1974).

For faecal coliforms the null hypothesis was accepted as no significant difference between laboratory results was found:

($v = 25$, $t = 0.94$, $t_{0.05(2),25} = 2.060$, $p = 0.3547$).

For enterococci, however, the null hypothesis was rejected as a significant difference between laboratory results was found:

($v = 25$, $t = 4.42$, $t_{0.05(2),25} = 2.060$, $p = 0.0002$). Of the 26 pairs of observations, Microtech Laboratories reported the lower value on 18 occasions.

While there was a significant difference between laboratories for enterococcus analyses, enterococci are only used as an indicator of residual faecal contamination. Faecal coliforms are the indicator used by health authorities to assess recent faecal contamination and hence the suitability of the water for contact recreation.

5. RESULTS AND DISCUSSION

5.1 Faecal bacteria

Monthly assessment

Bacteriological data were assessed against the NHMRC (1990) guidelines. The number of months that each site complied with the guidelines is summarised in Table 3.

Based on the faecal coliform criteria, 12 of the 13 sites were suitable for secondary contact recreation throughout their sampling period (Table 3). Hawkesbury River at Macquarie Park [F] did not comply with the guidelines for secondary contact in February 1995.

Eleven of the 13 sites also complied with the faecal coliform criteria for primary contact recreation throughout their sampling period. The remaining two sites (Hawkesbury River at Macquarie Park [F] and South Creek at Governor Phillip Park ramp [G]) did not comply for five and four months respectively.

Of the 13 sites, however, six exceeded the enterococcus reference value for primary contact recreation for periods of one to six months (Table 3). The reference value was developed for marine and estuarine waters and is not used by health authorities to define suitability for primary contact recreation. Enterococci tend to survive longer in water than faecal coliforms so their presence at elevated levels in water that contains few faecal coliforms may indicate some residual faecal bacterial contamination.

Of the six sites with elevated enterococcus values, four had low faecal coliform values. These four sites, then, may have experienced some residual faecal bacterial contamination at times: Menangle Bridge and Berowra Creek for one month; Cattai National Park for two months; and

Table 3
Number of months between October 1994 and March 1995 that each site complied with NHMRC (1990) guidelines for **primary** and **secondary** contact recreation

Site code	Primary contact		Secondary contact
	Faecal coliforms	Enterococci	Faecal coliforms
Menangle Bridge [A]	6	5	6
Bents Basin [B]	6	6	6
Tench Reserve [C]	6	3	6
Jellybean Pool [D]	6	6	6
Yarramundi Bridge [E]	6	6	6
Macquarie Park [F]	1	0	5
South Creek [G]	2	2	6
Cattai National Park [H]	6	4	6
Sackville Ferry [I]	2*	2*	2*
Lower Portland [J]	6	6	6
Wisemans Ferry [K]	6	6	6
One Tree Reach [L]	6	6	6
Berowra Ferry [M]	6	5	6

* This site was sampled in February and March 1995 only.

Tench Reserve for three months. These findings suggest that, when these sites have received contaminated water, the contamination has occurred some distance upstream. By the time the contaminated water has reached the recreation site, the contamination is is no longer fresh, most faecal bacteria have died off and only a few more resistant organisms remain.

Comparison with the winter 1994 study period shows that suitability for secondary contact recreation was similar, with most sites complying throughout the season.

Macquarie Park [F] and South Creek [G] complied with the NHMRC (1990) faecal coliform criteria for primary contact recreation for fewer months during this summer than during the previous winter. Several sites (Menangle Bridge [A], Tench Reserve [C], Macquarie Park [F], Cattai NP [H] and Berowra [M]) exceeded the enterococcus guideline value more frequently during this summer than during the previous winter.

Only three sites (Bents Basin, Tench Reserve and South Creek) can be compared with the results for the summer 1993-94 season as these are the only sites which were sampled during both summer seasons in the exact same locations. In April 1994, sites were relocated on the basis of recreational use and to provide spatial coverage of the river between Menangle and Berowra Creek. Comparison with the previous summer shows that all three sites were suitable for secondary contact recreation for the entire study period during both summer seasons (EPA 1994). Suitability for primary contact recreation at these three sites during the previous summer was also similar.

Seasonal assessment

Assessing the data from an overall seasonal perspective (Table 4) and using faecal coliforms as the indicator, it can be concluded that all sites were suitable for secondary contact recreation during summer 1994-1995; and, with the exception of Hawkesbury River at Macquarie Park [F], also were suitable for primary contact recreation. South Creek [G], however, had an elevated enterococcus value, so probably experienced residual faecal bacterial contamination.

During the previous winter period, all sites were suitable for both primary and secondary contact recreation when assessed on a seasonal basis (EPA 1995). Seasonal compliance for most sites during this summer season was similar to the results for the winter 1994 season, with the exception of Macquarie Park [F]. This site showed a higher faecal coliform seasonal

median and 80th percentile and enterococci seasonal geometric mean for this summer period than for the winter period. South Creek [G] also showed a higher enterococci seasonal geometric mean for this summer period.

Conclusion

From the monthly and seasonal assessments it can be concluded that, on the basis of faecal bacterial contamination, both Macquarie Park and South Creek were generally unsuitable for primary contact recreation during summer 1994-95. Both sites were, however, usually suitable for secondary contact recreation. Other sites monitored were generally suitable for both primary and secondary contact recreation.

Table 4
Seasonal compliance at each site using the NHMRC (1990) bacteriological criteria for **primary** and **secondary contact** recreation

Site	Faecal coliforms		Enterococci
	Seasonal median (cfu/100 mL)	Seasonal 80th percentile (cfu/100 mL)	Seasonal geometric mean (cfu/100 mL)
Menangle Bridge [A]	24	64	19
Bents Basin [B]	3	28	5
Tench Reserve [C]	34	92	29
Jellybean Pool [D]	3	35	6
Yarramundi Bridge [E]	7	34	8
Macquarie Park [F]	343	1131	229
South Creek [G]	112	244	96
Cattai National Park [H]	30	68	16
Sackville ferry [I]	7	11	7
Lower Portland [J]	4	9	3
Wisemans Ferry [K]	4	15	2
One Tree Reach [L]	1	6	2
Berowra Ferry [M]	6	15	6
NHMRC (1990) limit primary contact	**150**	**600**	**33**
NHMRC (1990) limit secondary contact	**1000**	**4000**	-

5.2 Algae

A blue-green algal bloom (*Microcystis* spp. and *Anabaena* spp.) affected the recreational water quality between Cattai and Wisemans Ferry during the period December 1994 to March 1995. Cattai was affected by the bloom in December 1994; Sackville and Lower Portland from January to March 1995; and Wisemans Ferry in February 1995 (Table 5). During these periods the samples contained concentrations of blue-green algal cells in excess of 15,000 cells/mL and therefore exceeded the ANZECC (1992) guidelines for direct contact recreation.

Filamentous algae were present at Yarramundi Bridge for most of the season.

5.3 Visual clarity and colour

Horizontal Secchi distance was measured at six sites: Menangle Bridge [A], Bents Basin State Recreation Area [B], Tench Reserve ramp [C], Glenbrook Creek [D], Macquarie Park [F] and South Creek [G]. The number of observations and percentage of measurements of Secchi distance that were greater than 1.6 m for each site are shown in Table 6. Horizontal Secchi distances at Hawkesbury River at Macquarie Park [F] and South Creek at Governor Phillip Park [G] were always less than 1.6 m. When horizontal Secchi distance is less than 1.6 m, visual clarity is impaired and swimming may not have been safe.

Table 5
Number of samples collected at Windsor, Cattai, Sackville, Lower Portland and Wisemans Ferry that exceeded ANZECC (1992) guidelines for algae concentrations suitable for **direct contact recreation** (the number of samples analysed is in brackets)

	No. of samples exceeding 15,000 cells/mL				
Month	**Windsor**	**Cattai**	**Sackville Ferry**	**Lower Portland**	**Wisemans Ferry**
October 1994	0 (4)	0 (4)	-	0 (4)	0 (4)
November 1994	0 (5)	0 (5)	-	0 (5)	0 (5)
December 1994	0 (4)	2 (4)	-	0 (4)	0 (4)
January 1995	0 (4)	1 (4)	-	2 (4)	0 (4)
February 1995	0 (4)	1 (4)	3 (4)	4 (4)	3 (4)
March 1995	0 (5)	0 (5)	1 (5)	2 (5)	0 (5)

Vertical Secchi depth was measured at Cattai NP, Sackville ferry, Lower Portland, Wisemans Ferry, One Tree Reach and Berowra ferry. Data for these sites are listed in Appendix A. Cattai NP and Sackville had the poorest clarity, with maximum vertical Secchi depths of 0.9 m. Vertical Secchi depth at Lower Portland varied from 0.5–1.9 m, Wisemans Ferry from 0.3–3.3 m, One Tree Reach from 0.4–3.1 and Berowra ferry from 0.3–2.4 m.

5.4 pH

During October and November 1994 pH levels at Yarramundi Bridge [E] and Cattai National Park [H] were elevated (>pH 9.0) on nine and six sampling occasions respectively, thereby rendering the water unsuitable for primary contact recreation. This was probably caused by the photosynthetic activity of filamentous algae at Yarramundi [E] and phytoplankton at Cattai National Park [H]. On one sampling occasion in February, pH exceeded 9 at Sackville [I] and Lower Portland [J], probably caused by the blue-green algae bloom in the area. At all other sites, pH was suitable for primary contact recreation throughout the study period (Table 6).

5.5 Temperature

Water temperatures ranged from 16.1°C at Jellybean Pool [D] in October 1994 to 28.5°C at Macquarie Park [F] in December 1994. Temperatures were suitable for primary contact recreation at all sites during summer 1994-95.

5.6 Surface films

Surface films were detected at some sites on some occasions (see Appendix A and Tables 6 & 7). The highest occurrences of surface films were at sites where there are boat launching ramps (Tench Reserve [C] and South Creek [G]).

5.7 Overall assessment of recreational water quality

The percentage compliance of each site with the relevant guidelines for **primary** and **secondary** contact recreation for the entire sampling period is summarised in Tables 6 and 7 respectively. Summary of these data follows. Detailed site assessments are provided in Appendix A, and include bacteriological data, the range and mean of the physico-chemical data, the number of observations for each site and the bacterial and rainfall data plotted through time.

A composite index, which provides in a single value an overall assessment of the suitability of each site for either primary or secondary contact recreation, is provided in Tables 6 and 7. This index is presented for the first time in this report and is intended to facilitate interpretation and understanding of an otherwise complex set of data. The index records the percentage of time during summer 1994-95 that all parameters at the site

Table 6
Percentage compliance against each index, including the composite index, at each site for **primary contact recreation**, October 1994 to March 1995
(the number of observations is in brackets and NM is 'not measured')

Site	Percentage compliance						
	Faecal coliforms	Algae	Clarity	pH	Temp.	Oily films	Composite index
A	97 (30)	100 (30)	45 (29)	100 (30)	100 (30)	100 (30)	50
B	93 (30)	100 (30)	75 (28)	100 (30)	100 (30)	97 (30)	80
C	90 (30)	100 (30)	61 (28)	100 (30)	100 (30)	90 (30)	63
D	90 (30)	100 (30)	59 (29)	100 (30)	100 (30)	100 (30)	63
E	97 (30)	100 (30)	NM	69 (29)	100 (30)	97 (30)	67
F	33 (30)	100 (26)	0 (29)	100 (29)	100 (30)	87 (30)	0
G	67 (30)	100 (26)	0 (29)	100 (29)	100 (30)	57 (30)	3
H	93 (30)	85 (26)	NM	79 (29)	100 (29)	97 (30)	53
I	100 (10)	55 (9)	NM	90 (10)	100 (10)	100 (10)	60
J	100 (30)	69 (26)	NM	97 (29)	100 (29)	100 (30)	67
K	100 (30)	88 (26)	NM	100 (29)	100 (29)	100 (30)	90
L	100 (30)	100 (26)	NM	100 (29)	100 (30)	100 (30)	100
M	97 (30)	100 (26)	NM	100 (28)	100 (30)	83 (30)	80

A Nepean River at Menangle Road Bridge
B Nepean River at Bents Basin State Recreation Area
C Nepean River at Tench Reserve ramp (Regentville)
D Glenbrook Creek at Jellybean Pool
E Nepean River at Yarramundi Bridge
F Hawkesbury River at Macquarie Park (Windsor)
G South Creek at Governor Phillip Park ramp (Windsor)
H Hawkesbury River at Cattai National Park
I Hawkesbury River at Sackville ferry
J Hawkesbury River at Lower Portland
K Hawkesbury River at Wisemans Ferry
L Hawkesbury River at One Tree Reach
M Berowra Creek at the ferry

complied with the relevant guidelines. For example, where the index for a site is 100, this means that every parameter complied with the guidelines on every sampling occasion, i.e. there was full compliance throughout the season. Where, however, the index is say 60, this means that on 40% of occasions at least one parameter did not comply with the relevant guidelines, i.e. there was full compliance only 60% of the time.

Water temperatures at all sites were suitable for primary contact recreation for the entire sampling period (Table 6). Secchi distance was consistently below 1.6 m at Macquarie Park [F] and South Creek [G], with the remaining sites showing variable compliance. Oily films were occasionally present and appear to be associated with the operation of power boats. Percentage compliance of faecal bacterial levels varied from 33% to 100%, with most (11 of 13) sites complying at least 90% of the time. Cattai NP [H], Sackville ferry [I], Lower Portland [J] and Wisemans Ferry [K] sites had high levels of blue-green algae at various times, thus affecting suitability for direct contact recreation.

Table 7
Percentage compliance against each index, including the composite index, at each site for **secondary contact recreation**, October 1994 to March 1995
(the number of observations is in brackets)

Site	Percentage compliance			
	Faecal coliforms	**Algae**	**Oily films**	**Composite index**
Menangle Bridge [A]	97 (30)	100 (30)	100 (30)	97
Bents Basin [B]	100 (30)	100 (22)	97 (30)	97
Tench Reserve [C]	97 (30)	100 (30)	90 (30)	87
Jellybean Pool [D]	100 (30)	100 (30)	100 (30)	100
Yarramundi Bridge [E]	100 (30)	100 (30)	97 (30)	97
Macquarie Park [F]	77 (30)	100 (26)	87 (30)	67
South Creek [G]	93 (30)	100 (26)	57 (30)	53
Cattai National Park [H]	100 (30)	85 (26)	97 (30)	80
Sackville ferry [I]	100 (10)	55 (9)	100 (10)	60
Lower Portland [J]	100 (30)	69 (26)	100 (30)	67
Wisemans Ferry [K]	100 (30)	88 (26)	100 (30)	90
One Tree Reach [L]	100 (30)	100 (26)	100 (30)	100
Berowra Ferry [M]	97 (30)	100 (26)	87 (30)	80

A comparison of the summer 1994-95 data with those from winter 1994 (EPA 1995) shows that percentage compliance for faecal coliforms, algae, clarity, pH and oily films were similar at most sites during both seasons. Temperatures, however, showed 100% compliance in summer at all sites compared with failures at most sites for much of the winter period. Percentage compliance with faecal coliform criteria at Macquarie Park [F] and South Creek [G] was lower for the summer season than for the winter season. Algal levels at Lower Portland had a higher percentage compliance during summer than during the previous winter season.

Composite indexes for the 13 sites for primary contact recreation ranged from 0 (Macquarie Park) to 100 (One Tree Reach) (Table 6). Macquarie Park failed to comply with at least one criterion on any occasion while One Tree Reach complied on all occasions. Even though percentage compliance for clarity at South Creek [G] was zero, this site scored an index of 3 as there was a missing value for this parameter on one occasion (the method used for calculating the composite index does not include missing values). Most sites were suitable for primary contact recreation for more than half the time.

- Menangle Bridge [A] was unsuitable for 50% of the time due mainly to poor clarity (horizontal Secchi distance) and high faecal coliform levels
- Bents Basin [B] was unsuitable for 20% of the time due mainly to poor clarity
- Tench Reserve [C] was unsuitable for 37% of the time due mainly to poor clarity, although there was also occasionally oily films and high faecal coliform levels
- Jellybean Pool [D] was unsuitable for 37% of the time due to poor clarity, although there was occasionally high faecal coliform levels
- Yarramundi Bridge [E] was unsuitable for 33% of the time due mainly to high pH levels
- Macquarie Park [F] was unsuitable for 100% of the time due mainly to poor clarity, high faecal coliform levels and oily films
- South Creek [G] was unsuitable for 97% of the time due mainly to poor clarity, high faecal coliform levels and oily films
- Cattai NP [H] was unsuitable for 47% of the time due mainly to high pH and elevated densities of blue-green algae

- Sackville [I] Ferry was unsuitable for 40% of the time due mainly to elevated densities of blue-green algae
- Lower Portland [J] was unsuitable for 33% of the time due mainly to elevated densities of blue-green algae
- Wisemans Ferry [K] was unsuitable for 10% of the time due mainly to elevated densities of blue-green algae
- One Tree Reach [L] was suitable 100% of the time
- Berowra Creek [M] was unsuitable for 20% of the time due mainly to oily films and occasionally high faecal coliform levels.

Based on faecal coliform results, all sites except Macquarie Park [F] were mostly suitable for **secondary contact recreation** during the 1994-95 summer season (Table 7). Sackville Ferry [I] and Lower Portland [J] were unsuitable for direct contact activities for some of the sampling period due to presence of an algal bloom (Table 7).

Percentage compliance with faecal coliform criteria for secondary contact recreation was slightly lower during this summer at five sites (A, C, F, G and H) compared to than during winter (EPA 1995). Compliance with the algae criterion during summer was similar to the winter season, except for Lower Portland which had an increased percentage compliance during summer. The number of occasions that oily films were observed was also similar to the previous winter at all sites.

Jellybean Pool [D] and One Tree Reach [L] both had composite indixes of 100 and thus were suitable for secondary contact recreation during the entire sampling period. Menangle Bridge [A], Bents Basin [B] and Yarramundi Bridge [E] had index scores of 97 and were suitable for secondary contact recreation 97% of the time. The remaining sites were suitable for secondary contact recreation for more than half the time. South Creek [G] had the lowest index, 53, oily films being the usual cause of non-compliance.

5.8 Regression analyses

Establishing the existence of relationships between the parameters measured during this study is important because should a strong relationship be found, it may be possible to use the independent variable to predict the dependent variable. For example, to predict bacterial density or turbidity from rainfall.

Regression analyses of faecal coliform densities against rainfall resulted in varying coefficients of determination. No strong relationship was found at Bents Basin [B], Tench Reserve [C] or Macquarie Park [F]. Stronger relationships were found at Menangle Bridge [A], Glenbrook Creek [D], South Creek [G] and Berowra [M] with the r^2 values ranging from 0.570 to 0.806 (Appendix E).

Regression analyses of enterococcus densities on rainfall also resulted in varying coefficients of determination. No relationship was found at Macquarie Park [F] (r^2=0.004). Stronger relationships were found at Menangle Bridge [A], Yarramundi Bridge [E] South Creek [G] and Berowra [M] with r^2 values ranging from 0.534 to 0.829. The highest relationship was found at Berowra [M] both for faecal coliforms and enterococcus. The relationships between bacteriological densities and rainfall were generally higher than in winter 1994, possibly due to the higher rainfall in the summer period.

There was a positive relationship between enterococci and turbidity at Menangle Bridge, Bents Basin, Tench Reserve, Glenbrook Creek, Yarramundi Bridge, South Creek and Berowra Creek (Appendix E). Faecal coliform densities also were positively related with turbidity at Menangle Bridge, Bents Basin, Yarramundi Bridge, South Creek and Berowra Creek (Appendix E). No strong relationships were found at the remaining sites, indicating that factors other than turbidity had the primary influence on faecal coliform densities in the mainstream downstream of Windsor. High turbidity levels downstream of Windsor were often caused by the presence of algae in the water column and therefore not correlated with runoff. Faecal bacterial levels were generally low at these sites which also makes strong relationships unlikely.

Positive relationships between turbidity and rainfall were found at Tench Reserve (r^2 = 0.546), South Creek (r^2 = 0.748)and Berowra Creek (r^2 = 0.605) (Appendix E). No strong relationship was evident for the remaining sites with r^2 values ranging from 0.000 at Wisemans Ferry to 0.299 at Menangle.

There was a significant positive relationship between faecal coliforms and *E. coli*, with an r^2 value of 0.996. The relationship between faecal coliforms and *E. coli*, using the standard equation for a straight line (y=ax+b, where 'a' is the gradient and 'b' is the y intercept), was found to be:

E. coli = 0.905*(faecal coliforms) - 4.76(n = 303)

A positive relationship was found between (horizontal Secchi distance)$^{-1}$ and turbidity at Menangle, Bents Basin, Tench Reserve and Glenbrook. There was no strong relationship at South Creek and Macquarie Park (Appendix E). Cattai, Sackville, Wisemans Ferry, One Tree Reach and Berowra showed positive relationships between (vertical Secchi depth)$^{-1}$ and turbidity (Appendix E).

In general, it was found that faecal bacterial levels and turbidity increased with increasing rainfall at the following sites: Menangle Bridge, South Creek and Berowra ferry, but not at the remaining sites.

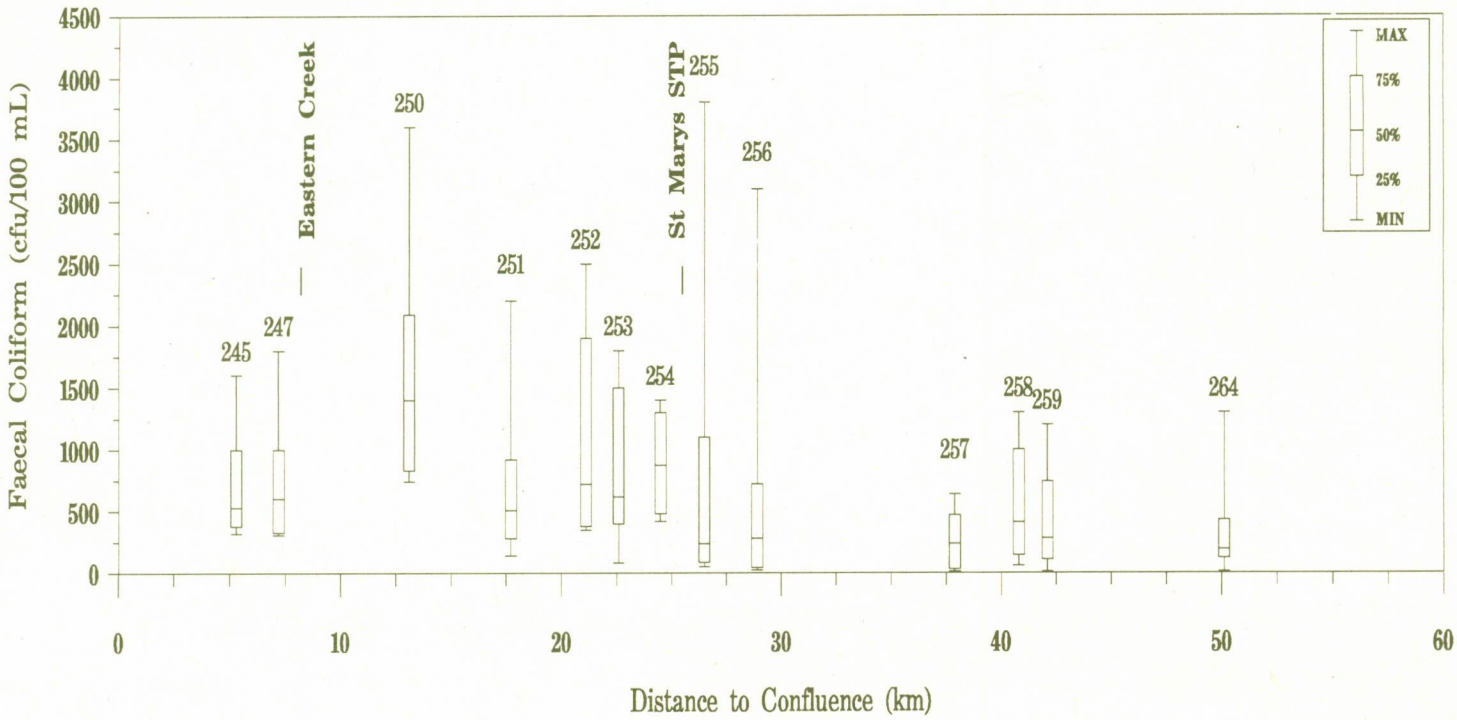
5.9 South Creek, Eastern Creek and Cattai Creek study

The results from this study are shown in Figures 5 and 6 and Table 8. Sites 245 and 247 are plotted on both Figures 5 and 6 as these sites are located downstream of the confluence of South Creek and Eastern Creek. The highest bacterial densities were found in Eastern Creek at Level Crossing Road [262] and in South Creek at Richmond Road Bridge [250]. The median values for these sites were 2000 and 1400 cfu/100 mL respectively. Further work is required to establish the causes of the high bacterial densities at these sites.

A median of 23 cfu/100 mL was found at Badgery's Creek [265] (Table 8). Median values at the remaining sites ranged from 140 to 820 cfu/100 mL. It should be noted that these results cannot be compared to the NHMRC (1990) guidelines as the sample frequency was fortnightly, rather than five samples per month as required by NHMRC (1990). There was a general trend of decreasing water quality with increasing distance from the headwaters of the creeks. This trend seems to reverse at the two most downstream sites (245 and 247), possibly due to the tidal influence and consequent dilution at these sites (Figures 5 and 6).

The high faecal bacterial densities found in South Creek confirms this as the source of the high densities experienced at the recreational site on South Creek at Governor Phillip Park. Further investigation is planned in order to determine the exact sources of contamination. Intensive sampling in the vicinity of Macquarie Park is planned to identify the source(s) of contamination at this site.

Figure 5
Faecal coliforms in South Creek, from Elizabeth Drive, Luddenham, to the confluence at Windsor
Data collected 20 December 1994 to 9 May 1995

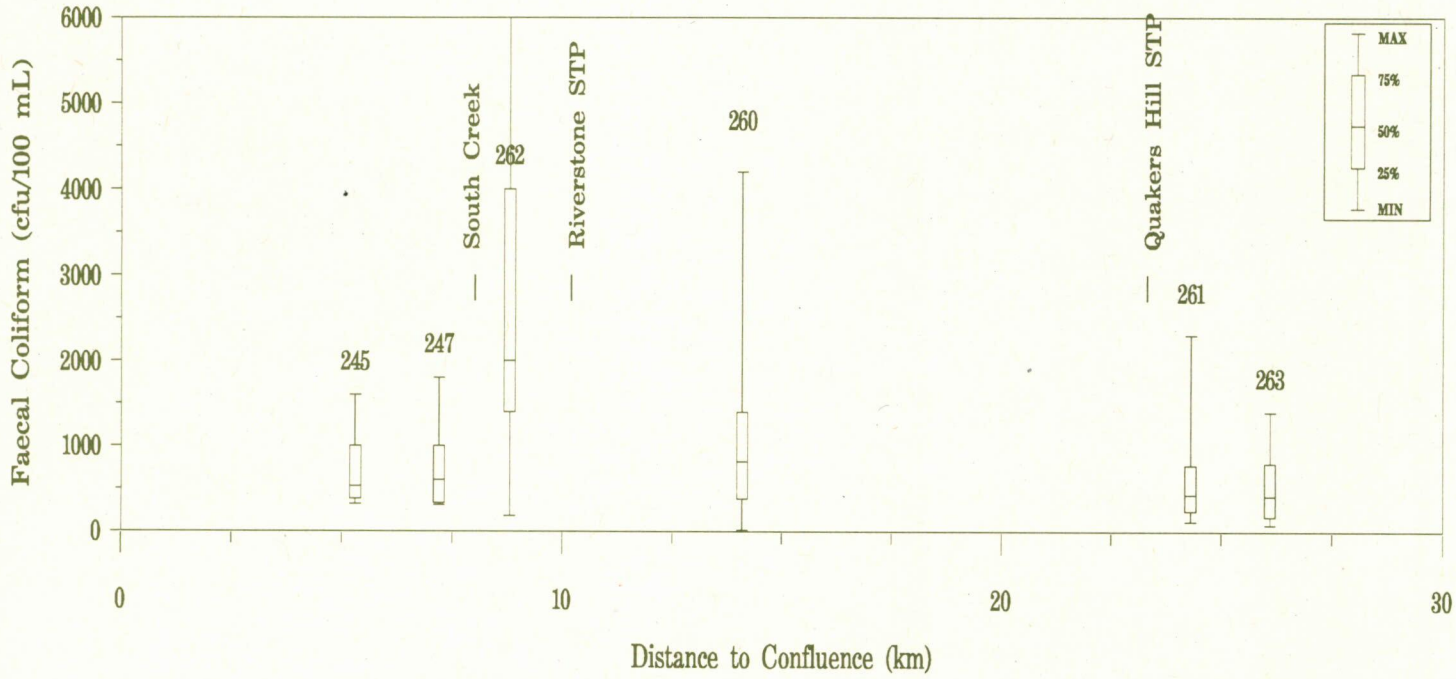


Note:
The number above the bars indicates the station number.

Figure 6

Faecal coliforms in Eastern Creek/South Creek, from Power Street, Blacktown, to the confluence at Windsor

Data collected 20 December 1994 to 9 May 1995



Note:
The number above the bars indicates the station number.
The maximum value of 36,000 at site 262 (distance = 8.8 km) was excluded from the graph.

Table 8
Summary faecal coliform results (cfu/100 mL) for Badgerys Creek, Kemps Creek and Cattai Creek, December 1994 to May 1995

	Percentage compliance			
Site name	**Badgerys Ck**	**Kemps Ck**	**Cattai Ck**	**Cattai Ck**
Ste no.	**265**	**267**	**270**	**272**
Maximum	500	1200	870	650
75th percentile	210	470	315	410
Median	23	280	170	140
25th percentile	20	68	38	95
Minimum	8	24	23	10

Site locations:

265 Badgerys Creek at Elizabeth Dr

267 Kemps Creek at Elizabeth Dr

270 Cattai Creek at Cattai Ridge Rd

272 Cattai Creek at Pitt Town Rd

6. CONCLUSIONS

From October 1994 to March 1995 (summer season) 12 recreational sites in the Hawkesbury-Nepean River system were suitable for secondary contact recreation (boating, wading). An extra site, which was added at Sackville in February 1995, was suitable for secondary contact recreation for the two months it was sampled. High faecal bacterial levels at Macquarie Park (Windsor) rendered the site unsuitable for secondary contact recreation during February 1995. A bloom of cyanobacteria (blue-green algae) between Cattai and Wisemans Ferry affected the recreational water quality during the period December 1994 to March 1995. Compliance with the relevant criteria for secondary contact recreation (faecal coliforms, algae and surface films) was similar to or slightly lower than compliance for the 1994 winter season.

Eleven of the 13 sites complied with the faecal coliform criteria for primary contact recreation for the entire study period. Two sites, Macquarie Park (Windsor) and South Creek (Windsor), failed for five and four months respectively. There was some evidence of residual faecal bacterial contamination at four other sites for one to three months. Most sites complied with the ANZECC (1992) criteria for pH and surface films at least 90 % of the time. Two sites (Macquarie Park, Windsor, and South Creek, Windsor) consistently failed the criterion for horizontal Secchi distance (i.e. clarity).

Water temperatures at all sites were suitable for primary contact recreation throughout the season.

Faecal coliform samples collected from the South Creek subcatchment from December 1994 to May 1995 showed very high bacterial densities. The highest median densities were found in Eastern Creek at Level Crossing Road and in South Creek at Richmond Road Bridge. The high faecal bacterial densities found in South Creek confirm this as the source of the high densities experienced at the recreational site on South Creek at Governor Phillip Park. Further investigation is planned in order to determine the exact sources of contamination. Intensive sampling in the vicinity of Macquarie Park is planned to identify the source(s) of contamination at this site.

Regression analyses of rainfall and faecal bacterial densities were performed. In general, it was found that faecal bacterial densities and turbidity increased with increasing rainfall at the following sites: Menangle Bridge, South Creek and Berowra ferry.

The EPA will continue to study recreational water quality in the Hawkesbury-Nepean River during the 1995 winter season. Results from the study will be published at the end of winter.

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APPENDIX A — DATA FROM EACH OF THE 13 SITES

Site A — Nepean River at Menangle Road Bridge

Site description

The samples were collected from the shore, about 50 m upstream of the bridge, on the eastern bank of the river. At that point the river is about 20 m wide and several metres deep.

Map ID: 9029 - 2 - S (1:25 000 topographic)
Latitude: 33°25'40" S
Longitude: 150°53'43" E

Recreational use

This site is a popular swimming location, with a picnic area nearby.

Compliance with guidelines

This site complied with the NHMRC (1990) bacteriological guidelines, using faecal coliforms as the indicator organism, for primary and secondary contact recreation during the 1994-95 summer season. This site, however, exceeded the enterococcus guideline value for primary contact recreation in January 1995. Surface films and algal blooms were not observed at this site. The water was usually clear.

Table A-A1
Summary data — Nepean River at Menangle Road Bridge,
6 October 1994 to 29 March 1995
(where total dissolved solids (mg/L) = electrical conductivity (µS/cm) x 0.64)

Parameter	Number of results	Minimum	Mean	Maximum
Electrical Conductivity (iS/cm)	30	166	509	716
Tbtal Dissolved Solids (mg/L)	30	106	326	458
Temperature (°C)	30	17.5	22.4	26.8
pH	30	6.5	7.6	8.8
Turbidity (NTU)	30	0	1.9	9
Salinity (‰)	30	0.1	0.2	0.4
Horizontal Secchi Distance (m)	29	0.6	1.6	2.8

Table A-A2
Bacteriological data for Nepean River at Menangle Road Bridge, [A] Faecal coliforms, [B] Enterococci & [C] *E. coli*, cfu/100mL

	A	B	C
06-OCT-94	29	10	22
	14	7	
	31	5	
12-OCT-94	29	9	12
	11	25	
	23	8	
18-OCT-94	88	35	86
	90	36	
	180	35	
24-OCT-94	20	33	18
	12	23	
	14	19	
30-OCT-94	72	80	82
	160	56	
	72	15	
05-NOV-94	9	13	6
	4	1	
	1	1	
11-NOV-94	42	8	45
	46	12	
	51	13	
17-NOV-94	43	81	38
	13	5	
	15	27	
23-NOV-94	32	27	13
	38	25	
	21	34	
29-NOV-94	44	13	28
	55		
	65	88	
05-DEC-94	71	38	100
	47	31	
	69	48	
12-DEC-94	32	18	25
	72	32	
	61	52	
17-DEC-94	90	32	56
	41	31	
	110	84	
23-DEC-94	40	14	40
	16	8	
	10	16	
29-DEC-94	80	19	88
	60	25	
	44	10	

	A	B	C
04-JAN-95	18	7	5
	22	4	
	13	13	
10-JAN-95	60	84	120
	110	66	
	92	98	
16-JAN-95	32	36	16
	17	12	
	10	10	
22-JAN-95	880	440	700
	1100	340	
	5600	1400	
28-JAN-95	64	18	76
	19	15	
	74	24	
03-FEB-95	5	2	1
	7	5	
	4	5	
09-FEB-95	15	2	13
	10	11	
	6	9	
15-FEB-95	14	24	29
	37	22	
	29	30	
21-FEB-95	14	3	10
	12	7	
	20	13	
27-FEB-95	11	230	12
	13	10	
	9	6	
05-MAR-95	40	73	
	200	75	
	590	58	
11-MAR-95	23	18	
	20	37	
	33	48	
17-MAR-95	4	0.5	
	25	14	
	18	13	
23-MAR-95	0.5	25	0
	0.5	19	
	0.5	18	
29-MAR-95	0.5	11	0.5
	0.5	6	
	11	8	

Figure A1 - Nepean River @ Menangle Bridge
Faecal coliform densities and associated rainfall

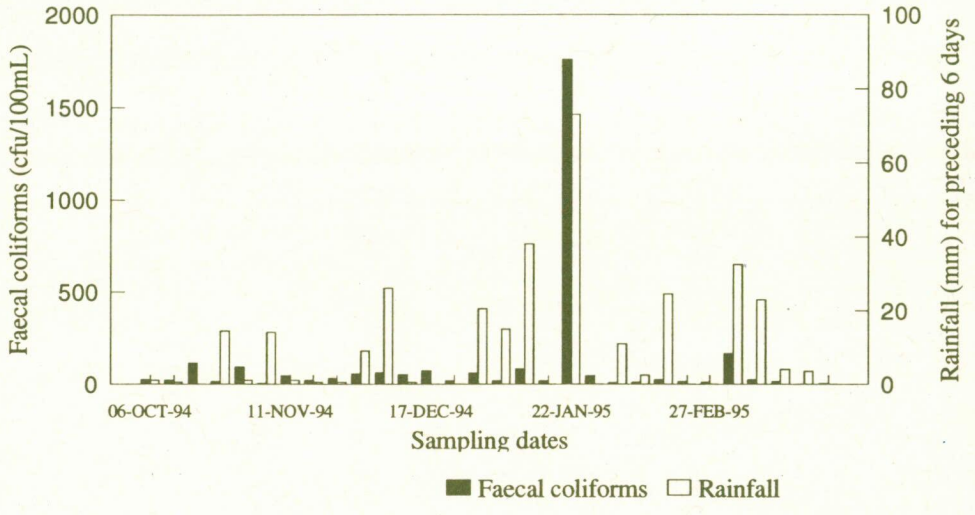
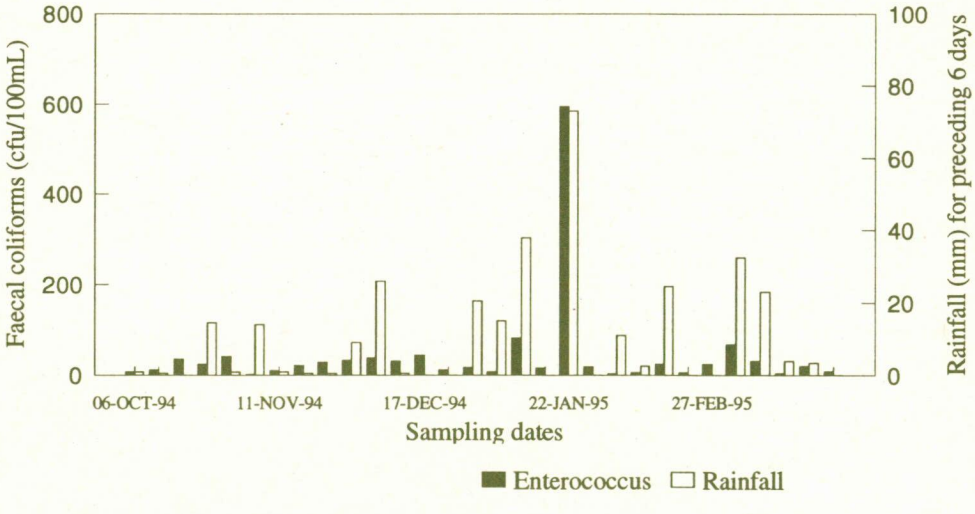


Figure A2 - Nepean River @ Menangle Bridge
Enterococcus densities and associated rainfall



Site B — Nepean River at Bents Basin State Recreation Area

Site description

This section of the river forms a wide and deep basin with an area of about 250 m x 150 m, and 24 m deep. The samples were collected from the shore, within 50 m of either side of the bridge, at the point where the river leaves the basin. Compared to the previous sampling period (October 1993 to March 1994), flow was low.

Map ID: 9030 - 3 - S (1:25 000 topographic)
Latitude: 33° 55' 59" S
Longitude: 150° 37' 53" E

Recreational use

This is a popular camping area and swimming location.

Compliance with guidelines

This site complied with the NHMRC (1990) guidelines over the entire sampling period. Oily films were observed on one sampling occasion. Horizontal Secchi distance was generally above the minimum of 1.6 m recommended by the ANZECC (1992) guidelines.

Table A-B1
Summary data — Nepean River at Bents Basin State Recreation 6 October 1994 to 29 March 1995
(where total dissolved solids (mg/L) = electrical conductivity (µS/cm) x 0.64)

Parameter	Number of results	Minimum	Mean	Maximum
Electrical Conductivity (iS/cm)	29	340	672	830
Total Dissolved Solids (mg/L)	29	218	430	531
Temperature (°C)	30	16.8	22.4	27.1
pH	30	7.0	7.9	8.3
Turbidity (NTU)	30	0	3.1	31
Salinity (‰)	30	0.2	0.3	0.4
Horizontal Secchi Distance (m)	28	0.1	1.9	2.8

Table A-B2
Bacteriological data for the Nepean River at Bents Basin State Recreation Area,
[A] Faecal coliforms, [B] Enterococci & [C] *E. coli*,
cfu/100mL

	A	B	C		A	B	C
06-OCT-94	1	4	1	04-JAN-95	51	4	32
	1	1			44	3	
	2	1			38	5	
12-OCT-94	3	2	3	10-JAN-95	5	6	4
	4	2			9	15	
	2	4			11	32	
18-OCT-94	15	3	12	16-JAN-95	4	34	
	33	11			86	42	
	80	7			53	29	
24-OCT-94	12	5	7	22-JAN-95	210	360	250
	4	2			290	360	
	6	9			220	200	
30-OCT-94	1	0.5	2	28-JAN-95	2	14	3
	2	2			0.5	22	
	6	0.5			1	10	
05-NOV-94	1	1	1	03-FEB-95	0.5	5	1
	1	1			1	4	
	0.5	0.5			1	4	
11-NOV-94	1	3	0.5	09-FEB-95	1	4	1
	0.5	2			0.5	14	
	0.5	0.5			0.5	3	
17-NOV-94	9	2	4	15-FEB-95	21	25	19
	2	6			35	23	
	3	0.5			15	33	
23-NOV-94	5	3	4	21-FEB-95	5	4	7
	2	1			5	94	
	1	0.5			5	7	
29-NOV-94	8	0.5	1	27-FEB-95	1	3	2
	9	6			2	1	
	17	2			2	1	
05-DEC-94	0.5	3	0.5	05-MAR-95	0.5	5	
	2	2			0.5	4	
	0.5	6			3	3	
12-DEC-94	1	5	0.5	11-MAR-95	7	32	
	3	2			21	15	
	3	6			10	22	
17-DEC-94	330	5	240	17-MAR-95	1	3	
	350	12			1	0.5	
	310	6			3	1	
23-DEC-94	110	2	40	23-MAR-95	1	11	5
	55	2			0.5	4	
	79	41			0.5	4	
29-DEC-94	170	5	190	29-MAR-95	0.5	7	0.5
	210	9			0.5	32	
	130	7			0.5	10	

Figure B1 - Nepean River @ Bents Basin

Faecal coliform densities and associated rainfall

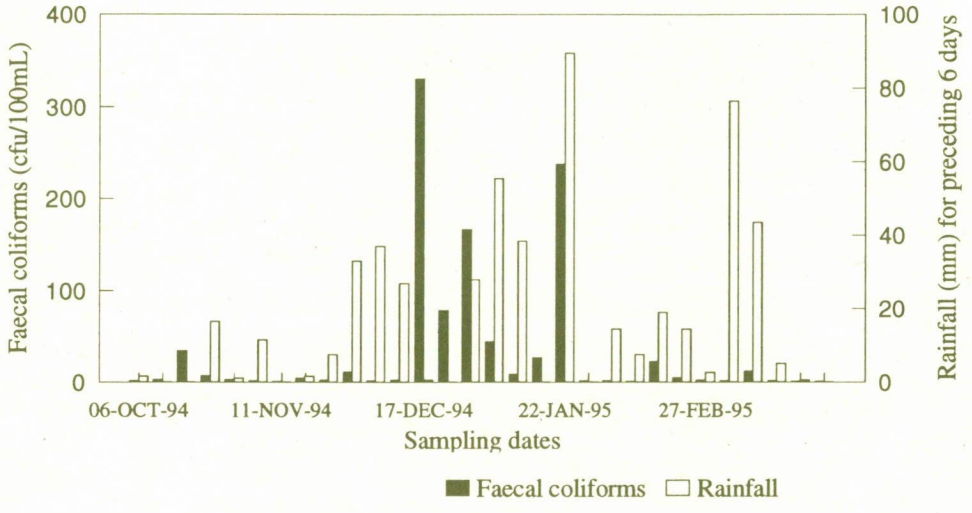
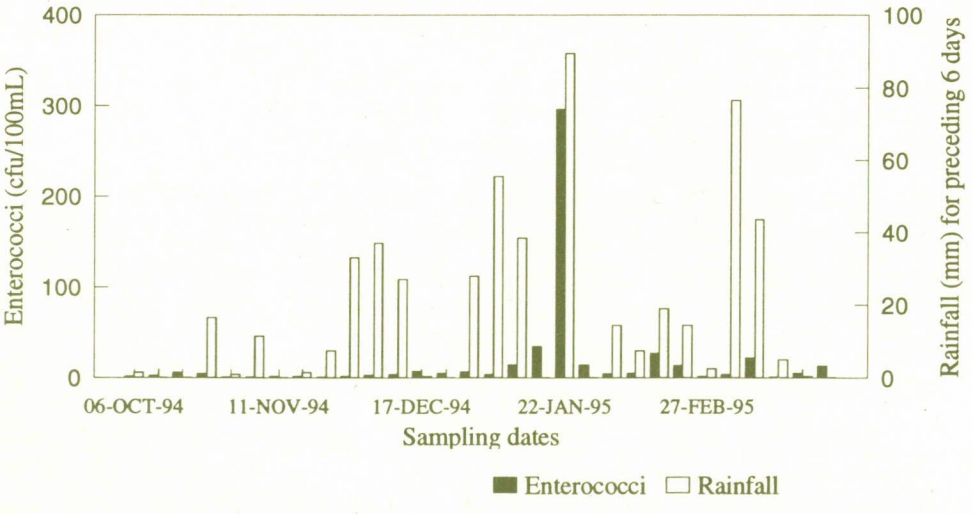


Figure B2 - Nepean River @ Bents Basin SRA

Enterococcus densities and associated rainfall



Site C — Nepean River at Tench Reserve ramp (Regentville)

Site description

The samples were collected from the boat ramp at Tench Reserve, Regentville (downstream of the Western Motorway bridge). The river is about 150 m wide and about 3 m deep at this point.

Map ID: 9030 - 3 - N (1:25 000 topographic)
Latitude: 33° 46' 0" S
Longitude: 150° 39' 39" E

Recreational use

This stretch of river is used for swimming, canoeing, rowing, boat launching, fishing and jet-skiing.

Compliance with guidelines

This site complied with the NHMRC (1990) bacteriological guidelines, using faecal coliforms as the indicator organism, for primary and secondary contact recreation during the 1994-95 summer season. This site, however, exceeded the enterococcus guideline value for primary contact recreation in January, February and March 1995. Surface films were observed on three sampling occasions. No algal blooms were observed at this site. The water was usually clear.

Table A-C1
Summary data — Nepean River at Tench Reserve ramp, (Regentville), 6 October 1994 to 29 March 1995
(where total dissolved solids (mg/L) = electrical conductivity (µS/cm) x 0.64)

Parameter	Number of results	Minimum	Mean	Maximum
Electrical Conductivity (iS/cm)	30	144	246	382
Total Dissolved Solids (mg/L)	30	92	157	244
Temperature (°C)	30	18.0	23.3	27.7
pH	30	6.9	7.8	8.2
Turbidity (NTU)	30	0	1.6	9
Salinity (‰)	30	0.1	0.1	0.2
Horizontal Secchi distance (m)	28	0.6	1.7	2.5

Table A-C2
Bacteriological data for Nepean River at Tench Reserve ramp (Regentville),
[A] Faecal coliforms, [B] Enterococci & [C] *E. coli*, cfu/100mL

	A	B	C
06-OCT-94	8	1	1
	3	4	
	9	10	
12-OCT-94	20	14	12
	23	69	
	8	3	
18-OCT-94	74	300	20
	21	10	
	30	15	
24-OCT-94	5	12	12
	12	25	
	7	64	
30-OCT-94	19	34	18
	25	14	
	24	74	
05-NOV-94	1800	7	1900
	580	2	
	43000	80	
11-NOV-94	15	1	10
	12	15	
	20	5	
17-NOV-94	46	81	3
	20	18	
	17	19	
23-NOV-94	56	45	12
	28	5	
	23	7	
29-NOV-94	40	52	10
	40	52	
	28	28	
05-DEC-94	34	23	0.5
	24	30	
	38	31	
12-DEC-94	58	430	30
	50	10	
	46	220	
17-DEC-94	41	15	84
	110	26	
	13	11	
23-DEC-94	300	68	260
	77	10	
	32	23	
29-DEC-94	74	33	32
	35	23	
	44	36	

	A	B	C
04-JAN-95	520	23	50
	340	29	
	530	57	
10-JAN-95	23	10	20
	17	12	
	18	8	
16-JAN-95	23	12	19
	16	24	
	41	19	
22-JAN-95	150	62	120
	150	78	
	130	80	
28-JAN-95	34	1800	32
	43	77	
	93	100	
03-FEB-95	8	26	22
	4	47	
	13	23	
09-FEB-95	16	8	7
	2	10	
	9	14	
15-FEB-95	94	49	30
	280	80	
	37	11	
21-FEB-95	61	20	50
	700	560	
	75	27	
27-FEB-95	23	59	27
	62	48	
	220	78	
05-MAR-95	4400	3400	
	700	330	
	300	200	
11-MAR-95	1	400	
	30	80	
	500	300	
17-MAR-95	80	43	
	66	54	
	53	29	
23-MAR-95	1	4	2
	0.5	13	
	4	5	
29-MAR-95	0.5	14	8
	0.5	13	
	0.5	20	

Figure C1 - Nepean River @ Tench Reserve boat ramp
Faecal coliform densities and associated rainfall

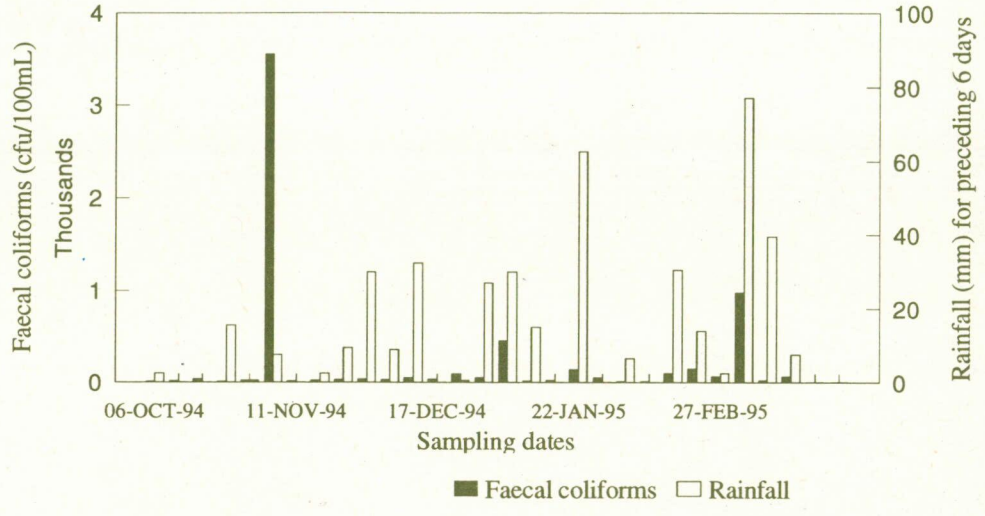
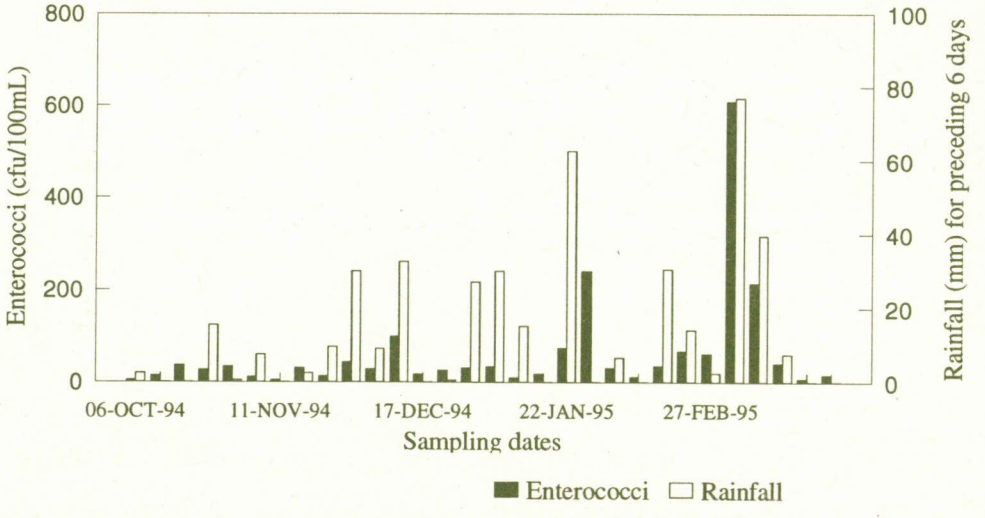


Figure C2 - Nepean River @ Tench Reserve boat ramp
Enterococcus densities and associated rainfall



Site D — Glenbrook Creek at Jellybean Pool

Site description

The samples were collected from the shore at Jellybean Pool. The creek is several metres wide at this point and 1-3 m deep. There was a constant flow during the sampling period, with flow increasing after periods of rain.

Map ID: (1:25 000 topographic)
Latitude: 33° 46' 85" S
Longitude: 150° 37' 15" E

Recreational use

This is a popular swimming and picnicking location.

Compliance with guidelines

This site complied with the NHMRC (1990) guidelines for the whole sampling period. The creek usually looked turbid after rain but was clear at other times. No algal blooms or surface films were observed.

Table A-D1
Summary data — Glenbrook Creek at Jellybean Pool,
6 October 1994 to 29 March 1995
(where total dissolved solids (mg/L) = electrical conductivity (µS/cm) x 0.64)

Parameter	Number of results	Minimum	Mean	Maximum
Electrical Conductivity (iS/cm)	30	112	171	256
Total Dissolved Solids (mg/L)	30	72	109	164
Temperature (°C)	30	16.1	21.4	26.6
pH	30	5.1	5.8	7.5
Turbidity (NTU)	30	0	2.7	14
Salinity (‰)	30	0.1	0.1	0.1
Horizontal Secchi Distance (m)	29	0.4	1.8	3.2

Table A-D2
Bacteriological data for Glenbrook Creek at Jellybean Pool, [A] Faecal coliforms, [B] Enterococci & [C] *E. coli*, cfu/100mL

	A	B	C
06-OCT-94	1	1	1
	2	1	
	1	1	
12-OCT-94	2	1	4
	1	1	
	1	1	
18-OCT-94	1	2	1
	1	3	
	1	1	
24-OCT-94	1	1	1
	3	1	
	1	1	
30-OCT-94	0.5	1	2
	2	0.5	
	2	0.5	
05-NOV-94	1	0.5	0.5
	0.5	0.5	
	1	0.5	
11-NOV-94	1	0.5	1
	1	0.5	
	0.5	0.5	
17-NOV-94	0.5	1	0.5
	0.5	1	
	0.5	0.5	
23-NOV-94	15	10	5
	8	6	
	10	15	
29-NOV-94	31	14	20
	43	66	
	45	36	
05-DEC-94	200	16	210
	72	10	
	15	10	
12-DEC-94	27	13	12
	17	18	
	6	3	
17-DEC-94	16	9	11
	6	8	
	16	3	
23-DEC-94	8	8	12
	9	8	
	5	8	
29-DEC-94	62	27	30
	33	21	
	19	38	
04-JAN-95	180	39	76
	290	26	
	210	48	
10-JAN-95	6	9	1
	58	52	
	6	12	
16-JAN-95	10	7	5
	12	12	
	6	7	
22-JAN-95	200	70	200
	180	48	
	230	26	
28-JAN-95	1	40	0.5
	5	45	
	3	33	
03-FEB-95	1	4	1
	8	2	
	3	2	
09-FEB-95	2	3	0.5
	1	5	
	1	2	
15-FEB-95	51	8	56
	66	11	
	48	10	
21-FEB-95	4	6	2
	1	5	
	1	1	
27-FEB-95	3	3	2
	0.5	52	
	4	6	
05-MAR-95	600	2800	
	1700	680	
	13	2000	
11-MAR-95	38	11	
	22	6	
	40	20	
17-MAR-95	1	3	
	1	3	
	0.5	0.5	
23-MAR-95	0.5	4	3
	1	3	
	1	5	
29-MAR-95	0.5	1	0.5
	0.5	0.5	
	0.5	2	

Figure D1 - Glenbrook Creek @ Jellybean Pool

Faecal coliform densities and associated rainfall

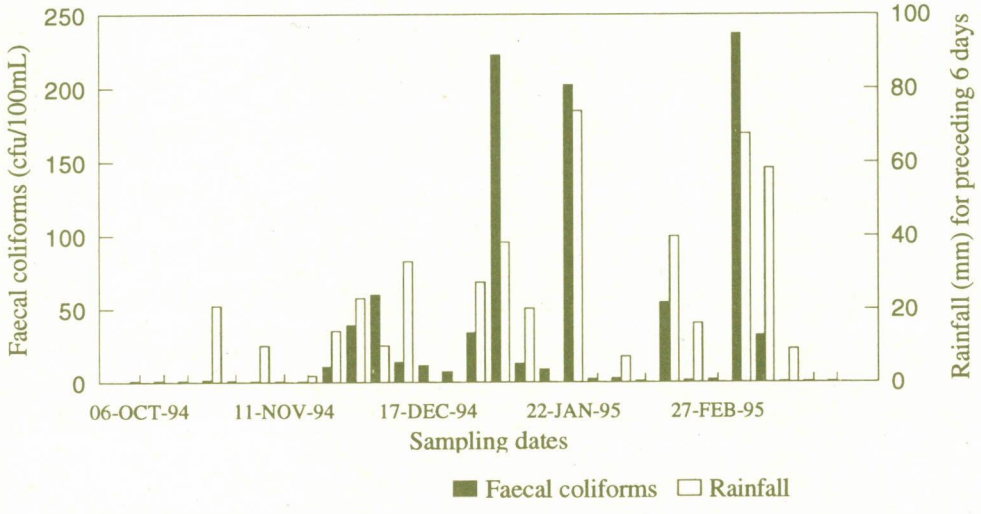
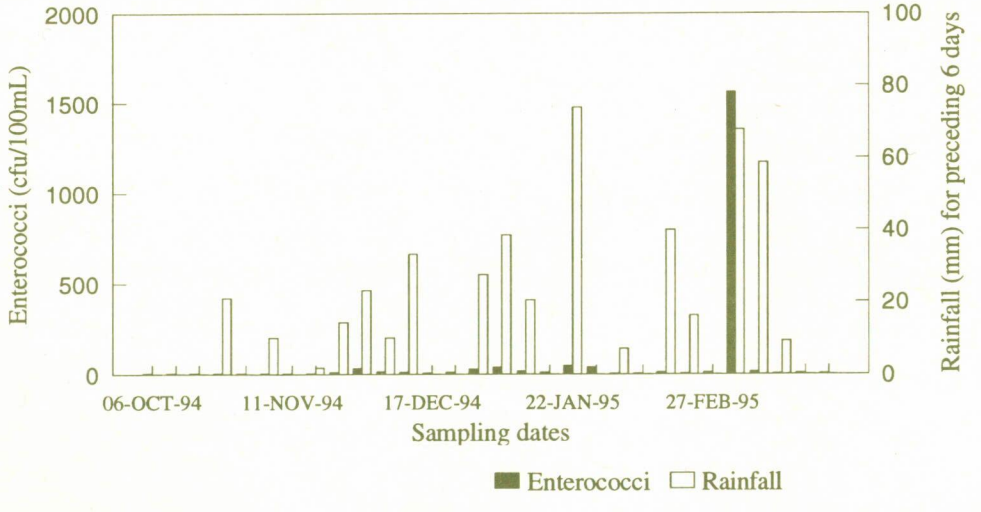


Figure D2 - Glenbrook Creek @ Jellybean Pool

Enterococcus densities and associated rainfall



Site E — Nepean River at Yarramundi Bridge

Site description

The samples were collected from the shore, 40 m upstream of the Springwood Road bridge, on the western side of the river. At this point the river is about 30 m wide. The level was higher than normal on a couple of sampling occasions due to rainfall. During these times, the nearby lagoon was connected to the mainstream river and flow was greatly increased.

Map ID: 9030 - IV - N (1:25 000 topographic)
Latitude: 33° 37' 30" S
Longitude: 150° 40' 50" E

Recreational use

This is a popular fishing, picnicking and wading location.

Compliance with guidelines

This site complied with the NHMRC (1990) guidelines for the whole sampling period. Surface films were present on one occasion. Algal blooms were not observed, but submerged macrophytes and algal mats were present in areas. Horizontal Secchi distance could not be measured at this site for logistical reasons. pH exceeded the ANZECC (1992) recommendations for primary contact recreation on 9 sampling occasions.

Table A-E1
Summary data — Nepean River at Yarramundi Bridge,
6 October 1994 to 29 March 1995
(where total dissolved solids (mg/L) = electrical conductivity (µS/cm) x 0.64)

Parameter	Number of results	Minimum	Mean	Maximum
Electrical Conductivity (iS/cm)	30	68	351	452
Total Dissolved Solids (mg/L)	30	44	225	289
Temperature (°C)	30	18.6	24.5	28.2
pH	29	6.3	8.4	10.2
Turbidity (NTU)	30	0	4.3	28
Salinity (‰)	30	0	0.2	0.2

Table A-E2
Bacteriological data for Nepean River at Yarramundi Bridge, [A] Faecal coliforms, [B] Enterococci & [C] *E. coli*, cfu/100mL

	A	B	C
06-OCT-94	1	1	2
	5	12	
	4	1	
12-OCT-94	5	1	4
	7	3	
	5	1	
18-OCT-94	1	3	2
	1	1	
	3	2	
24-OCT-94	1	4	1
	3	6	
	1	100	
30-OCT-94	0.5	5	0.5
	0.5	0.5	
	0.5	2	
05-NOV-94	2	2	5
	6	23	
	12	9	
11-NOV-94	1	0.5	1
	3	0.5	
	0.5	0.5	
17-NOV-94	150	28	170
	140	7	
	300	270	
23-NOV-94	5	280	3
	0.5	1	
	2	5	
29-NOV-94	1	3	4
	1	17	
	5	28	
05-DEC-94	5	3	1
	5	3	
	0.5	0.5	
12-DEC-94	9	76	3
	16	63	
	1	32	
17-DEC-94	2	7	0.5
	0.5	4	
	0.5	4	
23-DEC-94	20	0.5	36
	10	4	
	3	7	
29-DEC-94	21	9	8
	26	1	
	24	8	

	A	B	C
04-JAN-95	32	22	0.5
	35	22	
	58	62	
10-JAN-95	4	0.5	4
	2	0.5	
	7	2	
16-JAN-95	11	4	7
	33	43	
	15	5	
22-JAN-95	66	540	70
	100	360	
	110	220	
28-JAN-95	20	150	14
	34	260	
	64	390	
03-FEB-95	21	7	15
	16	4	
	30	24	
09-FEB-95	17	5	
	10	0.5	
	14	2	
15-FEB-95	62	8	76
	24	6	
	42	2	
21-FEB-95	17	0.5	12
	23	4	
	100	18	
27-FEB-95	320	100	350
	27	31	
	2	1	
05-MAR-95	4100	2000	
	110	600	
	660	620	
11-MAR-95	18	62	
	15	53	
	21	28	
17-MAR-95	9	9	
	9	0.5	
	18	2	
23-MAR-95	4	0.5	16
	0.5	14	
	0.5	17	
29-MAR-95	16	12	11
	7	14	
	0.5	5	

Figure E1 - Nepean River @ Yarramundi Bridge
Faecal coliform densities and associated rainfall

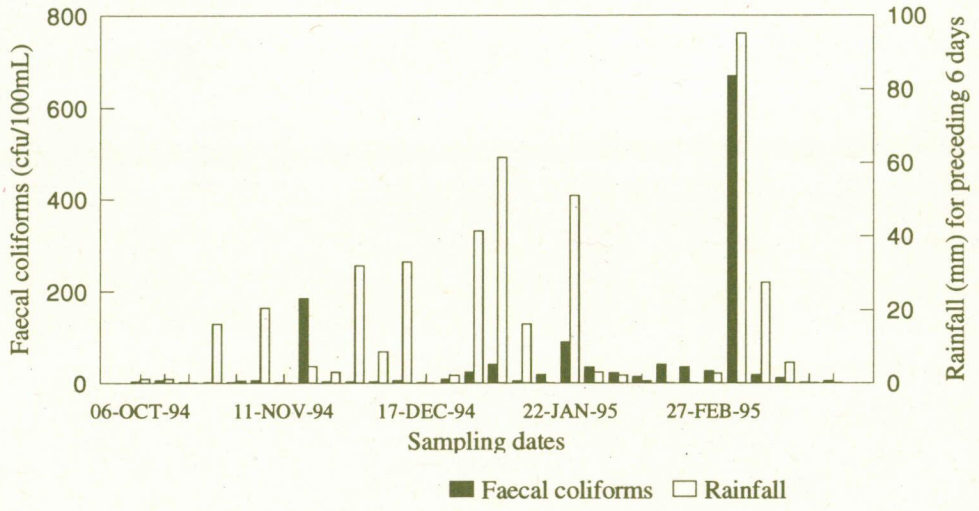
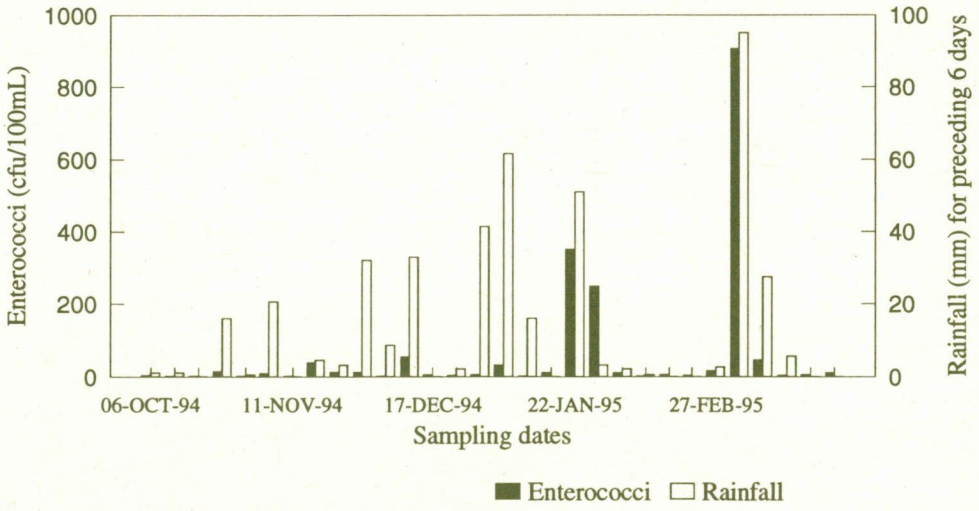


Figure E2 - Nepean River @ Yarramundi Bridge
Enterococcus densities and associated rainfall



Site F — Hawkesbury River at Macquarie Park (Windsor)

Site description

The samples were collected from the shore about 100 m upstream of the Windsor Bridge. The Hawkesbury River is tidal at this point and is about 100 m wide. Depth at this site varies. This site has a sandy beach about 30 m long.

Map ID: 9030 - 1 - N (1:25 000 topographic)
Latitude: 33° 36' 20" S
Longitude: 150° 49' 15" E

Recreational use

This site is a popular picnicking, fishing and wading location. Downstream of this site is popular for water-skiing.

Compliance with Guidelines

This site only complied with the NHMRC (1990) primary contact recreation guidelines, using faecal coliforms as the indicator, in March 1995. However the site exceeded the enterococcus guideline value during that month. There were oily films on three occasions. The water looked brown and turbid on most occasions.

Table A-F1
Summary data — Hawkesbury River at Macquarie Park (Windsor), 6 October 1994 to 29 March 1995
(where total dissolved solids (mg/L) = electrical conductivity (µS/cm) x 0.64)

Parameter	Number of results	Minimum	Mean	Maximum
Electrical Conductivity (iS/cm)	30	98	345	516
Total Dissolved Solids (mg/L)	30	63	221	330
Temperature (°C)	30	19.7	24.1	28.5
pH	29	6.7	7.9	9.0
Turbidity (NTU)	30	8	15.7	31
Salinity (‰)	30	0.1	0.2	0.3
Horizontal Secchi Distance (m)	29	0.1	0.4	0.7

Table A-F2
Bacteriological data for Hawkesbury River at Macquarie Park (Windsor),
[A] Faecal coliforms, [B] Enterococci & [C] *E. coli*,
cfu/100mL

	A	B	C
06-OCT-94	540	1000	100
	1200	1200	
	640	2200	
12-OCT-94	150	110	140
	180	96	
	90	290	
18-OCT-94	180	100	130
	210	130	
	290	120	
24-OCT-94	120	60	160
	160	30	
	260	150	
30-OCT-94	290	640	360
	360	130	
	1100	560	
05-NOV-94	64	20	70
	110	14	
	33	11	
11-NOV-94	150	73	170
	450	180	
	90	25	
17-NOV-94	700	45	670
	850	66	
	160	130	
23-NOV-94	62	44	75
	83	21	
	87	29	
29-NOV-94	770	180	550
	50	1000	
	1300	420	
05-DEC-94	510	310	500
	190	210	
	210	30	
12-DEC-94	820	240	520
	740	240	
	3100	600	
17-DEC-94	990	780	1100
	1200	920	
	600	720	
23-DEC-94	760	290	280
	160	230	
	160	230	
29-DEC-94	1700	360	520
	840	240	

	A	B	C
04-JAN-95	180	110	72
	200	92	
	180	100	
10-JAN-95	310	82	340
	320	120	
	320	78	
16-JAN-95	410	240	90
	1100	230	
22-JAN-95	420	560	480
	420	220	
	520	420	
28-JAN-95	410	520	1200
	8000	2100	
	2000	620	
03-FEB-95	12	41	190
	140	15	
	150	59	
09-FEB-95	3200	4200	3400
	2100	4600	
	500	840	
15-FEB-95	42000	18000	38000
	12000	2400	
	52000	34000	
21-FEB-95	400	40	320
	200	35	
	170	72	
27-FEB-95	3600	570	4000
	1900	350	
	3700	1000	
05-MAR-95	1100	400	
	600	710	
	2100	740	
11-MAR-95	600	90	
	700	140	
	400	18	
17-MAR-95	124	68	
	0.5	7600	
	64	160	
23-MAR-95	0.5	100	0.5
	200	130	
	0.5	120	
29-MAR-95	0.5	45000	0.5
	0.5	120	
	200	1100	

Figure F1 - Hawkesbury River @ Macquarie Park

Faecal coliform densities and associated rainfall

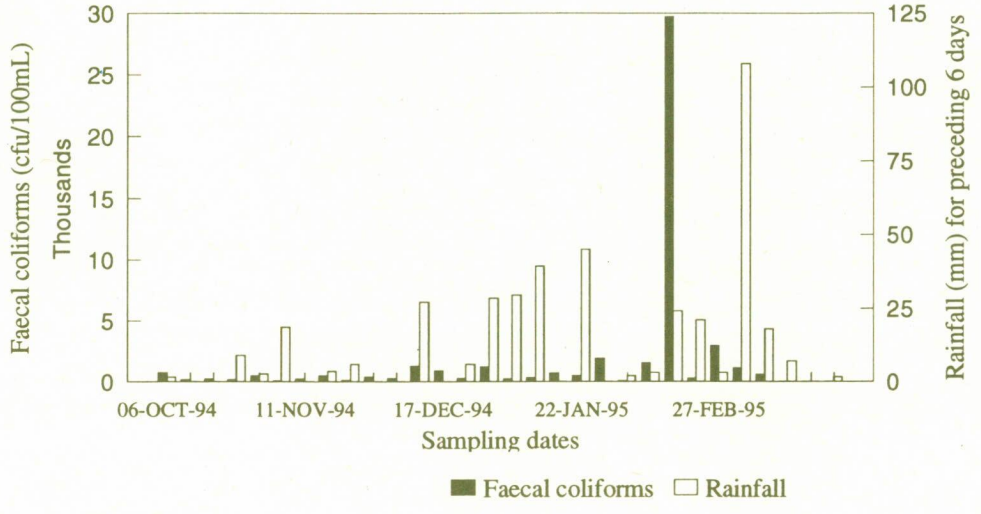
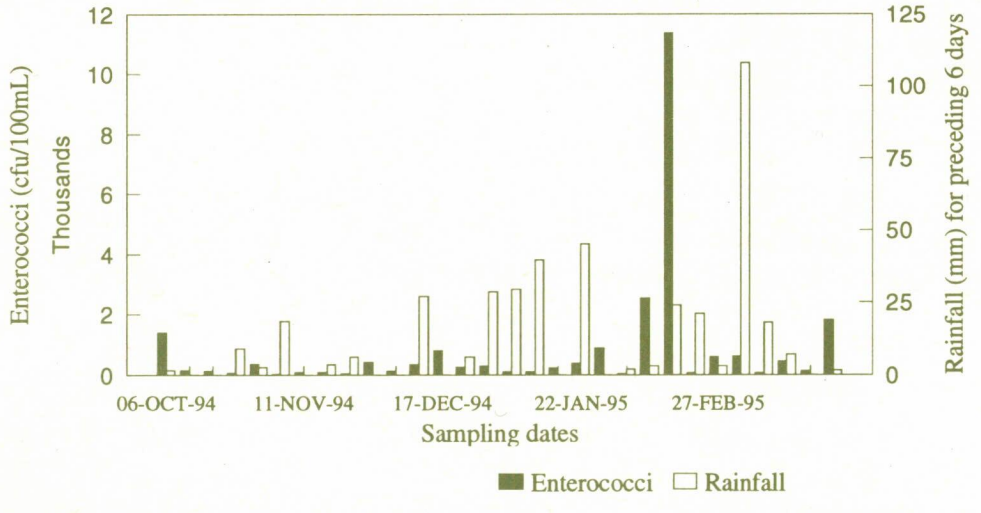


Figure F2 - Hawkesbury River @ Macquarie Park

Enterococcus densities and associated rainfall



Site G — South Creek at Governor Phillip Park ramp (Windsor)

Site description

The samples were collected from the boat ramp at Governor Phillip Park. South Creek is tidal at this point and is about 20 m wide and several metres deep.

Map ID: 9030 - 1 - N (1:25 000 topographic)
Latitude: 33° 36' 00" S
Longitude: 150° 49' 90" E

Recreational use

This is a very popular site for boat launching. Downstream of this site is popular for water-skiing.

Compliance with guidelines

This site did not comply with the NHMRC (1990) guidelines for primary contact recreation in December 1994, January 1995, February 1995, and March 1995. The water looked green or brown on all sampling occasions and was never clear. Oily films were present on almost half the sampling occasions (total of 13).

Table A-G1
Summary data — South Creek at Governor Phillip Park ramp (Windsor), 6 October 1994 to 29 March 1995
(where total dissolved solids (mg/L) = electrical conductivity (µS/cm) x 0.64)

Parameter	Number of results	Minimum	Mean	Maximum
Electrical Conductivity (iS/cm)	30	234	452	706
Total Dissolved Solids (mg/L)	30	150	289	452
Temperature (°C)	30	18.5	23.5	28.0
pH	29	6.9	7.6	8.6
Turbidity (NTU)	30	4.6	40.4	250
Salinity (‰)	30	0.1	0.2	0.4
Horizontal Secchi Distance (m)	29	0.1	0.3	0.8

Table A-G2
Bacteriological data for South Creek at Governor Phillip Park ramp (Windsor),
[A] Faecal coliforms, [B] Enterococci & [C] *E. coli*, cfu/100mL

	A	B	C
06-OCT-94	37	10	32
	44	9	
	45	1	
12-OCT-94	140	44	150
	130	1200	
	110	26	
18-OCT-94	31	17	21
	33	11	
	20	9	
24-OCT-94	110	28	120
	54	18	
	120	36	
30-OCT-94	440	64	290
	190	66	
	380	110	
05-NOV-94	96	26	100
	95	7	
	120	16	
11-NOV-94	40	19	48
	47	11	
	46	23	
17-NOV-94	24	22	5
	36	19	
	26	35	
23-NOV-94	47	29	42
	76	13	
	67	20	
29-NOV-94	120	70	120
	170	52	
	130	70	
05-DEC-94	76	58	69
	60	60	
	60	120	
12-DEC-94	110	32	60
	110	34	
	110	48	
17-DEC-94	70	41	90
	6	45	
	0.5	140	
23-DEC-94	220	110	400
	260	200	
	120	160	
29-DEC-94	1700	530	680
	740	400	
	470	270	

	A	B	C
04-JAN-95	650	240	120
	380	180	
	58	220	
10-JAN-95	1300	160	240
	210	130	
	290	210	
16-JAN-95	140	270	120
	100	88	
	120	270	
22-JAN-95	2200	900	2000
	2800	1100	
	1600	580	
28-JAN-95	30	220	80
	220	230	
	150	210	
03-FEB-95	200	230	160
	40	270	
	210	170	
09-FEB-95	130	130	140
	290	380	
	170	230	
15-FEB-95	270	170	52
	310	68	
	150	50	
21-FEB-95	150	140	200
	250	160	
	400	110	
27-FEB-95	150	61	160
	210	72	
	160	53	
05-MAR-95	55000	6100	
	48000	7800	
	63000	5200	
11-MAR-95	300	92	
	100	94	
	400	200	
17-MAR-95	300	100	
	300	200	
	100	40	
23-MAR-95	21	250	14
	0.5	7100	
	10	1100	
29-MAR-95	4	74	0.5
	0.5	70	
	0.5	200	

Figure G1 - South Creek @ Governor Phillip Park
Faecal coliform densities and associated rainfall

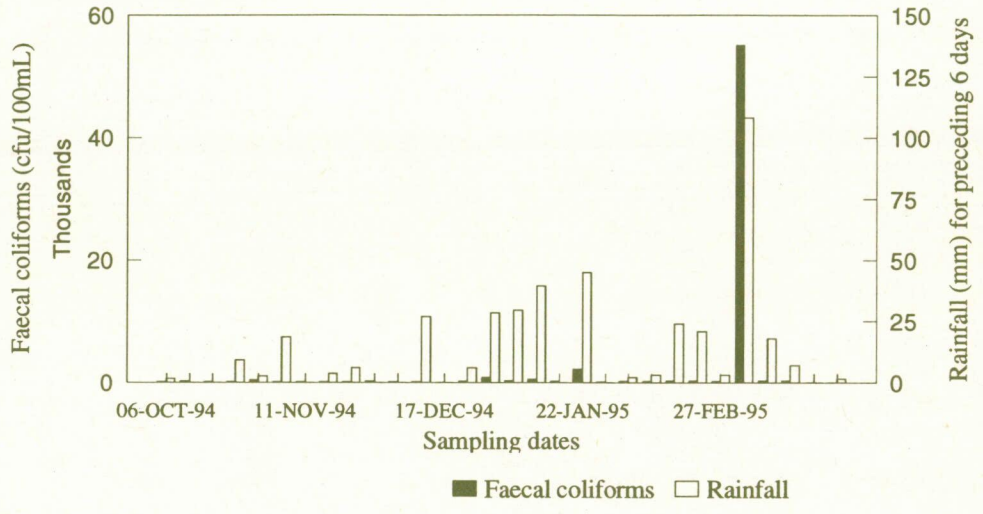
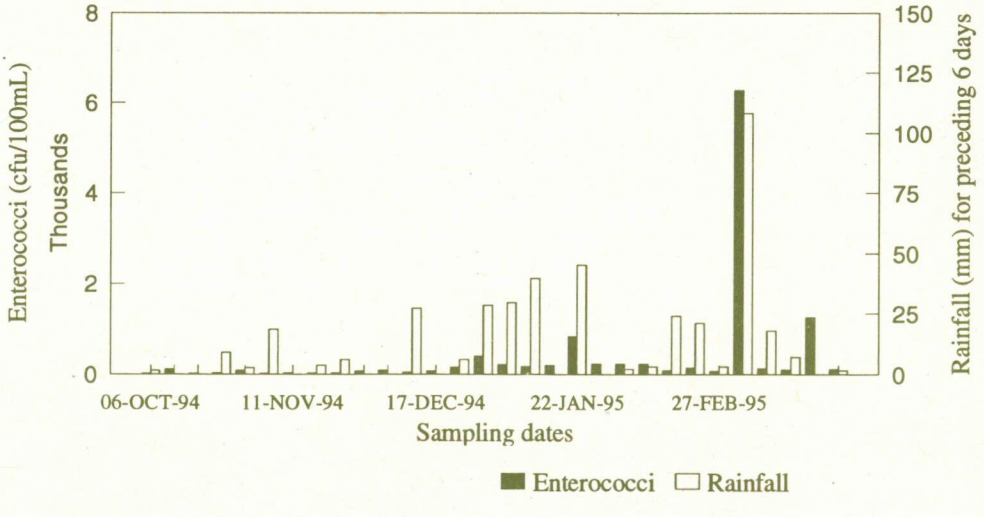


Figure G2 - South Creek @ Governor Phillip Park
Enterococcus densities and associated rainfall



Site H — Hawkesbury River at Cattai National Park

Site description

The samples were collected by boat near the Cattai National Park (downstream of Cattai Creek). This site is tidal, with depth ranging from 3 to 12 m across the main channel. The river is about 100 m wide at this point.

Map ID: 9030 - 1 - N (1:25 000 topographic)
Latitude: 33° 33' 42" S
Longitude: 150° 53' 19" E

Recreational use

The site is a popular water-skiing location.

Compliance with guidelines

This site complied with the NHMRC (1990) bacteriological guidelines for the entire period, using faecal coliforms as the indicator. However, the site exceeded the enterococcus guideline value during January and March 1995. During the study period, four samples were collected in the vicinity each month for algal analysis. Five samples between December 1994 and February 1995 were reported as containing more than 15,000 cells per mL of blue-green algae. Surface films were reported on one occasion.

Table A-H1
Summary data — Hawkesbury River at Cattai National Park, 6 October 1994 to 29 March 1995
(where total dissolved solids (mg/L) = electrical conductivity (µS/cm) x 0.64)

Parameter	Number of results	Minimum	Mean	Maximum
Electrical Conductivity (iS/cm)	29	21	464	686
Total Dissolved Solids (mg/L)	29	13	297	439
Temperature (°C)	29	17.9	23.1	27.9
pH	29	6.6	8.1	9.4
Turbidity (NTU)	27	0	34.9	240
Salinity (‰)	29	0	0.2	0.4
Vertical Secchi depth (m)	29	0.1	0.5	0.9

Table A-H2
Bacteriological data for the Hawkesbury River at Cattai National Park, [A] Faecal coliforms, [B] Enterococci & [C] *E. coli*, cfu/100mL

	A	B	C		A	B	C
06-OCT-94	19	4	1	04-JAN-95	66	35	47
	22	1			65	28	
	23	2			76	21	
12-OCT-94	19	9	19	10-JAN-95	62	13	51
	23	3			72	30	
	17	8			88	44	
18-OCT-94	12	12	20	16-JAN-95	37	11	25
	11	4			33	8	
	14	7			52	20	
24-OCT-94	35	23	34	22-JAN-95	130	840	1200
	24	22			1300	810	
	46	20			1200	560	
30-OCT-94	24	17	27	28-JAN-95	100	63	95
	4	0.5			74	44	
	32	17			100	42	
05-NOV-94	35	5	27	03-FEB-95	70	27	70
	37	4			90	20	
	16	6			50	14	
11-NOV-94	13	5	14	09-FEB-95	58	39	58
	10	4			70	29	
	13	4			45	23	
17-NOV-94	28	11	3	15-FEB-95	25	21	36
	15	15			30	22	
	20	6			21	25	
23-NOV-94	14	1	16	21-FEB-95	90	16	42
	19	5			64	120	
	5	2			68	27	
29-NOV-94	19	2	16	27-FEB-95	28	29	43
	14	7			41	8	
	12	4			42	20	
05-DEC-94	21	13	2	05-MAR-95	20	500	
	25	12			1300	2100	
	17	6			1600	130	
12-DEC-94	20	12	10	11-MAR-95	38	38	
	30	9			48	33	
	13	7			62	51	
17-DEC-94	26	14	40	17-MAR-95	43	35	
	30	10			25	30	
	25	7			32	15	
23-DEC-94	24	3	70	23-MAR-95	76	25	75
	50	5			44	44	
	28	5			64	48	
29-DEC-94	25	16	3	29-MAR-95	0.5	22	0.5
	25	16			22	25	
	29	16			0.5	18	

Figure H1 - Hawkesbury River @ Cattai NP

Faecal coliform densities and associated rainfall

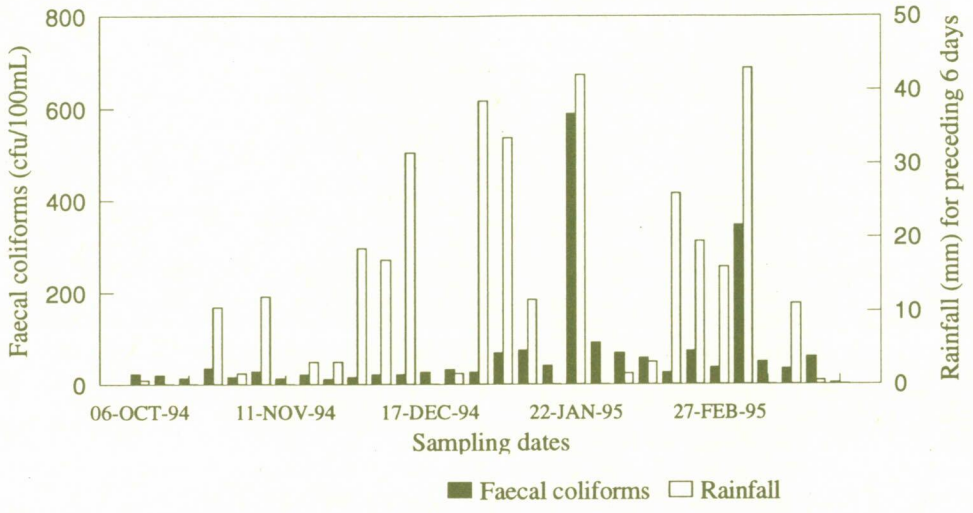
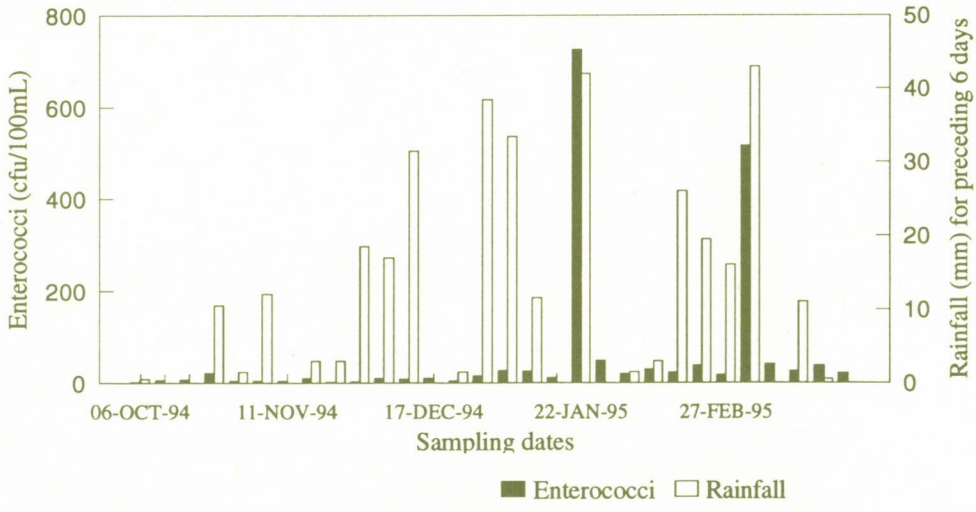


Figure H2 - Hawkesbury River @ Cattai NP

Enterococcus densities and associated rainfall



Site I — Hawkesbury River at Sackville ferry

Site description

Samples were collected near the Sackville ferry. The site is tidal, with a depth of at least 3 m at low tide. The river is approximately 150 m wide.

Map ID: 9030 - 1 - N (1:25 000 topographic)
Latitude: 33°30'8" S
Longitude: 150°52'22" E

Recreational use

The site is a popular boating and water-skiing location.

Compliance with guidelines

This site was only sampled in February and March 1995. The site complied with the NHMRC (1990) bacteriological guidelines for primary and secondary contact during both sampling months. Blue-green algae concentrations exceeded 15,000 cells per mL on four sampling occasions in February 1995. Surface films were not observed.

Table A-I1
Summary data — Hawkesbury River at Sackville ferry,
3 February 1994 to 29 March 1995
(where total dissolved solids (mg/L) = electrical conductivity (µS/cm) x 0.64)

Parameter	Number of results	Minimum	Mean	Maximum
Electrical Conductivity (iS/cm)	9	18	250	364
Total Dissolved Solids (mg/L)	9	12	160	233
Temperature (°C)	9	21.3	23.9	25.9
pH	9	6.5	8.2	9.5
Turbidity (NTU)	9	8.9	22.1	42
Salinity (‰)	9	0	0.1	0.2
Vertical Secchi depth (m)	9	0.5	0.7	0.9

Table A-I2
Bacteriological data for Hawkesbury River at Sackville ferry, [A] Faecal coliforms, [B] Enterococci & [C] *E. coli*, cfu/100mL

	A	B	C
03-FEB-95	12	7	30
	8	12	
	11	5	
09-FEB-95	6	7	3
	12	5	
	4	4	
15-FEB-95	1	2	7
	14	5	
	12	8	
21-FEB-95	9	4	7
	6	5	
	5	6	
27-FEB-95	14	4	12
	18	7	
	14	10	
05-MAR-95	280	16	
	11	22	
	13	17	
11-MAR-95	0.5	38	
	52	28	
	30	30	
17-MAR-95	30	11	
	0.5	18	
	21	14	
23-MAR-95	4	4	4
	0.5	5	
	2	3	
29-MAR-95	4	5	3
	0.5	1	
	0.5	1	

Figure I1 - Hawkesbury River @ Sackville Ferry
Faecal coliform densities and associated rainfall

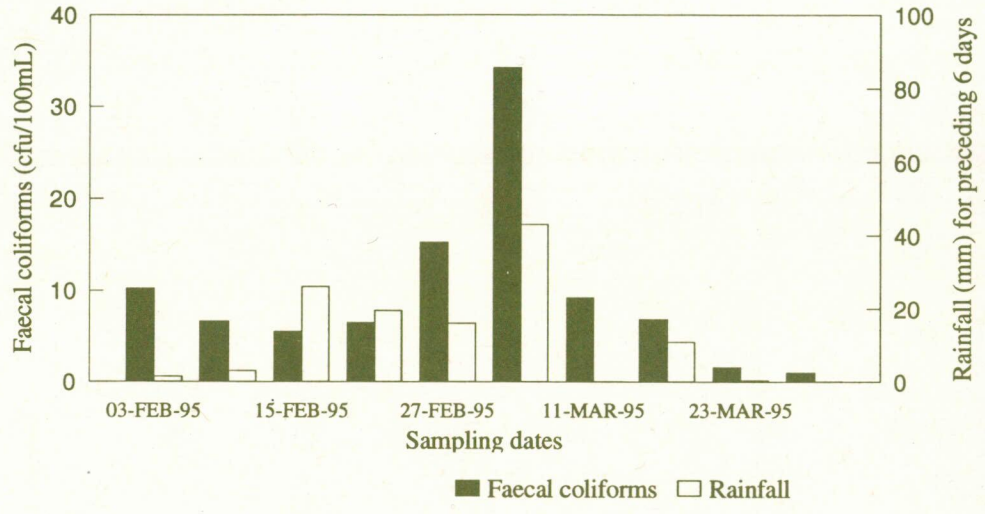
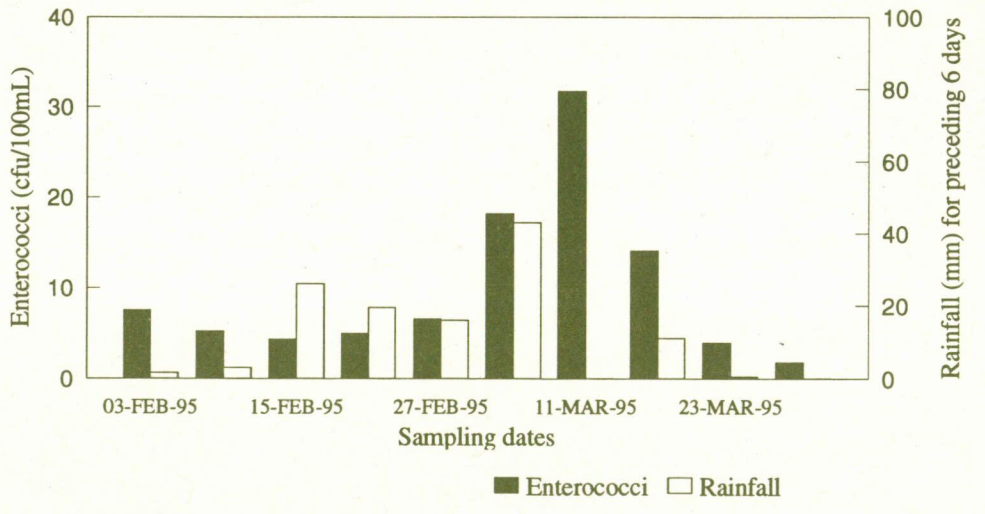


Figure I2 - Hawkesbury River @ Sackville Ferry
Enterococcus densities and associated rainfall



Site J — Hawkesbury River at Lower Portland

Site description

Samples were collected by boat downstream of the Colo River, near the South Sydney Junior Rugby League Club's recreational facilities. The river is 200 m wide and at least 3 m deep at this point.

Map ID: 9031 - 2 - S (1:25 000 topographic)
Latitude: 33°25'40" S
Longitude: 150°53'43" E

Recreational use

The site is a popular water-skiing location.

Compliance with guidelines

Bacteriological densities complied with the NHMRC (1990) guidelines during the entire sampling period. This site did not comply with the ANZECC (1992) guidelines on 8 sampling occasions in January, February and March 1995 because of a blue-green algal bloom in the vicinity (Tables 2 and 3 and Appendix K). Oily films were not observed.

Table A-J1
Summary data — Hawkesbury River at Lower Portland,
6 October 1994 to 29 March 1995
(where total dissolved solids (mg/L) = electrical conductivity (µS/cm) x 0.64)

Parameter	Number of results	Minimum	Mean	Maximum
Electrical Conductivity (iS/cm)	29	13	3641	10260
Total Dissolved Solids (mg/L)	29	8	2330	6566
Temperature (°C)	29	17.7	23.1	27.4
pH	29	6.3	7.7	9.5
Turbidity (NTU)	27	0	11.4	29
Salinity (‰)	29	0	2.0	5.8
Vertical Secchi depth (m)	29	0.5	1.2	1.9

Table A-J2
Bacteriological data for Hawkesbury River at Lower Portland, [A] Faecal coliforms, [B] Enterococci & [C] *E. coli*, cfu/100mL

	A	B	C
06-OCT-94	2	1	1
	2	4	
	2	1	
12-OCT-94	7	1	4
	11	1	
	4	1	
18-OCT-94	6	1	5
	4	2	
	1	2	
24-OCT-94	1	1	1
	1	1	
	2	1	
30-OCT-94	4	3	7
	3	4	
	18	5	
05-NOV-94	6	1	10
	8	4	
	3	1	
11-NOV-94	0.5	0.5	3
	1	3	
	1	0.5	
17-NOV-94	10	0.5	6
	6	2	
	10	1	
23-NOV-94	5	3	5
	3	0.5	
	1	0.5	
29-NOV-94	0.5	0.5	8
	2	0.5	
	12	2	
05-DEC-94	8	13	1
	4	11	
	3	9	
12-DEC-94	5	5	4
	9	2	
	6	2	
17-DEC-94	3	3	1
	3	4	
	7	1	
23-DEC-94	16	3	8
	10	5	
	5	6	
29-DEC-94	18	3	0.5
	18	4	
	3	0.5	
04-JAN-95	4	10	3
	3	4	
	2	0.5	
10-JAN-95	3	3	1
	5	2	
	7	0.5	
16-JAN-95	2	5	3
	4	5	
	7	2	
22-JAN-95	90	56	140
	170	51	
	110	80	
28-JAN-95	0.5	2	2
	6	5	
	10	4	
03-FEB-95	10	5	0.5
	10	0.5	
	10	0.5	
09-FEB-95	8	4	2
	0.5	1	
	0.5	0.5	
15-FEB-95	2	1	8
	2	3	
	1	7	
21-FEB-95	9	5	7
	12	10	
	5	2	
27-FEB-95	8	1	3
	5	1	
	3	6	
05-MAR-95	12	11	
	120	35	
	6	11	
11-MAR-95	15	27	
	18	21	
	17	15	
17-MAR-95	0.5	0.5	
	7	1	
	4	5	
23-MAR-95	3	2	8
	0.5	6	
	1	1	
29-MAR-95	0.5	4	11
	2	2	
	2	3	

Figure J1 - Hawkesbury River @ Lower Portland

Faecal coliform densities and associated rainfall

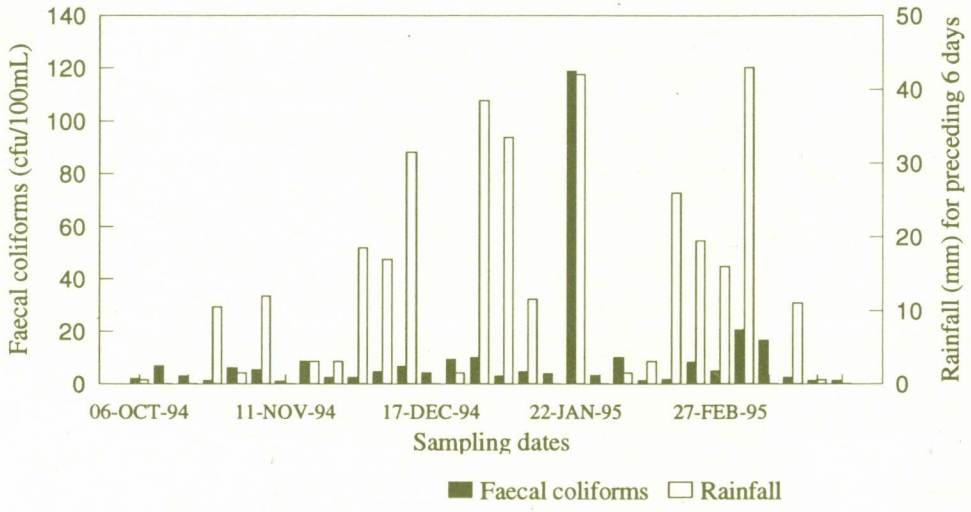
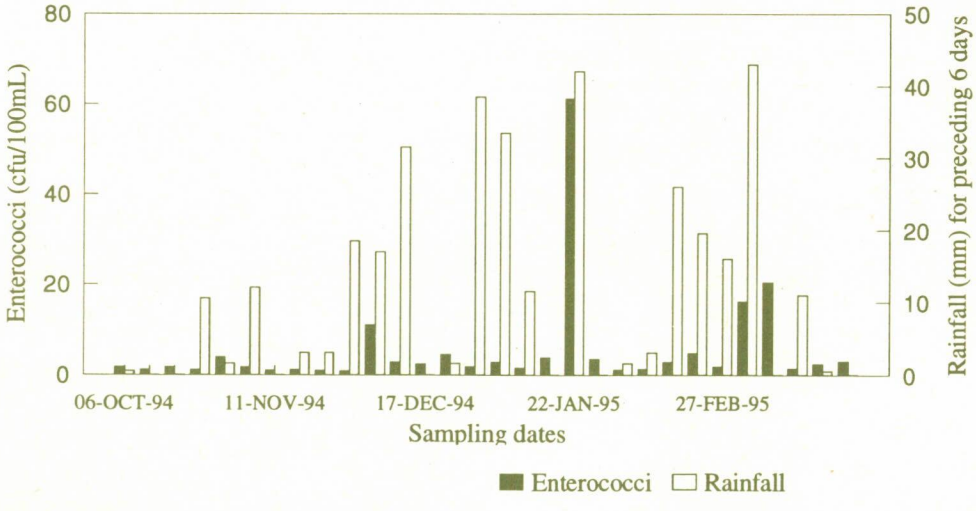


Figure J2 - Hawkesbury River @ Lower Portland

Enterococcus densities and associated rainfall



Site K — Hawkesbury River at Wisemans Ferry

Site description

Samples were collected by boat upstream of the MacDonald River, near the Webbs Creek ferry. The river at this point is about 300 m wide and at least 3 m deep (at low tide).

Map ID: 9031 - 2 - S (1:25 000 topographic)
Latitude: 38°23'30" S
Longitude: 150°58'45" E

Recreational use

This is a popular boating, swimming and water-skiing location.

Compliance with guidelines

This site complied with the NHMRC (1990) guidelines for the entire sampling period and no surface films were observed. Three algal samples collected in the vicinity in February 1995 were reported as having an algal level greater than 15,000 cells per mL. Surface films were not observed.

Table A-K1
Summary data — Hawkesbury River at Wisemans Ferry,
6 October 1994 to 29 March 1995
(where total dissolved solids (mg/L) = electrical conductivity (µS/cm) x 0.64)

Parameter	Number of results	Minimum	Mean	Maximum
Electrical Conductivity (iS/cm)	29	16	15352	28100
Total Dissolved Solids (mg/L)	29	10	9825	17984
Temperature (°C)	29	17.8	23.0	27.1
pH	29	6.3	7.4	8.5
Turbidity (NTU)	27	0	11.5	48
Salinity (‰)	29	0	9.2	17.3
Vertical Secchi depth (m)	27	0.3	1.7	3.3

Table A-K2
Bacteriological data for Hawkesbury River at Wisemans Ferry, [A] Faecal coliforms, [B] Enterococci & [C] *E. coli*, cfu/100mL

	A	B	C		A	B	C
06-OCT-94	2	1	2	04-JAN-95	9	5	7
	3	1			3	6	
	1	1			8	8	
12-OCT-94	1	1	2	10-JAN-95	5	1	3
	3	1			11	0.5	
	3	1			4	1	
18-OCT-94	5	2	4	16-JAN-95	4	0.5	0.5
	6	2			3	1	
	12	1			1	1	
24-OCT-94	4	1	2	22-JAN-95	12	4	20
	2	1			13	2	
	3	2			24	2	
30-OCT-94	3	1	2	28-JAN-95	10	9	6
	5	3			20	4	
	3	1			20	3	
05-NOV-94	6	5	5	03-FEB-95	20	10	50
	0.5	1			7	8	
	1	1			30	5	
11-NOV-94	0.5	0.5	2	09-FEB-95	15	8	10
	1	0.5			22	4	
	1	0.5			30	4	
17-NOV-94	0.5	2	0.5	15-FEB-95	3	0.5	4
	2	0.5			5	0.5	
	1	0.5			6	0.5	
23-NOV-94	5	2	3	21-FEB-95	7	2	3
	4	4			4	0.5	
	2	0.5			2	1	
30-NOV-94	24	3	36	27-FEB-95	10	0.5	16
	30	15			5	2	
	16	10			18	1	
05-DEC-94	4	1	5	05-MAR-95	30	29	
	7	2			45	31	
	6	6			28	33	
12-DEC-94	3	3	3	11-MAR-95	4	13	
	0.5	0.5			13	8	
	5	1			30	16	
17-DEC-94	1	1	2	17-MAR-95	25	15	
	0.5	0.5			0.5	12	
	1	1			4	16	
23-DEC-94	8	1	6	23-MAR-95	0.5	3	4
	2	4			0.5	4	
	0.5	1			7	2	
29-DEC-94	20	11	11	29-MAR-95	2	7	6
	10	11			12	22	
	17	6			11	1	

Figure K1 - Hawkesbury River @ Wisemans Ferry
Faecal coliform densities and associated rainfall

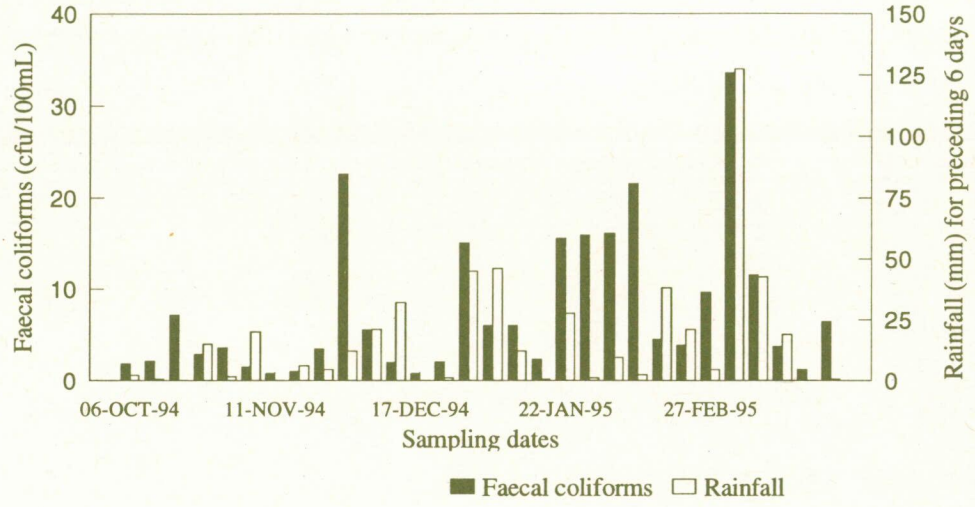
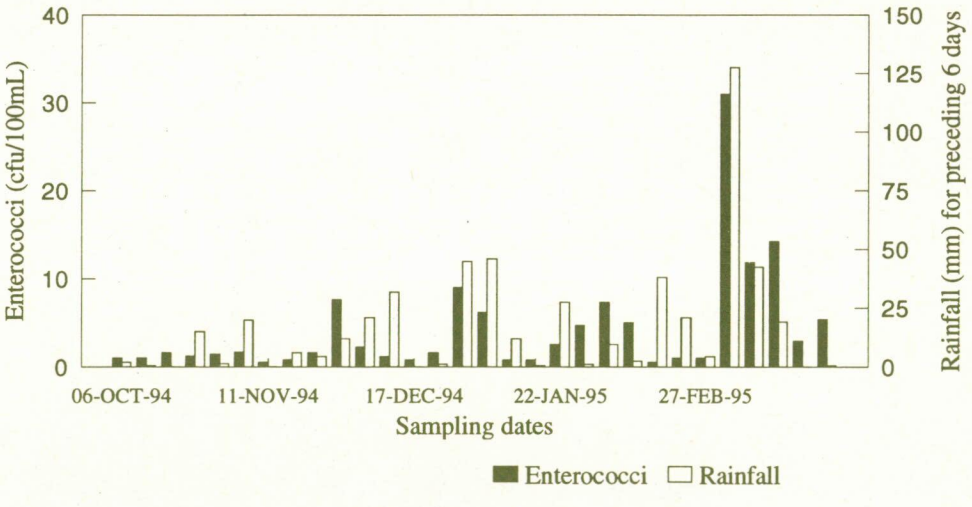


Figure K2 - Hawkesbury River @ Wisemans Ferry
Enterococcus densities and associated rainfall



Site L — Hawkesbury River at One Tree Reach

Site description

Samples were collected by boat from One Tree Reach (Gunderman) downstream of Laughtondale. The river is about 300 m wide and several metres deep at this point.

Map ID: 9131 - III - S (1:25 000 topographic)
Latitude: 33°25'28" S
Longitude: 151°01'46" E

Recreational use

This site is a popular water-skiing location.

Compliance with guidelines

This site complied with the NHMRC (1990) guidelines for the entire sampling period. No algal blooms were observed in the vicinity of this site. No surface films were observed.

Table A-L1
Summary data — Hawkesbury River at One Tree Reach,
6 October 1994 to 29 March 1995
(where total dissolved solids (mg/L) = electrical conductivity (µS/cm) x 0.64)

Parameter	Number of results	Minimum	Mean	Maximum
Electrical Conductivity (iS/cm)	30	34	24031	38100
Total Dissolved Solids (mg/L)	30	22	15380	24384
Temperature (°C)	30	17.5	23.1	27.0
pH	29	6.5	7.3	7.7
Turbidity (NTU)	28	0	13.0	95
Salinity (‰)	30	0	14.8	24.2
Vertical Secchi depth (m)	28	0.4	1.6	3.1

Table A-L2
Bacteriological data for Hawkesbury River at One Tree Reach, [A] Faecal coliforms, [B] Enterococci & [C] *E. coli*, cfu/100mL

	A	B	C		A	B	C
06-OCT-94	2	1	1	04-JAN-95	1	2	4
	2	1			1	6	
	1	1			2	11	
12-OCT-94	1	1	1	10-JAN-95	0.5	1	0.5
	1	1			0.5	0.5	
	2	1			0.5	0.5	
18-OCT-94	1	1	1	16-JAN-95	4	1	2
	1	1			4	2	
	1	1			5	2	
24-OCT-94	1	1	1	22-JAN-95	10	2	7
	1	1			10	3	
	1	2			13	3	
30-OCT-94	0.5	0.5	1	28-JAN-95	8	3	4
	1	0.5			3	1	
	2	0.5			8	5	
05-NOV-94	1	0.5	0.5	03-FEB-95	7	2	1
	13	2			8	0.5	
	0.5	0.5			20	1	
11-NOV-94	0.5	0.5	3	09-FEB-95	3	1	3
	1	0.5			1	0.5	
	0.5	0.5			3	1	
17-NOV-94	0.5	0.5	0.5	15-FEB-95	2	2	4
	4	0.5			4	2	
	1	2			3	0.5	
23-NOV-94	1	0.5	1	21-FEB-95	7	2	3
	0.5	0.5			7	1	
	0.5	1			1	2	
30-NOV-94	24	37	28	27-FEB-95	14	4	12
	24	12			11	8	
	25	60			2	3	
05-DEC-94	3	9	1	05-MAR-95	29	36	
	3	4			23	15	
	2	12			25	8	
12-DEC-94	0.5	0.5	2	11-MAR-95	24	18	
	0.5	0.5			11	18	
	0.5	10			28	27	
17-DEC-94	0.5	1	1	17-MAR-95	4	0.5	
	1	0.5			0.5	6	
	0.5	0.5			0.5	7	
23-DEC-94	2	0.5	0.5	23-MAR-95	0.5	0.5	0.5
	0.5	0.5			0.5	6	
	1	0.5			0.5	3	
29-DEC-94	2	0.5	0.5	29-MAR-95	0.5	1	1
	2	3			0.5	2	
	3	4			0.5	1	

Figure L1 - Hawkesbury River @ One Tree Reach

Faecal coliform densities and associated rainfall

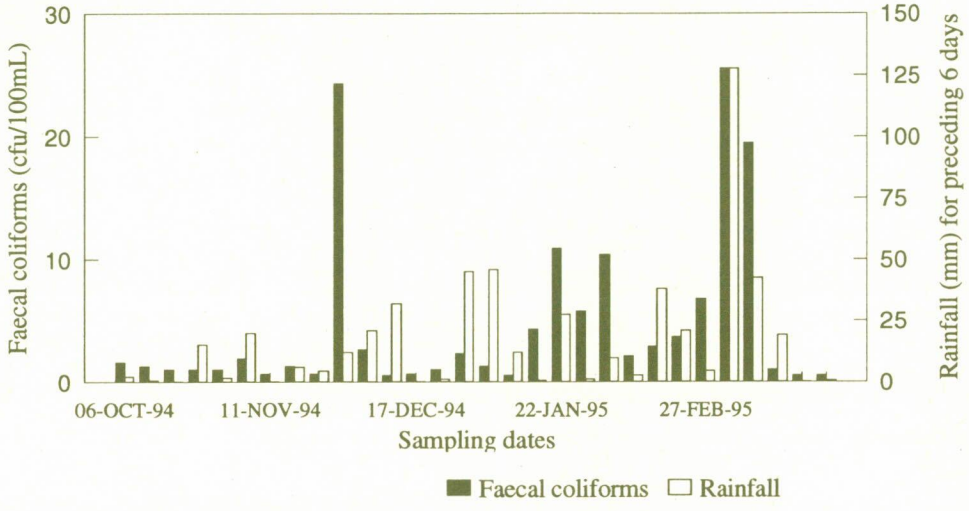
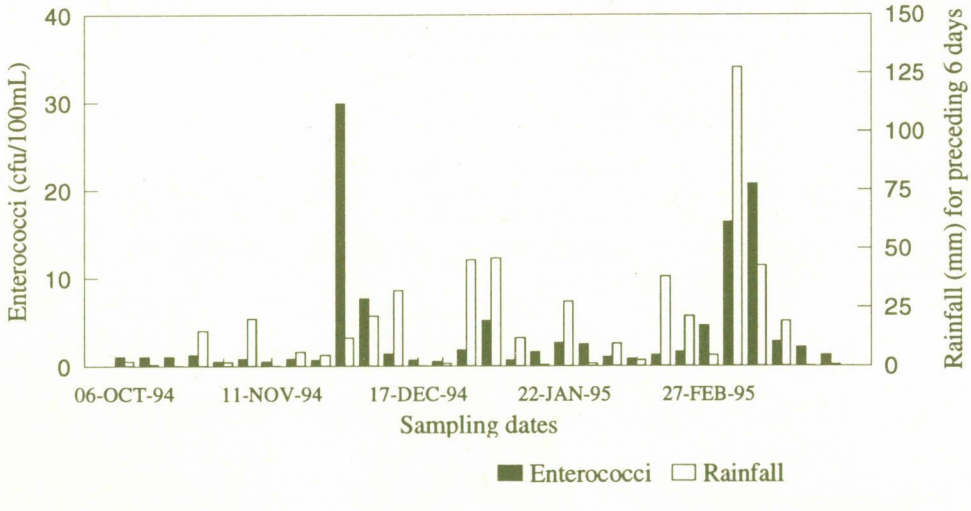


Figure L2 - Hawkesbury River @ One Tree Reach

Enterococcus densities and associated rainfall



Site M — Berowra Creek at the ferry

Site description

Samples were collected from the shore near the Berowra ferry. The creek is 250 m wide and several metres deep at this point. The creek is tidal.

Map ID: 9130 4 - N (1:25 000 topographic)
Latitude: 33°23'30" S
Longitude: 150°58'45" E

Recreational use

This site is a popular boating, fishing, swimming and picnicking location.

Compliance with guidelines

This site complied with the NHMRC (1990) bacteriological guidelines, using faecal coliforms as the indicator organism, for primary and secondary contact recreation during the 1994-95 summer season. This site, however, exceeded the enterococcus guideline value for primary contact recreation in March 1995. Surface films were observed on five sampling occasions.

Table A-M1
Summary data — Berowra Creek at the ferry,
6 October 1994 to 29 March 1995
(where total dissolved solids (mg/L) = electrical conductivity (µS/cm) x 0.64)

Parameter	Number of results	Minimum	Mean	Maximum
Electrical Conductivity (iS/cm)	30	966	41438	50182
Total Dissolved Solids (mg/L)	30	618	26520	32116
Temperature (°C)	30	16.9	22.7	27.0
pH	28	6.8	7.5	8.2
Turbidity (NTU)	28	0	9.2	105
Salinity (‰)	30	0.5	26.8	33.0
Vertical Secchi depth (m)	14	0.3	1.5	2.4

Table A-M2
Bacteriological data for the Berowa Creek at the ferry, [A] Faecal coliforms, [B] Enterococci & [C] *E. coli*, cfu/100mL

	A	B	C
06-OCT-94	180	28	100
	1	1	
	1	1	
12-OCT-94	2	3	2
	6	1	
	2	1	
18-OCT-94	3	1	1
	1	1	
	3	1	
24-OCT-94	4	6	3
	4	4	
	10	5	
30-OCT-94	1	2	7
	3	2	
	2	4	
05-NOV-94	48	160	38
	52	55	
	44	41	
11-NOV-94	4	0.5	4
	5	4	
	9	0.5	
17-NOV-94	7	1	4
	7	2	
	2	0.5	
23-NOV-94	0.5	2	3
	0.5	0.5	
	9	1	
30-NOV-94	4	8	36
	26	7	
	13	3	
05-DEC-94	1	1	6
	13	2	
	3	4	
12-DEC-94	7	1	4
	15	1	
	0.5	2	
17-DEC-94	3	0.5	1
	2	0.5	
	1	1	
23-DEC-94	14	8	10
	14	4	
	3	7	
29-DEC-94	24	13	20
	7	12	
	10	9	

	A	B	C
04-JAN-95	190	160	26
	150	120	
	140	82	
10-JAN-95	66	16	39
	64	18	
	50	23	
16-JAN-95	4	5	1
	4	6	
	66	7	
22-JAN-95	5	5	6
	17	11	
	16	12	
28-JAN-95	4	6	3
	0.5	3	
	1	1	
03-FEB-95	1	1	3
	2	1	
	1	5	
09-FEB-95	1	2	2
	3	0.5	
	3	2	
15-FEB-95	16	9	5
	33	65	
	6	45	
21-FEB-95	20	10	12
	17	6	
	11	9	
27-FEB-95	2	0.5	6
	4	0.5	
	8	0.5	
05-MAR-95	29000	4200	
	7500	4500	
	5600	160	
11-MAR-95	42	38	
	54	61	
	30	29	
17-MAR-95	15	31	
	1	21	
	20	12	
23-MAR-95	6	13	23
	7	22	
	10	14	
29-MAR-95	0.5	100	2
	1	21	
	0.5	33	

Figure M1 - Berowra Creek @ the Ferry

Faecal coliform densities and associated rainfall

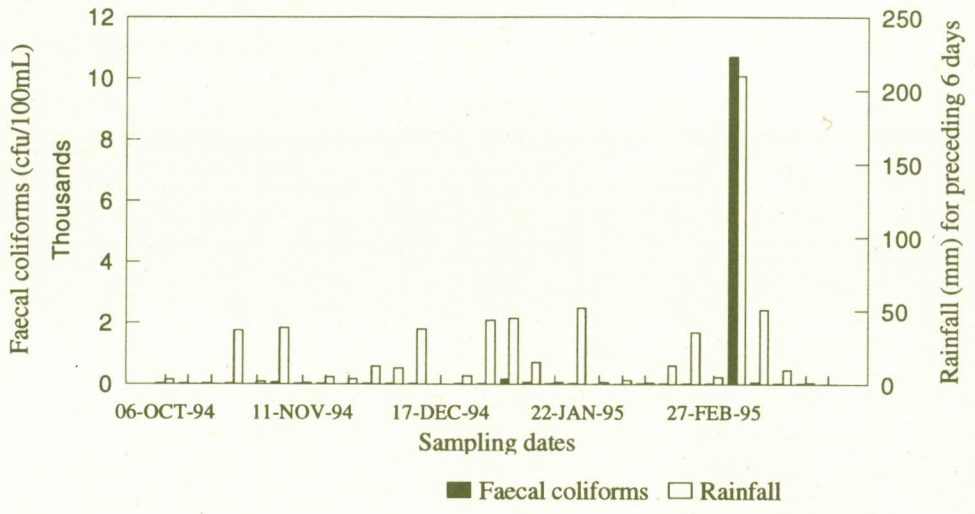
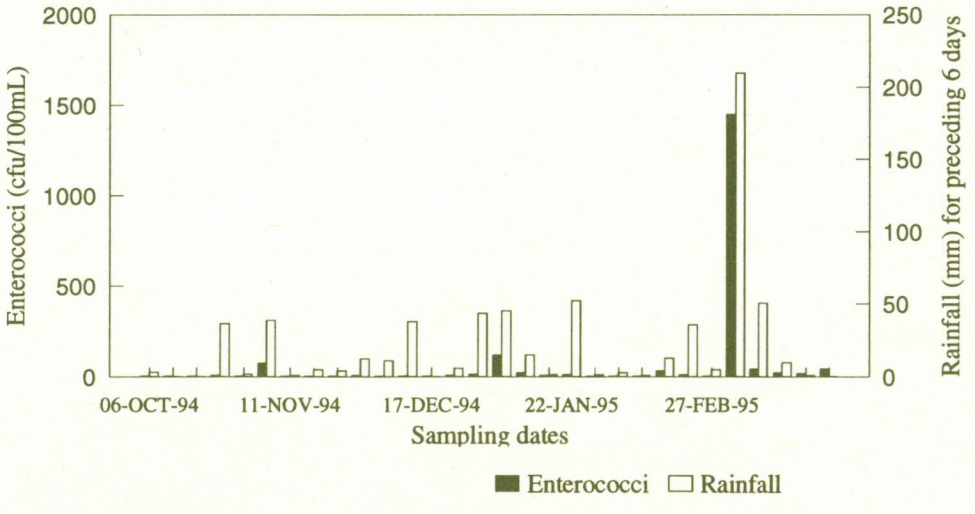


Figure M2 - Berowra Creek @ the Ferry

Enterococcus densities and associated rainfall



APPENDIX B — FIELD SHEET

ENVIRONMENT PROTECTION AUTHORITY
HAWKESBURY-NEPEAN RIVER
RECREATIONAL WATER QUALITY
FIELD SHEET

NAME OF COLLECTORS:

SITE NAME: SECTION NO:

SAMPLE CODES:

DATE: TIME:

FIELD MEASUREMENTS:

pH:

TEMP: °C

EC: µS/cm

TURB: NTU

SECCHI: m

FIELD OBSERVATIONS (State Yes or No for points 1-4. If Yes include details):

Presence of:

1. nuisance organisms (e.g. macrophytes, phytoplankton scums, algal mats)?
2. oily films on surface or on shoreline?
3. floating debris or grease?
4. odour or frothing?

Colour/appearance of water (e.g. turbid, cloudy, flow conditions, etc):

(When all entries are completed and sample collected)

SIGNATURE:

APPENDIX C — RAINFALL GAUGE INFORMATION

Table C.1
Rainfall gauge location and station numbers

Site location	Rainfall gauge location	Rainfall gauge station no.
Nepean River at Menangle Road Bridge	Menangle Meteorological Station	568168
Nepean River at Bents Basin State Recreation Area	Warragamba Meteorological Station	568045
Nepean River at Tench Reserve boat ramp	Regentville (Factory Road)	567163
Glenbrook Creek at Jellybean Pool	Glenbrook Sewage Treatment Plant	563064
Nepean River at Yarramundi Bridge	Grose Wold	563080
Hawkesbury River at Macquarie Park	Riverstone Sewage Treatment Plant	567100
South Creek at Governor Phillip Park	Riverstone Sewage Treatment Plant	567100
Hawkesbury River at Cattai National Park	Wilberforce	563081
Hawkesbury River at Sackville ferry	Wilberforce	563081
Hawkesbury River at Lower Portland	Wilberforce	563081
Hawkesbury River at Wisemans Ferry	Wisemans Ferry Bowling Club	567108
Hawkesbury River at One Tree Reach	Wisemans Ferry Bowling Club	567108
Berowra Creek at the ferry	Hornsby Heights Sewage Treatment Plant	566053

APPENDIX D — GRID REFERENCES FOR SOUTH CREEK, EASTERN CREEK AND CATTAI CREEK SITES

Site code	Site Location	Map ID *	Latitude	Longitude
245	South Creek at Chisholm Place	9030-I-S	33°37'36"S	150°49'17"E
247	South Creek at Sanctuary Drive	9030-I-S	33°38'04"S	150°49'21"E
250	South Creek at Richmond Road Bridge	9030-I-S	33°40'45"S	150°48'39"E
251	South Creek at Stoney Creek Road	9030-I-S	33°41'34"S	150°47'06"E
252	South Creek at Sixth Avenue	9030-I-S	33°42'28"S	150°45'54"E
253	South Creek at Ninth Avenue	9030-I-S	33°43'10"S	150°45'52"E
254	South Creek at ADI Crossing	9030-I-S	33°43'37"S	150°45'45"E
255	South Creek at Hartog Drive	9030-I-S	33°44'33"S	150°45'05"E
256	South Creek at Christie Street	9030-II-N	33°45'05"S	150°45'44"E
257	South Creek at Luddenham Road Bridge	9030-II-N	33°48'24"S	150°45'56"E
258	South Creek at Lot 815 Luddenham Road	9030-II-N	33°49'36"S	150°45'41"E
259	South Creek at Water Supply Pipeline	9030-II-N	33°49'52"S	150°45'55"E
260	Eastern Creek at Garfield Road	9030-I-S	33°41'11"S	150°51'03"E
261	Eastern Creek at Richmond Road	9030-I-S	33°44'33"S	150°51'50"E
262	Eastern Creek at Level Crossing Road	9030-I-S	33°38'49"S	150°50'05"E
263	Eastern Creek at Power Street	9030-II-N	33°45'21"S	150°51'28"E
264	South Creek at Elizabeth Drive	9030-II-S	33°52'38"S	150°45'58"E
265	Badgerys Creek at Elizabeth Drive	9030-II-S	33°52'32"S	150°45'14"E
267	Kemps Creek at Elizabeth Drive	9030-II-S	33°52'58"S	150°47'50"E
270	Cattai Ck at Cattai Ridge Road	9030-I-N	33°35'00"S	150°56'24"E
272	Cattai Creek at Pitt Town Road	9030-I-N	33°36'09"S	150°55'43"E

* 1:25000 topographic maps

APPENDIX E — REGRESSION ANALYSIS RESULTS

Table E.1
Coefficients of determination (r^2) for linear regression of faecal bacterial densities on rainfall (where n is the number of measurements)

Site	r^2 for faecal coliforms (n)	r^2 for enterococci (n)
Nepean River at Menangle Road Bridge	0.570 (30)	0.617 (30)
Nepean River at Bents Basin State Recreation Area	0.059 (30)	0.326 (30)
Nepean River at Tench Reserve ramp	0.018 (30)	0.438 (30)
Glenbrook Creek at Jellybean Pool	0.608 (30)	0.234 (30)
Nepean River at Yarramundi Bridge	0.463 (30)	0.534 (30)
Hawkesbury River at Macquarie Park	0.010 (30)	0.004 (30)
South Creek at Governor Phillip Park	0.678 (30)	0.669 (30)
Hawkesbury River at Cattai National Park	0.327 (30)	0.348 (30)
Hawkesbury River at Lower Portland	0.218 (30)	0.204 (30)
Hawkesbury River at Wisemans Ferry	0.338 (30)	0.645 (30)
Hawkesbury River at One Tree Reach	0.341 (30)	0.192 (30)
Berowra Creek at the ferry	0.806 (30)	0.829 (30)

Table E.2
Coefficients of determination (r^2) for linear regression of faecal bacterial densities on turbidity (where n is the number of measurements)

Site	r^2 for faecal coliforms (n)	r^2 for enterococci (n)
Nepean River at Menangle Road Bridge	0.594 (30)	0.618 (30)
Nepean River at Bents Basin State Recreation Area	0.421 (30)	0.826 (30)
Nepean River at Tench Reserve	0.017 (30)	0.692 (30)
Glenbrook Creek at Jellybean Pool	0.394 (30)	0.742 (30)
Nepean River at Yarramundi Bridge	0.570 (30)	0.499 (30)
Hawkesbury River at Macquarie Park	0.049 (30)	0.019 (30)
South Creek at Governor Phillip Park	0.654 (30)	0.721 (30)
Hawkesbury River at Cattai National Park	0.227 (27)	0.314 (27)
Hawkesbury River at Sackville Ferry	0.023 (9)	0.095 (9)
Hawkesbury River at Lower Portland	0.174 (27)	0.165 (27)
Hawkesbury River at Wisemans Ferry	0.046 (27)	0.020 (27)
Hawkesbury River at One Tree Reach	0.040 (28)	0.001 (28)
Berowra Creek at the ferry	0.757 (28)	0.746 (28)

Table E.3
Coefficients of determination (r^2) for linear regression of turbidity on rainfall (where n is the number of measurements)

Site	r^2 (n)
Nepean River at Menangle Road Bridge	0.299 (30)
Nepean River at Bents Basin State Recreation Area	0.191 (30)
Nepean River at Tench Reserve	0.546 (30)
Glenbrook Creek at Jellybean Pool	0.185 (30)
Nepean River at Yarramundi Bridge	0.212 (30)
Hawkesbury River at Macquarie Park	0.012 (30)
South Creek at Governor Phillip Park	0.748 (30)
Hawkesbury River at Cattai NP	0.123 (27)
Hawkesbury River at Lower Portland	0.222 (27)
Hawkesbury River at Wisemans Ferry	0.000 (27)
Hawkesbury River at One Tree Reach	0.012 (28)
Berowra Creek at the ferry	0.605 (28)

Table E.4
Coefficients of determination (r^2) for linear regression of (Secchi distance)$^{-1}$ on turbidity
(where n is the number of measurements)

Site	r^2 (n)
Nepean River at Menangle Road Bridge	0.625 (29)
Nepean River at Bents Basin State Recreation Area	0.898 (28)
Nepean River at Tench Reserve	0.561 (28)
Glenbrook Creek at Jellybean Pool	0.842 (29)
Hawkesbury River at Macquarie Park	0.052 (29)
South Creek at Governor Phillip Park	0.357 (29)

Table E.5
Coefficients of determination (r^2) for linear regression of (Secchi depth)$^{-1}$ on turbidity
(where n is the number of measurements)

Site	r^2 (n)
Hawkesbury River at Cattai National Park	0.924 (26)
Hawkesbury River at Sackville Ferry	0.884 (8)
Hawkesbury River at Lower Portland	0.435 (26)
Hawkesbury river at Wisemans Ferry	0.662 (24)
Hawkesbury River at One Tree Reach	0.546 (26)
Berowra Creek at the ferry	0.916 (14)