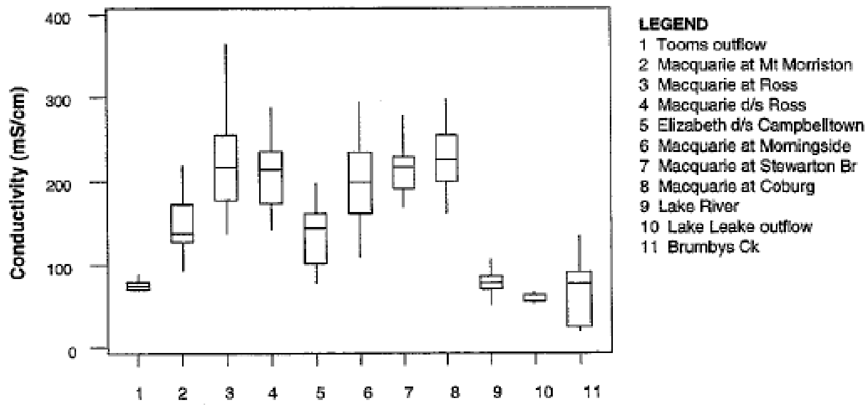

Figure 2.3 Box and whisker plots showing statistics for electrical conductivity from monthly monitoring at sites in the Macquarie catchment.

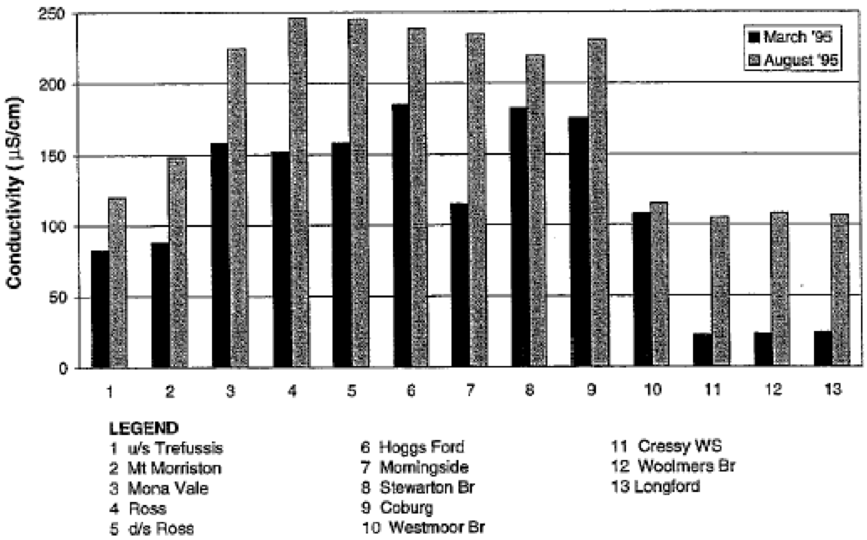

Figure 2.5 Longitudinal transects of electrical conductivity along the Macquarie River performed during 1995.

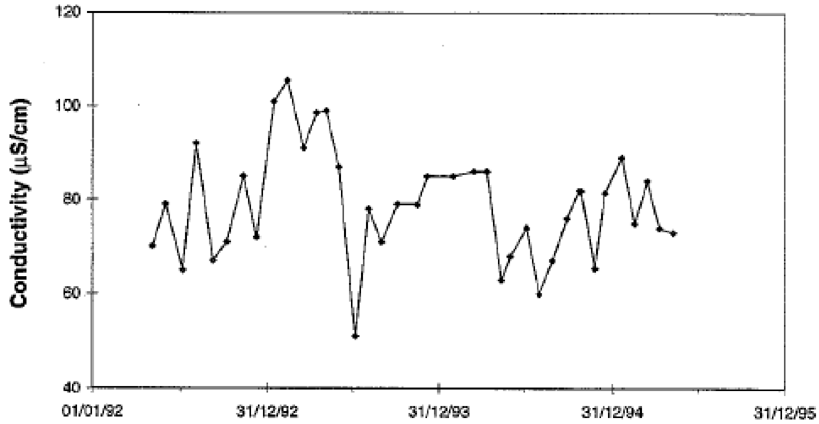

Figure 2.4a Seasonal changes in electrical conductivity in the Lake River.

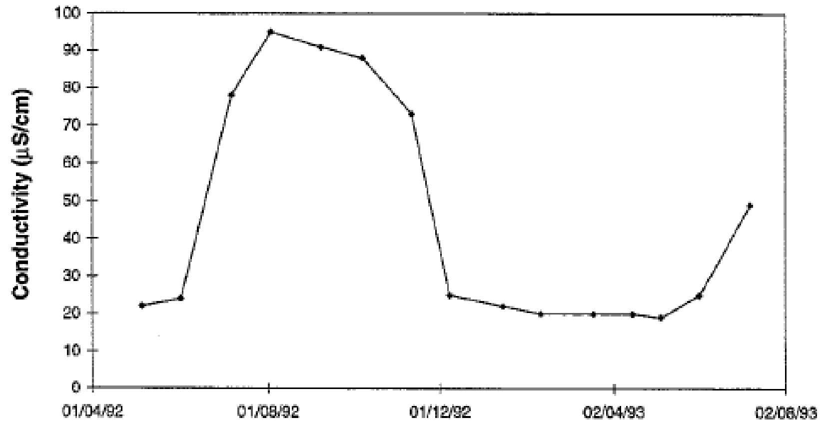

Figure 2.4b Changes in electrical conductivity in Brumbys Creek between May, 1992 and July, 1993.

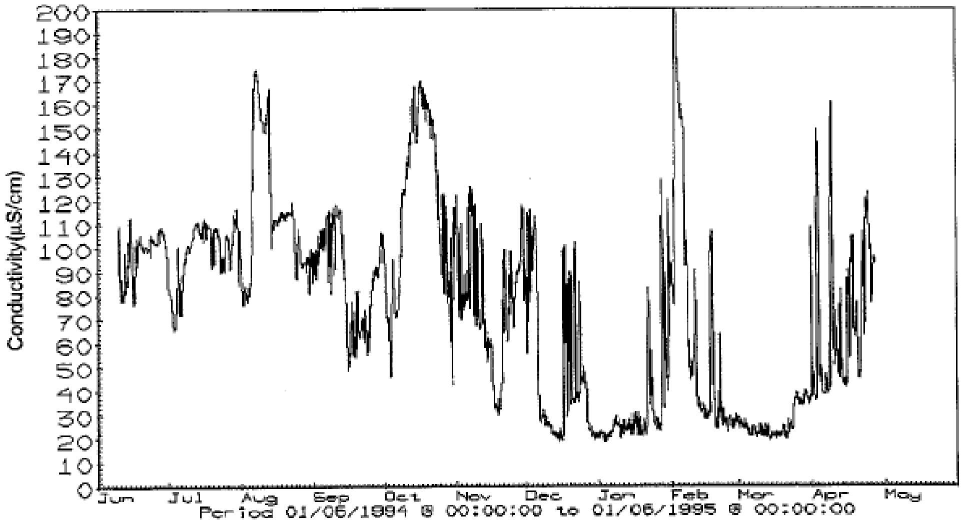

Figure 2.6 Time series of electrical conductivity for the South Esk at Longford between June 1994 and June 1995. *Data collected by permanent probes.

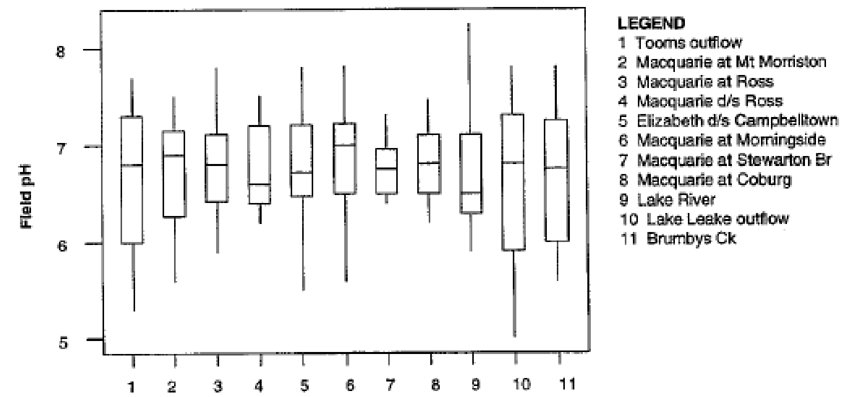

Figure 2.7 Box and whisker plots showing statistics for field pH from monthly monitoring sites in the Macquarie catchment.

Turbidity and Suspended Solids

Monthly data on the concentration of suspended solids was collected at all stations, however turbidity data was only collected at 7 sites during the latter 18 months of the study. Turbidity and suspended solids concentrations are commonly related, as turbidity is an indirect measure of the amount of suspended particles in the water. In the Macquarie catchment suspended solids were low at all sites with median levels well below 5 mg/L. However greater differences exists between sites where turbidity was monitored (Figure 2.8).

Within the Macquarie River, turbidity is generally less than 5 NTU. Both the Elizabeth and Lake rivers are more turbid, with median turbidity values of 10.7 and 13.5 NTU respectively. The impact of inflow from the Elizabeth is also responsible for the higher than expected turbidity at Morningside in the Macquarie River. Although these tributaries appear dirtier than the Macquarie into which they flow, they carry little sediment as much of their turbidity is due to very fine suspended clay particles.

The longitudinal transect of the Macquarie River during August 1995 (Figure 2.9) shows the effect significant rain in the catchment had on turbidity levels in the river after a prolonged dry period.

Heavy rain throughout the catchment two days prior to the survey caused a 5-10 fold increase in turbidity at monitoring stations in the lower Macquarie River. The resulting flood in the Macquarie appears on this plot at the uppermost sites where the resuspension of sediment caused turbidity readings of 80-100 NTU. During higher flow in tributaries such as the Isis, Elizabeth and Lake rivers, turbidity levels of between 15 and 48 NTU were measured.

Dissolved Oxygen

Dissolved oxygen (DO) concentrations were measured at five sites in the catchment during the second half of the study. Median concentrations at these sites was between 9.4 and 10.7 mg/L (Figure 2.10). However concentrations below 6.5 mg/L were measured at Ross and Coburg, indicating that slight oxygen depletion during summer was occurring in some areas. While such readings could be regarded as marginal, they are above the ANZECC (1992) guidelines which set a threshold of 6 mg/L for the protection of aquatic organisms.

DO at sites in the Macquarie generally exhibited a broad seasonal variation with lowest levels occurring between December and February, which generally corresponds with highest temperatures and lowest flows. High temperature tends to decrease the solubility of oxygen in water and low flows tend to prevent atmospheric oxygen entering the water through turbulence. Other factors affecting this seasonal pattern are instream ecological processes, the most dominant being photosynthesis and respiration of aquatic plants.

2.3 General Ionic characterisation

The chemical constituents which determine the ionic character of water in the Macquarie catchment were measured on a quarterly basis at six monitoring sites during the study. These are commonly referred to as the ‘dissolved salts’ of water and together contribute to the conductivity of the water.

The ionic character of the water generally reflects the soil and parent rock type through which the water flows. In the Macquarie catchment, the Elizabeth and Lake rivers, which flow out of areas dominated by dolerite, are more dilute and tend to have relatively lower calcium and magnesium concentrations and hence lower alkalinity (ability to resist pH changes) and hardness (ability to produce soap lather). The dilute nature of these waters

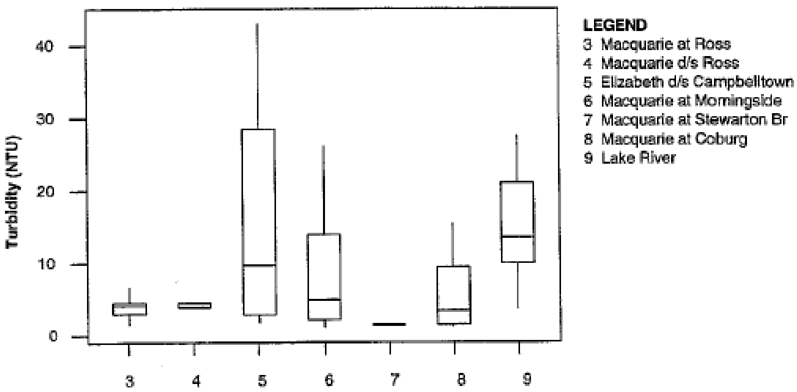

Figure 2.8 Box and whisker plots showing statistics for turbidity from monthly monitoring at sites in the Macquarie catchment.

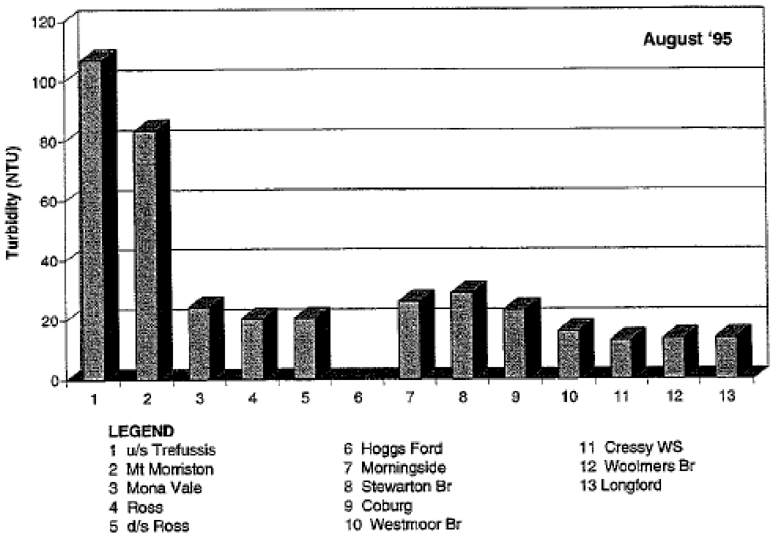

Figure 2.9 Longitudinal transect of turbidity along the Macquarie River performed during August, 1995. Runoff from heavy rain the night before the survey is resulted in high turbidity levels in upper catchment sites.

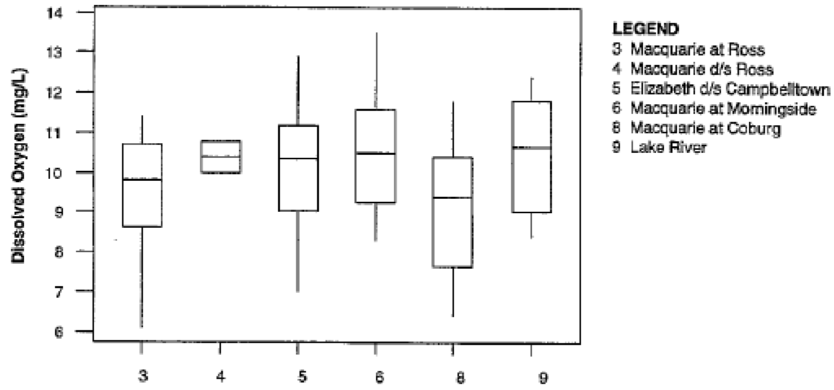

Figure 2.10 Box and whisker plots showing statistics for dissolved oxygen from monthly monitoring at sites in the Macquarie catchment during the latter 18 months of the study.

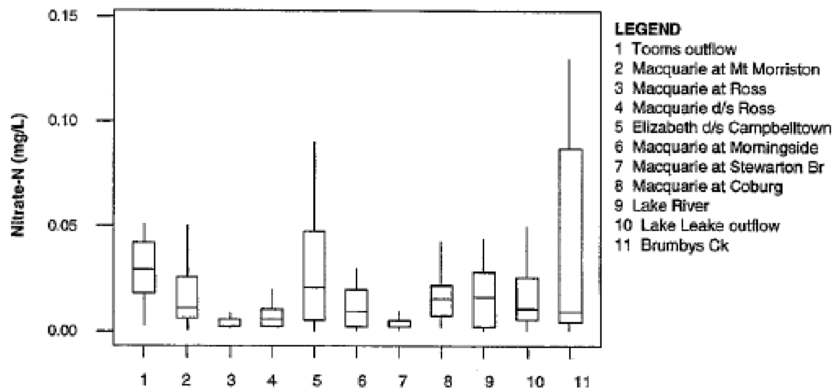

Figure 2.11 Box and whisker plots showing statistics for nitrate - N from monthly monitoring at sites in the Macquarie catchment.

make them susceptible to large pH changes which was evident in the pH plots displayed earlier.

TABLE Ionic parameters measured at sites in the Macquarie catchment.

	Alkalinity (mg/L)	**Hardness** (mg/L)	**Chloride** (mg/L)	**Calcium** (mg/L)	**Potassium** (mg/L)
Ross	25	75	42	13	0.65
Elizabeth	12	38	23	6.8	0.41
Morningside	20.5	62	39	10.2	0.52
Coburg	19	67	43.5	11	0.77
Lake River	12.5	32	7.2	6.55	0.46

Values are medians of dataset. A summary of all ionic parameters is presented in Appendix A.

Higher concentrations of all parameters is found in the Macquarie River where greater contact with soil and evaporative processes combine to mineralise the water. During the low flows of summer, much of the water in the Macquarie River resides for some considerable time in long pools termed 'broadwaters'. This may provide greater opportunity for dissolution of ions into the water column and concentration through evaporation. Wetlands are also known to contribute dissolved ions to rivers (UNESCO, 1992).

2.4 Nutrients

The nutrients discussed in this section include the forms of nitrogen and phosphorus most commonly associated with plant growth and productivity. The forms of nitrogen are ammonia-N, nitrite-N, nitrate-N and Total Kjeldahl-N (TKN) which is organic N + ammonia-N. The first three forms were measured at all sites in the Macquarie catchment, however TKN was only measured at 5 sites late in the study. Discussion in this report will be limited to nitrate-N, which makes up the largest portion of dissolved nitrogen, and Total N which is derived by calculation (as TKN+Nitrate-N+Nitrite-N). As nitrite-N and ammonia-N were generally only present at very low levels relative to nitrate-N and TKN, these forms of nitrogen will not be discussed.

It is worth noting however, that isolated readings of ammonia-N as high as 1.3 mg/L were detected at some sites during summer sampling. The isolated occurrence of these readings at sites where no obvious pollution was taking place makes their interpretation difficult. However, literature states that concentrations of this order can be caused the decay of organic material after excessive plant growth, discharge of domestic sewage effluent and fertiliser runoff (UNESCO, 1992).

The forms of phosphorus; Total P (TP) and Dissolved Reactive P (DRP), were measured at all sites. The analysis of TP includes all phosphorus both bound to particulate matter and dissolved in the water. The dissolved phosphorus, measured as DRP, is generally considered as largely free and available to aquatic plants and algae. In natural waters DRP generally makes up only a very small fraction of TP. Therefore, unless higher levels of DRP have been detected, the following discussion will focus on TP only.

2.4.1 Station conditions and Trends

Nitrate-N

Nitrate-N concentrations in the Macquarie catchment was much lower than in either the Meander or the South Esk catchments. Median concentration at all sites was below 0.04 mg/L with Tooms River and the Elizabeth River below Campbelltown having the highest median nitrate-N concentrations of 0.03 and 0.022 mg/L respectively (Figure 2.11).

The large nitrate-N range shown for Brumbys Creek is due to a single high reading of 0.44 mg/L which is highly likely to be due to sampling error. Several readings of over 0.05 mg/L were measured at this site.

The lower nitrate-N levels throughout the catchment may be governed by concentrations in the impoundments in the headwaters as river flows in most parts of the Macquarie are sustained by controlled releases from these storages rather than from groundwater sources. The correlation between nitrate-N in storage releases and the concentrations downstream is clearly evident in Figure 2.12, which compares nitrate-N concentrations in the Lake River with those measured in Woods Lake during the same period. Lake River flow is controlled by releases from Woods Lake (data courtesy IFC and HEC).

A possible exception to this is the Elizabeth below Campbelltown which is approximately 43 km downstream from Lake Leake. The variation in nitrate-N levels at this site is clearly seasonal, with higher concentrations occurring during winter flows (Figure 2.13). This is most probably due to flows in the river being sustained through the winter from groundwater sources rather than lake releases, which generally only occur during the summer. It is well known that nitrate-N is easily transported in water movement below the root zone (Goldman and Horne, 1983; Webb and Walling, 1985). During the summer, groundwater movement would be minimal as this area receives little rain, however winter rains may cause greater groundwater movement.

Higher concentrations during winter are also known to occur due to reduced plant uptake and incomplete ground cover which can intercept nitrate-N released by mineralization or fertilizer application (Wright, et al., 1991). In addition, forestry activity in the upper catchment may have had some effect as increased leaching of nitrate-N has also been found in areas where clearing of forests has occurred (Stevens and Hornung, 1988).

Total N

Sufficient TKN data for the calculation of Total N was collected at five sites in the catchment. It is evident that TKN (largely organic nitrogen) is the dominant form of nitrogen in the system, with median Total N concentrations at these sites ranging between 0.3 and 0.6 mg/L (Figure 2.14).

These levels are higher than was found in rivers in the South Esk and roughly similar to concentrations in rivers of the Meander catchment. The added TN load from the sewage treatment plant upstream of the site on the Elizabeth River may explain the higher concentration of TN at this site.

The ANZECC (1992) guidelines for the protection of freshwaters in Australia is 0.1 - 0.75 mg/L for Total N and it is suggested that concentrations above this may cause deleterious effects on the aquatic ecosystem (i.e. cause algal blooms). During prolonged low flows in the Macquarie during the summer of 1994-95, there was considerable growth of filamentous algae at many sites. At most of these sites the low TP concentrations (refer next section) was more likely to have limited algal growth than the level of nitrogen.

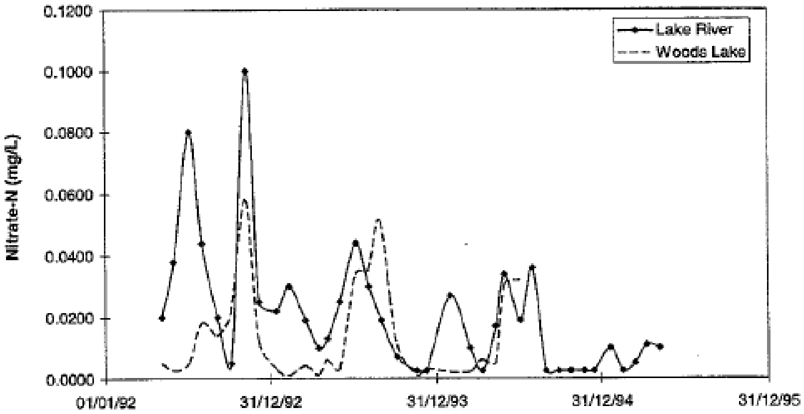

Figure 2.12 Changes in Nitrate-N concentration in the Lake River upstream of the Macquarie River and in Woods Lake between 1992 and 1995.

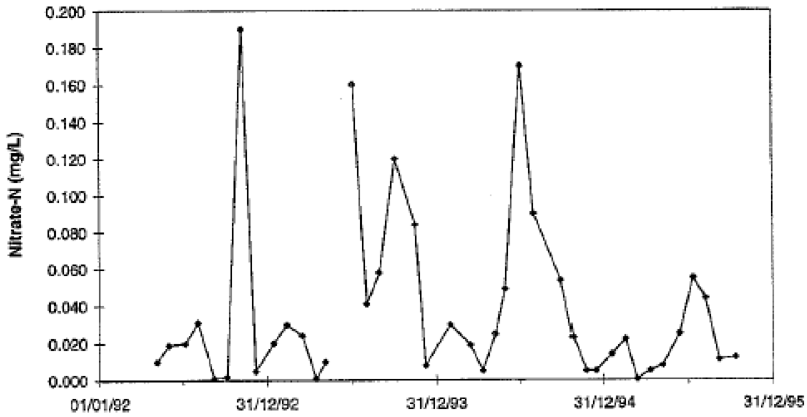

Figure 2.13 Monthly changes in Nitrate - N concentration in the Elizabeth River downstream of Campbelltown between 1992 and 1995.

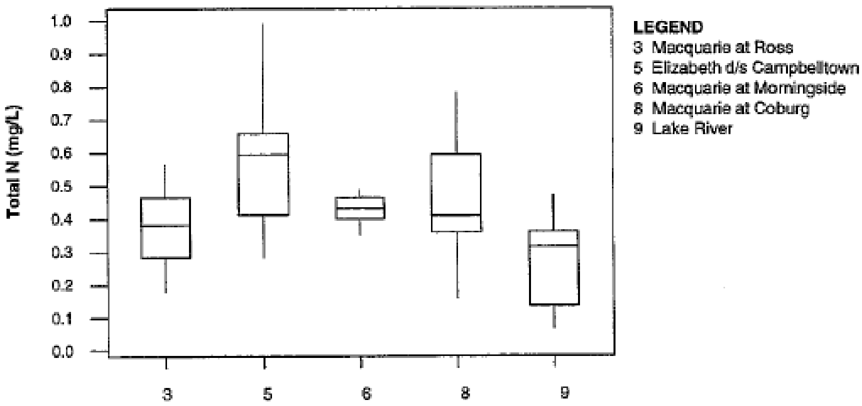

Figure 2.14 Box and whisker plots showing statistics for Total N concentration from monthly monitoring at sites in the Macquarie catchment.
Total N calculated from 12-17 samples.

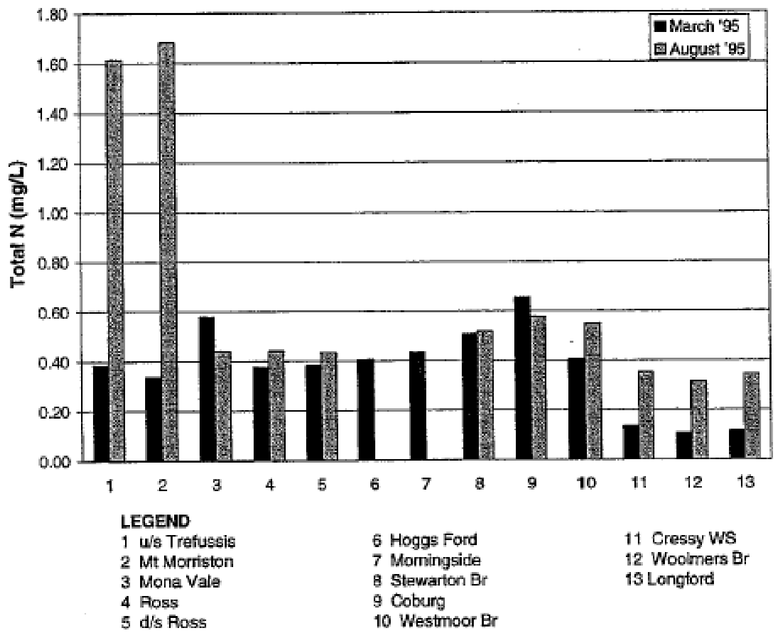

Figure 2.15 Longitudinal transects of Total N concentration along the Macquarie River performed during March and August, 1995.

Longitudinal transects of the Macquarie River during 1995 show that Total N concentrations are fairly uniform along the entire length of river upstream of Brumbys Creek. Elevated levels in the upper reaches during the winter survey demonstrate the large impact of flooding on TN levels in the river. A larger proportion of the TN at this time is made up of nitrate-N.

During both winter and summer transects, it is apparent that successive dilution by inflows from the Lake River and Brumbys Creek decrease the TN concentration in the Macquarie River downstream of Coburg (Figure 2.15). This dilution is most significant during summer when flow in the river below Coburg is almost totally dominated by the more dilute waters originating from the Central Highlands.

Total P

Most sites in the Macquarie catchment have very low total phosphorus (TP) concentrations. With the exception of the Elizabeth River, concentrations of TP at most sites was below 0.02 mg/L (Figure 2.16). Unlike rivers in both the South Esk and Meander catchments, no increase in TP levels towards the bottom of the Macquarie catchment was evident.

The much higher level of TP at the site on the Elizabeth River clearly shows the impact of discharge from the sewage treatment plant at Campbelltown. Furthermore, depending on flows in the river, up to 90% of the phosphorus measured at this site was in the dissolved form (DRP). TP concentrations in the Macquarie River downstream of the Elizabeth River junction may also be influenced by discharge from this source as relatively high proportions of dissolved phosphorus were also measured at this site. During most of this study, prolific growth of attached algae was always present at this site.

Phosphorus concentrations in the Lake River ranged between 0.004 - 0.05 mg/L. When compared to TP monitoring in Woods Lake during the same period (Figure 2.17), it appears that like nitrate-N, TP levels in the river are at least partially related to conditions in the lake (data courtesy IFC and HEC). Woods Lake is a shallow and exposed storage which is subject to nutrient fluctuations as a result of various factors including lake level management and climatic conditions. Factors affecting changes in water quality in Woods Lake are a subject of ongoing investigation by the IFC as part of a consultancy for the HEC.

The transects of the Macquarie give a picture of TP variations within the river, particularly during stable summer flows (Figure 2.18). In the summer survey phosphorus concentrations throughout the river generally varied between 0.017 - 0.023 mg/L. Sites where phosphorus was significantly higher than this were at Mona Vale just upstream of the junction with the Blackman River (TP = 0.046 mg/L), and at a site immediately downstream of the sewage treatment plant at Ross (TP = 0.032 mg/L). At both these sites, catchment activities in the area provide a possible explanation for these higher TP concentrations.

During higher winter flows, after significant rain in the catchment, the concentration of TP at all sites was generally higher (0.022 - 0.031 mg/L). A flood making its way down the Macquarie is clearly identified by the higher concentration of TP measured in the upper two sites (0.07 mg/L). Concentrations of TP in tributaries of the Macquarie during this time were also significantly higher than during summer, as is shown in the plot of TP in the Elizabeth River (Figure 2.19).

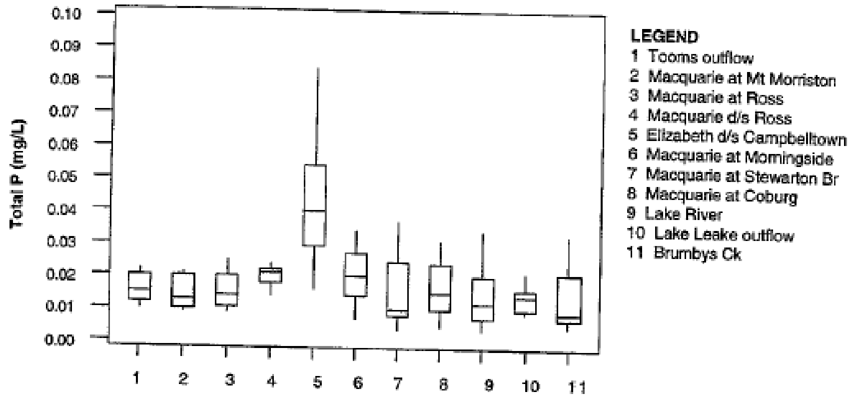

Figure 2.16 Box and whisker plots showing statistics for Total P concentration from monthly monitoring at sites in the Macquarie catchment.

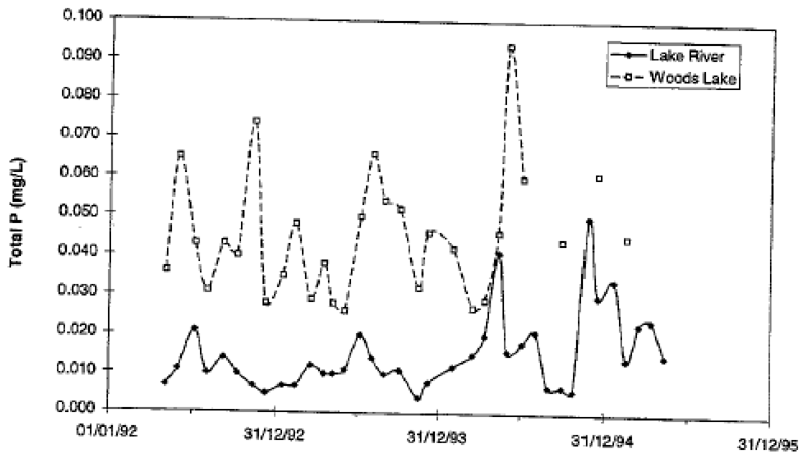

Figure 2.17 Changes in Total P concentration in the Lake River upstream of the Macquarie River and in Woods Lake between 1992 and 1995.

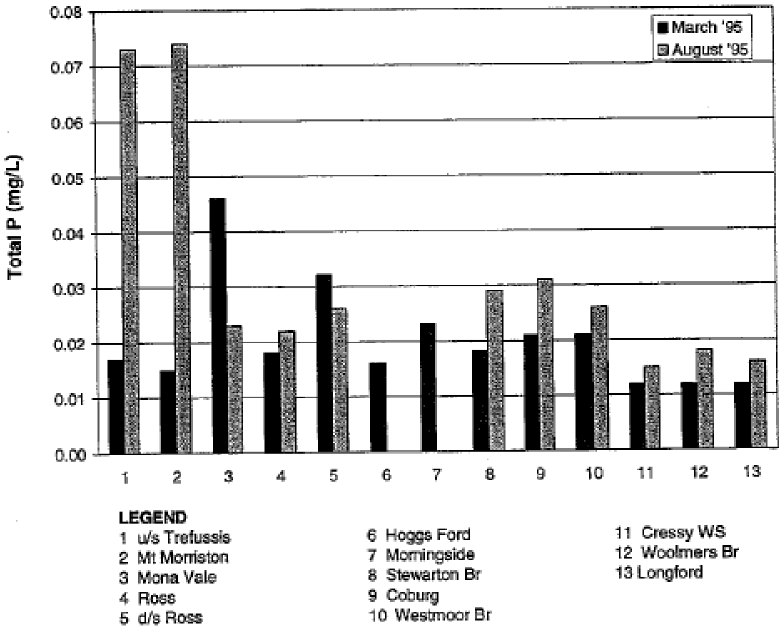

Figure 2.18 Longitudinal transects of Total P concentration along the Macquarie River performed during March and August, 1995.

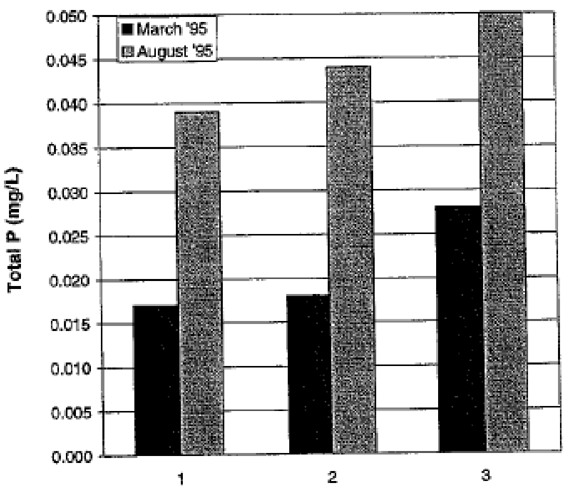

Figure 2.19 Longitudinal sampling of Total P concentration at sites in the Elizabeth River during March and August, 1995.

2.4.2 Catchment Budget + Point Inputs

Phosphorus export loads were calculated for four sites in the Macquarie catchment for the period between May 1992 and October 1995. Although monitoring at some sites was not carried out for the whole duration of the study (Tooms River and Lake Leake outflow) fairly stable TP concentrations at these stations indicated that further monitoring was not required to increase the accuracy of load estimates. At other sites (Mt Morriston and Morningside) additional spot sampling during higher flows was performed to achieve better load estimates.

Flood sampling in the Macquarie catchment was not commenced until the last year of the study, which coincided with a drought in the area. As a result, the flood samples which were taken were from only minor events in relation to the major floods which took place during 1992-93 (220 & 436 cumec flood peaks in the Macquarie river at Morningside). In light of this, the following estimates of export of all nutrients should be considered conservative, and are likely to be much lower than the actual loads exported.

At the site on the Elizabeth River below Campbelltown, TP and TN export could only be estimated for the short period during which flow was monitored (16/2/95 - 5/9/95). The only other site with sufficient TN data for calculating nitrogen export load was Macquarie at Morningside. At all other sites, insufficient TKN data was collected to permit estimates of TN export. Therefore, at these sites export of dissolved inorganic nitrogen (DIN) was estimated. This form of nitrogen, which is made up mostly of nitrate-N, is always a small proportion of the total nitrogen concentration and hence loads of DIN at these sites will be much smaller than the TN load.

Standard regression analysis was used to estimate nutrient loads at sites where river flow was monitored. Relationships between P and N (or DIN) concentration and flow were established using either normal or log transformed data, and the resulting relationship(s) was then used to convert the flow record to a concentration time series. Load estimates made in this way are known to have no greater accuracy than about +/- 15% (Refs.) and the following figures should be viewed with this in mind.

In some cases, flow weighted means and flow partitioning methods were used where no reasonable relationships between flow and concentration existed. For outflow from the lakes (Tooms and Leake) a mean concentration was used for load calculations as nutrient concentrations showed little variation.

Flood Concentrations

During flooding in rivers of the Macquarie catchment, nutrient concentrations increased up to 40 times their normal concentrations at some sites. The table below lists the maximum concentrations of some nutrients measured during high flows in various places throughout the catchment. The most notable increase is for nitrate-N which for much of the time at most sites is very low. It tends to indicate that during significant rainfall events, nitrate-N which may not be entering rivers during drier period due to lack of groundwater flow, is readily mobilised.

TABLE Maximum concentrations of nutrients measured during flooding in the Macquarie catchment.

	Maximum (mg/L)
Turbidity	107
Nitrate-N	0.34
Ammonia-N	0.052
Total N	1.4
Dissolved Reactive P	0.025
Total P	0.075

Point Sources

Point source inputs to the Macquarie system are minimal with the only major sources being the sewage treatment plants at Ross and Campbelltown. Both discharge treated wastewater directly to rivers; at Ross to the Macquarie River and at Campbelltown to the Elizabeth River. During limited sampling of the treatment plants, concentration and flow was measured to give estimates of nutrient loads. The following estimates of annual nutrient loads being discharged from the sewage treatment are given below. It was assumed that daily discharge volume was constant, although illegal connection of stormwater drains to the septic system is probable, with resulting discharge during rain events likely to be greater.

TABLE Nutrient discharge estimates from sewage treatment plants based on limited spot samples.

Location	**Annual Water Discharge** (ML)	**Annual P Discharge** (kg)	**Annual N Discharge** (kg)	**DIN Discharge** (kg)
Ross	22.3	73	2,628	2,194
Campbelltown	111.3	847	4,785	3,581

The most notable figures in this table are those for nitrogen discharge In a system where nitrate-N is low, a large percentage of the nitrogen discharged by both the treatment plants is in the dissolved form.

Phosphorus Export

Using the additional data collected during river flooding to estimate export loads for P from the stream gauging sites and the estimated discharge from the STP's at Ross and Campbelltown, the total P export for the entire period of the study is presented graphically in the Figure 2.20. The only site for which this could not be calculated was the Elizabeth below

For the entire 3.4 years over which monitoring was carried out, a total of 24, 478 kg of phosphorus was estimated to have been exported from the upper 2041 km^2 of the Macquarie catchment. The total volume of water discharged during the study was 402,256 ML, 77% of which flowed from the catchment during the first 20 months. Two major floods during this time were responsible for much of this discharge and a large percentage of the P load for the period (>80%) was carried by these floods.

The catchment area above Mt Morriston (937 km^2) contributed 43.3% to the total export load of P at Morningside, with only a small fraction of the P load originating from Tooms Lake and Lake Leake. A large proportion of the 13,884 kg of P entering the Macquarie river between Mt Morriston and Morningside appears to have come from diffuse sources, however

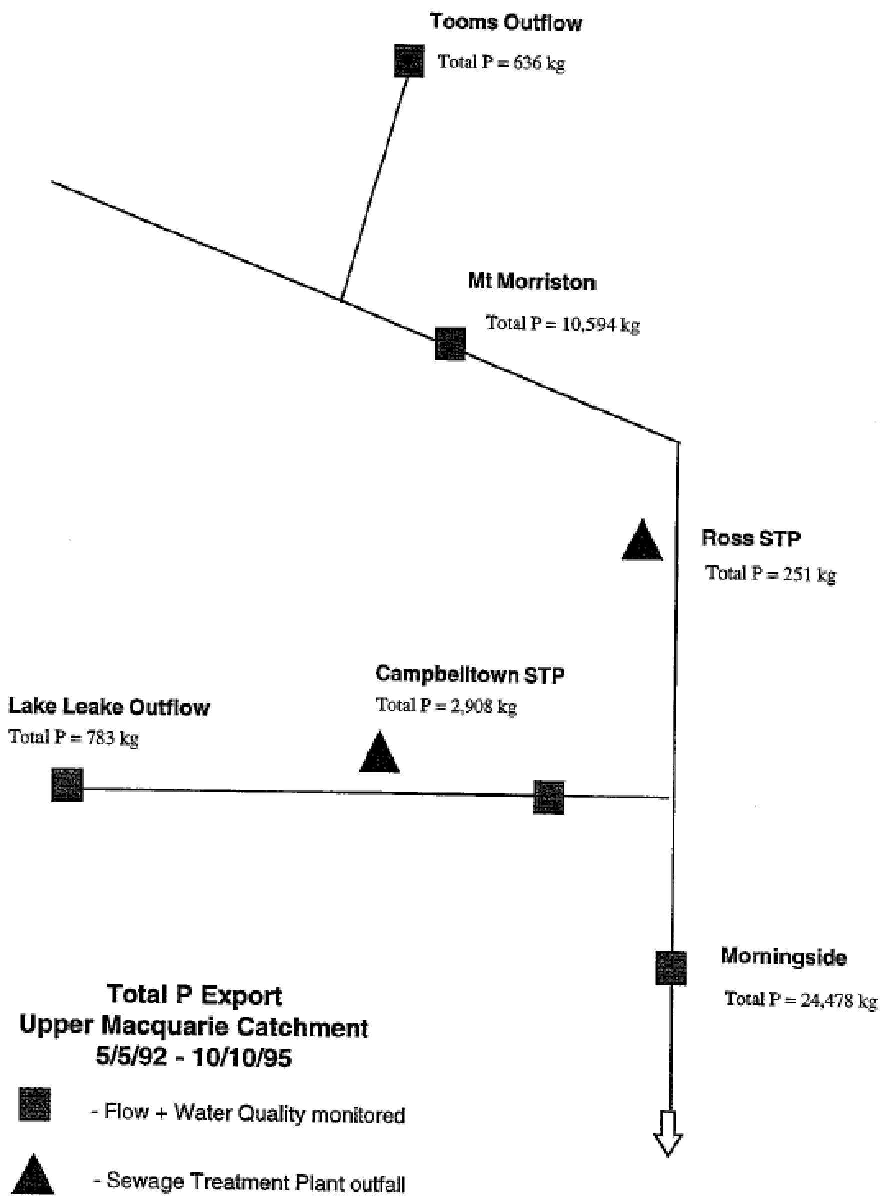

Figure 2.20 Estimated export loads of Total Phosphorus for sites in the Macquarie catchment over the period of the study.

the combined load of P from the sewage treatment plants is 3,159 kg which is 13% of the export measured at Morningside. (The impact of P loads from the Campbelltown STP on P loads in the Elizabeth river is included in a discussion of loads during 16/2/95 to 5/9/95 below). Significant pickup of P in the Elizabeth river downstream of Lake Leake is likely to have occurred through surface runoff, and a significant P load to the Macquarie is also likely to have come from the Blackman River, which is currently undergoing logging in the upper catchment.

The tables below give the annual estimates of discharge volumes at each site, the estimated P load and the export coefficient for the corresponding period. The export coefficient corrects for catchment area and discharge volume and allows comparison of export between catchments of different sizes.

As would be expected from any water storage, annual export loads of TP from both Lake Leake and Tooms Lake are very low, with the maximum annual load from both lakes occurring in the first eight months of the study (1992). Although lower in TP concentration, P export from Lake Leake was greater than from Tooms Lake for all years. The relatively low P loads from both lakes is to be expected as it is well known that lakes act as nutrient and sediment sinks. Nutrients and suspended matter entering the lake in runoff from the surrounding countryside tend to settle out of the water before it leaves the lake.

At Mt Morriston most of the estimated load of P (around 20, 000 kg) was exported during the early period of the study and the export coefficients during this period are by far the highest recorded in the catchment during the entire study. The highest coefficient of 0.095 kg/mm/ km^2 was for 1993, despite a higher volume of water being discharged during the eight months of 1992. This is because a very large flood with a peak flow of 314 cumecs and a total discharge volume of 44,503 ML (74% of annual discharge) was estimated to have carried a large load of P (5,400 kg). This load was carried over only 4 days, clearly illustrating that in rivers such as those of the Macquarie catchment, most of the annual load of P is carried in a very short time.

This picture is reflected at the next site on the Macquarie downstream at Morningside, where the export coefficient for 1993 is also greater than that for the eight months of 1992. Export coefficients at all sites is much lower in the 1994 and 1995 periods, when a drought in the region kept flows (and hence P loads) to a minimum. It is worth noting that during this time the P load from Tooms Lake contributes much more to the load downstream at Mt Morriston (55%) than in any other year.

In 1995, export coefficients at both Mt Morriston and Morningside have increased due to drought - breaking rains in the catchment. The export coefficient for a similar period at the site on the Elizabeth river is greater than these. It has been found at sites in the Meander and South Esk catchments that tributary sites often have higher export coefficients than their mainstream counterparts, and is most probably a result of several factors including greater catchment activity, more active erosion and higher water velocities.

	Area	Period	Discharge	P Export	Coefficient
	(Km^2)		(ML)	(kg)	kg/mm/km^2
					(=kg/ML)
Tooms Lake	60	5/5/92 - 31/12/92	13502	230	0.017
		1/1/93 - 31/12/93	11936	202	0.017
		1/1/94 - 31/12/94	8794	150	0.017
		1/1/95 - 10/10/95	3177	54	0.017
Mt Morriston	937	5/5/92 - 31/12/92	71,780	3,902	0.079
		1/1/93 - 31/12/93	59,734	5,700	0.095
		1/1/94 - 31/12/94	14,702	271	0.018
		1/1/95 - 10/10/95	22,670	721	0.032
Morningside	2041	5/5/92 - 31/12/92	183805	12,913	0.037
		1/1/93 - 31/12/93	127665	8,454	0.047
		1/1/94 - 31/12/94	39835	1,234	0.028
		1/1/95 - 10/10/95	50951	1,877	0.029
Lake Leake	70	5/5/92 - 31/12/92	23204	325	0.014
		1/1/93 - 31/12/93	16369	229	0.014
		1/1/94 - 31/12/94	10677	151	0.014
		1/1/95 - 10/10/95	5601	78	0.014
Lower Elizabeth	421	16/2/95 - 5/9/95	21794	937	0.043

Nitrogen Export

As stated earlier, sufficient TKN data for the estimation of Total N export was only collected at two sites in the Macquarie catchment. At Morningside on the Macquarie river, Total N export for the study was estimated at 417.13 tonnes, with most of this load being exported during the first 20 months of the study. As was found for TP, the largest export coefficients occurred during 1993 with coefficients in subsequent years 45% lower.

A comparison of export of N from the Elizabeth River with that estimated in the Macquarie River at Morningside downstream, shows that during that seven months approximately 60% of both the flow and the N load in the Macquarie River at Morningside came from the Elizabeth River. Despite the difference in catchment areas drained by these two sites (421 and 2041 km^2), the export coefficients for both sites are almost the same, indicating that export mechanisms for N in both catchment may be similar.

Comparison of these values with those measured in the South Esk and Meander catchments shows that while lower values occurred in the South Esk during prolonged low flows, values of up to 3.011 kg/mm/km^2 were also measured (St Pauls River, 1995). In the Meander catchment, export coefficients were typically in a similar range to those in the Macquarie.

As Total N could not be estimated for all sites, the amount of dissolved nitrogen (DIN) export has been estimated. The results for total DIN loads at all sites for the study are shown diagramatically in Figure 2.21, with the annual load figures, as well as the annual discharge volume and export coefficients presented in the Table below.

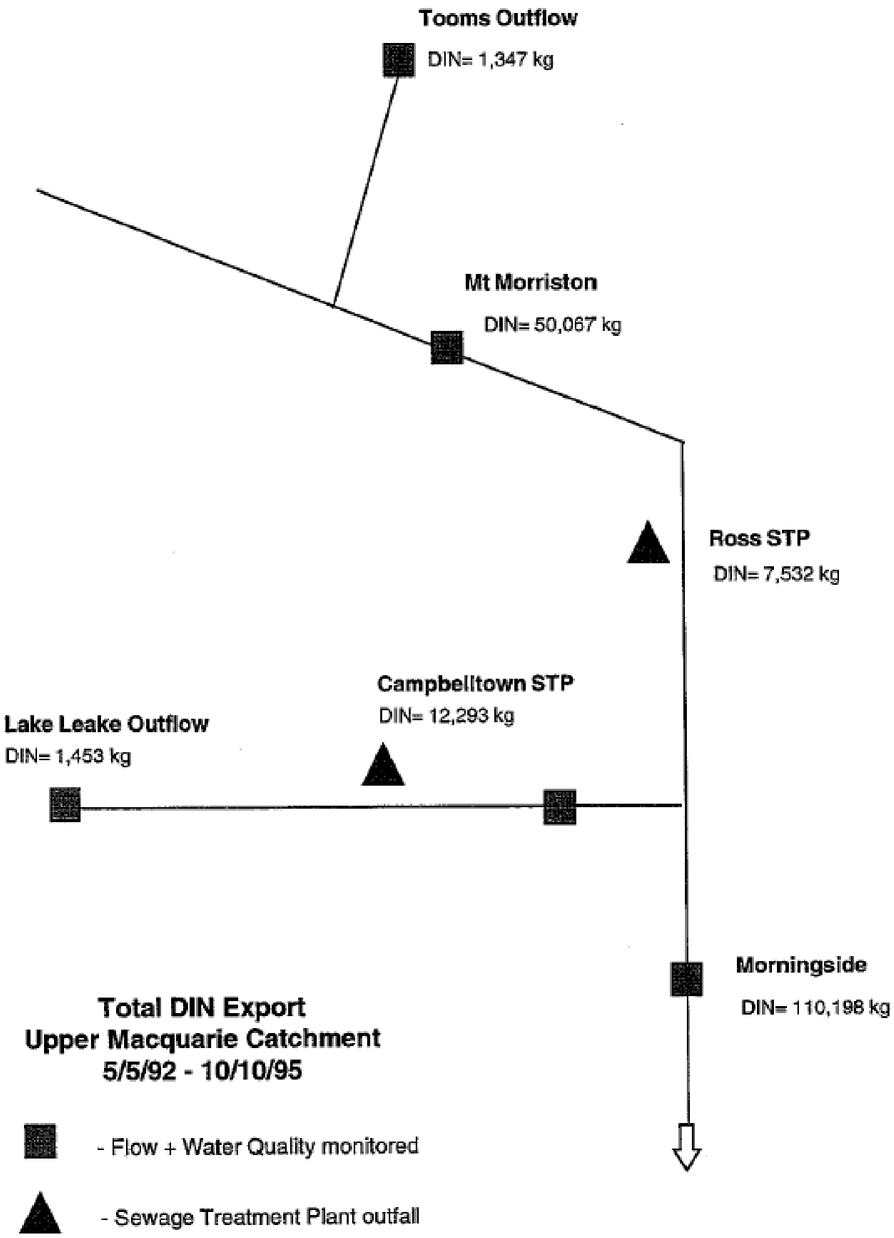

Figure 2.21 Estimated export loads of Dissolved Inorganic Nitrogen (DIN) for sites in the Macquarie catchment over the period of the study.

TABLE Export loads and co-efficients for the Macquarie at Morningside and the Elizabeth River downstream of Campbelltown.

	Area	Period	Discharge	N Export	Coefficient
	(Km^2)		(ML)	(kg)	kg/mm/km^2
					(=kg/ML)
Morningside	2041	5/5/92 - 31/12/92	183805	182,107	0.991
		1/1/93 - 31/12/93	127665	168,809	1.322
		1/1/94 - 31/12/94	39835	28,629	0.719
		1/1/95 - 10/10/95	50951	37,581	0.738
Morningside	2041	# 16/2/95 - 5/9/95	35401	26,285	0.742
Lower Elizabeth	421	# 16/2/95 - 5/9/95	21794	16,204	0.744

Total estimated DIN export from the Macquarie catchment above Morningside was 110.2 tonnes, which is approximately 26% of the total N export estimated at this site(from the TN export table above). The most obvious feature of this diagram is that there is a two to five-fold increase in DIN loads over the estimated P loads at most sites. The relative contributions of DIN from the sewage treatment plants is significant as they contribute 18% of the total DIN load (up from 13% for P), with the bulk of this load being discharge to the river during low flows, when DIN concentrations in the river are naturally low. This is highlighted in the discussion below on nutrient loads during 16/2/95 - 5/9/95.

	Area	Period	Discharge	DIN Export
	(Km^2)		(ML)	(kg)
Tooms Outflow	60	5/5/92 - 31/12/92	13502	486
		1/1/93 - 31/12/93	11936	430
		1/1/94 - 31/12/94	8794	317
		1/1/95 - 10/10/95	3177	114
Mt Morriston	937	5/5/92 - 31/12/92	71777	27,157
		1/1/93 - 31/12/93	59,734	19,414
		1/1/94 - 31/12/94	14,702	733
		1/1/95 - 10/10/95	22,670	2,763
Morningside	2041	5/5/92 - 31/12/92	183805	51,854
		1/1/93 - 31/12/93	127665	38,578
		1/1/94 - 31/12/94	39835	8,329
		1/1/95 - 10/10/95	50951	11,437
Lake Leake	70	5/5/92 - 31/12/92	23204	603
		1/1/93 - 31/12/93	16369	426
		1/1/94 - 31/12/94	10677	278
		1/1/95 - 10/10/95	5601	146
Lower Elizabeth	421	16/2/95 - 5/9/95	21,794	2,268

As was noted in earlier sections, much of DIN in rivers of the Macquarie catchment is comprised of nitrate-N, which is present at very low concentrations during baseflows. However concentrations during higher flows increase substantially, indicating that nitrate-N which cannot get to the river during low flows is transported mainly during rainfall events, when subsurface flows can operate. This is very similar to the transport of phosphorus, which is most commonly transported to the river in surface runoff during rain events.

The Total P and DIN loads for the autumn - winter period in 1995 have been plotted to allow the nutrient load at Elizabeth d/s Campbelltown to be included in catchment budget estimates Figures 2.22 and 2.23). The figures clearly show that the load of TP, and to a lesser extent DIN, being exported from the Elizabeth River catchment contributes significantly to the total load estimated at Morningside, just downstream. It also shows that the STP at Campbelltown is a large contributor to this load, making up 50% of the P load and 87% of the DIN load in the Elizabeth River.

This load is considerable, especially when much of the TP discharged from the STP is as DRP which is more freely available for plant and algal growth. The impact on DRP levels during low flows was still apparent several kilometres downstream in the Elizabeth River, where DRP contributed up to 90% of TP in monthly samples.

Closer examination of the estimated P loads also reveal that the total load from Mt Morriston, the STP at Ross and the load from the Elizabeth River amount to a greater total than was estimated at Morningside downstream (1420 kg as opposed to 1335 kg estimated at Morningside). The presumable loss of 85 kg of P is easily accounted for as instream aquatic plants, algae and riparian vegetation (namely willows) could easily have extracted a significant amount of P from the river, especially during the warmer, low flow periods of spring and summer. Phosphorus attached to suspended matter would also have settled out of the water column in the stretch of river between Mt Morriston and Morningside. During flooding, when the river extends out over the flood plain, decreased velocities also encourage some of the P to be deposited in this area outside of the main river channel, causing some net loss of P.

It is notable that DIN, which is all dissolved, does not show a similar behaviour to that of P, and loads in fact increase downstream.

2.5 Microbiological data

As a result of some community concern over the health aspects of drinking water, some sampling for bacteria was carried out throughout the catchment during the period of the study. A survey of rivers in the catchment was carried out in late November 1994 and included most sites later used in longitudinal transects for nutrients and metals. The survey involved sampling of both ‘undisturbed’ water (that is natural flowing water) and ‘sediment disturbed’ water (that is water containing sediment which has been resuspended from the river bed). This method has been employed in other parts of the world to assess the ‘potential’ population of bacteria living in the sediment and capable of contaminating the water column during high flow events. The amount of bacteria in the ‘disturbed’ water also gives an indication of the general level of contamination occurring in the area in the longer term, as bacteria is known to survive for longer when attached to particulate matter (Sherer, et. al., 1988).

Results using this technique are influenced to some degree by the amount and nature of the sediment being resuspended and as a result cannot be considered a ‘standard’ method. In this

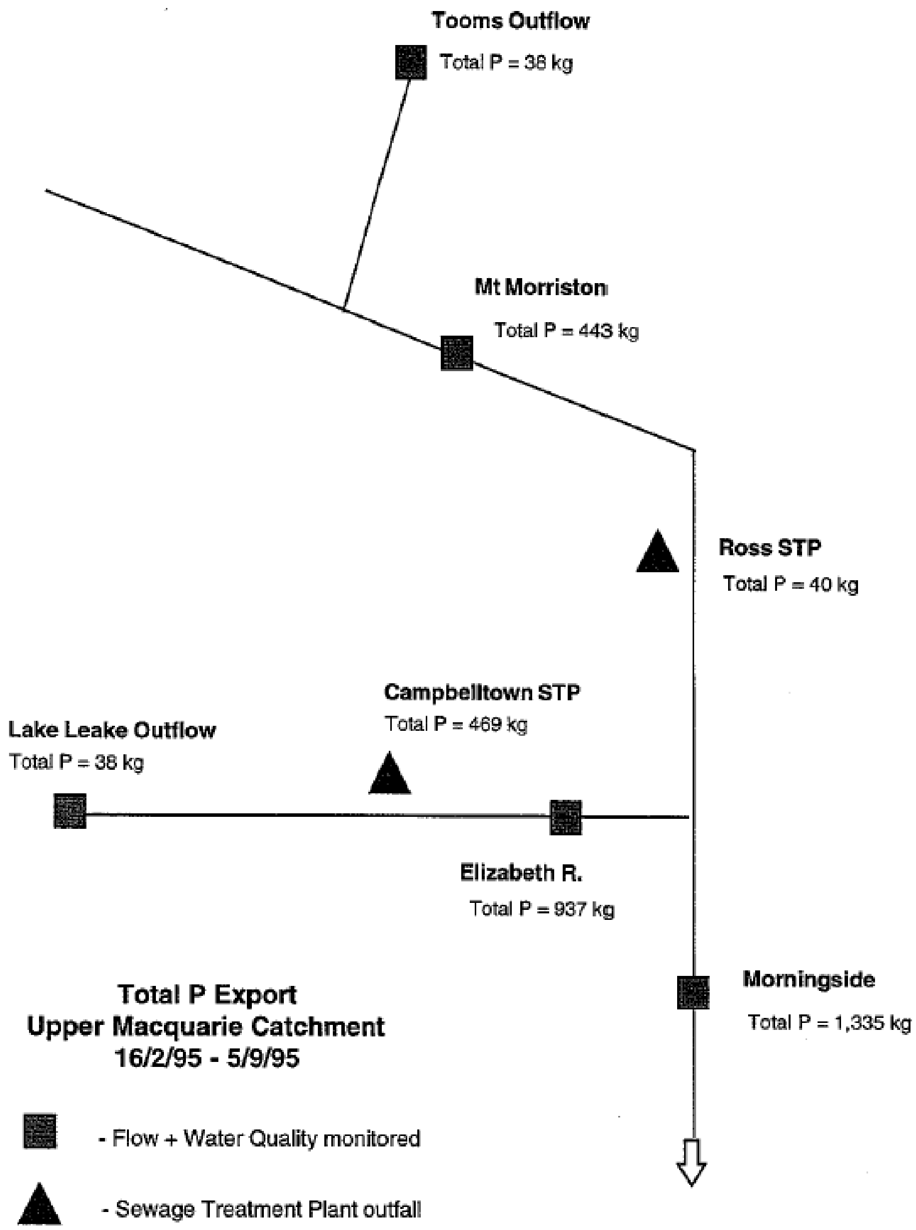

Figure 2.22 Estimated export loads of Total Phosphorus for sites in the Macquarie catchment over seven months of 1995.

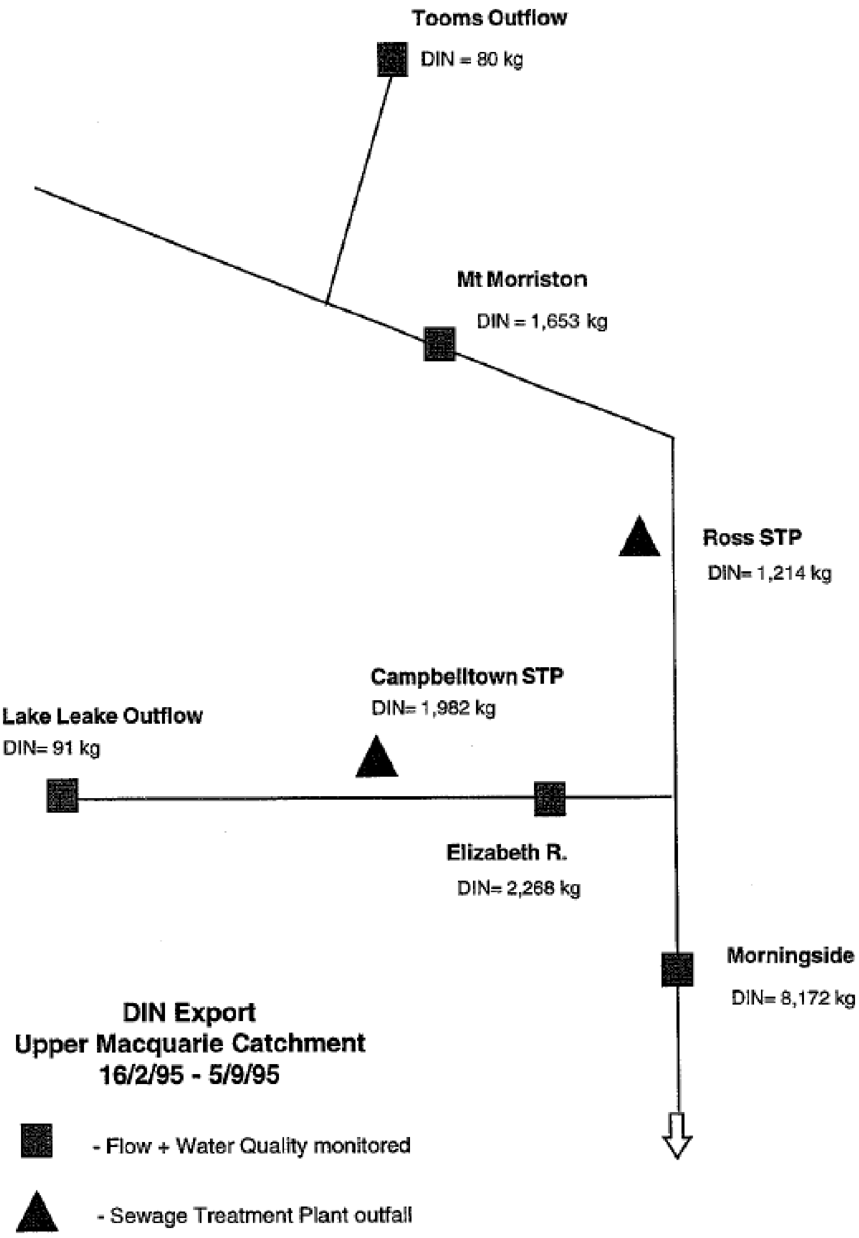

Figure 2.23 Estimated export loads of Dissolved Inorganic Nitrogen (DIN) for sites in the Macquarie catchment over seven months of 1995.

case the result have simply been used to gain an snapshot of the pattern of bacterial degradation of streams in the Macquarie catchment at the time of the survey.

For ambient water the ANZECC Guidelines of 1992 give the following recommendations on bacterial limits for various activities.

	Faecal coliforms (count per 100ml)	**Total coliforms** (count per 100ml)
Recreation		
Primary Contact	<150 or 80% < 600	
Secondary Contact	<000 or 80% < 4000	
Raw Drinking Water		
Humans	None should be detected	<10 or 95% < 1
Livestock	< 1000 or 4/5 < 5000	

It should be stressed that the guidelines require larger numbers of samples (at least 5) and taken over a longer period of time. The single values discussed below should be viewed in light of this.

Macquarie River

Levels of bacteria in 'undisturbed' samples from the Macquarie river indicate that large areas of the river are not heavily contaminated (Figure 2.24a), with nine of the thirteen sites sampled having bacterial levels within standards for primary contact (swimming and bathing).

However, several sites in the upper half of the river had high levels of faecal indicators with faecal streptococci numbers well in excess of 200 per 100 ml. These tended to be sites where stock had direct access to the river, particularly cattle. At other sites where stock access was not as apparent, levels of indicators in 'undisturbed' samples were lower. The only other site having high levels of faecal indicators was at Woolmers Bridge low down in the Macquarie.

Examination of data from 'disturbed' samples from the Macquarie (Figure 2.24b) shows that contamination of the sediments is generally highest in the upper reaches of the river. Highest contamination was found at the site immediately downstream of the Ross sewage treatment plant, where very high numbers of faecal coliforms were found in the sediment, indicating long term contamination in that location. Significant contamination is also apparent at Woolmers Bridge, where 'undisturbed' sampled also showed high levels of faecal coliforms.

Tributaries

Sampling of tributaries of the Macquarie river was limited to the Blackman, Elizabeth, Isis and Lake rivers as well as Brumbys Creek. Sites within all tributaries but the Isis showed contamination of 'undisturbed' samples at levels above the guideline for primary contact (150 faecal coliforms per 100 ml) and was generally highest in the Elizabeth River and Brumbys Creek (Figure 2.25a). At the site in Brumbys Creek near the DPIF Research station, *E. coli* numbers were well above the guidelines set for consumption by livestock. The 'disturbed' sample also indicated that this site suffered from long term contamination by animal waste.

Long term contamination at most sites was indicated by the level of faecal bacteria in 'disturbed' samples (Figure 2.25b). The Blackman and the lower Brumbys Creek sites showed least evidence of contamination although in the case of the latter site, very little sediment capable of harbouring bacteria was present.

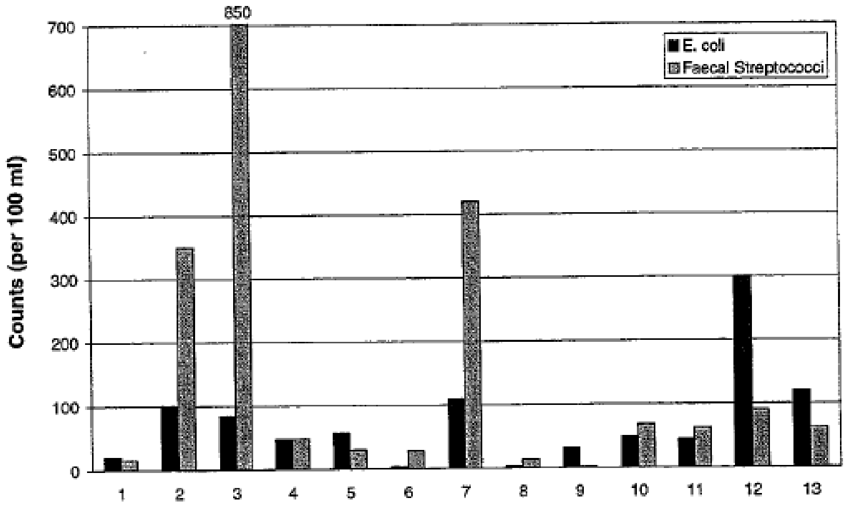

Figure 2.24a Microbiological survey of 'undisturbed water' at sites in the Macquarie River during spring 1994.

LEGEND
1 u/s Trefussis
2 Mt Morriston
3 Mona Vale
4 Ross
5 d/s Ross
6 Hoggs Ford
7 Morningside
8 Stewarton Br
9 Coburg
10 Westmoor Br
11 Cressy WS
12 Woolmers Br
13 Longford

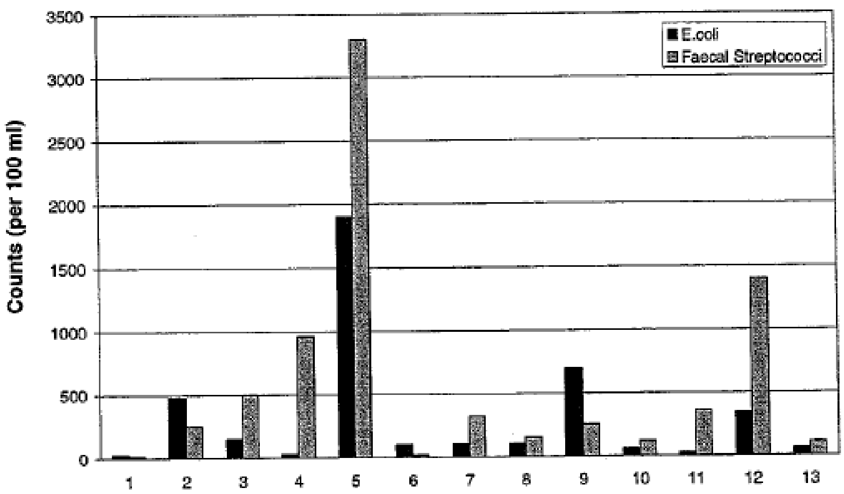

Figure 2.24b Microbiological survey of 'disturbed water' (containing resuspended sediment) at sites in the Macquarie River during spring 1994.

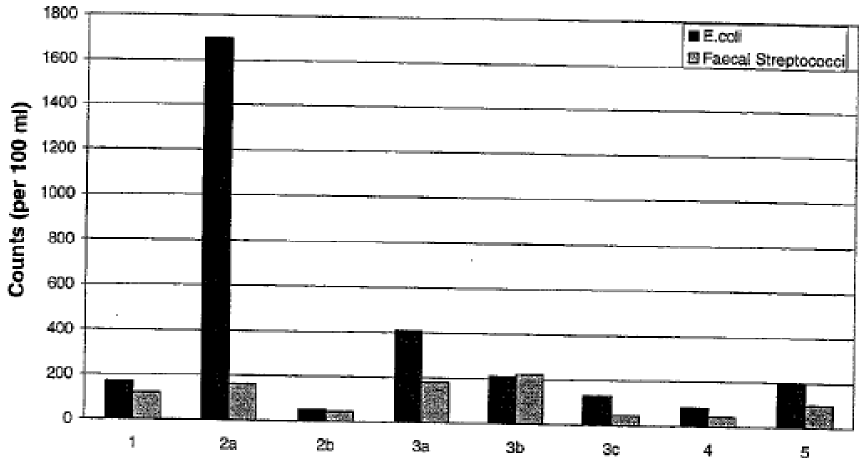

Figure 2.25a Microbiological survey of some tributaries of the Macquarie River sampling 'undisturbed water' during spring, 1994.

LEGEND

1 - Blackman at Mona Vale
2a - Brumby at No 2 Weir
2b - Brumbys at Bottom Weir
3a - Elizabeth u/s Campbelltown
3b - Elizabeth at Campbelltown Pond
3c - Elizabeth u/s Macquarie
4 - Isis at Barton
5 - Lake at Little Forest

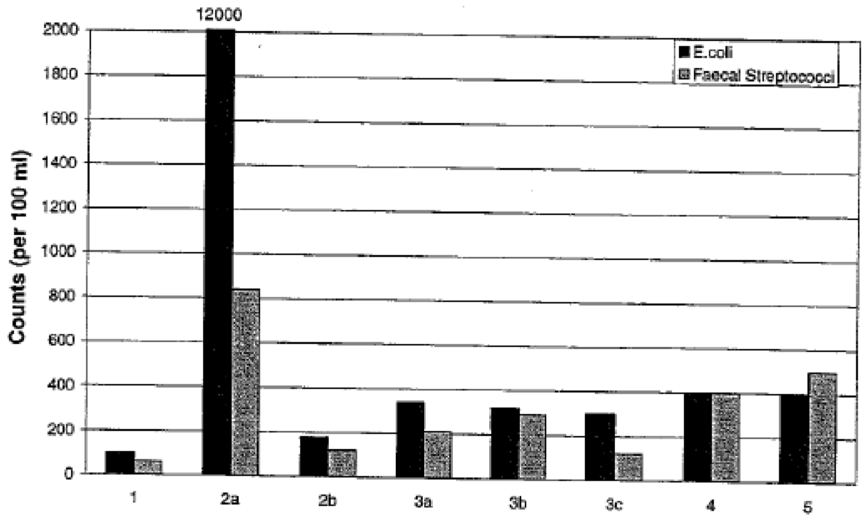

Figure 2.25b Microbiological survey of some tributaries of the Macquarie River sampling 'disturbed water' during spring, 1994.

The general picture from this brief survey is that large areas of the Macquarie are relatively free of faecal coliforms and that contaminated areas tend to be limited to parts of the catchment where animal or human activities are greatest. It must be stressed that these results are based on only a single visit to each site and as such does not conclusively prove or disprove continued faecal contamination at these sites.

2.6 Heavy Metals

Samples for heavy metals analysis were taken during longitudinal sampling for nutrients and physical parameters during March 1995. The metals analysed for were Cadmium, Copper, Lead, Zinc and Arsenic. Detection levels for the first three was 1 μg /L with a detection limit for Zinc and Arsenic of 5 μg/L and 10 μg/L respectively.

In all 21 sites throughout the Macquarie catchment were sampled, with samples taken from the Elizabeth, Blackman, Lake, Isis and Macquarie rivers as well as Brumbys Creek. No significant levels of Cadmium, Lead or Arsenic were detected.

TABLE Summary of results from heavy metals sampling in the Macquarie catchment.

	Cadmium (μg/L)	**Copper** (μg/L)	**Lead** (μg/L)	**Zinc** (μg/L)	**Arsenic** (μg/L)
Maximum	< 1	3	<1	< 5	< 10
Minimum	< 1	< 1	< 1	< 5	< 10
No. Samples	21	21	21	21	21

This result was expected as no significant mining activity or chemical related processing occurs in the catchment.

2.7 Special Studies

No special studies were carried out in the Macquarie catchment during this study.

3.0 River Ecology

Ecological studies were not carried out in this part of the South Esk Basin during the term of this study.