DEPARTMENT *of*
PRIMARY INDUSTRIES,
WATER *and* ENVIRONMENT

Tasmania

Water Quality Of Rivers In The Ringarooma Catchment

A Report Forming Part of The Requirements for State of Rivers Reporting

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Executive Summary

This report presents and discusses in detail the results of a year long study into the water quality of rivers and streams in the Ringarooma catchment. Sampling at a number of sites across the catchment was undertaken on a monthly basis, while more comprehensive catchment coverage was obtained through 'snapshot' surveys conducted during the summer and winter periods. This work was undertaken as part of a greater project collecting information on the 'State of Rivers' in the Ringarooma catchment. This report should be viewed together with the reports on hydrology, aquatic ecology and river condition which are attached.

The main points arising from the study into water quality are;

⇒ Rivers throughout the catchment are acidic, with average pH at all sites between 5.4 and 6.5. Of the 10 sites monitored on a monthly basis, the New River was most acidic, with a minimum pH reading of 4.88.

⇒ Dissolved oxygen concentrations, which are a good indicator of ecological health, were largely reflective of a healthy river system. Lowest concentrations were measured in the New River during summer, when dissolved oxygen levels are depleted and may cause stress to fish and other aquatic life.

⇒ Ambient baseflow turbidity levels at all sites was good, although there was a gradual increase in turbidity towards the lower reaches of the Ringarooma River. Higher turbidity was recorded during periods following rainfall events, when runoff caused increases of 200-400% in the Ringarooma River.

⇒ Conductivity at all sites was very low and indicative of waters which are low in dissolved salts such as sodium, magnesium, calcium and chloride. Water throughout the catchment can be classified as very 'soft'.

⇒ Nitrate nitrogen concentrations were highest in the tributaries draining the middle of the catchment (between Ringarooma and Derby) and may be responsible for increased concentrations in the Ringarooma River at Long Bridge and Moorina. Higher concentrations at most sites corresponded with higher baseflows between July and October.

⇒ Snapshot surveys of nitrogen across 23 sites in the catchment highlighted Legerwood Rivulet, the New River and the Dorset River as having highest concentrations, while lowest levels were recorded in the Maurice, Weld and Wyniford rivers.

⇒ Results from tests for ammonia nitrogen show that sites in the middle and upper catchments may be showing the impact from intensive animal industries in the area. Together with other nutrient data, it appears that the majority of nutrient input to the Ringarooma River is from tributaries draining the middle section of the catchment. Legerwood Rivulet was highlighted as one tributary which has elevated nutrient concentrations.

⇒ Snapshot surveys of *E. coli* at sites throughout the catchment showed that waterways in the upper and middle section of the catchment are most affected by faecal pollution, reflecting the intensity of animal based agriculture in that area. Levels of bacteria were greatest in summer when elevated water temperature increases the lifetime of faecal coliforms in the environment.

⇒ While most sites showed heavy metal concentrations at or below limits of detection through analysis, significant results for aluminium were obtained from Legerwood Rivulet, the Wyniford River and the Weld River. In the Wyniford River it is present in dissolved form and further testing is needed to determine its impact on aquatic life.

⇒ During significant flooding on September 23rd, turbidity at several sites in the Ringarooma River was 100 times greater than baseflow conditions, while nutrient concentrations were up to 10 times greater. At Moorina, instantaneous loads of nitrogen and phosphorus being transported down river were calculated at 1,666 kg/hr and 346 kg/hr respectively.

⇒ Export yields at Moorina, corrected for catchment size, were estimated at 431 kg/hr of suspended solids, 2.75 kg/hr of nitrogen and 0.57 kg/hr of phosphorus.

A GLOSSARY OF TERMS

Baseflow
Flow in a stream is essentially a function of overland flow, subsurface flow and groundwater input. During periods when there is no contribution of water from precipitation, flow in a stream is composed of water from deep subsurface and groundwater sources and is termed 'baseflow'.

Box and Whisker Plots
One common method of examining data collected at varous sites is to plot the data from each site as a 'box and whisker' plot. These plots display the median (or the middle of the data) as a line across the inside of the box. The bottom and top edges of the box mark the first and third quartiles respectively, indicating the middle 50% of the data. The ends of the whiskers show the extremes of the data and together enclose 95% of the data.

Catchment
The land area which drains into a particular watercourse (river, stream or creek) and is a natural topographic division of the landscape. Underlying geological formations may alter the perceived catchment area suggested solely by topography (limestone caves are an example of this).

Discharge
The volume of water passing a specific point during a particular period of time. It usually refers to water flowing in a stream or drainage channel, but can also refer to waste water from industrial activities.

Dissolved Oxygen
Oxygen is essential for all forms of aquatic life and many organisms obtain this oxygen directly from the water in the dissolved form. The level of dissolved oxygen in natural waters varies with temperature, turbulence, photosynthetic activity and atmospheric pressure. Dissolved oxygen varies over 24 hour periods as well as seasonally and can range from as high as 15 mg/L to levels approaching 0 mg/L. Levels below 5 mg/L will begin to place stress on aquatic biota and below 2 mg/L will cause death of fish.

Ecosystem
An environment, the physical and chemical parameters that define it and the organisms which inhabit it.

Electrical Conductivity (EC)
Conductivity is a measure of the capacity of an aqueous solution to carry an electrical current, and depends on the presence of ions; on their total concentration, mobility and valence. Conductivity is commonly used to determine salinity and is mostly reported in microSiemens per centimetre (µS/cm) or milliSiemens per centimetre (mS/cm) at a standard reference temperature of 25^{o} Celsius.`

Export Loads / Export Coefficients
The calculation of export loads of nutrients, or any other parameter, involves using nutrient concentration data collected over a wide variety of flow conditions and from various seasons. This information, when plotted against flow at the time of collection, can reveal relationships between flow and concentration which can then be used to produce a synthetic time series of concentration. With this, the load of a particular nutrient leaving the catchment can be estimated (estimates of export loads should be regarded as having no greater accuracy than +/- 15%).

The export coefficient (also known as the Runoff Coefficient) corrects for catchment size so that export loads from variously sized catchments can be compared. The most commonly used formula to perform this correction is;

Discharge (ML) / **Catchment Area** (km^2) = **X** ($mm\ km^{-2}$)

Total Load (kg) / **X** = **Y** ($kg\ mm^{-1}$)

Y / Catchment Area (km^2) = **Export Coefficient** ($kg\ mm^{-1}\ km^{-2}$)

Where Z is the Export Coefficient and is equivalent to Total Load (kg) / Discharge (ML).

Faecal Coliforms (also known as 'thermotolerant coliforms')

Faecal coliform bacteria are a sub-group of the total coliform population that are easy to to measure and are present in virtually all warm blooded animals. Although measurement of this group is favoured by the NHMRC (1996) as suitable indicators of faecal pollution, it is recognised that members of this group may not be exclusively of faecal origin. However their presence in samples implies increased risk of disease. Pathogenic bacteria are those which are considered capable of causing disease in animals.

General Ions

General ions are those mineral salts most commonly present in natural waters. They are primarily sodium, potassium, chloride, calcium, magnesium, sulphate, carbonates and bicarbonates. Their presence affects conductivity of water and concentrations are very variable in surface and groundwaters due to local geological, climatic and geographical conditions.

Hydrograph

A plot of flow (typically in a stream) versus time. The time base is variable so that a hydrograph can refer to a single flood event, to a combination of flood events, or alternatively to the plot of all flows over a month, year, season or any given period.

Macroinvertebrate

Invertebrate (without a backbone) animals which can be seen with the naked eye. In rivers common macroinvertebrates are insects, crustaecans, worms and snails.

Median

The middle reading, or 50th percentile, of all readings taken.

i.e. Of the readings 10, 13, 9, 16 and 11

[Re-ordering these to read 9, 10, 11, 13 and 16]

The median is 11.

The **Mean**, or Average, is the sum of all values divided by the total number of readings (which in this case equals 11.8).

Nutrients

Nutrients is a broad term which encompasses elements and compounds which are required by plants and animals for growth and survival. In the area of water quality the term is generally used with only phosphorus and nitrogen in mind, though there are many other elements that living organisms require for survival.

Reaction (pH) and Alkalinity

The pH is a measure of the acidity of a solution and ranges in scale from 0 to 14 (from very acid to very alkaline). A pH value of 7 is considered 'neutral'. In natural waters, pH is generally between 6.0 and 8.5, although dilute waters naturally high in organic content may have a pH of around 5.0. In waters with little or no buffering capacity, pH is related to alkalinity which is controlled by concentrations of carbonates, bicarbonates and hydroxides in the water. Waters of low alkalinity (< 24 ml/L as $CaCO_3$) have a low buffering capacity and are susceptible to changes in pH from outside sources.

Suspended Solids

Suspended solids are typically comprised of clay, silt, fine particulate organic and inorganic matter and microscopic organisms. Suspended solids are that fraction which will not pass through a 0.45μm filter and as such corresponds to non-filterable residues. It is this fraction which tends to contribute most to the turbidity of water.

Total Kjeldahl Nitrogen (TKN)

The Kjeldahl method determines nitrogen in water and is dominated by the organic and ammoniacal forms. It is commonly used to determine the organic fraction of nitrogen in samples and when the ammonia nitrogen is not removed, the term 'kjeldahl nitrogen' is applied. If the ammonia nitrogen be determine separately, 'organic nitrogen' can be obtained by difference.

Total Nitrogen (TN)

Nitrogen in natural waters occurs as Nitrate, Nitrite, Ammonia and complex organic compounds. Total nitrogen concentration in water can be analysed for directly or through the determination of all of these components. In this report, Total Nitrogen has been calculated as the sum of Nitrate-N + Nitrite-N + TKN.

Total Phosphorus (TP)

Like nitrogen, phosphorus is an essential nutrient for living organisms and exists in water as both dissolved and particulate forms. Total phosphorus can be analysed directly, and includes both forms. Dissolved phosphorus mostly occurs as orthophosphates, polyphosphates and organic phosphates However, dissolved phosphorus is easily bound to particulate material and in natural waters particulate phosphorus generally contributes more to total phosphorus levels.

Transect

In this report, river transects were carried out to gain some idea of the change in water quality conditions along the entire length of a river. This technique hinges on sampling at as many points along the a river as possible in a short time. Another important pre-requisite is that hydrologic conditions in the river are stable and that no recent rain has fallen and introduces disproportional inputs from any particular area. The main aim in employing this technique is to highlight the areas where water quality is better or worse relative to the rest of the river. It must be stressed that this technique provides only a snapshot of conditions at that time and should not be extrapolated beyond that period.

Turbidity

Turbidity in water is caused by suspended material such as clay, silt, finely divided organic and inorganic matter, soluble coloured compounds and plankton and microscopic organisms. Turbidity is an expression of the optical properties that cause light to be scattered and absorbed rather than transmitted in a straight line through the water. Standard units for turbidity are 'nephelometric turbidity units' (NTU's) standardised against Formazin solution.

B SUMMARY OF NATIONAL GUIDELINES FOR WATER QUALITY

Australian Water Quality Guidelines as per ANZECC draft (1998)
As part of a National strategy to "pursue the sustainable use of the nation's water resources by protecting and enhancing their quality while maintaining economic and social development' the Australian and New Zealand Environment and Conservation Council (ANZECC) has been developing guidelines for water quality for a range of Australian waters. Since 1992, a document titled 'Australian Water Quality Guidelines For Fresh and Marine Waters (ANZECC, 1992) ' has been available for use as a reference tool for catchment management plans and policies. At the time of its release, the guidelines were based on the best scientific information available.

Since 1995, that document has been under review, and a new draft has recently been released for public comment. The updated version has changed the emphasis of guideline setting, suggesting a 'risk assessment' approach which utilises the concept of increased risk with increasing departure from 'safe' levels. It also restates the principle that they are simply guidelines to be used in the absence of local data, and that where local data can be obtained, they should be used to develop local water quality standards. This needs to be kept in mind when examining the following tables which summarise the new draft guidelines. The figures quoted are suggested as interim trigger levels for assessing risk of adverse effects on different ecosystem types (for essentially natural ecosystems).

1. Proposed Trigger Levels for Nutrients

Ecosystem Type	**[TP]** (µg/L)	**[TN]** (µg/L)	**Key Ecosystem-specific factors**
Lowland River	37	1600	- light climate (turbidity)
			- flow
			- grazing
			- bioavailable nutrient [P or N]
Upland River	35	340	- light climate (turbidity)
			- substrate type
			- bioavailable nutrient [P or N]
			- grazing
Lakes and Reservoirs	50	440	- light climate (turbidity)
			- mixing (stratification)
			- bioavailable nutrient [P or N]

ANZECC (draft 1998) Australian Water Quality Guidelines for Fresh and Marine Waters - Draft

2. Proposed Trigger Levels for Dissolved Oxygen, Suspended Particulate Matter and Turbidity.

Ecosystem Type	**DO** (%sat)	**Susp. Solids#** (mg/L)	**Turbidity** (NTU)
Lowland River	90	6*	10
Upland River	92	2*	5
Lakes and Reservoirs	90	2*	4.5

= Recommend additional work to establish load based trigger levels;
* = professional judgement used to derive levels;
ANZECC (draft 1998) Australian Water Quality Guidelines for Fresh and Marine Waters - Draft

3. Proposed Trigger Levels for Conductivity, Temperature and pH.

Ecosystem Type	**EC (mS/cm)**	**Temp. Increase**	**Temp. Decrease**	**pH**
Lowland River	> 500*	< 80^{th} %ile	>20^{th} %ile	6.6 - 8.0
Upland River	> 110*	< 80^{th} %ile	>20^{th} %ile	6.5 - 7.5
Lakes and Reservoirs	> 60*	< 80^{th} %ile	>20^{th} %ile	7.8 - 8.3

* = professional judgement;
ANZECC (draft 1998) Australian Water Quality Guidelines for Fresh and Marine Waters - Draft

4. Proposed Microbiological Guidelines

The new guidelines for recreational waters propose a 'Bacterial Indicator Index' which requires routine sampling (at least 5 samples over a regular period not exceeding one month). It utilises statistics of the entire dataset to form the index in the following manner;

Bacterial Indicator Index = 2.5 x median/100mL + 80^{th} percentile/100mL

Using this formula to calculate the index, the following guideline has been suggested;

Primary Contact (eg swimming)
Bacterial Indicator Index should not exceed 800 for thermotolerant coliforms
or 300 for enterococci
Where more intensive monitoring is carried out the index should not exceed 550 for thermotolerant coliforms, or 200 for enterococci

Secondary Contact (eg boating)
Bacterial Indicator Index should not exceed 5000 for thermotolerant coliforms
or 2000 for enterococci

National Health and Medical Research Council

For drinking water, guidelines published by the National Health and Medical Research Council (NHMRC, 1996) suggest that no thermotolerant coliforms (eg *E. coli*) should be present in water used for drinking.

Units and Conversions:

mg/L = milligrams per litre (1000 milligrams per gram)

μg/L = micrograms per litre (1000 micrograms per milligram)

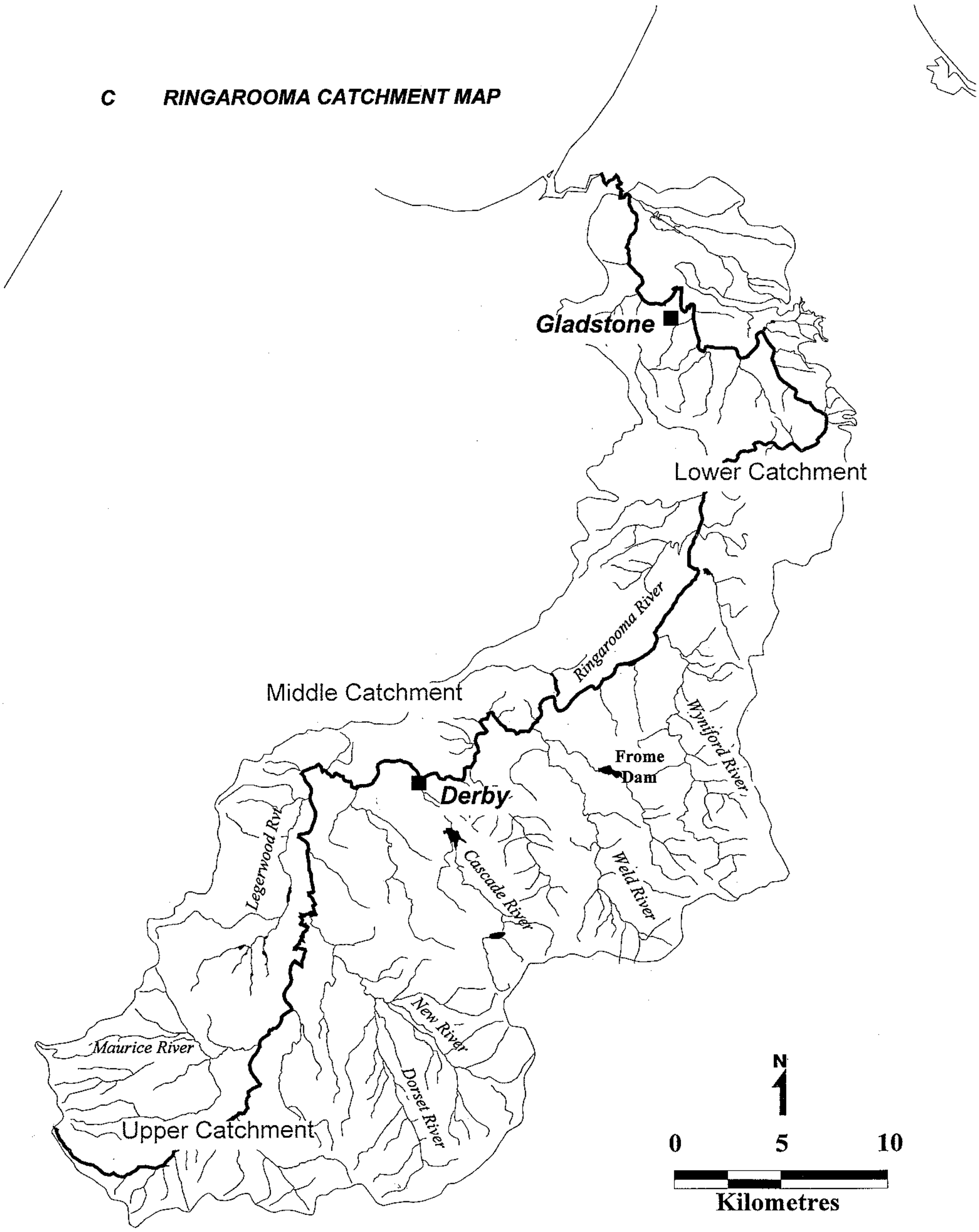
e.g. 1000 μg/L = 1 mg/L

μS/cm = Microsiemens per centimetre

m^3s^{-1} = cubic metre per second (commonly referred to as a 'cumec')

ML = 1 million litres (commonly referred to as a 'megalitre')

C RINGAROOMA CATCHMENT MAP



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Water Quality In the Ringarooma Catchment

1 Historical Data

The lack of a centralised database which is used and updated regularly by all major Government agencies engaged in water monitoring makes it difficult to collate and report on historical data from the catchment. However, the database currently used by the DPIWE contains some data collected by water managers in the past (DPIF, RWSC, DCHS, etc.). It is this data which will be briefly presented and commented on in this section. Significantly more resources would be needed to carry out a comprehensive report of all the data which has been collected by the various agencies and was considered beyond the capabilities of this study. It was also considered more important that data on the current conditions within the catchment be collected. Although every effort has been made to check data where possible, the quality of this data is generally unknown and therefore should be viewed with this in mind.

1.1 Ringarooma River

The only water quality data for the Ringarooma River on the DPIWE Hydrol database is from the Ringarooma River at Moorina, a site which is presently operated as a stream gauging site. Data has been collected intermittently at this site since 1977. A summary of data is presented in tabular form in Table 1.1 (a & b) below. While the record for many of the variables is patchy, a fair record has been collected for temperature and pH. This is due to the fact that both of these have been measured during routine stream gauging maintenance visits.

Both the average and median statistics have been given, as water quality data are often highly skewed. Where this occurs, the median is more representative of 'average' conditions in the river. This is well demonstrated by turbidity and suspended solids data, where the average is significantly higher than the median due to the presence of one very high record.

Table 1.1 Statistics of Historical Record - Ringarooma at Moorina (Hydrol Site #30)

(a)

	Temperature (^oC)	**Lab pH**	**Field pH (litmus)**	**Turbidity* (Hellige)**	**Turbidity* (NTU)**
Number of Readings	126	73	42	10	14
Period of Record	1977 - 1996	1977 - 1989	1982 - 1994	1986 - 1989	1985 - 1986
Maximum	22.0	8.6	7.7	34	42
Minimum	5.0	5.2	5.2	1.5	0.6
Average	12.1	6.6	6.3	6.04	7.54
Median	11.0	6.6	6.2	3.15	3.6

* Infrequent records during the period.

(b)

	Total Suspended Solids* (mg/L)	Filterable Residues* (mg/L)	EC at 25 ^{o}C (mS/cm)
Number of Readings	21	21	38
Period of Record	1985 - 1989	1985 - 1989	1983 - 1996
Maximum	63	63	83
Minimum	1	29	44
Average	11.7	46.3	67
Median	4.0	47	67

* Infrequent records during the period.

Water temperature at this site ranges from a minimum of about 5 - 6 ^{o}C in winter to as high as 22 ^{o}C in summer. A time series plot of this data shows that lowest water temperature occurs in July/August and warmest water occurs around February/March (Figure 1.1).

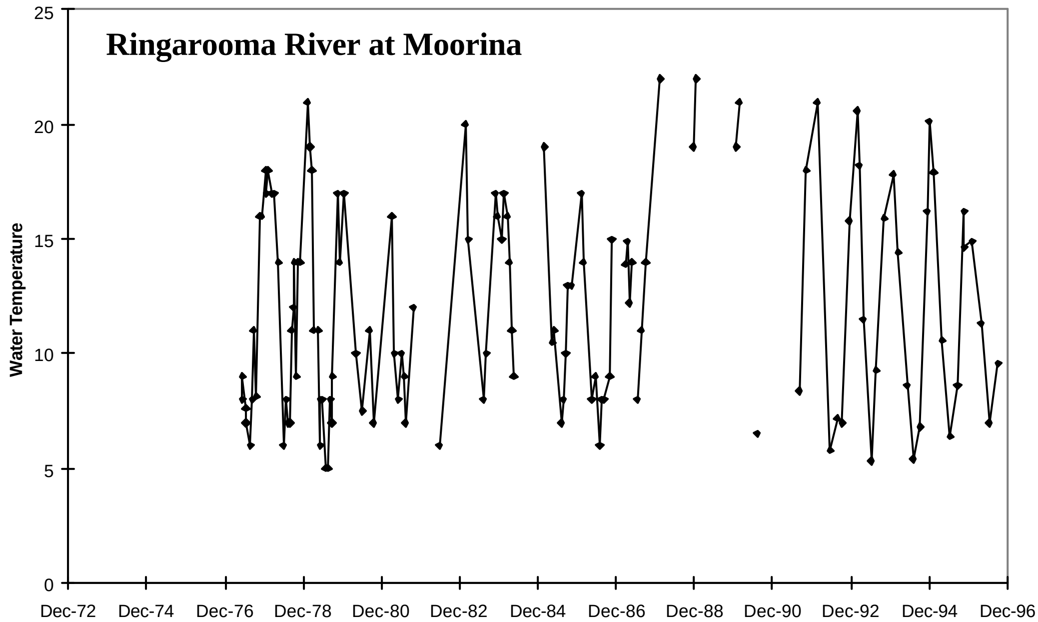


Figure 1.1 Time series plot of water temperature measured between 1977 and 1996 in the Ringarooma River at Moorina.

The other data indicate that the Ringarooma River at Moorina is very dilute (as shown by the low level of conductivity and filterable residues), is slightly acidic and has moderate to low levels of suspended solids (also reflected by turbidity data). No obvious trends could be found for any of the data.

1.2 Cascade River

Water quality data from the Cascade River upstream of the Cascade Dam is also available for the period 1984 to 1996. Most of the data at this site was collected during routine station maintenance and are of variables which can be measured with field equipment. It is evident that water quality in upper reaches of the Cascade River is characterised by lower temperature and pH than the Ringarooma at Moorina, very good clarity and very low conductivity (Tables 1.2 a & b). Although redox data is generally difficult to interpret, the few data are indicative of levels found in oxygenated surface waters (UNESCO, 1992). No data for chemical parameters (such as nutrients or metals) was found on the database.

Table 1.2 Statistics of Historical Record - Cascade River upstream of Cascade Dam (Hydrol Site #19210)

(a)

	Temperature (^{o}C)	**Lab pH***	**Field pH (litmus)**	**EC at 25 ^{o}C ($\mu S/cm$)**	**Colour* (Hazen)**
Number of Readings	64	7	47	19	6
Period of Record	1984 - 1996	1984 - 1989	1984 - 1993	1992 - 1996	1986 - 1989
Maximum	17.0	6.7	9.0	75	60
Minimum	4.0	4.7	4.5	36	10
Average	9.4	5.9	5.9	51	28
Median	8.1	5.9	5.9	50	25

* Infrequent records during the period.

(b)

	Filterable Residues* (mg/L)	**Turbidity* (NTU)**	**Redox (mV)**
Number of Readings	6	5	5
Period of Record	1986 - 1989	1986 - 1989	1990 - 1991
Maximum	78	1.3	121
Minimum	29	0.6	63
Average	47	0.9	93
Median	46	0.7	86

* Infrequent records during the period.

Some data has also been collected at a site in the Cascade River downstream of the dam, however it is very sparse and not considered substantially different from the upstream site and will not be presented here.

2 Waterwatch Activities

Waterwatch activities began in the Scottsdale area following the accidental release of pyrethrum and caustic soda into the Great Forester River in April 1994. The spill killed all of the macroinvertebrate and fish life in a section of the Great Forester River, and together with mounting community concern over other pollution incidents and perceptions of atrazine contamination of town water resulted in a public meeting from which 'Dorset Waterwatch' was formed. The members of this group represent a wide range of interests including education, forestry, local government, agriculture, aquaculture, industry health services and recreation.

The Dorset Sustainable Development Strategy, developed by Dorset Council through consultation with all stakeholders and sectors of the community, has identified water as a key issue in terms of protection of natural resources. Dorset Council have been most supportive of Waterwatch and provided a chairperson in the initial stages of forming the group and $3,000 for the purchase of chemicals and equipment. They continue to provide administrative support in the form of office space, computer, phone, postage, photocopying and an annual audit. Since 1996 Dorset Waterwatch have received financial assistance through NHT to employ a regional coordinator.

The group monitors water quality in the 3 major rivers in the municipality, the Brid, Ringarooma and Great Forester as well as Cox's Rivulet and waterways in the Waterhouse Protected Area. The data is used to gain a picture of baseline results as well as highlighting areas in need of improvement. The group also runs a community education campaign which has been fuelled by issues such as elevated turbidity levels during flood events in the major rivers and high phosphate levels in Coxs's Rivulet.

Waterwatch has collected a significant amount of water quality data at 5 sites on the Ringarooma River (Table 2.1), with lesser data being collected at a further 10 sites. The most frequent sampling has occurred at Moorina, where visits have been undertaken at roughly monthly intervals.

TABLE 2.1 Dorset Waterwatch site information

Site	Easting	Northing	Period of Record	Visits
Ringarooma @ Trenah	557350	5426700	1/7/96 - 23/9/98	10
Ringarooma @ Branxholm	561850	5442100	28/5/95 - 22/10/98	9
Ringarooma @ Long Bridge	5642300	5443900	3/5/96 - 23/9/98	9
Ringarooma @ Derby	567600	5444400	1/7/95 - 22/10/98	9
Ringarooma @ Moorina	572900	5446600	13/6/96 - 8/10/98	23
Ringarooma @ Ringarooma Br	560800	5434800	23/9/98	1
Ringarooma @ Gladstone	585500	5465700	19/7/95	1
Maurice River @ Cottons Br	558900	5430700	23/9/98	1
Ringarooma @ Cottons Br	559050	5430700	28/5/95 - 23/9/98	2
Ringarooma @ Boobyalla	576300	5474900	25/2/98	1
Green Lake			16/10/97 - 20/10/98	6
Yellow Lake			22/10/97 - 20/10/98	3
Little Blue Lake			16/10/97 - 22/10/98	6
Shallamar Ck - Mt Cameron			21/10/97 - 22/10/98	3
Sapphire Ck - Lunchspot			14/10/98 - 21/10/98	2

The following table summarises the data collected at this site (Table 2.2 a & b). The data generally indicate that water quality in this part of the river is good, with low conductivity turbidity and ortho-phosphorus (as P) levels, and healthy dissolved oxygen concentrations. The range in water temperature at this site is nearly identical to that derived from historical data.

Turbidity is normally measured by the Waterwatch group using a 'turbidity tube' which cannot measure below 7 NTU. Most of the turbidity data collected at this site by the group was at or below the detection limit of this equipment. The high turbidity reading (150 NTU) recorded in August 1996 during flood flows in the river at the time (in excess of 80 cumecs) and reflects the load of suspended material being transported by the river at that time.

TABLE 2.2 Dorset Waterwatch monitoring data from the Ringarooma River at Moorina (collected 13/6/96 - 8/10/98).

(a)

	Temperature (^oC)	Field pH (litmus)	Dissolved O_2 (mg/L)	Dissolved O_2 (% Sat)
Number of Readings	22	21	14	14
Maximum	22.0	6.5	12	120
Minimum	5.8	5.0	9	85
Average	12.0	5.9	11	102
Median	11.3	6	10	105

(b)

	Turbidity* (NTU)	**Ortho-phosphorus as P* (mg/L)**	**Conductivity (mS/cm)**
Number of Readings	22	19	22
Maximum	150	0.06	50
Minimum	< 7	< 0.015	10
Average	10.7	0.015	27
Median	< 7	< 0.015	30

* Where data has been recorded as "<", half the limit of detection was used to calculate statistics. This is standard practice for calculation of summary statistics.

Like turbidity, the large proportion of the ortho-phosphorus data is at or below detection limits of the Waterwatch kit, indicating relatively low nutrient levels in this section of the river. A high reading of 0.03 mg/L was measured at this site during significant flooding in September 1998, when turbidity of over 300 NTU was also recorded using a Hach turbidimeter.

Although nitrate nitrogen levels have also been measured at this site, this test is not sensitive enough to accurately record ambient environmental concentrations, and data will therefore not be reported.

Data collected at other sites on the Ringarooma River is very similar to that from Moorina, and shows that water quality throughout the Ringarooma River is generally good. Turbidity and ortho-phosphorus at all sites is largely below the detection limits of Waterwatch equipment. As would be expected, both water temperature and conductivity generally increase towards the bottom of the river (Figure 2.1 & 2.2).

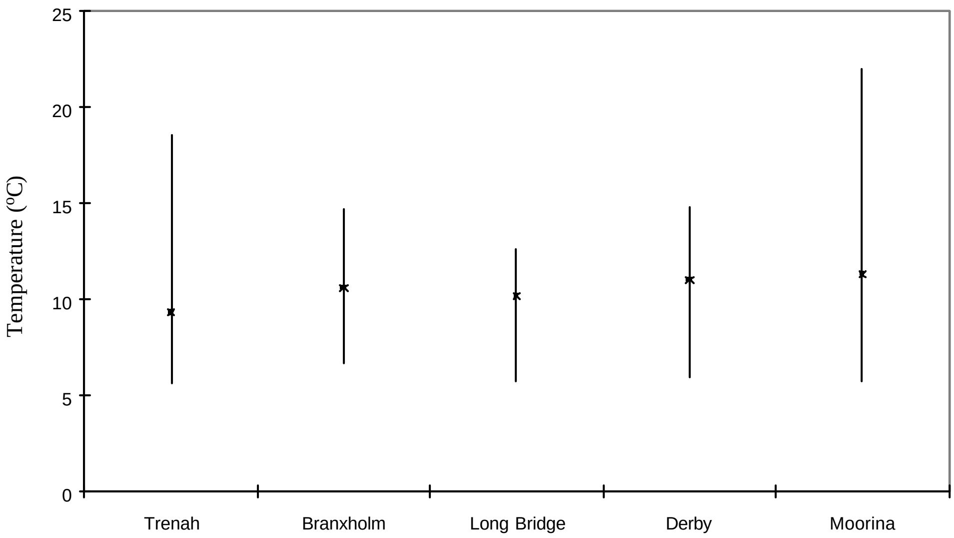


Figure 2.1 Median water temperature at five major Waterwatch monitoring sites in the Ringarooma River (vertical lines indicate maxima and minima).

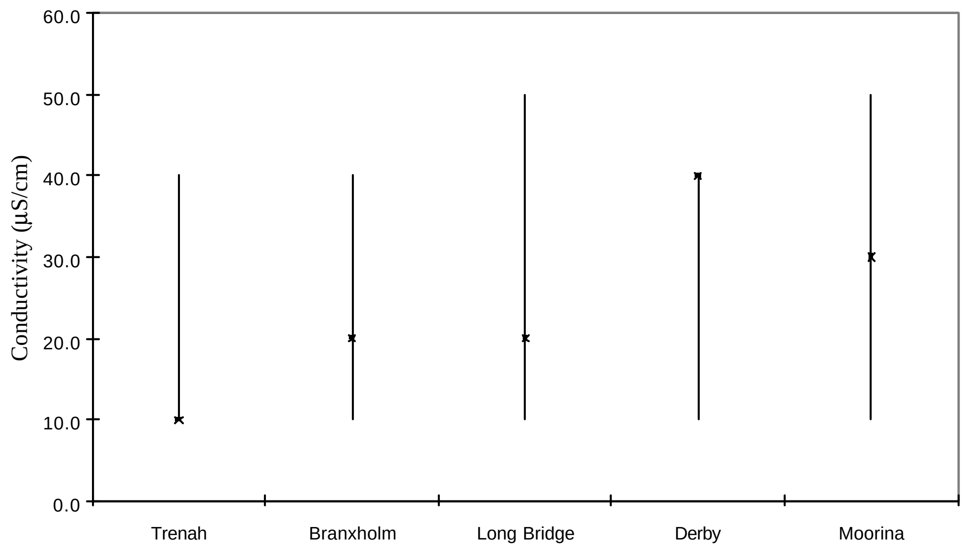


Figure 2.2 Median conductivity at five major Waterwatch monitoring sites in the Ringarooma River (vertical lines indicate maxima and minima).

3 Current Program

The following water quality data was collected during 1998 in response to a need for information on water quality in the catchment for catchment management and water allocation planning. The main aim of the program was to collect current data on the ambient quality of water throughout the catchment and report on background conditions as well as highlight areas where water quality is degraded. This data, when viewed in conjunction with land use and river condition information, should assist in identifying sites or areas which could be targeted for remediation activities in the future.

3.1 Monthly Monitoring

Monthly sampling was carried out at 6 sites while field testing for physical/chemical parameters was carried out at a further 4 sites, all of which are listed in the table below (Table 3.1).

Table 3.1 Location of sites where monthly water quality monitoring was carried out during the present study.

Site Name	Easting	Northing	Monitoring Type
Dorset River at New River Rd	565075	5431250	Phys-chem
New River at Singline Rd	567450	5431175	Phys-chem
Ringarooma Rv u/s Maurice Rv	559050	5430700	Phys-chem
Maurice Rv u/s Ringarooma Rv	558950	5430700	Phys-chem
Legerwood Rvt at Warrentinna Rd	561625	5443375	Phys-chem + Samples
Ringarooma Rv at Ringarooma	560750	5434800	Phys-chem + Samples
Ringarooma Rv at Long Bridge	564250	5443925	Phys-chem + Samples
Ringarooma Rv at Moorina	572900	5446625	Phys-chem + Samples
Ringarooma Rv at Pioneer	579300	5451650	Phys-chem + Samples
Ringarooma Rv at Gladstone	585475	5465750	Phys-chem + Samples

The physico-chemical parameters tested on site included turbidity, pH, electrical conductivity, water temperature and dissolved oxygen. Water samples were taken monthly and analysed for the following nutrients; ammonia nitrogen (NH_3/N), nitrate nitrogen (NO_3/N), nitrite nitrogen (NO_2/N), total Kjeldahl nitrogen (TK/N), dissolved reactive phosphorus (DR/P) and total phosphorus (TP). Total nitrogen (TN) was derived using the formula;

$$TK/N + NO_3/N + NO_2/N.$$

Every 3 months samples were also taken for general ion analysis to determine the content of various dissolved salts. These included determination of Iron, Calcium, Magnesium, Sulphate, Chloride, Sodium, Potassium, Silica, Hardness, Colour and Suspended Solids concentrations.

3.2 Physico-Chemical Results

In-stream pH

River pH was measured 'in situ' using temperature compensated, hand held meters. The data shows that rivers throughout the catchment appear to be quite acidic. The New River was most acid (median of 5.44), with a minimum pH recorded at this site of 5.0. All other sites had median pH levels between 6 and 6.5 (Figure 3.1). Widest pH variation during the year occurred at the Maurice River (u/s Ringarooma River) where the pH varied by more than 2 pH units.

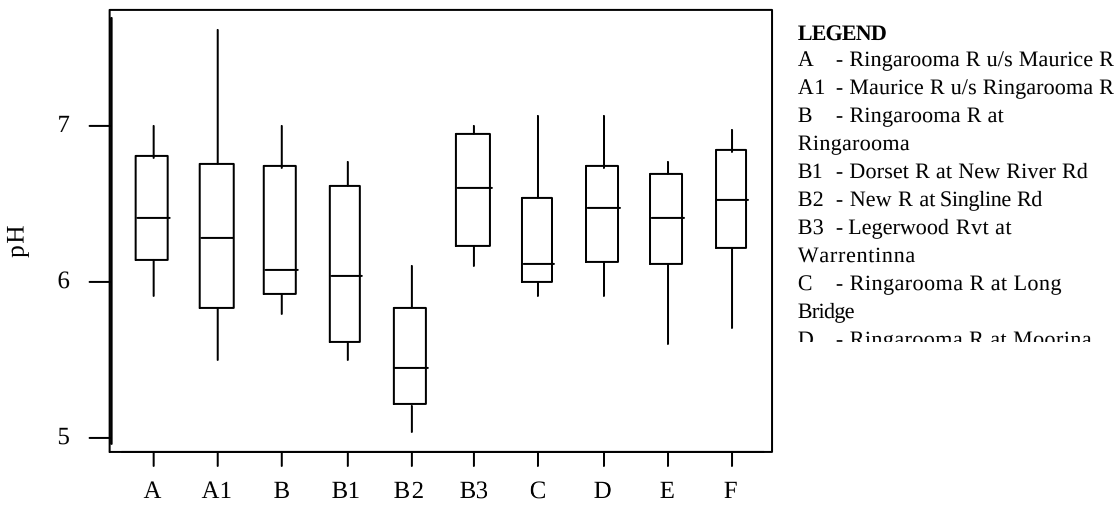


Figure 3.1 Statistics of pH variation at monitoring sites in the Ringarooma catchment (Jan - Dec 1998).

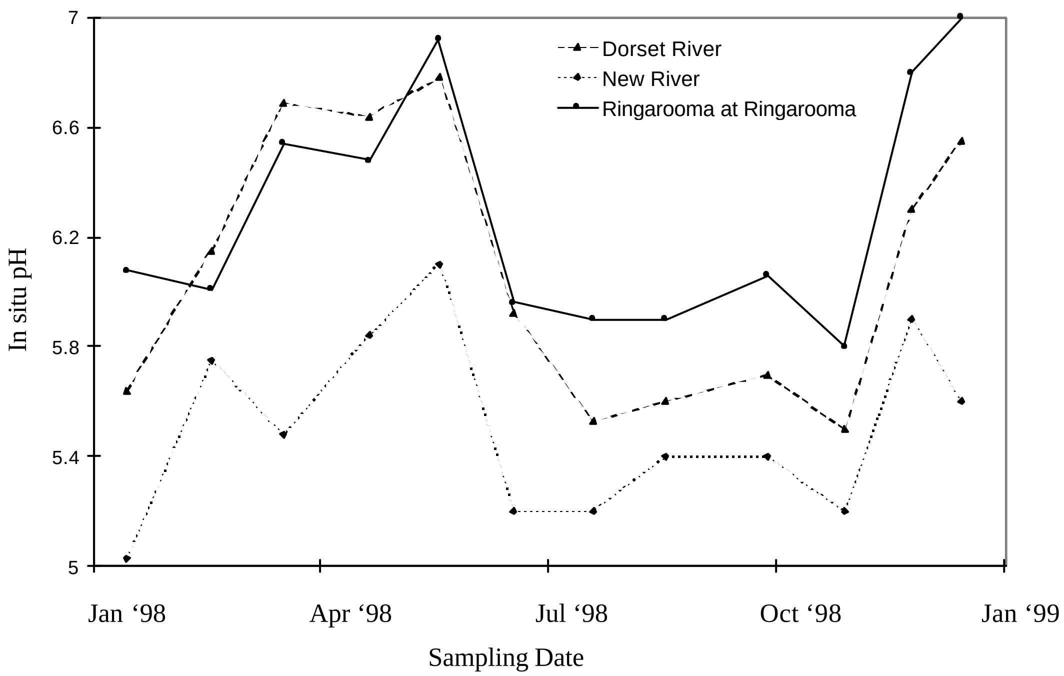


Figure 3.2 Monthly changes in water pH at three sites in the upper Ringarooma catchment, Jan - Dec 1998.

The annual change in pH was similar at all sites, with lowest pH occurring during the winter and spring months. A plot showing this variation at three sites in the upper part of the catchment is given below (Figure 3.2). It clearly demonstrates that while the pH of water in the New River was consistently lower, the pattern of change during the year reflected that shown by the other two sites. It also appears that during the summer months, the pH of the Dorset River is more similar to that of the Ringarooma River than the New River.

As the following sections will show, rivers throughout the Ringarooma catchment are very dilute and have very little in the way of dissolved minerals and salts (carbonates, calcium, sodium, magnesium, etc). The relative absence of carbonate and bicarbonate ions (indicated by the low alkalinity levels) means that these waters have minimal buffering capacity and can display relatively large pH changes.

The very low pH values recorded in the New River reflect the very dilute nature of this river, and may also be indicative of the effects of land clearance and drainage in this valley. It is known that removal of vegetation from soils which are thin and lacking in base cations (calcium and magnesium) can lead to acidification (Cresser & Edwards, 1988), as vegetation in these situations can be the only contributor of these buffering minerals.

Examination of the soils in the area around the Dorset and New rivers (Eldridge, pers. comm.) has found that in the footslopes there are soil layers with very high aluminium concentrations and these soils can have pH levels down as low as 3.5 - 4. It is very likely that these soils are causing a decrease in pH in these rivers, especially during winter and spring when river flows are sustained by groundwater reserves which percolate through these low pH soils.

Water Temperature

Water temperature was measured at all 10 sites during monthly site visits using hand held equipment. Water temperature ranged from as low as 4.9 ^{o}C in winter (at sites in the upper catchment) to 23 ^{o}C in the lower reaches of the Ringarooma River. The plot of basic statistics (Figure 3.3) shows that average water temperatures increase toward the bottom of the catchment.

The variation at sites in the Ringarooma River also appears to be greater than for sites in the tributaries (eg Dorset River, New River and Legerwood Rivulet). This seems to be due to data collected on 14 January, when daytime temperature was high (around 30°C) and sites low in the catchment were visited late in the day when water temperatures were highest. The extensive deposits of gravel in the river downstream of Pioneer would have further facilitated this warming.

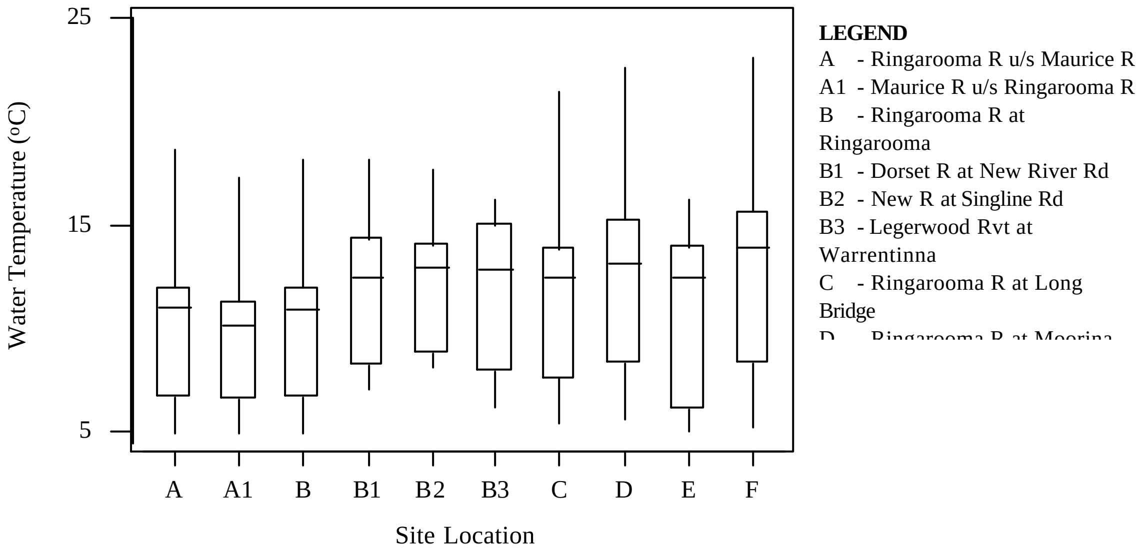


Figure 3.3 Statistics of water temperature at monitoring sites in the Ringarooma catchment, Jan - Dec 1998.

The monthly change in water temperature at four sites in the Ringarooma River is shown below in Figure 3.4. It shows how differences in water temperature between sites is greatest during the warmer months and least during winter (June - August) when higher river discharges occur.

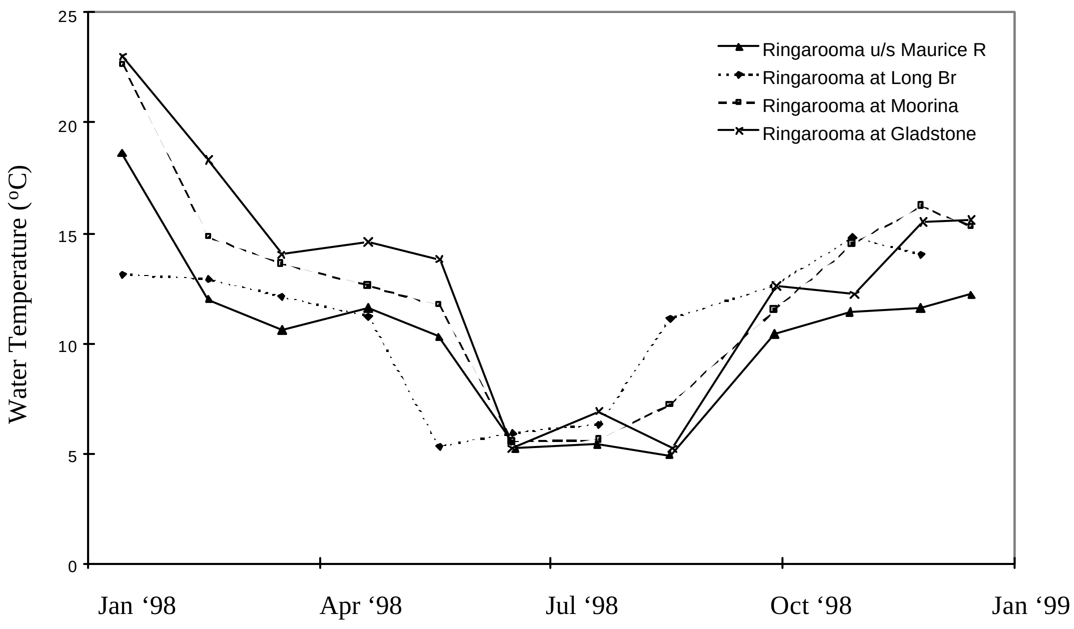


Figure 3.4 Monthly water temperature at four sites along the length of the Ringarooma River

(Jan - Dec, 1998).

Electrical Conductivity

Conductivity of water at all sites was very low, reflecting the dilute nature(low concentration of dissolved salts) of rivers in the catchment. The data (Figure 3.5) show that while conductivity was generally higher at sites lower in the catchment, at only one site (Legerwood at Warrentinna Rd) did conductivity exceed 100 µS/cm. The data clearly shows that in terms of salt levels, water throughout the catchment is very suitable for irrigation and other agricultural purposes.

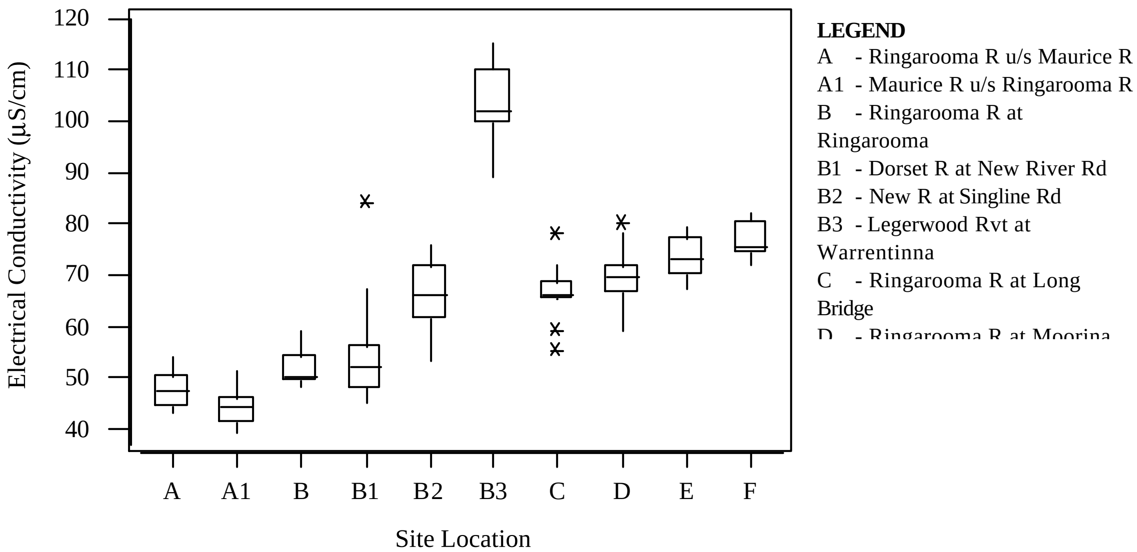


Figure 3.5 Statistics for monthly electrical conductivity at sites in the Ringarooma catchment (Jan - Dec, 1998).

Dissolved Oxygen

The concentration of dissolved oxygen in rivers is a good indicator of health of the aquatic ecosystem and low oxygen concentrations can often be the first signs of stress or degradation. During this study, dissolved oxygen levels were measured on site using hand held probes employing membrane diffusion along with silver / gold anode for oxygen detection. At all sites, oxygen was measured in flowing water.

The data is displayed in Figure 3.6 below and shows that oxygen levels at the majority of sites are indicative of a healthy environment. The exception to this was New River (B2) where dissolved oxygen was measured below 6 mg/L. The Australian Water Quality Guidelines for Fresh Waters (ANZECC, 1992) suggests that concentrations not fall below this level. It is known that concentrations below 6 mg/L can cause stress to fish and can be indicative of an imbalance in the environment.

Dissolved oxygen levels at New River were generally lower than all other sites during each sampling trip, although the reason for this was not clear. The reach of river where the site was located has been heavily modified, and there is active erosion presently occurring. There is also relatively little riparian vegetation along its banks, although rehabilitation efforts have been made in some sections. It is possible that this may be impacting on dissolved oxygen levels, though in what way cannot be inferred from the limited data which has been collected during this study. Further investigation in the future should be undertaken to resolve this question and identify the cause of these low oxygen levels.

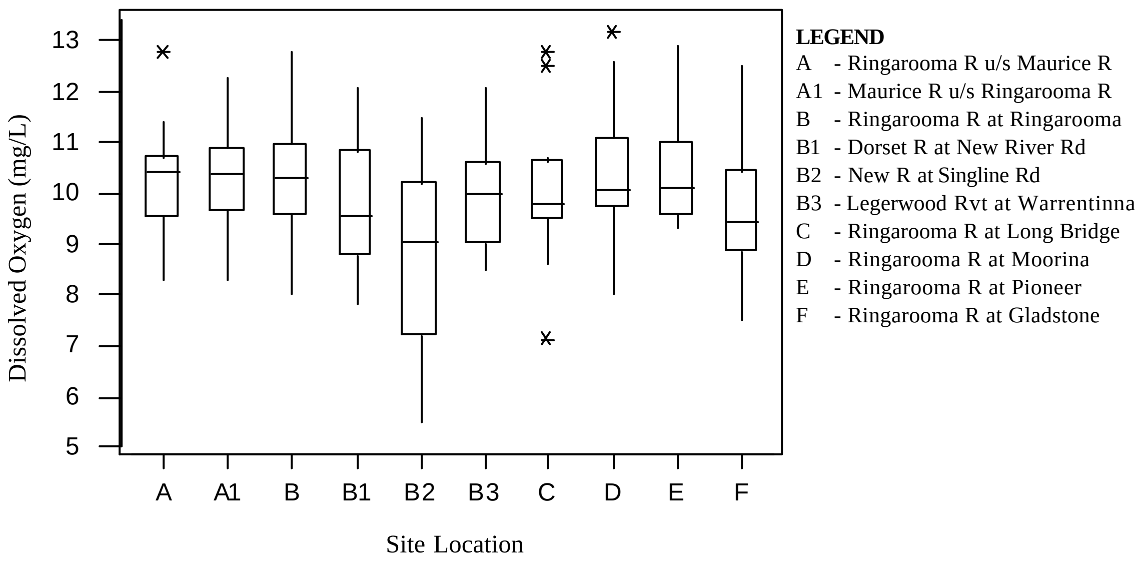


Figure 3.6 Statistics of monthly dissolved oxygen concentrations at sites in the Ringarooma catchment (Jan - Dec, 1998).

The monthly change in dissolved oxygen concentrations at several sites in the Ringarooma River is compared in Figure 3.7. The plot shows that lowest concentrations occurred at all four sites on the visit of 14/1/98, when river flows were relatively low (~ 1 cumec) and water temperature was the highest measured during the study. Both of these factors would have produced significant stress on aquatic life in the river at that time. During the winter, concentrations throughout the length of the river are well above 10 mg/L and appear to be much more homogeneous. Higher and more turbulent river flows and lower water temperatures contribute greatly to this condition.

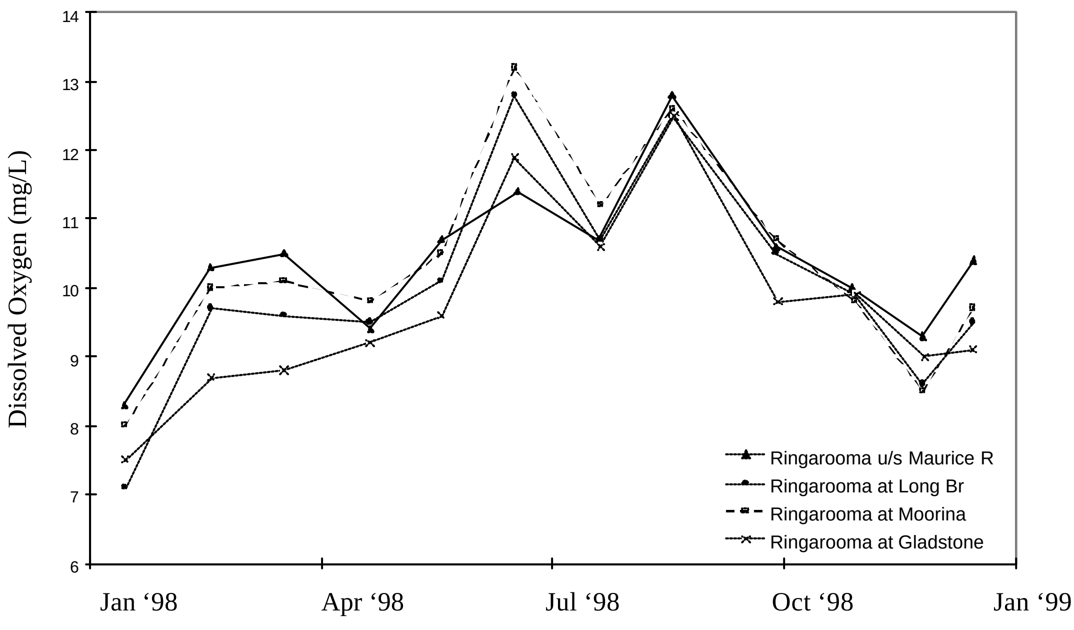


Figure 3.7 Monthly dissolved oxygen concentration at four sites along the length of the Ringarooma River (Jan - Dec, 1998).

Turbidity

Turbidity of water in rivers is an indicator of the amount of suspended material being transported by the river at the time of sampling. In agricultural regions, the majority of this material comes from diffuse sources such as soil disturbance or stream bank erosion. When seeking to determine the ambient (or baseline) turbidity levels in rivers, it is important to avoid collecting samples during or immediately following rainfall events when runoff water carries most material into streams. Separate sampling during such events can then be compared against what the river is normally like and is often useful in showing how levels increase with entry of runoff to rivers.

The monthly data from the 10 sites in the Ringarooma catchment illustrates how turbidity in the Ringarooma River increases gradually with distance downstream (Figure 3.8). At the uppermost site on the Ringarooma (u/s Maurice River confluence), median turbidity during the study was 1.99 NTU while at Gladstone median turbidity was 5.7 NTU. The data at the lower 2 sites on the Ringarooma River is influenced by higher readings (shown as outliers) which highlight the effects of rainfall in the headwaters several days prior to sampling. [It can take 3-4 days for rainwater falling in the top of the catchment to produce river level rises in the Ringarooma River at Gladstone].

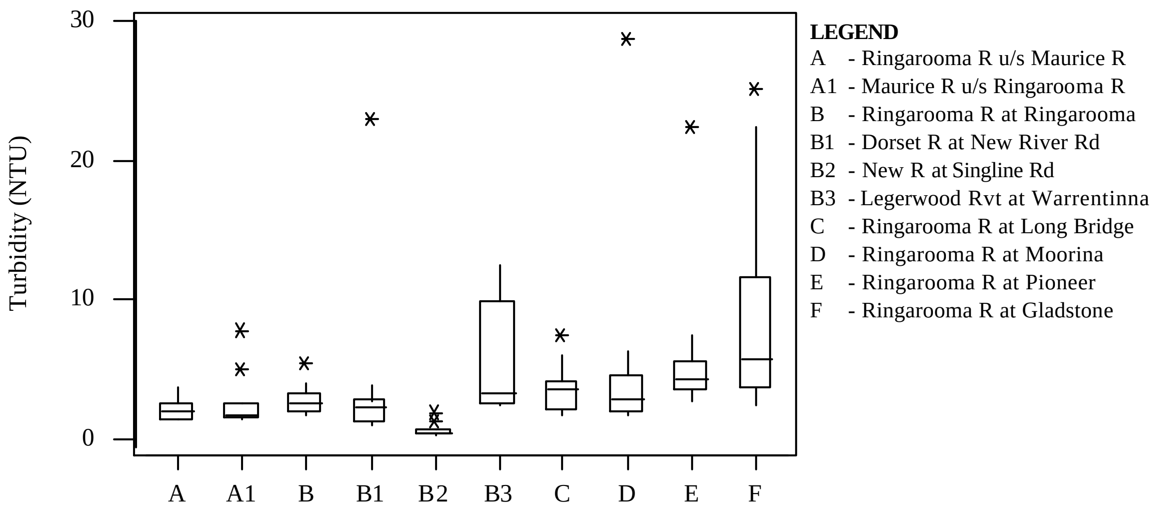


Figure 3.8 Statistics of monthly turbidity at sites in the Ringarooma catchment (Jan - Dec, 1998).

Of the tributary sites monitored, Legerwood Rivulet showed highest median turbidity (3.3 NTU) while New River was extremely clear (median = 0.42 NTU, maximum = 1.85 NTU and minimum = 0.18 NTU). The following table (Table 3.2) presents some guidelines which have been suggested for assessing turbidity in freshwaters in Tasmania. When viewed against these guidelines, it is clear that baseflow turbidity levels at all sites is indicative of good quality water.

TABLE 3.2 Suggested Tasmanian guidelines for assessing turbidity in freshwaters (Waterwatch and DPIWE).

	Good	**Fair**	**Poor**	**Degraded**
Mountain	< 5	< 8	8 - 12	> 12
Valley	< 10	< 15	15 - 20	> 20
Lowland	<12	< 18	18 - 25	> 25

Values are in Nephelometric Turbidity Units (NTU's).

3.3 General Ionic Composition

The chemical constituents which determine the ionic composition of river water typically reflect the soil and underlying geology of an area. Where water flows through limestone it will have higher concentrations of calcium and magnesium, and correspondingly higher hardness and alkalinity. Water draining a dolerite landscape generally has lower amounts of dissolved salts, though iron and silica may be more elevated.

During this study data on ionic composition was collected on a two monthly basis as these constituents are generally considered 'conservative' and vary only marginally over time. A summary of some of the data from these samples is given in the table below.

Table 3.3 A summary of some of the ionic parameters measured during the study.

	Hardness (mg/L)	**Iron** (mg/L)	**Calcium** (mg/L)	**Magnesium** (mg/L)	**Chloride** (mg/L)
Ringarooma River					
@ Ringarooma Rd	11.1	0.4	1.8	1.6	10.4
@ Long Br	13.3	0.5	2.3	1.9	12.0
@ Moorina	11.2	0.9	1.7	1.7	13.2
@ Pioneer	11.4	1.1	1.6	1.8	14.2
@ Gladstone	11.0	1.4	1.6	1.8	14.0
Legerwood Rvt					
@ Warrentinna Rd	10.3	0.3	1.7	1.5	9.9

Values are the median of the dataset (n = 6)

Hardness (and alkalinity) across all sites was very low, the highest levels being recorded in the middle of the Ringarooma River (at Long Bridge) which had a median hardness of about 13 mg/L. Water hardness at all sites can generally be considered very 'soft'. This is further highlighted by the very low concentrations of calcium (Figure 3.9) and magnesium at all sites monitored.

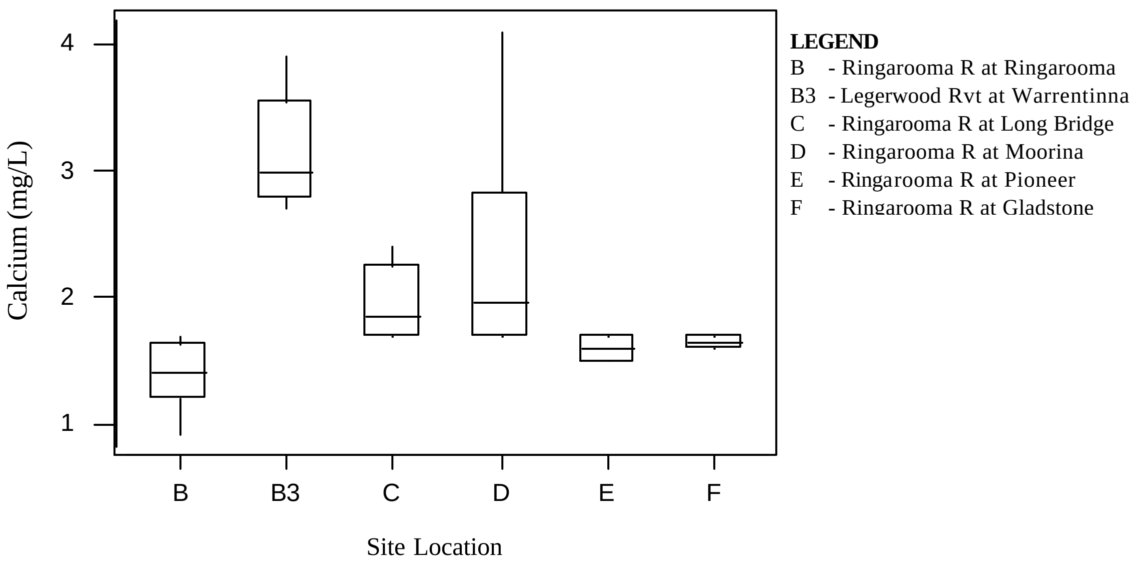


Figure 3.9 Statistics for calcium at sites in the Ringarooma catchment (Jan - Dec, 1998).

The very dilute nature of water in the Ringarooma River and Legerwood Rivulet is also demonstrated by the low concentrations of iron (Table 3.3) and other constituents like potassium (Figure 3.10) and sodium (Figure 3.11). Concentrations of both potassium and sodium showed a slight to moderate increase in concentration down the length of the Ringarooma River, and concentrations of both constituents are significantly higher in Legerwood Rivulet.

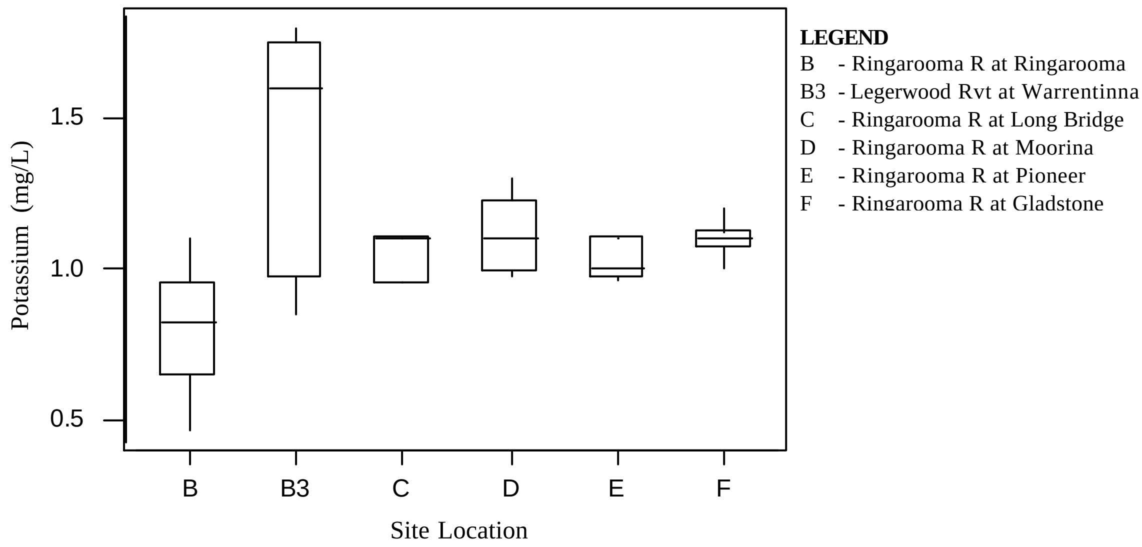


Figure 3.10 Statistics for potassium at sites in the Ringarooma catchment (Jan - Dec, 1998).

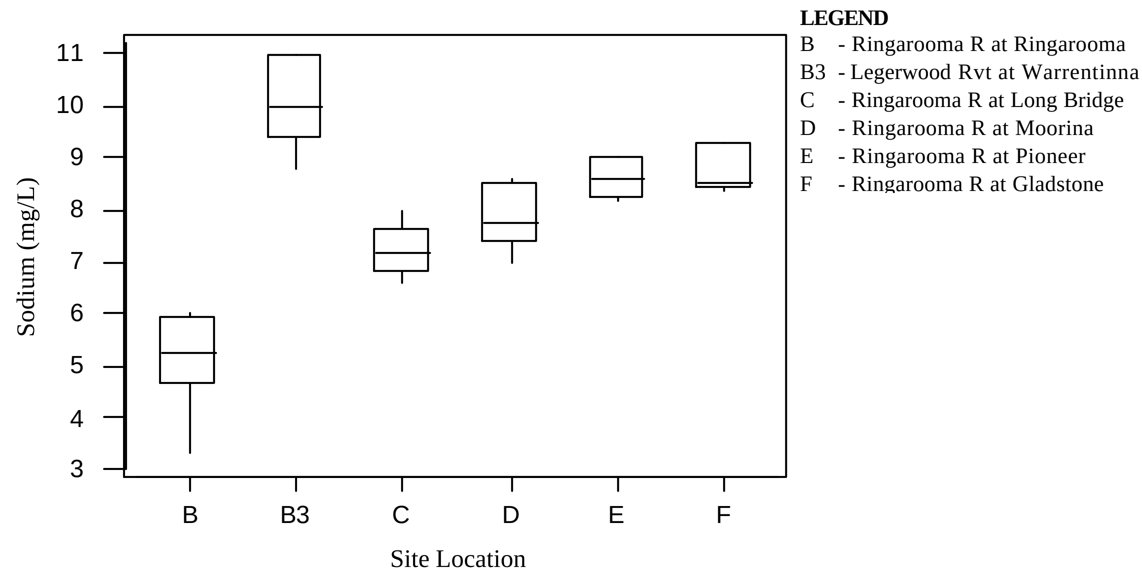


Figure 3.11 Statistics for sodium at sites in the Ringarooma catchment (Jan - Dec, 1998).

Sulphate is naturally present in surface waters as SO_4^{2-} , arising from the atmospheric deposition of oceanic aerosols or from geological sources such as leaching of sulphite minerals from sedimentary rocks

(UNESCO, 1992). In Tasmania, several studies to date have shown that concentrations in many natural waters is around 5 mg/L (Bobbi, *et al.*, 1996; DPIF, 1997; Bobbi, 1998) with streams receiving some form of polluted effluent having sulphate concentrations significantly higher than this (15 - 30 mg/L). All sites monitored during this study have shown concentrations well below this level (Figure 3.12).

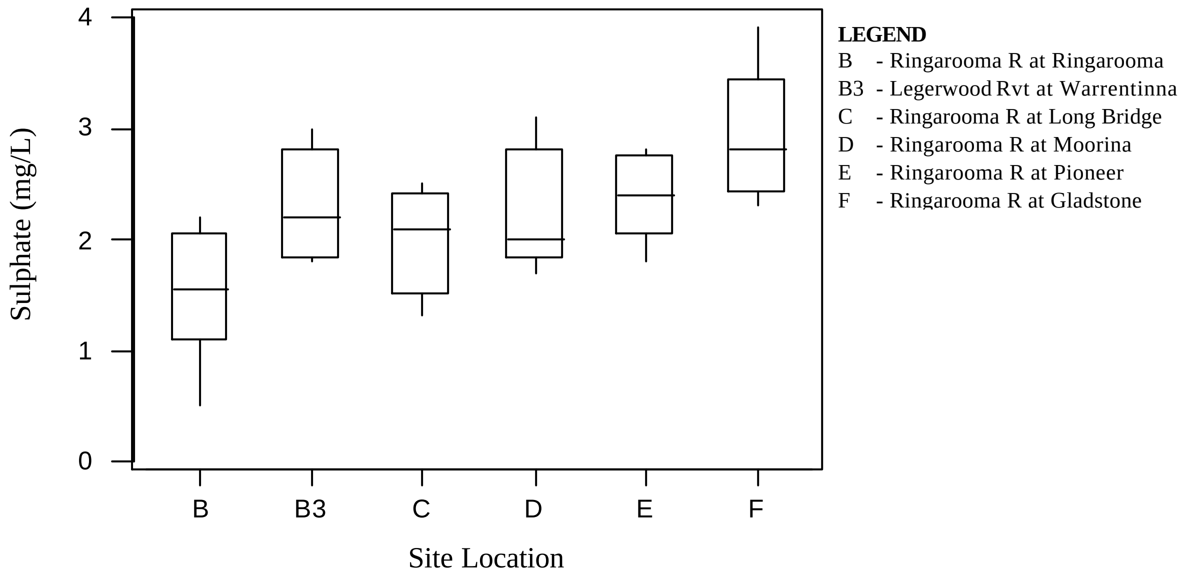


Figure 3.12 Statistics for sulphate at sites in the Ringarooma catchment (Jan - Dec, 1998).

3.4 Nutrient Results

The concentrations of nutrients such as nitrate, ammonia, organic nitrogen and the various forms of phosphorus are generally present at low levels in rivers draining agricultural areas. This generally makes field analysis for these parameters difficult as most detection kits cannot operate accurately at these levels. Therefore samples of water were collected during site visits and frozen until delivery to a NATA (National Association of Testing Authorities) registered laboratory which could then perform the relevant tests. These laboratories operate under strict quality control and are able to deliver results which are quality assured under NATA. Occasional duplicate and blank samples were delivered to further check field collection and preservation methods.

Nitrate Nitrogen

Nitrate nitrogen (NO_3/N) is very mobile in the environment and easily passes through soil into groundwater where it can strongly influence concentrations in rivers during baseflow conditions. Natural sources of NO_3/N are geological and plant and animal breakdown products. In the rural environment, the use of inorganic fertilisers, and increased levels of animal and plant wastes can have a significant impact on surface water NO_3/N concentrations (UNESCO, 1992). Clearing of land for cultivation and grazing also increases soil aeration, enhancing the action of nitrifying bacteria which increases the soil NO_3/N concentrations.

The results from monitoring in the Ringarooma catchment show that NO_3/N concentrations are highest at site in the middle part of the catchment (Figure 3.13). Legerwood Rivulet had a median NO_3/N concentration 0.845 mg/L. On three sampling occasions NO_3/N was recorded at over 1 mg/L. At most sites, there was a seasonal change, with highest NO_3/N concentrations during the late winter to spring period, when baseflow in the river reflects flushing from groundwater sources. This pattern has been found in other Tasmanian rivers (Bobbi, *et al.*, 1996).

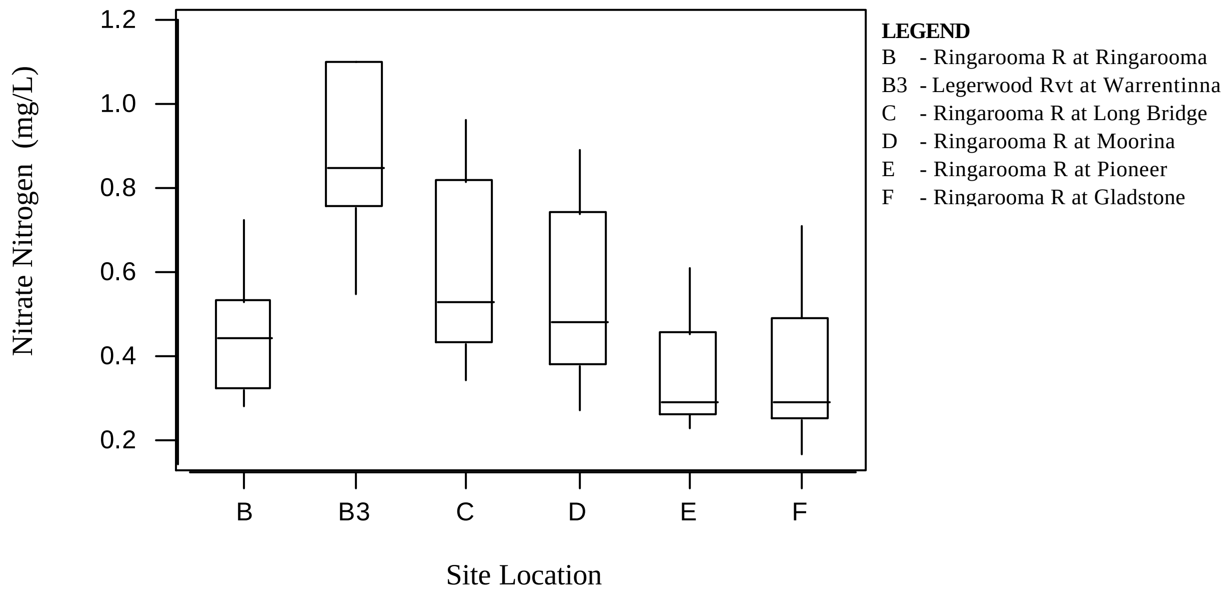


Figure 3.13 Statistics of monthly NO_3/N concentration at sites in the Ringarooma catchment (Jan - Dec, 1998).

While not significant (Mann-Whitney test), there is an apparent increase in NO_3/N in the Ringarooma River between Ringarooma Rd and sites in the middle of the catchment. The results from Legerwood Rivulet indicate that NO_3/N rich water may be entering the Ringarooma River through tributaries in this part of the catchment. While concentrations are more variable at Long Bridge and Moorina, both these sites have higher median NO_3/N concentrations than other Ringarooma River sites. Between Moorina and Gladstone there is a significant reduction in concentration (Mann-Whitney test) indicating that there is minimal input of NO_3/N to the river. Inflow of NO_3/N poor water (possibly from the Weld, Frome and other tributaries) may also be the reason for the decrease in NO_3/N concentration in the lower reaches of the Ringarooma River.

Ammonia Nitrogen

Ammonia nitrogen (NH_3/N) is naturally present in surface waters as a result of the breakdown of organic and inorganic material. However, NH_3/N is also generated by biota through excretion and production of organic waste, and as such higher concentrations can be an indicator of organic pollution (UNESCO, 1992). In the UK, high NH_3/N concentrations have been used as an indicator of impact by intensive dairying on water quality (NRA, 1992; Foy and Kirk, 1995).

While concentrations of NH_3/N in the Ringarooma catchment are much lower than for NO_3/N, the pattern of variation across sites is very similar (Figure 3.14). Highest NH_3/N concentrations were measured at sites in the upper catchment (0.12 mg/L at Ringarooma, 0.034 mg/L at Legerwood and 0.041 at Long Bridge) while for sites in the lower catchment, concentrations were only occasionally above detection limits (0.005 mg/L). If concentrations at Moorina, Pioneer and Gladstone are regarded as indicative of natural background levels, it can be stated that sites in the upper catchment may be showing evidence of impact from animal industries.

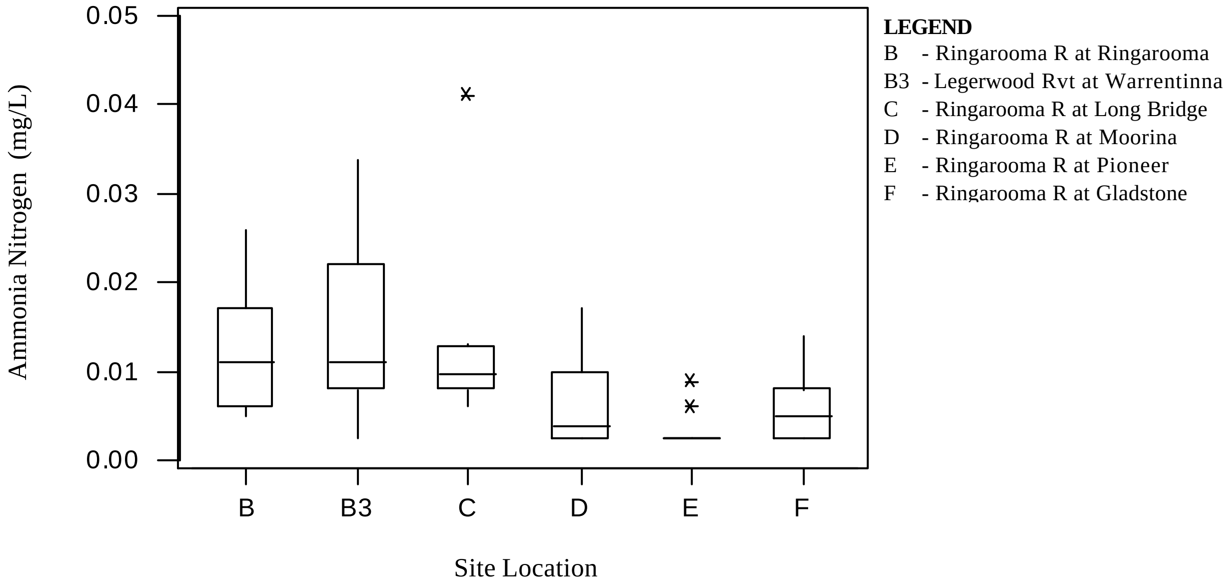


Figure 3.14 Statistics of monthly NH_3/N concentration at sites in the Ringarooma catchment (Jan - Dec, 1998) .

Organic Nitrogen

Organic nitrogen is cycled through the aquatic food chain by algae and bacteria, and like NO_3/N its concentration in surface waters usually fluctuates seasonally. Increased organic nitrogen is normally attributed to catchment activities such as intensive animal industries and inputs from such sources can alter the natural seasonal cycle. For most sites in the Ringarooma catchment, no clear seasonal change in organic nitrogen was found.

Of the 6 sites monitored, Legerwood Rivulet routinely had the highest organic nitrogen levels (Figure 3.15), with concentrations peaking between June and November. It appears that fluctuations at this site are controlled more by water flow than natural processes, as higher concentrations tended to occur during periods of higher flow. Runoff following rainfall is the most likely mechanism for this and may possibly indicate transfer of faecal material to the waterway during this time.

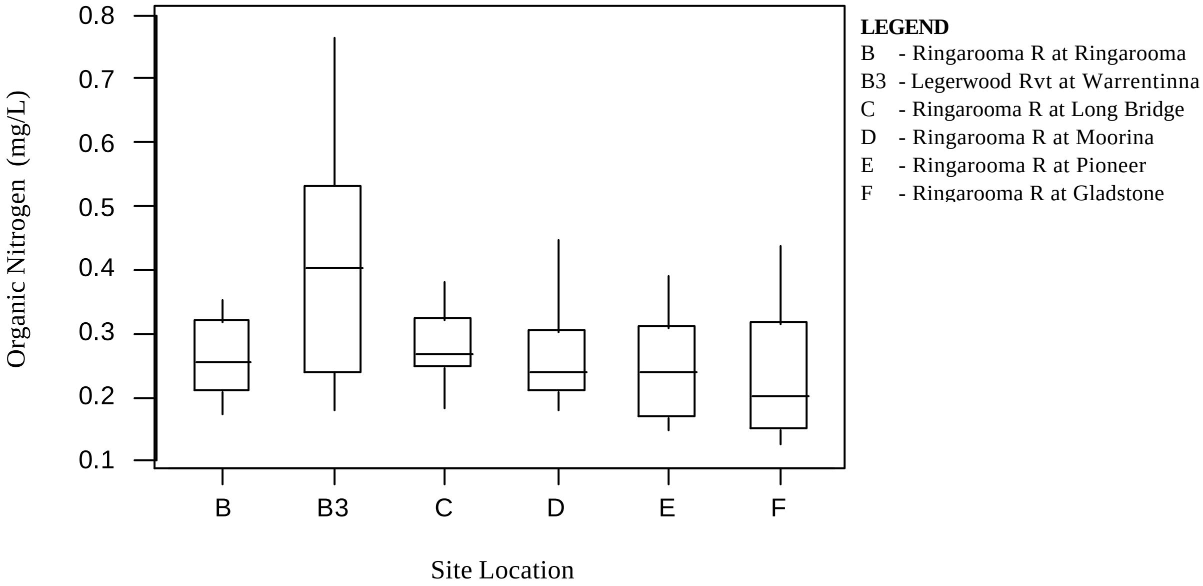


Figure 3.15 Statistics of monthly Organic Nitrogen concentration at sites in the Ringarooma catchment (Jan - Dec, 1998).

Total Nitrogen

Total nitrogen (TN) is simply the sum of Organic Nitrogen, NO_3/N and NO_2/N, though NO_2/N is not normally detected in environmental waters unless there is local pollution. Nitrite (NO_2/N) was only detected at trace levels in two samples taken during this study. The data for TN (Figure 3.16) therefore reflect patterns of both NO_3/N and organic nitrogen and as for both these variables, concentrations of TN were highest in Legerwood Rivulet. Median TN concentrations at all sites are listed in the table below, and like organic nitrogen levels, may be related to turbidity at this site, which was also relatively high compared to other sites (refer Figure 3.8).

TABLE 3.3 Median concentration of TN at sites in the Ringarooma catchment during 1998.

Site	**Median [TN] (mg/L)**
Ringarooma R at Ringarooma Rd	0.693
Legerwood Rivulet at Warrentinna Rd	1.198
Ringarooma R at Long Bridge	0.783
Ringarooma R at Moorina	0.703
Ringarooma R at Pioneer	0.543
Ringarooma R at Gladstone	0.583

(n = 12)

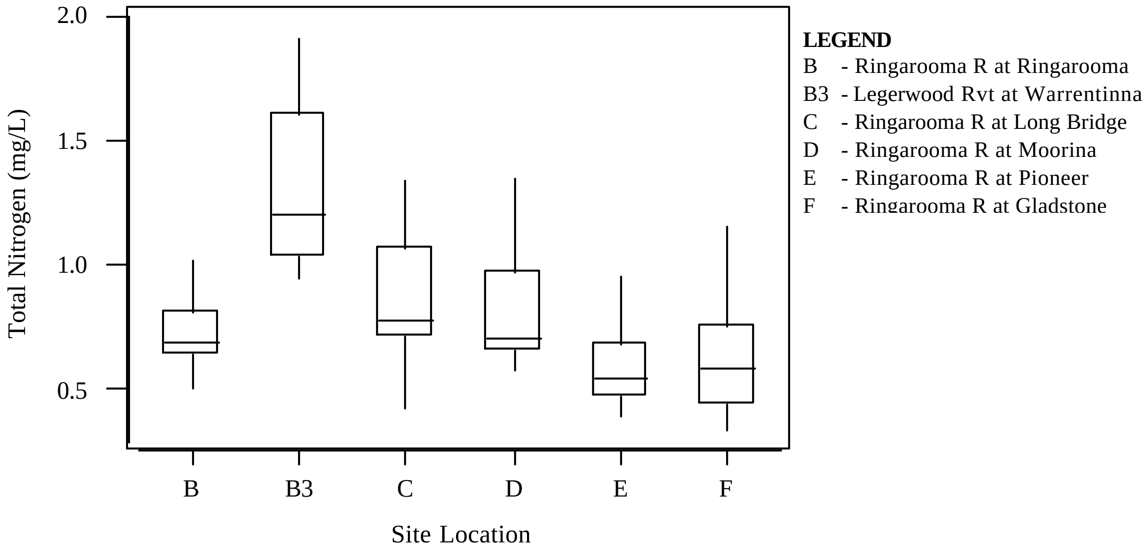


Figure 3.16 Statistics of monthly Total N concentration at sites in the Ringarooma catchment (Jan - Dec, 1998).

Total Phosphorus

While phosphorus is essential for growth and reproduction of aquatic plants and animals, it is normally present in natural surface waters at very low levels and is the nutrient which limits algal growth. When it is present in excess due to artificial inputs to rivers and lakes, it can trigger algal blooms which are a feature of eutrophication. Although plants generally require phosphorus in its dissolved form, it changes between various dissolved and particulate forms continuously depending on environmental conditions and biological processes (UNESCO, 1992). Therefore, where there is catchment activity which may produce increases in phosphorus, it is best to measure total phosphorus (TP) which includes particulate and dissolved forms, as at some stage all of this may become available for plant uptake. Most phosphorus is also normally present attached to organic and inorganic particulate material and can often be related to turbidity levels.

In the Ringarooma catchment, baseflow TP concentrations varied between the limit of detection (0.005 mg/L) and 0.06 mg/L. In the Ringarooma River, the site at Gladstone varied most (0.005 - 0.043 mg/L), although the median at this site was still relatively low (0.012 mg/L). The median TP concentration at all Ringarooma River sites was between 0.012 mg/L and 0.014 mg/L. Some more extreme values (highlighted in Figure 3.17 by the outlier markers) were measured at sites lower in the river, reflecting the delayed impact of earlier runoff events high in the catchment.

Once again, the increase in nutrient levels in Legerwood Rivulet are clearly displayed by TP concentrations. Median TP concentration of this rivulet is roughly twice that of most sites in the Ringarooma River, and clearly suggests that tributaries such as this may be contributing significant nutrient load to the main river.

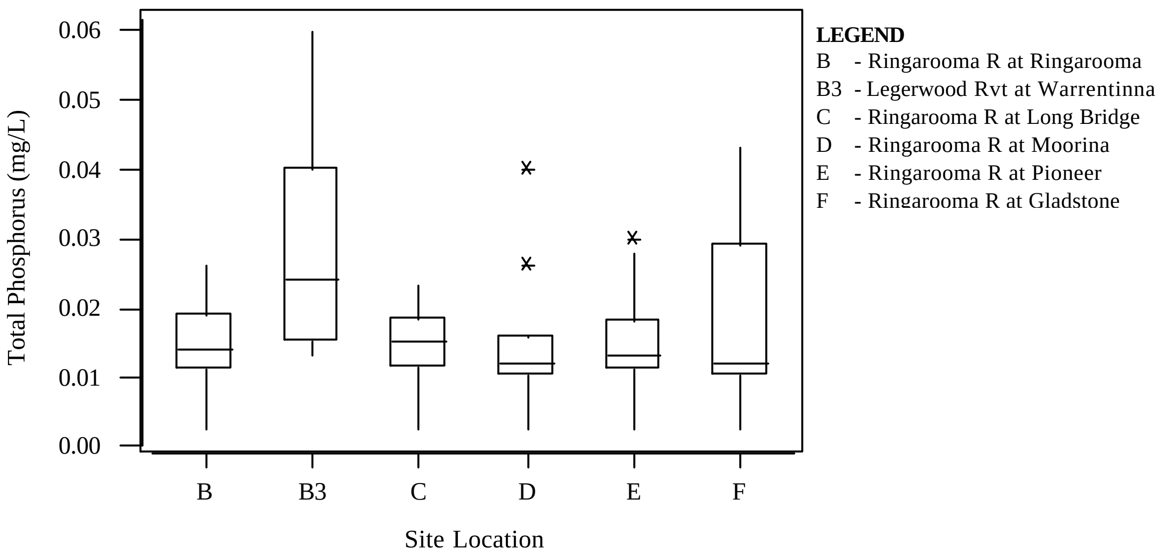


Figure 3.17 Statistics of monthly Total P concentration at sites in the Ringarooma catchment (Jan - Dec, 1998).

In summary, the monthly nutrient data demonstrate the increased level of nutrients and degradation of water quality in Legerwood Rivulet relative to the Ringarooma River. Although baseflow water quality in the Ringarooma River is generally good, sites in the middle reaches of the river indicate that tributaries such as Legerwood Rivulet are impacting on water quality in the main river. This result is not surprising as this area of the catchment contains the most productive land and is subject to most agricultural activity. It would therefore be beneficial to further investigate the condition and relative quality of water in other tributaries draining this region to establish whether Legerwood Rivulet is representative of other tributaries. To some degree the following section contributes some information on condition of tributaries, but more extensive data will still be required.

3.5 Catchment Survey

Catchment 'snapshot' surveys were conducted during stable baseflows in summer (22-23rd January) and winter (8th August) with the aim of highlighting areas where water quality was degraded relative to the rest of the catchment. This technique has been used in the past both in Tasmania (Bobbi, *et al*, 1996; Bobbi, 1998) and interstate (Grayson, *et al.*, 1997) and has proved useful. As rainfall and runoff variation across a catchment can negate the validity of assessments such as this, it is important that such 'snapshot' surveys are undertaken during stable climatic and hydrological conditions.

During the summer survey 21 sites were sampled across the catchment. This was increased to 24 during the winter, as sites which during the summer were not flowing now had sufficient flowing water in them (Figure 3.18; site coordinates are listed in Appendix 1). At all sites physical-chemical testing was performed. During the summer survey, water samples were taken at a subset of 11 sites, with analysis for nutrients, heavy metals and bacteria being undertaken. Two sites were unable to be sampled due to lack of water flow at the time. During the winter survey a subset of 19 sites were sampled for nutrients, heavy metals and bacterial analysis.

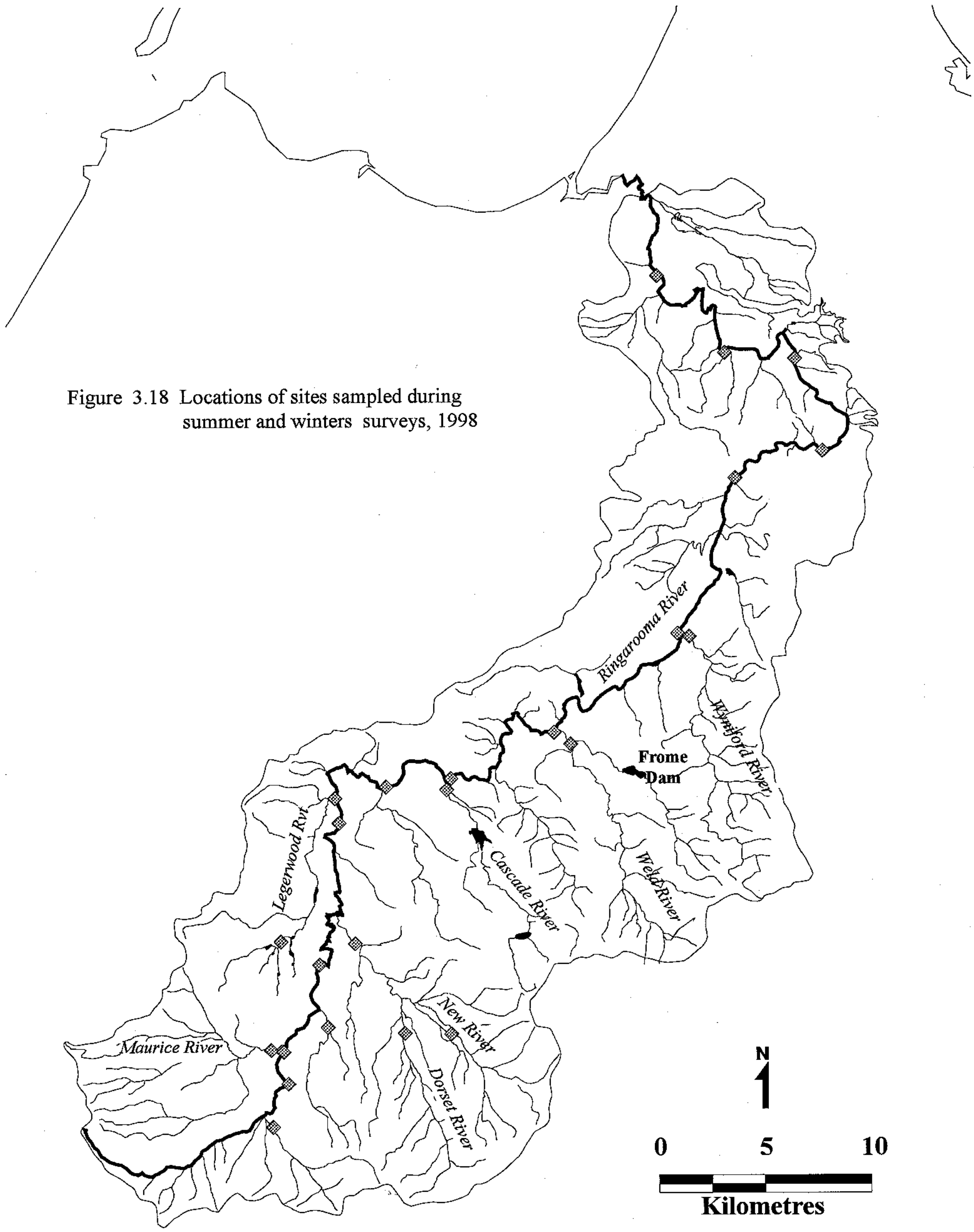


Figure 3.18 Locations of sites sampled during summer and winters surveys, 1998

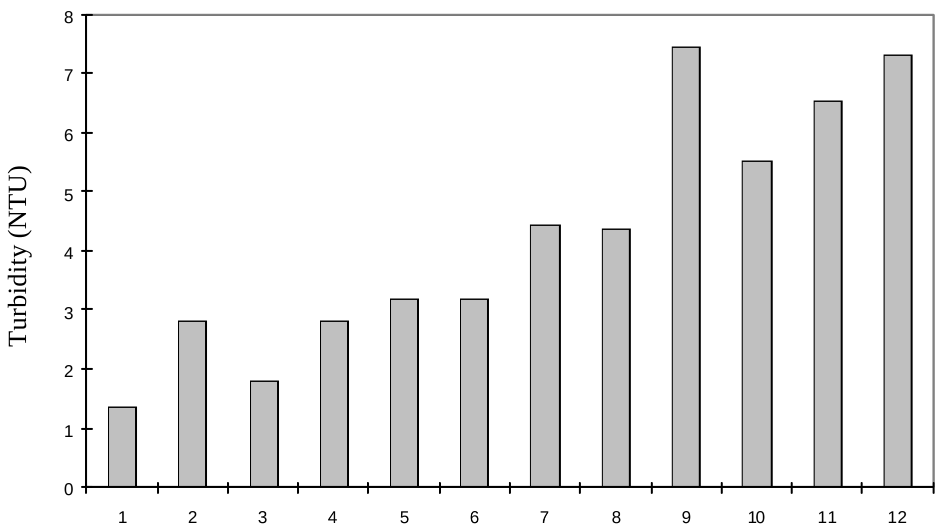
Catchment Survey - pH

All of the sites sampled during the surveys were generally acidic (pH less than 7), with lower pH levels in the summer survey, when flows were lowest. During the summer survey (Figure 3.19) 15 of the 21 sites sampled had pH values of less than 6, the lowest of these being 4.88 in the New River. This river had the lowest pH on both occasions, reinforcing the data collected during monthly monitoring. Reasons for the acidity of this river are difficult to determine exactly. Soil surveys in the area have shown that soil pH is generally low (pH 5 - 6) which may have some effect on groundwater (and hence river discharge water during baseflows). Drainage activities and removal of vegetation, resulting in lowering the water table, has been known to cause river water acidification elsewhere (Cresser & Edwards, 1988), and in the New River this may be a significant contributing factor. There is also a general lack of base cations (Ca^{2+} and Mg^{2+}) in waters throughout the catchment, making river water less able to withstand acidification.

Although the average pH was higher during the winter survey (6.42 compared to 5.83 during the summer), the pattern was virtually the same. The pH of river water in the Dorset and New rivers was again the lowest in the catchment (pH around 5.1 - 5.8).

Catchment Survey - Turbidity

The summer survey data for turbidity shows that water clarity was generally good across the catchment. Virtually all sites had turbidity levels of less than 5 NTU, with the exception of Legerwood Rivulet at Ringarooma Rd where turbidity was over 11 NTU (Figure 3.20a). During the winter the picture is different, with a general trend towards increased turbidity generally (12 of the 21 sites sampled on both occasions showed higher turbidity in winter) and a clearer trend of increasing turbidity towards the lower sections of the catchment (Figure 3.20b). This trend is seen more clearly in a plot of turbidity at sites down the length of the Ringarooma River at that time (Figure 3.21).



LEGEND

1 - Ringarooma at Maurice Rd	7 - Ringarooma at Moorina
2 - Ringarooma at Cottons Bridge	8 - Ringarooma at Garibaldi Rd
3 - Ringarooma at Ringarooma Rd	9 - Ringarooma at Mining Platform
4 - Ringarooma at Branxholm	10 - Ringarooma at Olgilvies Bridge
5 - Ringarooma at Long Bridge	11 - Ringarooma at Bells Bridge
6 - Ringarooma at Derby	12 - Ringarooma at Galloway Ck

Figure 3.21 Turbidity trend along the length of the Ringarooma River recorded during the winter survey, 1998.

This is a normal condition for most rivers during the higher baseflows of winter, when higher river velocity transports suspended material further downriver.

Figure 3.19 Field pH recorded during summer survey, 1998.

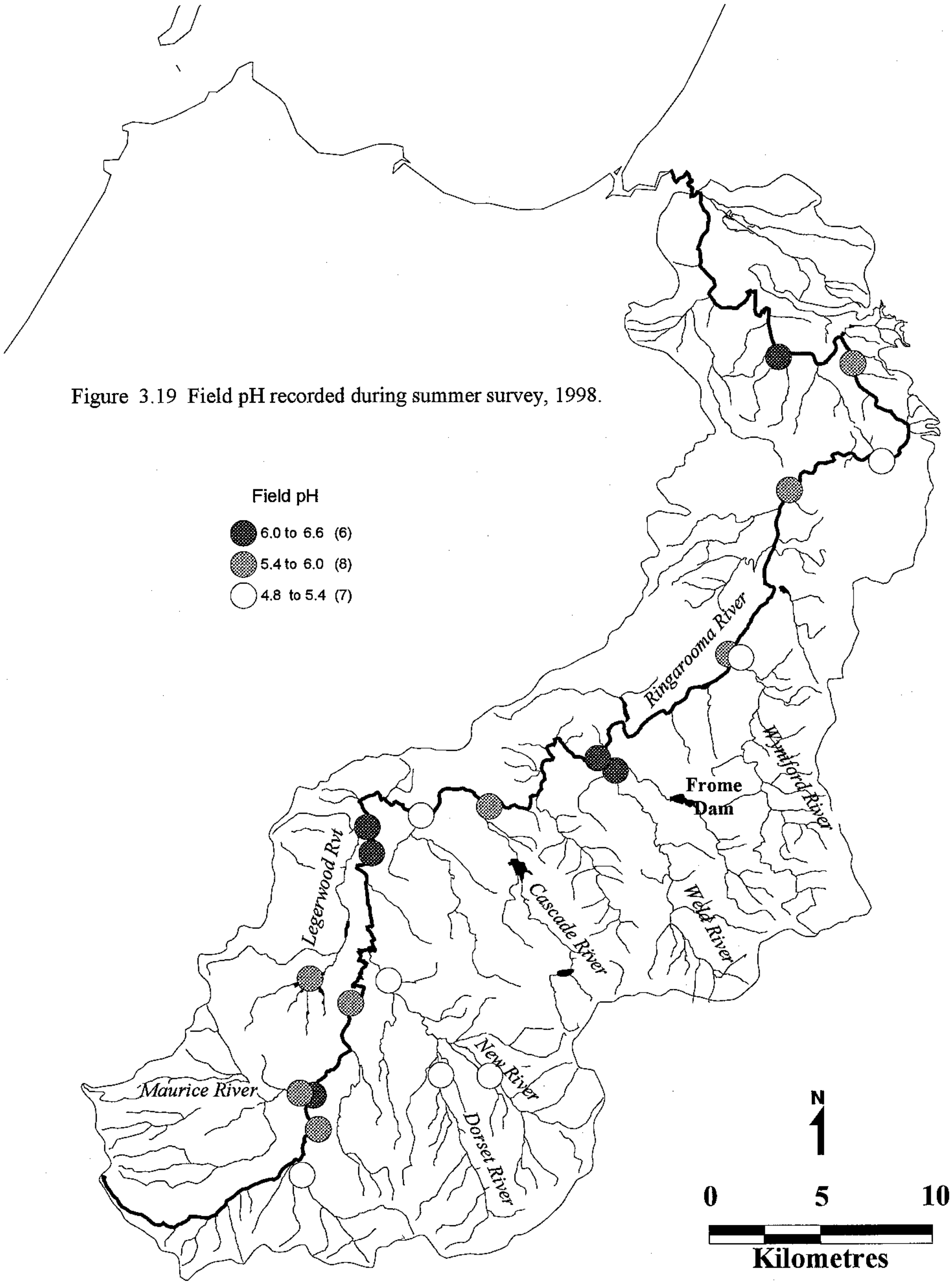
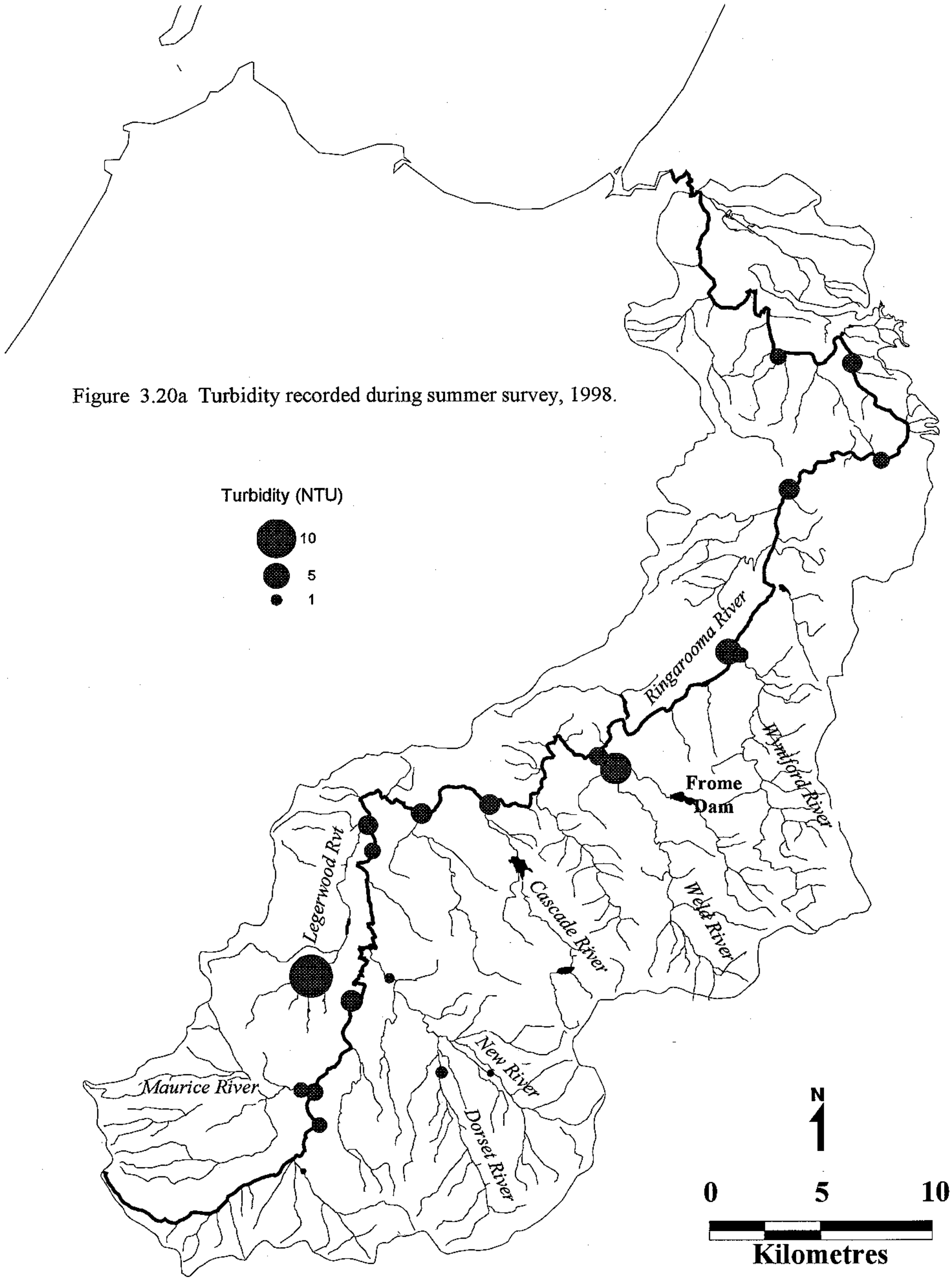


Figure 3.20a Turbidity recorded during summer survey, 1998.



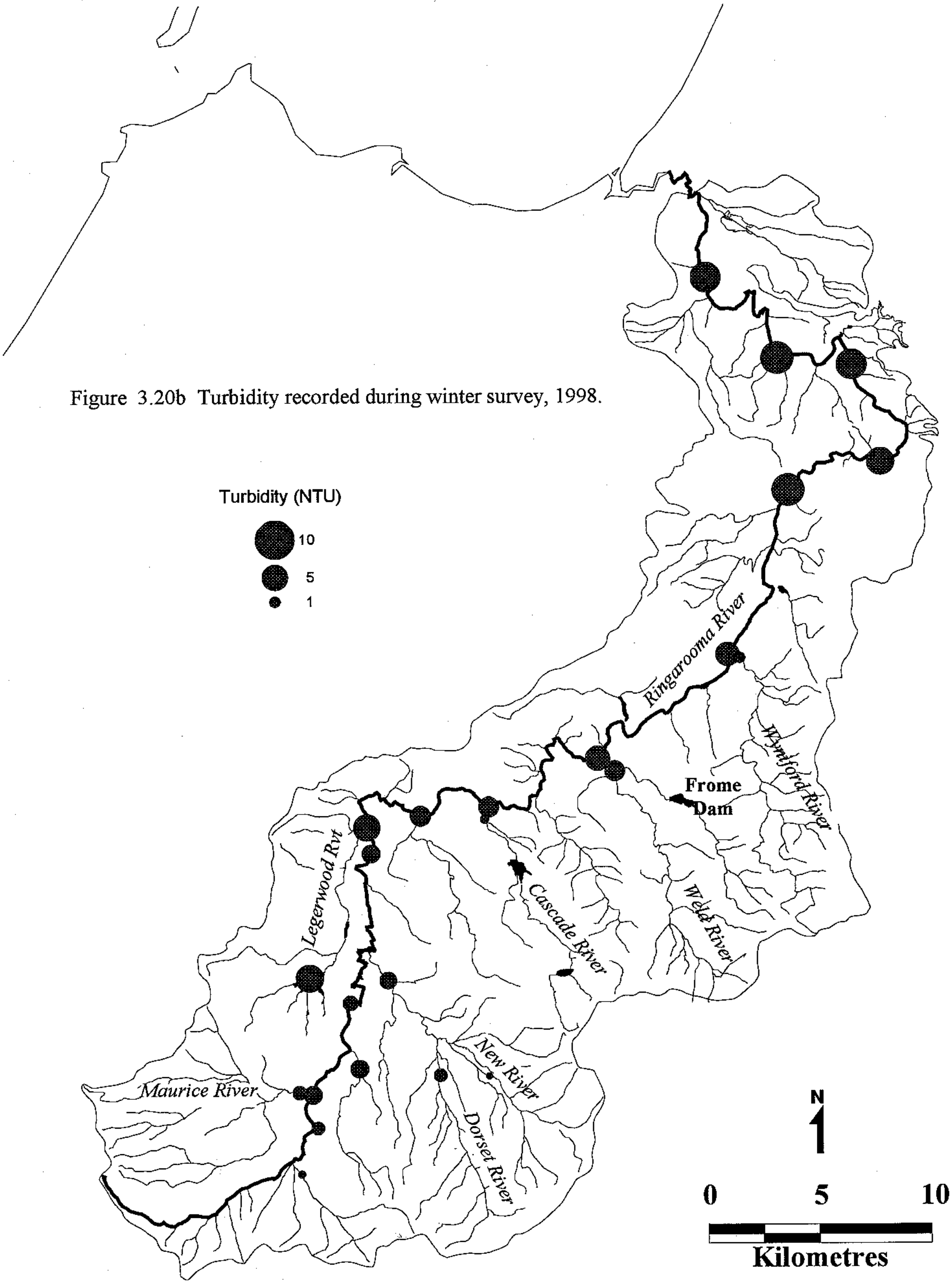
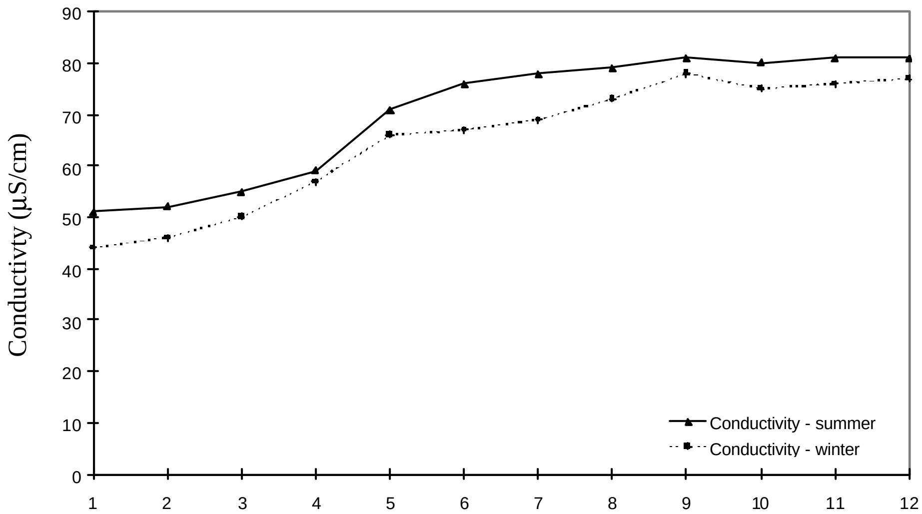


Figure 3.20b Turbidity recorded during winter survey, 1998.

Catchment Survey - Conductivity

Like turbidity, conductivity at all sites was generally low (during both summer and winter surveys), demonstrating the good quality of water across the catchment. On both occasions conductivity was below 100 µS/cm at most sites, with the exception of Legerwood Rivulet at Warrentinna Rd which was slightly higher. As conductivity levels were generally so low, no catchment plots are presented here. The average conductivity across sites during the summer survey was 73 µS/cm, while during winter the average was 67 µS/cm.

During each survey, there was a clear increase in conductivity down the length of the Ringarooma River (Figure 3.22), a pattern which has been found in other rivers in Tasmania (Bobbi, *et al*, 1996 - South Esk Basin; DPIF, 1997 - Mersey River). The difference between the summer and winter conditions is relatively small, which highlights the fact that there is only a minor seasonal variation to salinity levels in the river. Other rivers of similar size in Tasmania (eg. South Esk, Macquarie, Coal rivers) show a general seasonal pattern of change which is larger in magnitude.



LEGEND

1 - Ringarooma at Maurice Rd	7 - Ringarooma at Moorina
2 - Ringarooma at Cottons Bridge	8 - Ringarooma at Garibaldi Rd
3 - Ringarooma at Ringarooma Rd	9 - Ringarooma at Mining Platform
4 - Ringarooma at Branxholm	10 - Ringarooma at Olgilvies Bridge
5 - Ringarooma at Long Bridge	11 - Ringarooma at Bells Bridge
6 - Ringarooma at Derby	12 - Ringarooma at Galloway Ck

Figure 3.22 Conductivity trend in the Ringarooma River recorded during both catchment surveys, 1998.

Catchment Survey - Dissolved Oxygen

The level of dissolved oxygen was much more varied across sites during summer than in winter. During summer, when river flow is low and temperature is high, instream decomposition of organic material is a significant determinant of oxygen levels in streams. Streams which have higher organic and nutrient inputs will generally have lower levels of dissolved oxygen than those which do not. The data from the summer survey reflects this (Figure 3.23). Dissolved oxygen concentrations recorded at that time ranged between 5.9 and 9.1 mg/L. The majority of sites sampled (13 of 21) had daytime DO levels of between 7 and 8.5 mg/L. A further 6 sites showed DO levels above 8.5 mg/L. Two sites (Legerwood Rivulet at Ringarooma Rd and New River at Singline Rd) had DO levels which could be considered quite low relative to the others. Dissolved oxygen at the New River site showed DO levels less than 6 mg/L, indicating that this site may be stressed or impacted in some manner. ANZECC (1992) guidelines for the preservation of aquatic ecosystems recommend concentrations above 6 mg/L. Concentrations below 6 mg/L will cause stress on some aquatic organisms, and levels below about 4 mg/L can cause death.

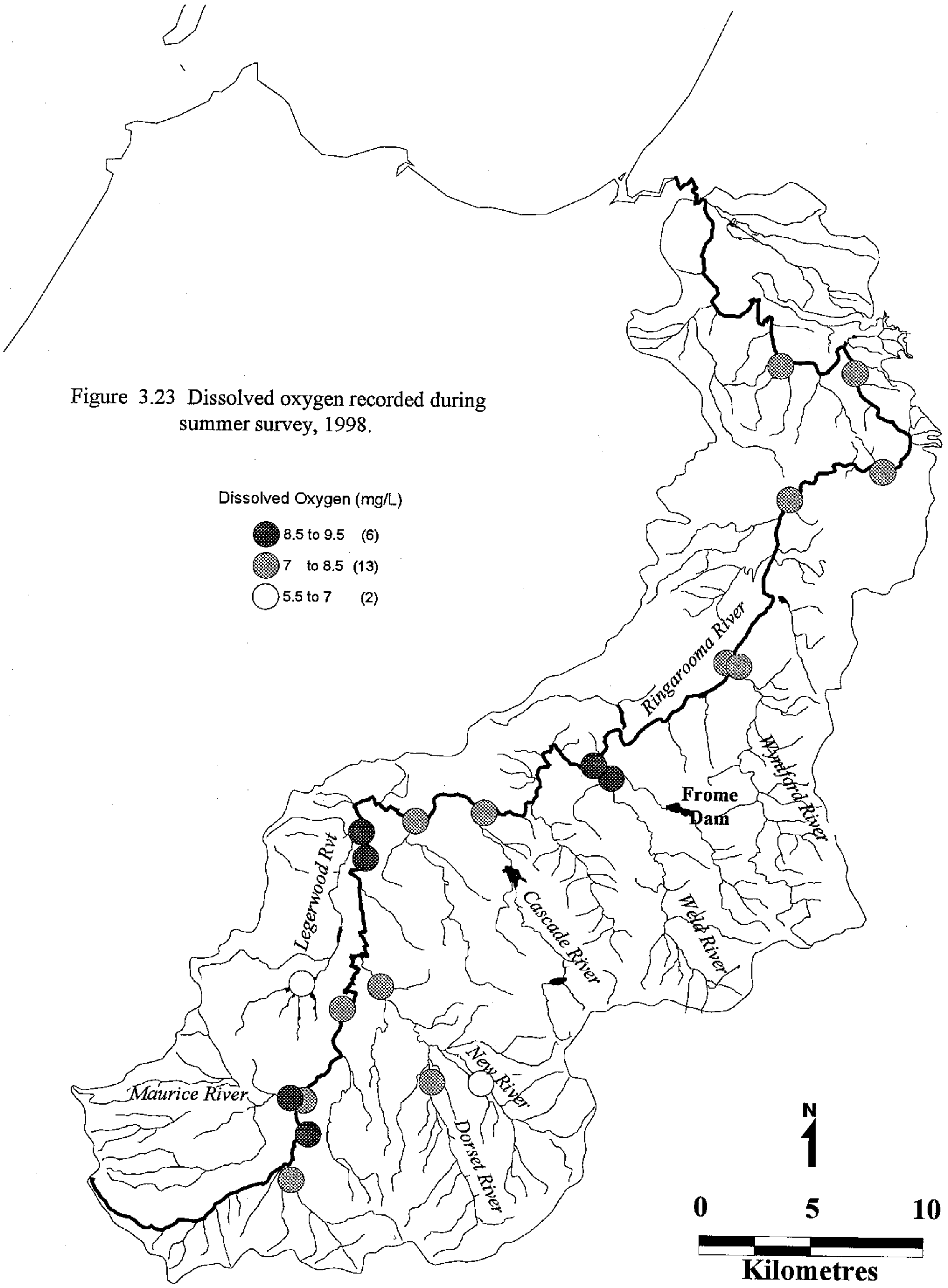
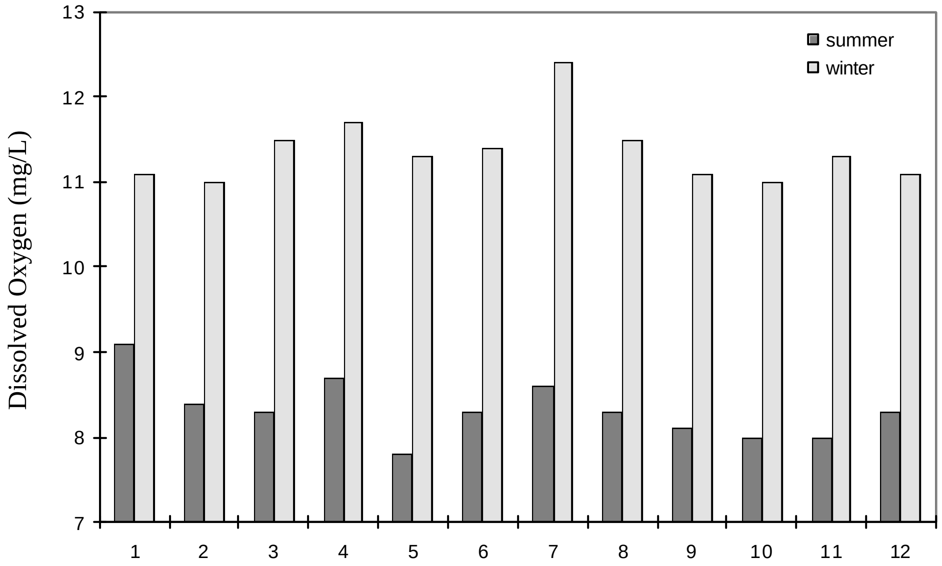


Figure 3.23 Dissolved oxygen recorded during summer survey, 1998.

Dissolved oxygen concentrations in the Ringarooma River during summer generally decreased towards the bottom of the catchment (Figure 3.24). Slight peaks occurred at Branxholm and Moorina, where rapids may have produced local increases. There was also a noticeable decrease at Long Bridge which may be indicative of a depositional zone in the river where organic decomposition and bacterial activity may be affecting oxygen levels.



LEGEND

1 - Ringarooma at Maurice Rd
2 - Ringarooma at Cottons Bridge
3 - Ringarooma at Ringarooma Rd
4 - Ringarooma at Branxholm
5 - Ringarooma at Long Bridge
6 - Ringarooma at Derby
7 - Ringarooma at Moorina
8 - Ringarooma at Garibaldi Rd
9 - Ringarooma at Mining Platform
10 - Ringarooma at Olgilvies Bridge
11 - Ringarooma at Bells Bridge
12 - Ringarooma at Galloway Ck

Figure 3.24 Trend in dissolved oxygen concentrations down the length of the Ringarooma River during summer and winter surveys, 1998.

This pattern was not found in the winter survey, as higher flows and colder water temperatures both increase the capacity of the water to hold higher concentrations of oxygen. During the winter survey, dissolved oxygen levels across all sites were much more uniform (average 11.2 mg/L). The minimum DO measured was 8.5 mg/L, again at New River. Highest DO levels (> 12 mg/L) were measured in the Weld and Cascade rivers as well as the Ringarooma at Moorina.

Catchment Survey - Bacteria

During the summer field survey, 12 sites in the catchment were sampled. The majority of these were located in the upper half of the catchment as this part of the catchment is where the main agricultural activity and rural population exists. During the winter survey, this was extended to include 19 sites, with better coverage in the lower catchment. Testing on both occasions was carried out for total coliforms, faecal coliforms (as *E. coli*) and faecal streptococci. As faecal coliforms are the indicator most often used to assess the bacterial contamination of waters, only the *E. coli* results will be discussed in this section.

As this sampling was also only a ‘snapshot’, it is not valid to compare results against either the ANZECC (1992) guidelines or the more recent, revised version of that document. Both these documents state that evaluation of microbiological quality should be based on median levels from data collected through routine monitoring. However, the data collected during the surveys can be used to highlight areas in the catchment where water quality is affected by faecal pollution. Where higher levels of faecal bacteria are reported, further investigation may be needed to adequately determine the level of pollution.

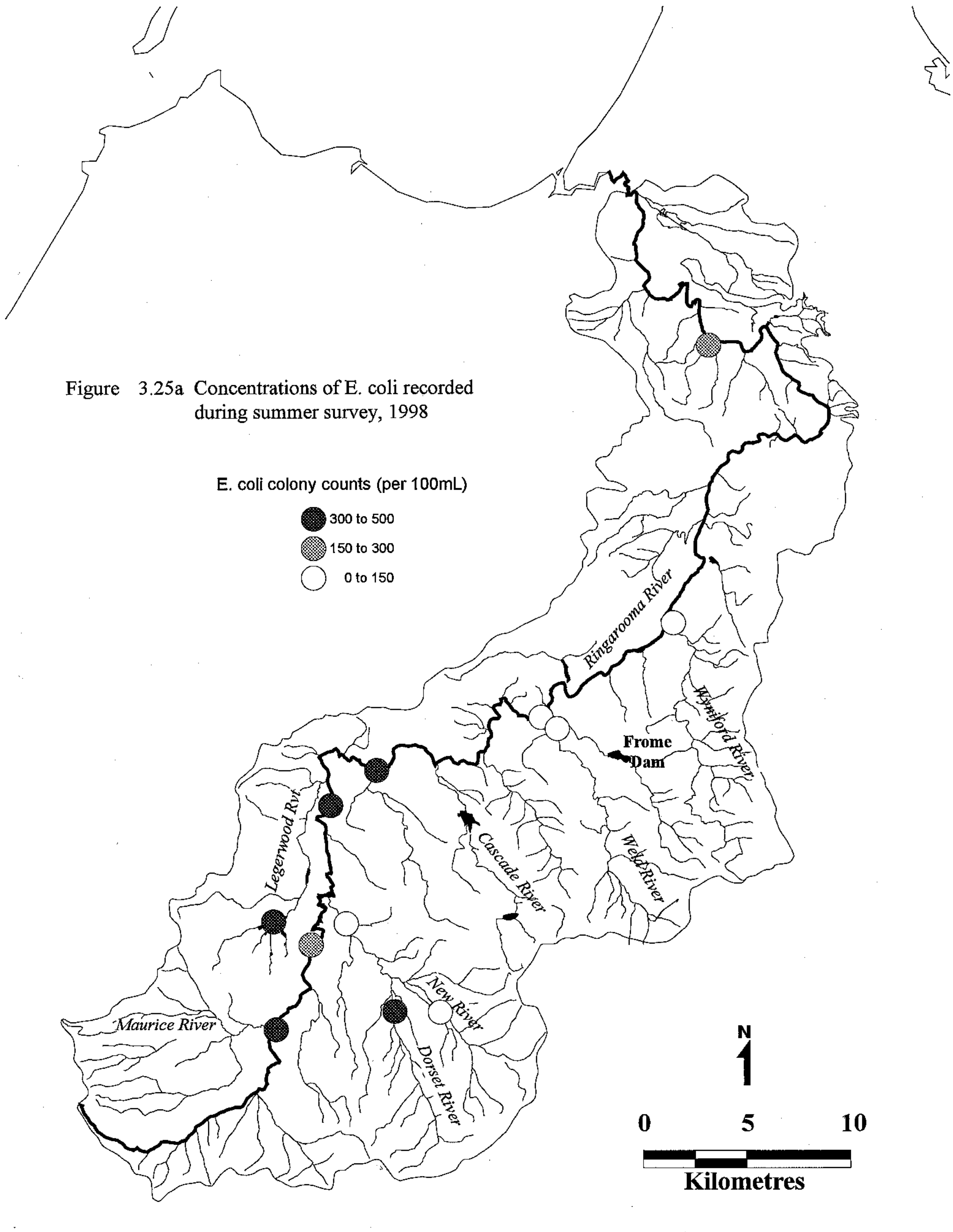


Figure 3.25a Concentrations of E. coli recorded during summer survey, 1998

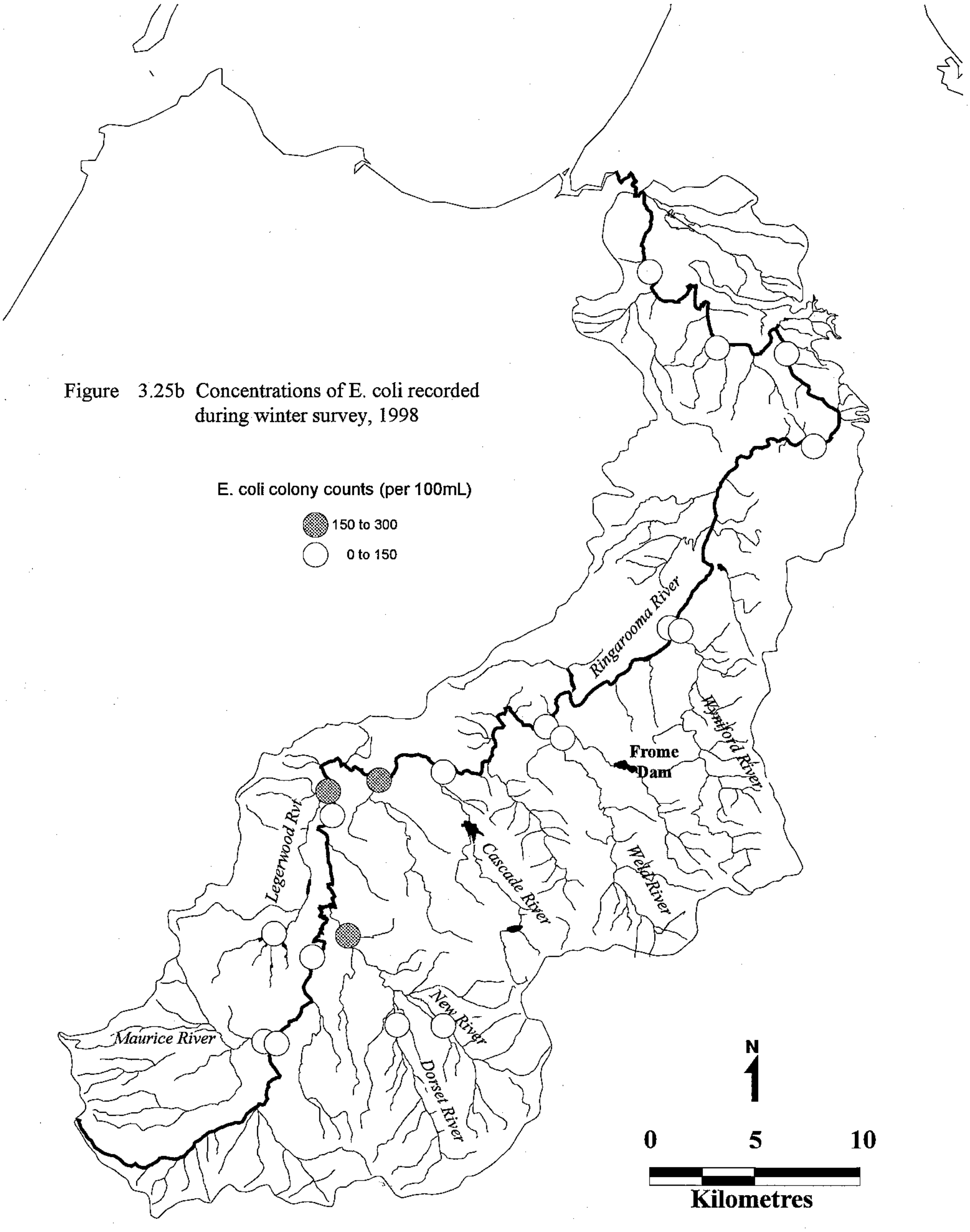
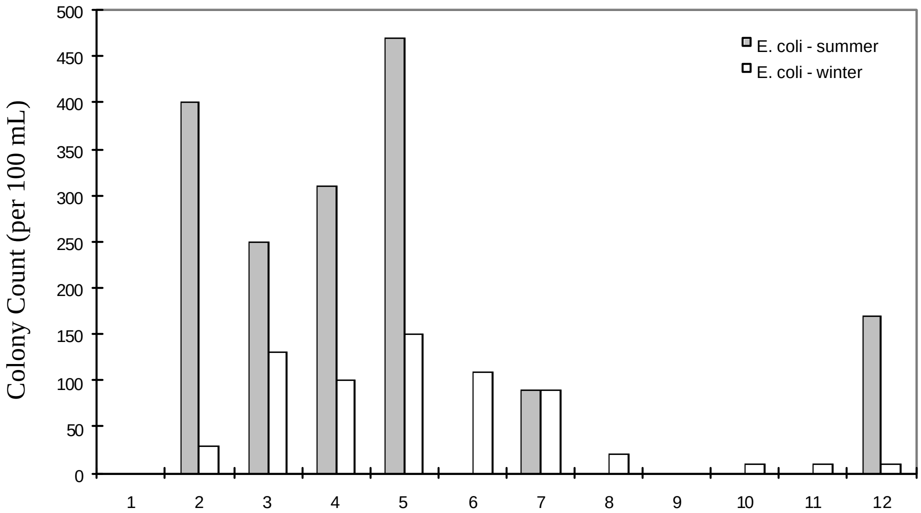


Figure 3.25b Concentrations of E. coli recorded during winter survey, 1998

During the summer survey (Figure 3.25a), higher faecal coliform levels were measured at sites in the middle and upper parts of the catchment. The most significant of these were the Ringarooma River at Cottons Bridge (400 coliforms /100ml) and Long Bridge (470 coliforms/100mL) and the upper reaches of Legerwood Rivulet (460 coliforms/100mL). This result was confirmed by faecal streptococci counts which were also high at these sites.

This situation was reinforced by data from the winter survey which clearly showed that sites lower in the catchment were of better quality than upper sites (Figure 3.25b). While seven more sites were sampled during the winter survey (19 sites), sites which had highest coliform levels during the summer survey also tended to be high during the winter survey. Coliform concentrations during winter however, were generally were much lower (average across sites; summer = 227 /100mL; winter = 80 /100mL).

In the Ringarooma River, *E. coli* data from both summer and winter show the same general pattern (Figure 3.26), with sites in the upper reaches having higher levels of bacteria.



LEGEND
1 - Ringarooma at Maurice Rd
2 - Ringarooma at Cottons Bridge
3 - Ringarooma at Ringarooma Rd
4 - Ringarooma at Branxholm
5 - Ringarooma at Long Bridge
6 - Ringarooma at Derby
7 - Ringarooma at Moorina
8 - Ringarooma at Garibaldi Rd
9 - Ringarooma at Mining Platform
10 - Ringarooma at Olgilvies Bridge
11 - Ringarooma at Bells Bridge
12 - Ringarooma at Galloway Ck

Figure 3.26 Longitudinal change in E. coli colony counts at sites along the Ringarooma River, recorded during the summer and winter surveys of 1998.

All of this data clearly indicates that faecal pollution is greatest in rivers draining the upper part of the catchment and reflects that fact that intensive animal industry is more prevalent in this area. Stock access to streams draining this area is also common and would enhance the movement of faecal material to streams and rivers. The higher faecal input to waterways in this area also constitutes a greater risk to human health and consumption, especially during summer months when higher water temperatures increase the lifetime of coliforms in the environment.

Catchment Survey - Total Nitrogen

There was no significant differences between surveys for Total N. The average Total N concentration during the summer was 0.77 mg/L while for winter the average was 0.71 mg/L (across all 19 sites). The only difference of any note was that Total N concentrations in the main river were slightly higher during winter. The data from the winter 'snapshot' is shown in Figure 3.27.

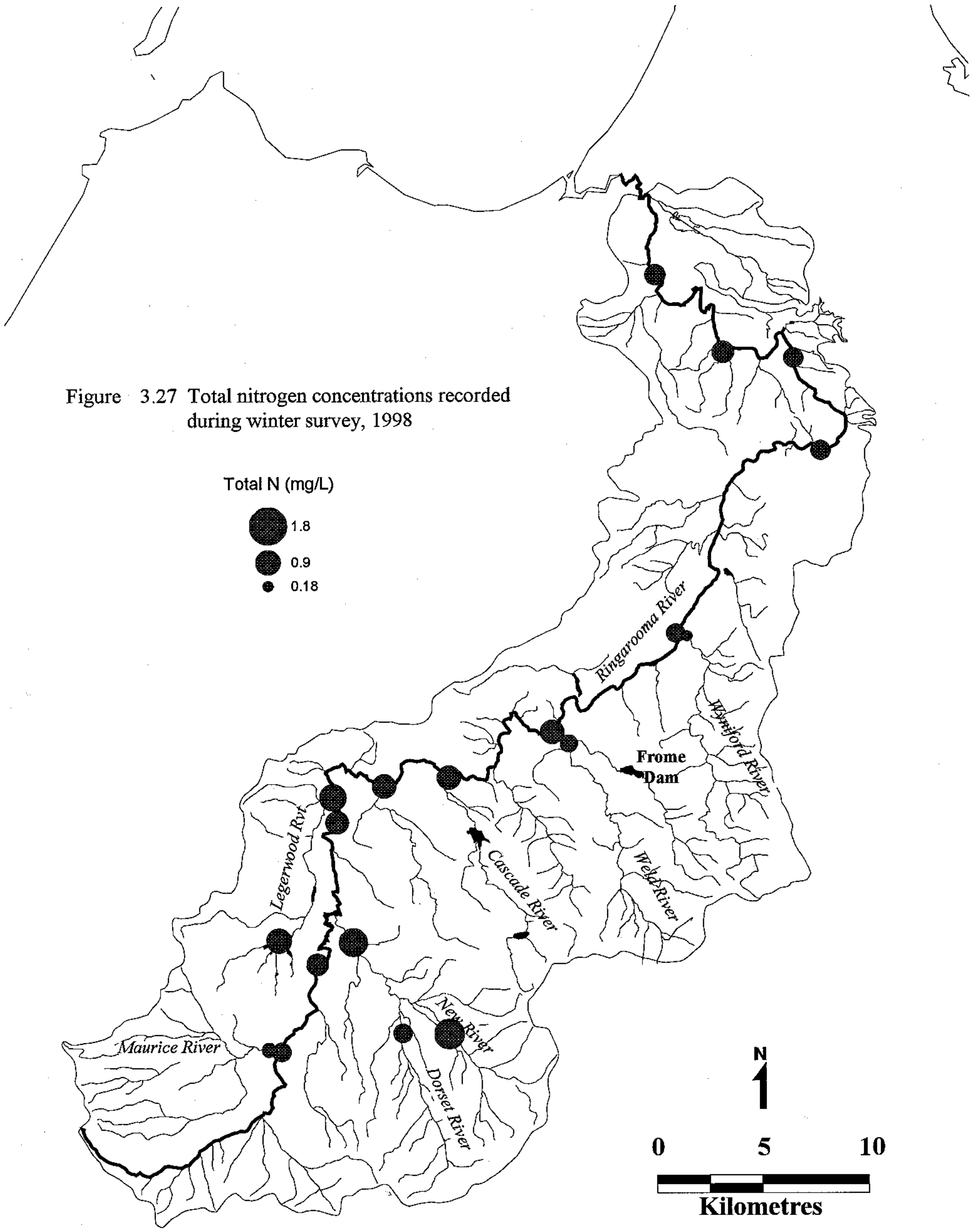


Figure 3.27 Total nitrogen concentrations recorded during winter survey, 1998

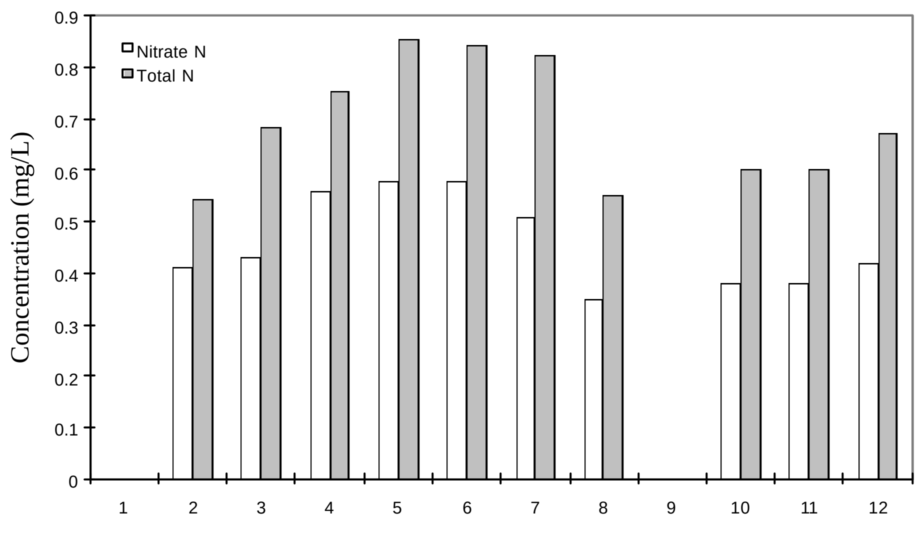
In both summer and winter 'snapshots', highest Total N concentrations occurred in the New River and lower Dorset River, and in the Legerwood River. At sites on each of these rivers, concentrations in excess of 0.9 mg/L was measured, the highest on both occasions being recorded in the New River (1.72 mg/L and 1.24 mg/L for summer and winter respectively). The lowest concentrations (< 0.5 mg/L) were recorded in the Maurice, Weld and Wyniford rivers.

During both surveys, it was found that at almost all sites sampled, NO_3/N contributed more than 60% of the Total N concentrations. This was especially apparent in the New River where NO_3/N was more than 80% of the Total N concentration on both sampling occasions. As has been mentioned in an earlier section, clearing of land for cultivation and grazing can also increase soil aeration, enhancing the action of nitrifying bacteria which increases the soil NO_3/N concentrations (UNESCO, 1992).

The only river sampled which did not follow this general trend was the Wyniford River, where NO_3/N levels were at or below detection limits (0.005 mg/L) and it was clear that organic material was the main contributor to Total N concentrations. NO_3/N was also relatively low in the Weld River compared to other sites in the catchment.

In the Ringarooma River, it was also clear that NO_3/N contributes significantly to levels of nitrogen in the river (Figure 3.28). It was also evident that there is greater input of nitrogen to the river between Branxholm and Moorina. This may reflect the relative contribution of groundwater to the river, as nitrate is easily transported by subsurface water, or it may reflect the impact of more localised catchment activities in the floodplain of the river along this section.

The significant drop in nitrogen concentration at Garibaldi Road is most likely to reflect the inflow of relatively 'nutrient-free' water from the Wyniford River. The effect of this dilution is apparent at all sites in the Ringarooma River downstream of the junction. As it also drains an area of high rainfall (Blue Tiers), the Wyniford River would also be adding a significant volume to Ringarooma River flows downstream of the junction of the two rivers.



LEGEND

1 - Ringarooma at Maurice Rd
2 - Ringarooma at Cottons Bridge
3 - Ringarooma at Ringarooma Rd
4 - Ringarooma at Branxholm
5 - Ringarooma at Long Bridge
6 - Ringarooma at Derby
7 - Ringarooma at Moorina
8 - Ringarooma at Garibaldi Rd
9 - Ringarooma at Mining Platform
10 - Ringarooma at Olgilvies Bridge
11 - Ringarooma at Bells Bridge
12 - Ringarooma at Galloway Ck

Figure 3.28 Nitrate nitrogen and Total nitrogen concentrations at sites in the Ringarooma River recorded during the winter survey, 1998.

Catchment Survey - Phosphorus

As the majority of phosphorus in 'natural' waters tends to be carried by particulate material, the data for total phosphorus concentrations tends to reflect turbidity (as turbidity is a measure of suspended material). This can be most easily seen in the data from the summer survey, where higher turbidity was recorded in the upper part of Legerwood Rivulet and also in the Weld River. The total phosphorus concentrations from both these sites reflect that result. At Legerwood Rivulet, total phosphorus was measured at 0.52 mg/L while at the site on the lower Weld River total phosphorus was measured at 0.21 mg/L (Figure 3.29a). The average concentration of all other sites sampled during the summer survey was 0.012 mg/L.

During the winter survey (Figure 3.29b) total phosphorus levels across all sites was lower, with an average concentration of 0.009 mg/L. In general, sites in the upper part of the catchment had lower TP concentrations than was found in summer, while sites lower in the catchment were slightly higher. Higher phosphorus levels were recorded at both sites in Legerwood Rivulet and two sites lower in the Ringarooma River.

Both surveys clearly indicate that Legerwood Rivulet has higher phosphorus levels relative to the rest of the catchment and that there may be significant export of phosphorus from this part of the catchment.

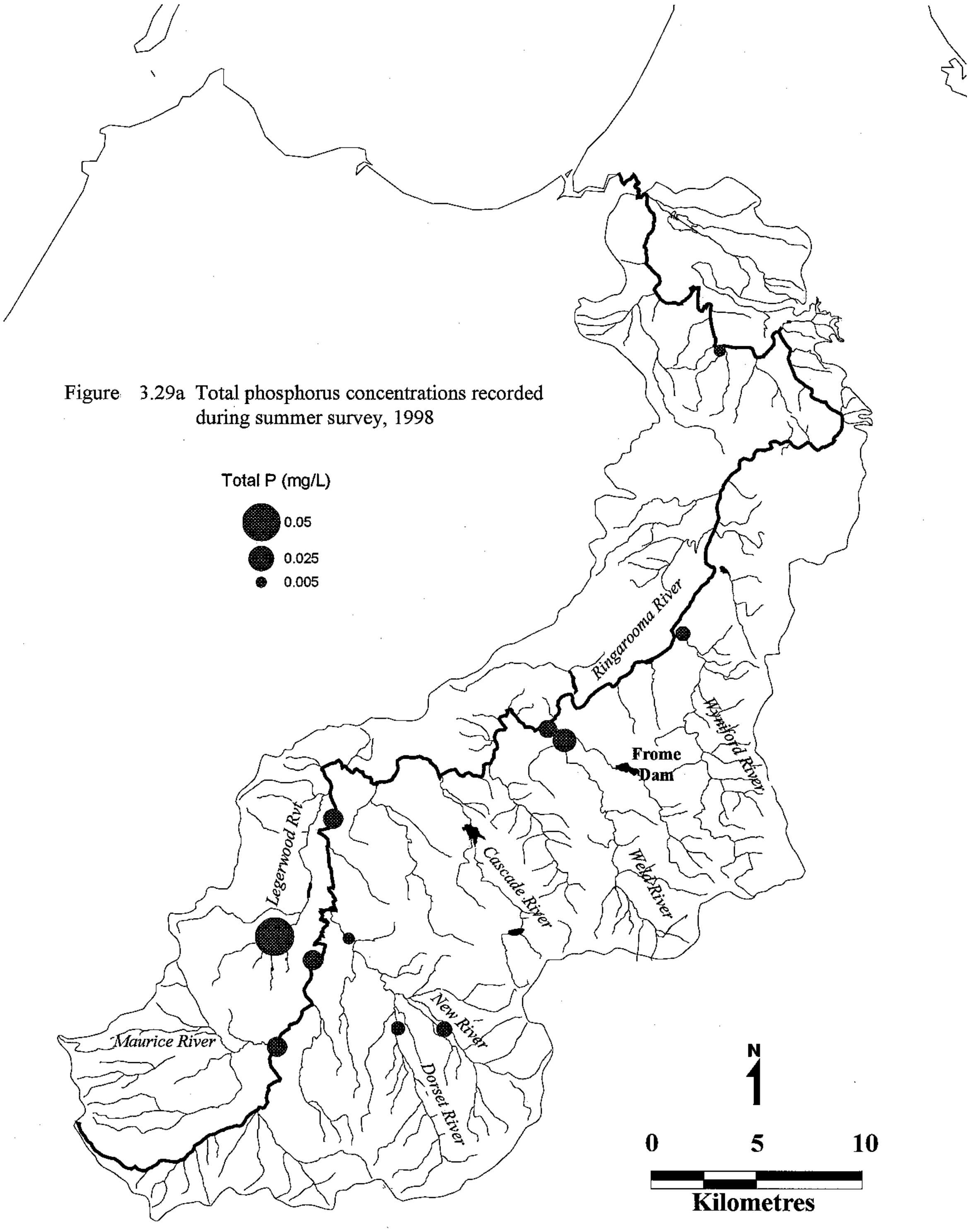
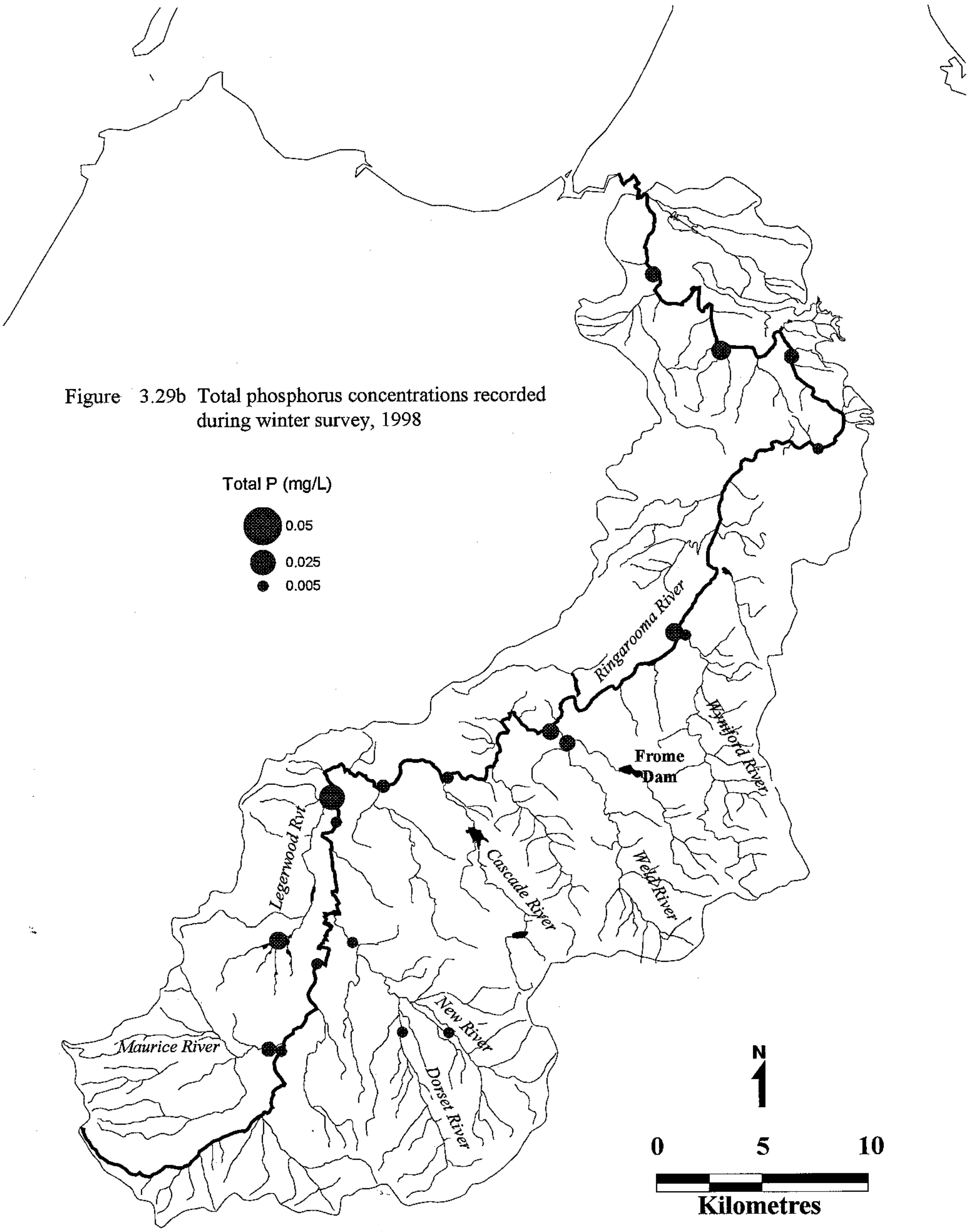


Figure 3.29a Total phosphorus concentrations recorded during summer survey, 1998

Figure 3.29b Total phosphorus concentrations recorded during winter survey, 1998



Catchment Survey - Metals

Samples during the snapshot surveys were analysed for some of the main metals commonly found in environmental waters and which may pose some risk to aquatic organisms or human health. Due to budget limitations, only total metal concentrations were determined, and the limit of detection of the various metals analysed for are listed below;

Metal	Limit of Detection
Aluminium	50 μg/L
Iron	20 μg/L
Zinc	1 μg/L
Copper	1 μg/L
Lead	1 μg/L
Cadmium	1 μg/L
Chromium	1 μg/L
Nickel	1 μg/L
Cobalt	1 μg/L

Before discussing the results, it is worth mentioning some characteristics of metals and how they relate to water quality guidelines.

Like many other chemical parameters commonly tested for in water, metals can be present in various forms, some of which are more toxic to aquatic life than others. They can be present attached to suspended matter, colloids, or complex organic compounds (eg humic substances). They can also be present in dissolved forms and these are generally the forms which are toxic to aquatic life (Dallas & Day, 1993).

The toxicity of metals can also vary according to the environment they are in. Acidic conditions tend to increase the toxicity of most metals while for others, high concentrations of hardness reduce metal toxicity (ANZECC, 1992).

To take into account all these factors, the National Water Quality Guidelines (ANZECC - draft, 1998) have proposed a strategy whereby basic testing begins with analysis for 'Total Metal' concentrations and if the result exceeds the guideline level, further analysis may be carried out to define the level and nature of toxicity. If, for example total copper concentration in a sample exceed the proposed guideline concentration of 0.33 μg/L, hardness of the water is tested to determine the toxicity. If the risk is still high, further testing for dissolved copper is then undertaken to determine whether the dissolved fraction poses a risk. If the risk is still considered high, then more specific testing to investigate its biological hazard may be needed.

This approach is termed 'hierarchical' and under this system, the first level of testing (in this case, for total metals) may be over-protective, as a large proportion of the metal may in fact be bound to particles. However, results from tests for totals is often the best and cheapest starting point. During these surveys, only total metal concentrations have been determined.

Hardness was measured at various sites during the summer survey and showed that across the catchment, all rivers are soft, with measured hardness (as $CaCO3$) at or below 15 mg/L. At this level the following guidelines have been suggested to protect aquatic ecosystems (AZECC, draft 1998).

TABLE 3.4 Proposed guideline values for various metals whose toxicity is influenced by water hardness (metal concentrations in µg/ L).

Hardness	**(mg/L as CaCO3)**	**Cd**	**Cr(III)**	**Cu**	**Pb**	**Ni**	**Zn**
Soft	(0 - 59)	0.013	9.0	0.33	1.2	0.68	2.4
Moderate	(60 - 119)	0.035	22.2	0.84	4.8	1.7	6.1
Hard	(120 - 179)	0.054	33.7	1.3	9.2	2.7	9.4

#ANZECC - draft (1998)

For aluminium the guideline is not hardness dependent and a value of 1.2 µg/L is proposed. The bioavailability of metals is also greatest in acid waters (< 6.5). Maximum toxicity of aluminium has been found to occur at a pH of about 5.0 - 5.2 and is known to be toxic to fish, though not necessarily invertebrates. Therefore, bearing these issues and influences in mind, and recognising the cautious nature of the approach, the following results from the summer and winter surveys is discussed.

Aluminium

The most significant feature of the data from both surveys was the levels of aluminium detected at various sites in the catchment (Figure 3.30a & b). Of the 11 sites sampled during the summer, 7 had levels below the detection limits of the analysis (< 50 µg/L). However, significant results were returned from Legerwood Rivulet at Ringarooma Rd, the Wyniford River and the Weld River (230 µg/L, 147 µg/L and 130 µg/L respectively). All three sites also showed high aluminium concentrations during the winter survey (Figure 3.30b), when concentrations throughout the catchment were higher (Range = 65 - 279 µg/L; Average = 156 µg/L; 18 sites).

At first glance these concentrations might cause some concern when compared against the guideline value of 1.2 µg/L proposed by ANZECC (draft 1998). However, plotting the winter data against turbidity measurements recorded at the time (Figure 3.31) clearly reveals a link between aluminium concentration and turbidity, suggesting that most of the aluminium is attached or bound to suspended particulate matter (eg clays). Where this occurs, the concentration of aluminium is likely to pose little or no risk to aquatic organisms as it is essentially inert (UNESCO, 1992).

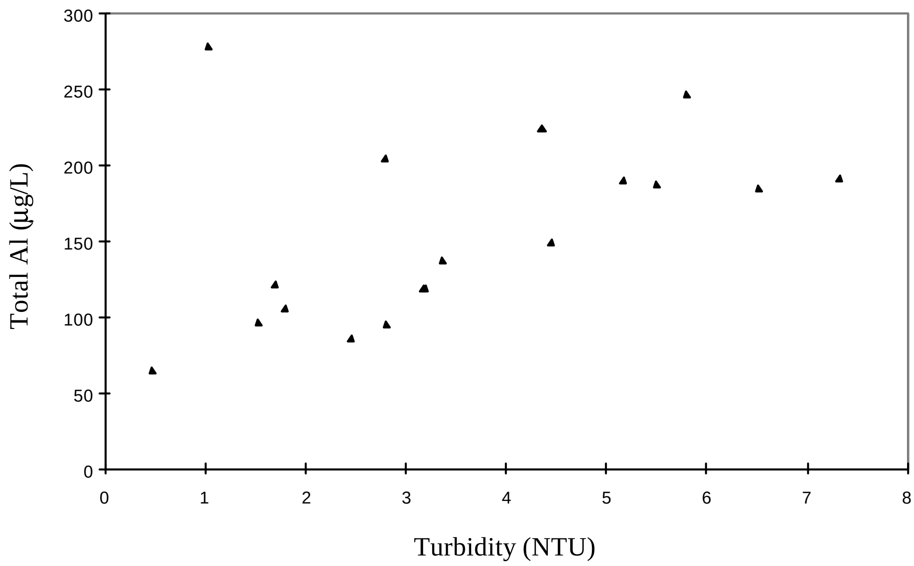


Figure 3.31 Relationship between Total Al concentration and turbidity at sites in the Ringarooma Catchment sampled during winter, 1998.

The exception to this appears to be the site on the Wyniford River, which had low turbidity (< 2 NTU) but relatively high aluminium concentrations on both visits (147 μg/L and 297 μg/L summer and winter samples respectively). It is possible that a significant amount of the aluminium present in the Wyniford

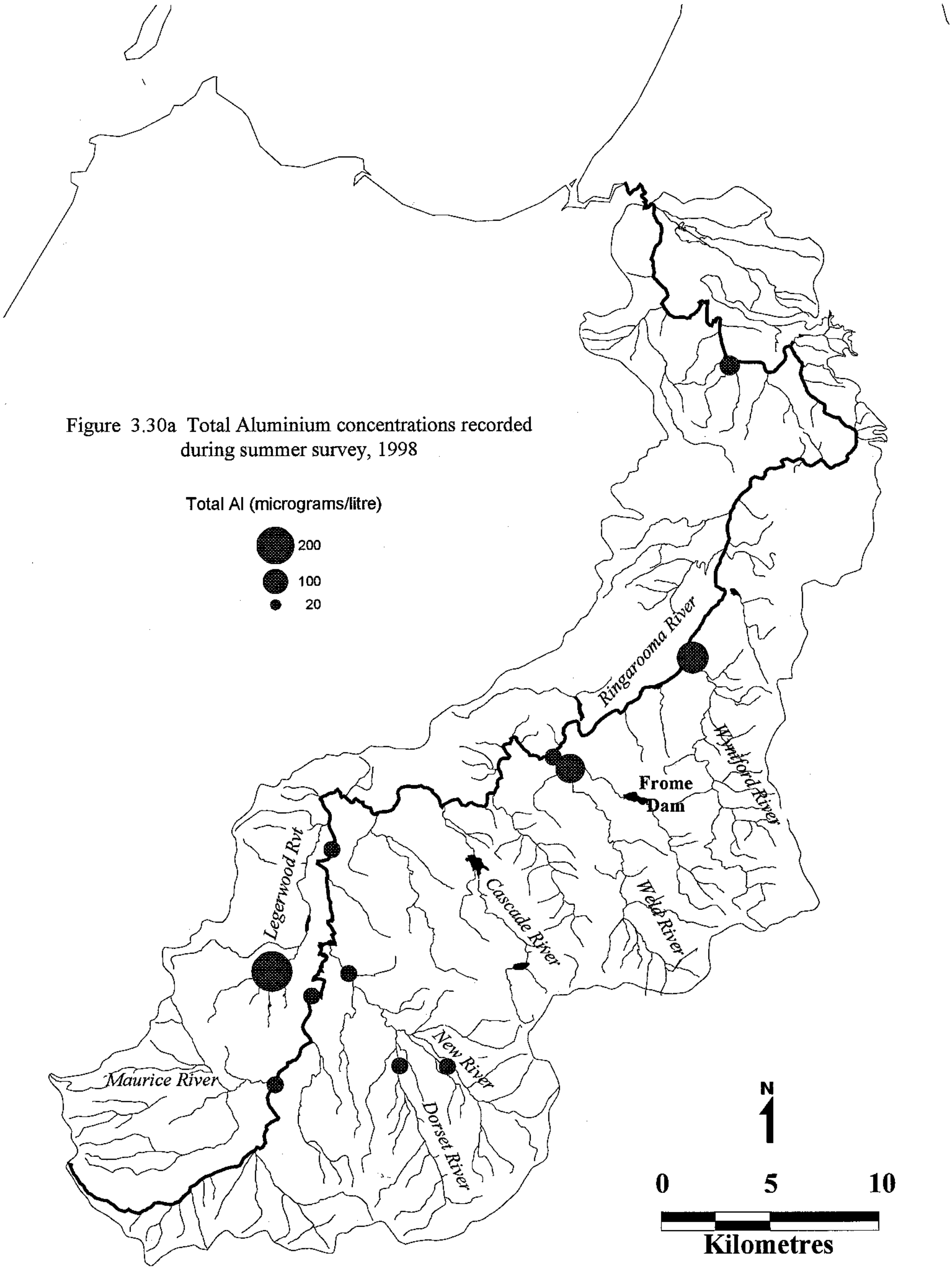


Figure 3.30a Total Aluminium concentrations recorded during summer survey, 1998

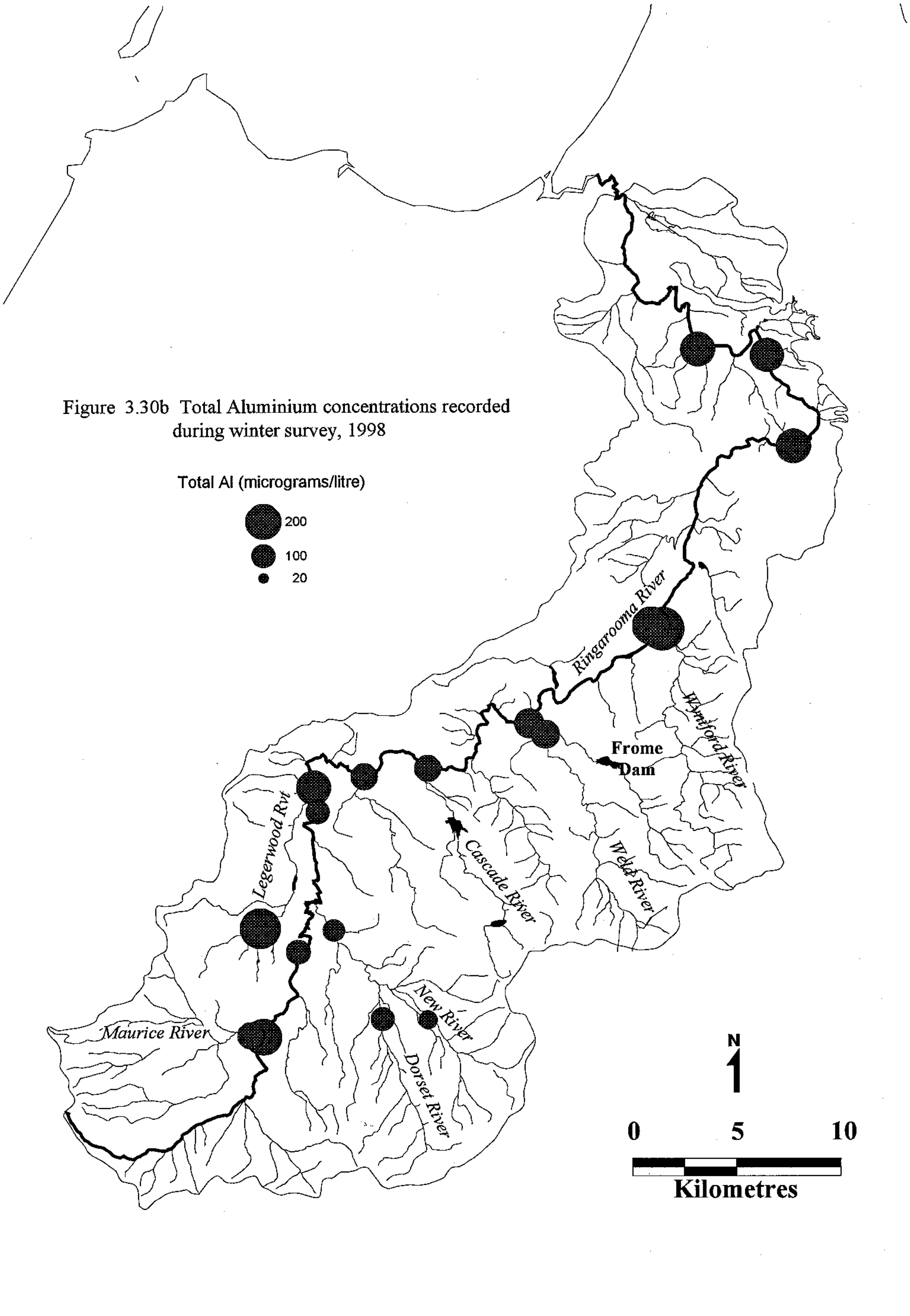


Figure 3.30b Total Aluminium concentrations recorded during winter survey, 1998

River is dissolved and may therefore pose some risk to the environment and should be investigated further.

While the site on Legerwood Rivulet at Ringarooma Road also had a high aluminium concentration during the summer survey, turbidity was also high (11.8 NTU) and it is therefore likely that a large proportion of the aluminium measured at this site was bound to suspended particulate material. Aluminium is often present in abundance in clays (Refs.). Similar comments can be made for zinc and copper, which were also high during the summer survey (29 µg/L and 7 µg/L respectively), though there may be some source of contamination entering the rivulet above this site. Lead was also detected at this site, though in small concentration (3 µg/L).

Iron

Iron concentrations were also measured during both summer and winter surveys (Figures 4.3.32a & b). Concentrations ranged from 1540 µg/L in Legerwood Rivulet during the summer survey to < 20 µg/L in the New River during the winter survey (summary table below).

TABLE 3.5 Summary of total iron concentrations measured during snapshot surveys of rivers in the Ringarooma River catchment, 1998.

	No. Sites	**Average**	**Median**	**Range**
Summer	11	519	292	<20 - 1540
Winter	18	369	372	<20 - 718

* All values are for Total Fe concentrations in µg/L.

In terms of drinking water guidelines, 4 of the summer sites and 12 of the winter sites are above the level where taste effects due to iron may occur, while for irrigation use all sites sampled were well under the safe levels recommended for irrigation in the short term (10years).

Recommended levels for drinking water (300 µg/L for aesthetics and taste) and irrigation use (10, 000 µg/L for short-term 10yrs use, 200 µg/L for long-term 100yrs use) NHMRC 1996 & ANZECC, 1992.

Other Metals

No cadmium, chromium, cobalt or nickel was detected at any site in the catchment during either of the surveys, and only minor concentrations of lead (< 2 µg/L) and zinc (< 3 µg/L) was detected at most sites (Table 3.6). Significant zinc concentrations were detected during the summer survey in the Ringarooma River at Moorina (7 µg/L), Branxholm (5 µg/L) and Ringarooma (6 µg/L), and also in Legerwood Rivulet at Ringarooma Road (29 µg/L). Winter concentrations were all at what appears to be background levels of around 1-3 µg/L and are not considered significant despite being slightly above the guideline levels proposed by ANZECC (1998 draft).

TABLE 3.6 Summary of total copper and total lead concentrations measured during snapshot surveys of rivers in the Ringarooma River catchment, 1998.

	No. Sites < 1 mg/L	**No. Sites 1 - 5 mg/L**	**No. Sites 5 - 10 mg/L**	**No. Sites > 10 mg/L**
Lead - summer	7 sites	4 sites		
Lead - winter	6 sites	12 sites		
Zinc - summer	0 sites	7 sites	3 sites	1 site
Zinc - winter	0 sites	18 sites		
Copper - summer	4 sites	6 sites	1 site	
Copper - winter	4 sites	14 sites		

The result from tests for copper are similar to that for zinc with all but one site showing low copper concentrations (≤1 μg/L) during the summer survey. The highest copper concentration was measured in Legerwood Rivulet at Ringarooma Road (7 μg/L), but may have been due to the high turbidity recorded there at the time. During the winter survey the background levels of copper were higher at most sites, with 14 of the 18 sites sampled having copper concentrations of 2 - 4 µg/L. As was found for aluminium, higher turbidity levels recorded during the winter survey may also explain these higher levels of copper.

In summary, although metal concentrations at many sites were above the new proposed ANZECC (1998 draft) water quality guidelines, it seems likely that most was attached to suspended particles, making it less toxic to aquatic organisms. Of the metals tested, aluminium concentrations were highest. One site where there may be greater risk to aquatic life is in the Wyniford River where high aluminium levels were recorded despite low turbidity. Iron concentrations were generally found to be above the recommended concentration for drinking water to avoid taste problems, however they appear to pose no risk for other uses (eg. stock watering and irrigation). Zinc and copper results showed that background levels were low but marginally above ANZECC (draft 1998) guidelines for protection of the environment. As for aluminium, these metal species may also be linked to turbidity, and further analysis of dissolved levels during winter is required to better assess the actual risk to aquatic organisms. Sites which have been identified as showing possible metal contamination are Legerwood Rivulet, the Wyniford River and the lower Ringarooma River.

3.6 Instantaneous Nutrient Loads

A water quality 'snapshot' was carried out during a significant flood on 23rd September, 1998. Flood waters in the Ringarooma River at Moorina reached 4.57m, which is equivalent to a flow of about 146 m^3s^{-1} (or 12614 $ML.day^{-1}$). Water sampling and field testing was performed at various sites down the length of the river (with assistance from the Waterwatch group), as well as at various sites on other rivers in nearby catchments. That data will also be presented here for comparison, though all of those rivers are smaller than the Ringarooma River and have different types of catchment activities. The rainfall intensity may also have varied between catchments, having a significant impact on the carrying capacity of runoff waters and the pollutant load they carried.

Concentrations measured during this runoff event are shown below (Table 3.7). Turbidity levels were measured at all sites, with highest readings taken in the Ringarooma River at Moorina, Derby and Branxholm where flood levels in the river were peaking. Highest turbidity levels generally occur in rivers during the period just prior to the flood peak, so the measurements taken at these sites during this flood represent the worst levels which would have occurred during that flood.

TABLE 3.7 Water quality data recorded during flooding in the Ringarooma catchment on the 23rd September, 1998.

Site	Date	River Level	Turbidity (NTU)	[TSS] (mg/L)	[TN] (mg/L)	[TP] (mg/L)
Ringarooma at Moorina	23/9/98 13:20	4.07	334	650	4.15	0.86
Ringarooma at Derby	23/9/98 *		288			
Ringarooma at Long Bridge	23/9/98 *		158			
Ringarooma at Branxhom	23/9/98 *		238			
Ringarooma at Ringarooma	23/9/98 12:00		150	150	2.11	0.25
Ringarooma at Cottons Br	23/9/98 *		198			
Great Forester at Forester Rd	23/9/98 15:25	2.255	151	120	1.83	0.22
Great Forester at Tonganah	23/9/98 11:15		178	150	2.74	0.36
Arnon River u/s Gt Forester	23/9/98 15:40		63			
Pearly Brook u/s Gt Forester	23/9/98 16:10		35			
Brid River u/s Tidal Limit	24/9/98 10:30	0.998	92	85	1.76	0.17
Pipers River d/s Yarrow Ck	24/9/98 14:00	1.27	57	30	1.26	0.066

* Waterwatch data collected with DPIWE instrument - time not recorded.

Turbidity measurements from the Great Forester River were comparable though slightly lower than for the Ringarooma River. Nutrient concentrations in both rivers were up to 10 times higher during the flood than were found under average baseflow conditions (refer Section 4.3.1) and clearly demonstrate the impact of runoff water on nutrient levels in both rivers.

Where water quality was measured at stream gauging sites, the data was able to be used to calculate instantaneous loads at the time of sampling. Loads are easily calculated by multiplying the volume of water flowing down the river at the time by the concentration of the particular parameter measured. Results of these calculations are presented in Table 3.8 below.

TABLE 3.8 Instantaneous loads of suspended solids (TSS), total nitrogen (TN) and total phosphorus (TP) measured in various rivers in the northeast during flooding in September, 1998.

Site	**Date**	**Flow (m^3s^{-1})**	**TSS Load (kg/hr)**	**TN Load (kg/hr)**	**TP Load (kg/hr)**
Ringarooma at Moorina	23/9/98 13:20	111.6	261,144	1,666	346
Great Forester at Forester Rd	23/9/98 15:25	49.7	21,470	328	39
Brid River u/s Tidal Limit	24/9/98 10:30	19.1	5,829	121	11.7
Pipers River d/s Yarrow Ck	24/9/98 14:00	43.2	5,740	241	12.6

Catchment areas for each site:

Ringarooma River at Moorina	606 km^2
Great Forester River at Forester Rd	193 km^2
Brid River u/s Tidal Limit	139 km^2
Pipers River u/s Yarrow Ck	298 km^2

The data show that highest loads were carried in the Ringarooma River, which was also discharging the largest volume of water at the time of sampling (111.6 m^3s^{-1}). Relatively higher river gradient (and hence stream velocity) at this site would facilitate the transport of heavier suspended material and increase the delivery of this to flood-plain areas downstream. A large percentage of the nutrient load measured would also be attached to this suspended material. Where this suspended material and its associated nutrients settles out is important in terms of how it may affect the river system. If the flood waters are allowed to spread out over the flood plain, a good deal of the sediment and nutrient load will actually be retained on the land outside the river and contribute to the fertility of the flood plain soils. If flood waters are constrained to the river channel, it is very likely that these will be stored in the river bed and may contribute to the formation of algal blooms and other nuisance plant growth during low summer flows.

Adjusting these figures for catchment size (Table 3.9) gives an indication of export loads (ie yield) leaving each catchment, and allows valid catchment to catchment comparison. Like the load figures shown above, the instantaneous catchment yield data show that the Ringarooma catchment above Moorina is losing relatively higher amounts of suspended solids and nutrients during flood flows than other nearby catchments.

TABLE 3.9 Measured instantaneous loads corrected for catchment size.

Site	**TSS Yield (kg/km^2)**	**TN Yield (kg/km^2)**	**TP Yield (kg/km^2)**
Ringarooma at Moorina	430.9	2.75	0.57
Great Forester at Forester Rd	111.2	1.7	0.20
Brid River u/s Tidal Limit	41.9	0.87	0.08
Pipers River d/s Yarrow Ck	19.3	0.81	0.04

Catchment yield of suspended solids (eg. soil and organic particulate material) at the time of sampling is almost four time higher from the Ringarooma upstream of Moorina than for the Great Forester River upstream of Forester Rd and more than ten times higher than was measured in the Brid River during concurrent flooding. Nutrient yields were also found to be highest in the Ringarooma River, although figures from the Great Forester River are more comparable. In summary, the data clearly show that for the rain event of September 23rd, losses from the upper Ringarooma catchment appear to be greater than for other nearby catchments.

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5 Appendix

(i) Site Locations - Water Quality (monthly)

Site Name	*Easting*	*Northing*	*Monitoring Type*
Dorset River at New River Rd	565075	5431250	Phys-chem
New River at Singline Rd	567450	5431175	Phys-chem
Ringarooma Rv u/s Maurice Rv	559050	5430700	Phys-chem
Maurice Rv u/s Ringarooma Rv	558950	5430700	Phys-chem
Legerwood Rvt at Warrentinna Rd	561625	5443375	Phys-chem + Samples
Ringarooma Rv at Ringarooma	560750	5434800	Phys-chem + Samples
Ringarooma Rv at Long Bridge	564250	5443925	Phys-chem + Samples
Ringarooma Rv at Moorina	572900	5446625	Phys-chem + Samples
Ringarooma Rv at Pioneer	579300	5451650	Phys-chem + Samples
Ringarooma Rv at Gladstone	585475	5465750	Phys-chem + Samples

 # Samples include ; Nutrients and General Ionic Composition.

(ii) Site Locations - Water Quality (catchment surveys)

Site Name	*Easting*	*Northing*	*Monitoring Type*
Ringarooma near Hardwickes Lagoon	578800	5468800	Phys-chem + Samples
Ringarooma at Galloway Ck	581900	5466100	Phys-chem + Samples
Ringarooma Rv at Gladstone	585475	5465750	Phys-chem + Samples
Ringarooma at Ogilvies Bridge	586800	5460975	Phys-chem + Samples
Ringarooma at mining platform	582350	5459625	Phys-chem
Ringarooma Rv at Pioneer	579300	5451650	Phys-chem + Samples
Wyniford River at Garibaldi Rd	579575	5451400	Phys-chem + Samples
Ringarooma Rv at Moorina	572900	5446625	Phys-chem + Samples
Weld River at Frome Rd	573750	5446025	Phys-chem + Samples
Ringarooma at Derby	567575	5444325	Phys-chem + Samples
Cascade River at Derby	567450	5444175	Phys-chem
Ringarooma Rv at Long Bridge	564250	5443925	Phys-chem + Samples
Ringarooma at Branxholm	561825	5442100	Phys-chem + Samples
Legerwood Rvt at Warrentinna Rd	561625	5443375	Phys-chem + Samples
Ledgerwood Rvt at Ringarooma Rd	558800	5436025	Phys-chem + Samples
Ringarooma Rv at Ringarooma Rd	560750	5434800	Phys-chem + Samples
Dorset River at Ruby Flats Rd	562600	5435900	Phys-chem + Samples
Dorset River at New River Rd	565075	5431250	Phys-chem + Samples
New River at Singline Rd	567450	5431175	Phys-chem + Samples
Ringarooma Rv u/s Maurice Rv	559050	5430700	Phys-chem + Samples
Maurice River at Neils Bridge	558250	5430450	Phys-chem + Samples
Ringarooma at Maurice Rd	559100	5428700	Phys-chem
Federal Ck at Maurice Rd	558300	5426475	Phys-chem
Carries Brook at East Maurice Rd			Phys-chem

 # Samples include ; Bacteria, Metals, Nutrients and some ionic parameters.