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Tasmania

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Water Quality of Rivers in the Inglis – Flowerdale Catchment

PART 1

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The Department of Primary Industries, Water and Environment

The Department of Primary Industries, Water and Environment provides leadership in the sustainable management and development of Tasmania's resources. The Mission of the Department is to advance Tasmania's prosperity through the sustainable development of our natural resources and the conservation of our natural and cultural heritage for the future.

The Water Resources Division provides a focus for water management and water development in Tasmania through a diverse range of functions including the design of policy and regulatory frameworks to ensure sustainable use of the surface water and groundwater resources; monitoring, assessment and reporting on the condition of the State's freshwater resources; facilitation of infrastructure development projects to ensure the efficient and sustainable supply of water; and implementation of the *Water Management Act 1999*, related legislation and the State Water Development Plan.

Executive Summary

The 'State of Rivers' study of the greater Inglis – Flowerdale catchment (including the catchments drained by Camp Creek and Seabrook Creek), commenced in January 1999. The study comprised water quality monitoring and investigations, river condition assessment, hydrological characterisation and aquatic health assessment (using the AUSRIVAS technique). This report provides an interpretation of the data collected from the water quality component of this study, and should be viewed together with the information presented in the other reports to get an overall picture of the condition of the water resources and the aquatic health of river systems within the Inglis-Flowerdale catchment.

The major findings arising from water quality monitoring in the catchment are:

- Waters throughout the catchment are dilute, containing little dissolved salts and have generally neutral to slightly alkaline pH. The exception is the Hebe River, which periodically has very low pH (4) and minimal buffering capacity (as indicated by the low alkalinity values).
- Unsealed gravel roads and gravel pits in the Inglis River catchment were found to have a considerable impact on turbidity levels in the Calder and lower Inglis Rivers during sampling after thunderstorm activity. Runoff from these areas during heavy rains appears to deliver substantial loads of suspended solids and sediment to the lower Inglis River, impacting on water quality and instream habitat in this reach of the river.
- Removal of riparian shade at some sites increased the summer water temperatures by as much as 5°C compared to similar sites where riparian cover was relatively intact. Summer water temperatures recorded at these sites exceeded 23°C, which is likely to cause acute stress to fish and other aquatic life.
- Nutrient concentrations in sub-catchments that are largely cleared and have a higher level of intensive agriculture (Camp Creek and Seabrook Creek) have higher concentrations of the major indicator nutrients (nitrate and phosphorus). In these catchments, winter rains appear to flush nitrates from the soil profile, causing much higher concentrations during the winter. In areas where there is still substantial vegetation (trees and shrubs) in the riparian zone (as in the middle reaches of the Inglis and Flowerdale Rivers), dissolved nitrate is significantly lower due to the greater denitrification provided by these buffer zones.
- A very high concentration of aluminium (1,580 µg/L) was recorded in the Hebe River, where low pH and high concentrations of dissolved organic material originating from the buttongrass swamp upstream may have resulted in increased leaching of aluminium from the soils in this area. Further investigation of this issue is recommended to determine the environmental threat posed by such high aluminium concentrations. Background aluminium concentrations throughout the catchment are between 50-150 µg/L.
- Much higher than expected suspended solids concentrations were recorded during floods in the lower Inglis River, compared to flood concentrations recorded simultaneously in the Duck and Montagu rivers. It appears that this was due mainly to the suspension and transport of locally derived sediment disturbed during the willow removal activities that took place in autumn 2000.
- Only approximate estimates of export loads for nitrogen and phosphorus could be made for the catchment, due to limitations imposed by the hydrological and water quality data. Bearing this in mind, the export coefficients derived for this catchment indicate that nitrogen and phosphorus loss is moderate within the Tasmanian context, being similar to that for the Pipers River in the northeast, but well below estimates made for the nearby Duck and Montagu catchments.

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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).

Cumecs
A measure of flow or discharge having the units of cubic metres per second. See '*Units and Conversions*' below.

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.

Diurnal Variation
'Diurnal variation' is a term that is used to describe the cyclical pattern of change that occurs within a daily timescale. Water temperature variation is a typical example of a parameter that varies 'diurnally', with lowest temperatures occurring in the hours before dawn and the highest temperatures occurring around the middle of the day. Many water quality parameters that are influenced by biological processes also tend to vary on a diurnal basis.

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 metre (mS/m) at a standard reference temperature of 25^{o} Celsius.

Eutrophication
The enrichment of surface waters with nutrients such as nitrates and phosphates, which cause nuisance blooms of aquatic plants and algae.

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 estimate the load of a particular nutrient leaving the catchment (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' - eg. *E.coli*)
Faecal coliform bacteria are a sub-group of the total coliform population that are easy 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 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 species in mind, though there are many other 'nutrients' that living organisms require for survival.

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. 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 CaCO3) have a low buffering capacity and are susceptible to changes in pH from outside sources.

Riparian Vegetation

Riparian vegetation are plants (trees, shrubs, ground covers and grasses) which grow on the banks and floodplains of rivers. A 'healthy' riparian zone is characterised by a homogeneous mix of plant species (usually native to the area) of various ages. This zone is important in protecting water quality and sustaining the aquatic life of rivers.

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 is determined separately, 'organic nitrogen' can be calculated 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.

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.

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 centimeter
m^3/s = cubic metre per second (commonly referred to as a 'cumec')
ML = 1 million litres (referred to as a 'megalitre')

Acronyms

ANZECC - Australian and New Zealand Environment and Conservation Council
ARMCANZ - Agricultural and Resource Management Council of Australia and New Zealand
DPIWE - Department of Primary Industries, Water and Environment
DPIF - Department of Primary Industry and Fisheries (replaced by DPIWE)
DCHS - Department of Community and Health Services
NHMRC - National Health and Medical Research Council
NHT – Natural Heritage Trust (formerly the National Landcare Program)
RWSC - Rivers and Water Supply Commission
NWRWA – North West Regional Water Authority

B SUMMARY OF NATIONAL GUIDELINES FOR WATER QUALITY

Australian Water Quality Guidelines as per ANZECC (2000)

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 (1992) ' has been available for use as a reference tool for catchment management plans and policies. Since 1995, these guidelines have been under review and have now been superseded by new and more rigorous guidelines (ANZECC, 2000). Where possible, these new guidelines have had a more regional focus. This new approach 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.

The revised guidelines also restate the principle that guidelines are only 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. For some water quality parameters, this approach has been taken, with data from Tasmanian systems (where available) being used to develop guidelines for use within Tasmania. In the National document, Tasmanian rivers have been broadly classified as upland or alpine rivers, as available data at the time was from upland river systems only. However it is important to note that some of the North West river systems originate below the 150m classification level for upland systems and can therefore be classified as lowland rivers.

Table 1. Trigger Levels for Nutrients, pH and Dissolved Oxygen (ANZECC, 2000).

Ecosystem Type	TP (µg/L)	FRP (µg/L)	TN (µg/L)	NOx (µg/L)	pH	DO (%sat)
Lowland River	50	20	500	40	6.5 - 8.0	<85 & >110
Upland River	13	5	480	190	6.5 to 7.5	<90 & >110
Lakes and Reservoirs	10	5	350	10	6.5 to 8.0	<90 & >110

Table 2. Trigger Levels for Conductivity and Turbidity (ANZECC, 2000).

Ecosystem type	Salinity (μScm^{-1})	Explanatory notes
Lowland Rivers	125-2200	Lowland rivers may have higher conductivity during low flow periods and if the system receives saline groundwater inputs. Low values are found in eastern highlands of Victoria ($125 \mu Scm^{-1}$) and higher values in western lowlands and northern plains of Vic ($2200 \mu Scm^{-1}$), NSW coastal rivers are typically in the range 200-300 μScm^{-1}.
Upland Rivers	30–350	Conductivity in upland streams will vary depending upon catchment geology. Low values found in Victorian alpine regions (30 μScm^{-1}) and eastern highlands (55 μScm^{-1}), high value (350 μScm^{-1}) in NSW rivers. Tasmanian rivers mid-range (90 μScm^{-1}).
Lakes/ Reservoirs	20–30	Conductivity in lakes and reservoirs are generally low, but will vary depending upon catchment geology. Values provided are typical of Tasmanian lakes and reservoirs.

Ecosystem type	Turbidity (NTU)	Explanatory notes
Lowland Rivers	6-50	Turbidity in lowland rivers can be extremely variable. Values at the low end of the range would be found in rivers flowing through well-vegetated catchments and at low flows. Values at the high end of the range would be found in rivers draining slightly disturbed catchments and in many rivers at high flows.
Upland Rivers	2–25	Most good condition upland streams have low turbidity. High values may be observed during high flow events.
Lakes & Reservoirs	1–20	Most deep lakes and reservoirs have low turbidity. However shallow lakes and reservoirs may have higher natural turbidity due to wind-induced resuspension of sediments. Lakes and reservoirs in catchment with highly dispersable soils will have high turbidity.

4. Proposed Microbiological Guidelines

Primary contact

The median bacterial content in samples of fresh or marine waters taken over the bathing season should not exceed:

- *150 faecal coliform organisms/100 mL (minimum of five samples taken at regular intervals not exceeding one month, with four out of five samples containing less than 600 organisms/100 mL);*
- *35 enterococci organisms/100 mL (maximum number in any one sample: 60–100 organisms/100 mL).*

Pathogenic free-living protozoans should be absent from bodies of fresh water. (It is not necessary to analyse water for these pathogens unless the temperature is greater than 24°C.)

Secondary contact

The median bacterial content in fresh and marine waters should not exceed:

- *1000 faecal coliform organisms/100 mL (minimum of five samples taken at regular intervals not exceeding one month, with four out of five samples containing less than 4000 organisms/100 mL);*
- *230 enterococci organisms/100 mL (maximum number in any one sample 450–700 organisms/100 mL).*

National Health and Medical Research Council - Drinking Water

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.

Water Quality of Rivers in the Inglis-Flowerdale Catchment

1 Historical Data

There is scant data on water quality in the Inglis/Flowerdale catchment stored on the DPIWE water information database. The only data that is available was collected from three sites in the catchment, two of which are located at sites where streamflow monitoring has previously been undertaken. Tables 1.1, 1.2 and 1.3 detail the data that has been extracted from the State database, and from these tables it can be seen that only a small dataset exists for sites in the Inglis River (sites 1220 – Inglis River d/s Flowerdale River & 14210 – Inglis River u/s Flowerdale River). The majority of data that has been collected at these two sites relates to water temperature and conductivity (Table 1.2), both of which can easily be recorded by field equipment. The data shows that water in the Inglis River is dilute (average conductivity of only 68 μS/cm), reflecting the lack of salt generating geological deposits in the catchment. Examination of the time series of conductivity data does not reveal any temporal trend for change and no plot has been included in this report.

The magnitude of the seasonal change in temperature in the river at this site is shown in the time series plot below (Figure 1.1). As expected, the variation mirrors seasonal changes in air temperature, with peak water temperature occurring in February and water temperature reaching a minimum in July. Highest water temperature at this site (23 ^{o}C) was recorded in February 1979, and is likely to have caused some stress to aquatic organisms in the river at that time.

Table 1.1: Statistical summary of historical water quality - Inglis River above Flowerdale River (Hydrol 14210)

INGLIS RIVER ABOVE FLOWERDALE RIVER JUNC					
Parameter	**n**	**Mean**	**Max**	**Min**	**Unit**
Field Conductivity @ Tref 20	23	67.78	144	31	uS/cm
Water Temperature	93	11.9	23	3	Degrees C

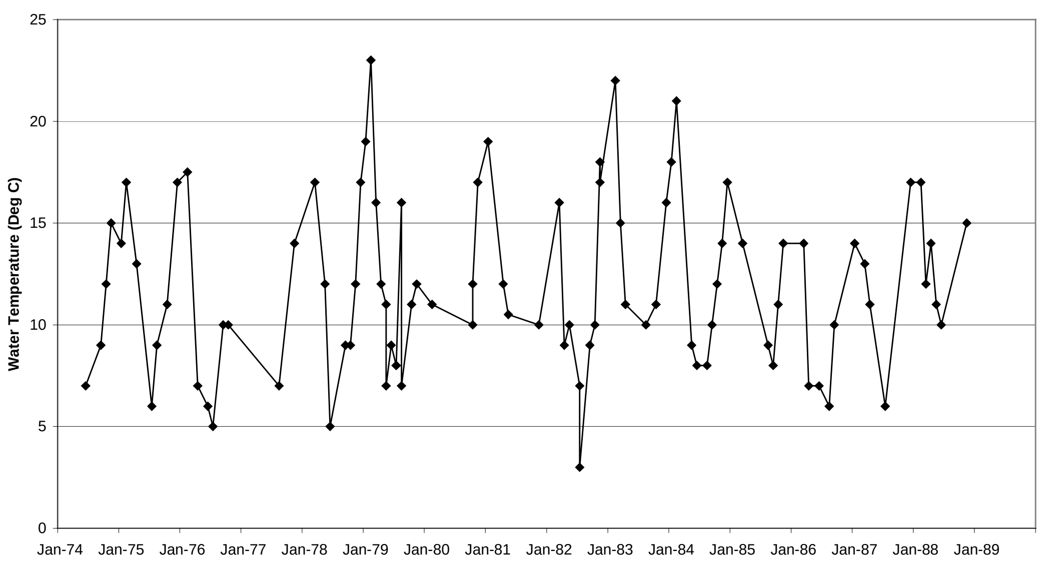

Figure 1.1: Water temperature measurements taken during stream gauging visits to site 14210 on the Inglis River between 1974 and 1989.

The DPIWE database contains some data on heavy metals in Inglis River at site 1220 (Table 1.2). These data were collected between November 1979 and June 1980 and appears to have been targeted at identifying potential pollution of the river by leaching from mines or refuse dumps. Both activities have occurred in the Inglis River catchment in the past, and gravel extraction continues to take place. The data in Table 1.2 shows that appreciable concentrations of most of the heavy metals tested for were detected during sampling. Very high concentrations of manganese and zinc appear to have been found (maximum concentrations of 37 mg/L and 26 mg/L respectively) and if these data are correct this represents significant and prolonged pollution of the river. However, as the quality of this data is unconfirmed, it is possible that these data represent measurements in *microgram* per litre rather than the much larger units of *milligrams* per litre. If this is the case, then the data indicates only a slight elevation of zinc and manganese concentration in the river, but the other metals are present at only trace levels.

Table 1.2: Statistical summary of historical water quality - Inglis River below Flowerdale River (Hydrol 1220)

INGLIS RIVER BELOW FLOWERDALE RIVER					
Parameter	**n**	**Mean**	**Max**	**Min**	**Unit**
Arsenic as As	5	3.8	5	3	mg/L
Cadmium (Total) as C	5	0.5	0.5	0.5	mg/L
Copper (Total) as Cu	4	1.5	2	1	mg/L
Lead (Total) as Pb	5	5	5	5	mg/L
Manganese (Total) as Mn	5	30.6	37	19	mg/L
Zinc (Total) as Zn	4	11.25	26	2	mg/L

A more extensive and comprehensive dataset exists for water quality in the Flowerdale River at Moorleah (site 14215). As Table 1.3 shows, water sampling at this location has covered variables relating to nutrient status, ionic composition as well as some of the more routine parameters measured using field-based equipment. The most extensive record at this site is for conductivity, which was recorded during visits to the site between 1982 and 1995. The time series plot of these data (Figure 1.2) shows that while there is some broad seasonal variability in conductivity, average conductivity is slightly higher than that recorded in the Inglis River.

The data for the major dissolved salts (calcium, magnesium, sodium, chloride, etc) shows that the main salts contributing to conductivity in the river are sodium and chloride, although there is periodic elevation in calcium (Ca) and magnesium (Mg) during low flows. These periodically higher concentrations of Ca and Mg tend to coincide with higher values for hardness and may be indicative of the influence of water emanating from minor limestone outcrops high in the catchment.

Iron concentrations in the Flowerdale River are quite high, with an average concentration of 1.06 mg/L at Moorleah. While this is of little environmental concern, this concentration of iron in water is likely to impact on the quality of the water for domestic use (ANZECC, 1992) and may form deposits in water distribution pipes.

The concentrations of the major nutrients (phosphorus and nitrogen) suggest that there is mild enrichment of the river, with total phosphorus and total nitrogen concentrations in the Flowerdale River periodically exceeding the ANZECC (2000) trigger level for the protection of lowland river systems in Tasmania (0.05 mg/L and 0.50 mg/L respectively). Nitrate concentration in the Flowerdale River is also slightly elevated (average 0.181 mg/L), and exceeds the trigger level for Tasmanian lowland rivers (0.04 mg/L).

Table 1.3: Statistical summary of historical water quality - Flowerdale River at Moorleah (Hydrol 14215)

FLOWERDALE RIVER AT MOORLEAH					
Parameter	**n**	**Mean**	**Max**	**Min**	**Unit**
Alkalinity (Total)	8	18.05	46	4.4	mg/L
Ammonia as N	7	0.007	0.011	0.005	mg/L
Calcium (Total) as C	8	3.8	7.5	2.3	mg/L
Chloride as Cl	9	14.93	16	9.9	mg/L
Field Cond @ TRef 20	36	86.92	178	45	uS/cm
Field Cond @ TRef 25	27	108.8	155	67	uS/cm
Filt Resid (103-105)	10	73.1	731	46	mg/L
Fluoride as F	8	0.1	0.1	0.1	mg/L
Iron (Total) as Fe	8	1.06	2.8	0.65	mg/L
Magnesium (Total) as	8	3.78	7.1	2	mg/L
Manganese	7	0.0275	0.08	0.02	mg/L
Molybdate Reactive S	7	6.87	12	1.7	mg/L
Nitrate as N	7	0.181	0.21	0.005	mg/L
Nitrite as N	7	0.005	0.005	0.005	mg/L
Potassium (Total) as	8	0.9	1.3	0.52	mg/L
Reactive Phosphorous	7	0.004	0.005	0.001	mg/L
Redox Europe Stnd Ox	5	177.2	108	52	mv
Silica as SiO_2	1	8.8	8.8	8.8	mg/L
Sodium (Total) as Na	8	9.06	11	6.9	mg/L
Sulphate (Total) as	7	2.47	3.4	1.9	mg/L
Total Dissolved Sol	8	78.13	120	25	mg/L
Total Hardness ($CaCO_3$)	8	23.25	48	0	mg/L
Total Kjeldahl (N)	7	0.32	0.65	0.14	mg/L
Total Phosphorus	7	0.024	0.064	0.012	mg/L

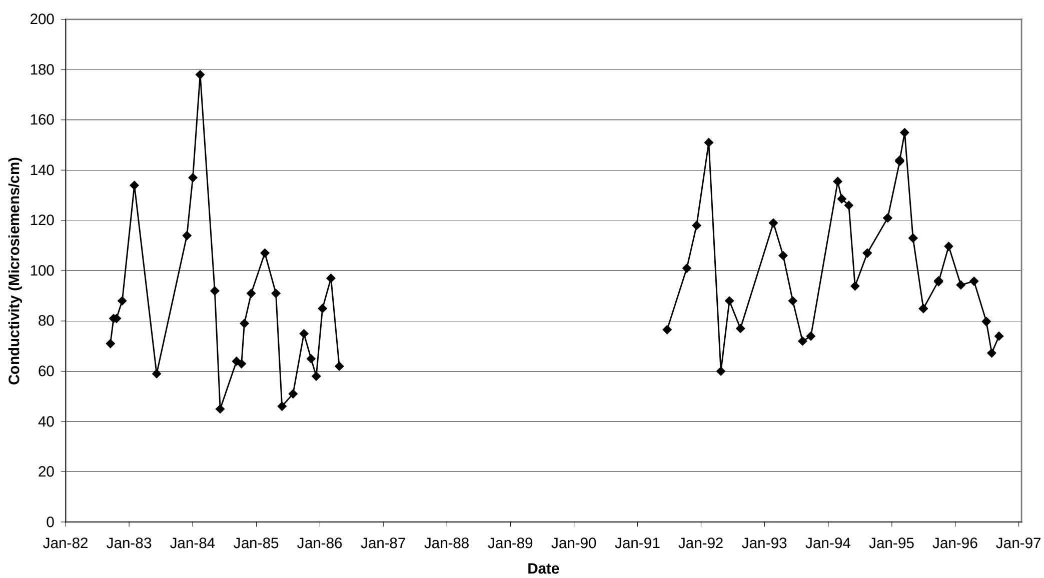

Figure 1.2: Conductivity (Tref 20 and Tref 25) measurements taken during stream gauging visits to site 14215 (Flowerdale River at Moorleah) between 1974 and 1994.

2 Waterwatch Activities

While Landcare groups have been active in the Wynyard area for about the last 8 years or so, Waterwatch has only recently been established and started collecting data on the water quality of rivers in the area. The dataset from this source is therefore quite small (Table 1.4) and is concentrated on the Calder, Inglis and Flowerdale rivers.

As only a small amount of data is available, interpretation is limited to only a few brief comments. Dissolved oxygen concentrations (7.5 – 9.2 mg/L) appear to indicate that ecosystem health at all sites is good, while the nutrient data suggests that these sites are also relatively unimpacted by runoff. Water throughout the catchment appears to be neutral to slightly acidic, and is moderately dilute, with conductivity ranging between 70-150 μS/cm. Water clarity is quite good, though the data is severely limited by the measurement technique, which has a lower detection limit of 7 NTU. No significant issues are highlighted by these data.

Table 1.4: Waterwatch data from waterways in the Inglis catchment collected between 29/12/1999 – 08/03/2001.

Site Name	Date	DO (mg/L)	EC (uS/cm)	N-NO3 (mg/L)	pH (Units)	Temp (C)	T-Phos (mg/L	Turb (NTU)
Calder Rv - Bassetts Rd	29/12/1999	9.5	90	0	7.2	16.1	0.015	7
Calder Rv - Bassetts Rd	28/02/2000	8.4	90	0	7.0	16.2	0.015	7
Calder Rv - Bassetts Rd	01/06/2000	8.2	90	0	7.0	18.2	0.015	7
Calder Rv @ Zig Zag Rd	29/12/1999	8.4	90	0	7.2	18.4	0.015	7
Flowerdale Rv @ Meunna Rd	06/01/2000	7.5	90	0	6.5	17.1	0.015	7
Flowerdale Rv @ Meunna Rd	28/02/2001	9.2	80	0	6.5	13.5	0.000	10
Flowerdale Rv @ Meunna Rd	08/03/2001		70			14.9		
Flowerdale Rv @ Gates Rd	26/02/2001	8.6	150	0	6.5	19.1	0.000	10
Flowerdale Rv @ Lapoinya Rd	08/03/2001		120			17.8		
Inglis Rv @ Stennings Rd	07/01/2000	7.5	90	0	6.6	17.1	0.015	7
Keith Rv @ Farqhars Rd	07/01/2000	8.0	110	0	7.0	17.6	0.000	7
Inglis River on Wynyard side of Woodhouse Rd	26/02/2001	8.6	120	0	6.5	18.2	0.000	10
Inglis Rv near Calder Rv	28/02/2001	8.8	120	0	6.5	18.2	0.000	10
Inglis Rv near Calder Rv	08/03/2001		80			17.7		
Inglis Rv @ Pages Rd	28/02/2001	8.4	110	0	6.5	16.6	0.000	10
Inglis Rv @ Pages Rd	08/03/2001		90			20.0		

3 Current Study

The water quality data for the 'State of Rivers' study in the Inglis-Flowerdale catchment was collected between January 1999 and December 2001. The main aim of sampling was to collect current data on the ambient quality of water and report on background conditions in the river system. These data, when viewed along with broader land-use and river condition information, should assist in identifying sites or areas that could be targeted for further investigations, remediation activities or a different management approach in the future. The data will also assist in any future development of *water quality objectives* (WQO's) that may be developed for the catchment under the '*State Policy for Water Quality Management*' (1997).

The collection of data was carried out at several levels. Monthly visits were undertaken at 27 sites to determine the physico-chemical nature of water in the catchment. The names and grid coordinates for these sites are listed in the Table 3.1, and shown geographically in Figure 3.1. Due to the costs associated with laboratory analysis, sampling for nutrients was carried out monthly at a subset of these sites (11 sites bolded in Table 2.1). Sampling for dissolved salts and general ionic composition was performed at these eleven sites on a quarterly basis.

Table 3.1: Sites monitored in the Inglis-Flowerdale catchment during the 'State of Rivers' program (January 1999 – December 2002). Bold sites denote locations where more comprehensive testing was performed during routine monthly sampling.

Site Name	Code	Easting	Northing
Big Creek at Wynyard	**IF1**	391300	5461650
Big Creek at Nursery Rd	**IF2**	389700	5459300
Blackfish Creek at Blackfish Rd	**IF3**	387700	5457350
Inglis River at Pump Station Rd	**IF4**	389650	5462800
Blackfish Creek at Stennings Rd	**IF5**	389200	5462050
Inglis River at Railway bridge	**IF6**	387100	5462800
Inglis River at Pages Rd	**IF7**	384750	5460100
Inglis River at Ingleford Rd	**IF8**	384050	5458200
Calder River u/s Inglis River	**IF9**	384200	5452400
Inglis River at West Calder Rd u/s Calder Rv	**IF10**	382300	5451200
Inglis River at Takone	**IF11**	385400	5442150
Rattler River at Takone	**IF12**	385300	5442100
Calder River at Takone Rd	**IF13**	388200	5443750
Inglis River 2k u/s Takone	**IF14**	385600	5440100
Blackfish Creek at Lowries Rd	**IF15**	388200	5449750
Flowerdale River at Preolenna Rd	**IF16**	387000	5463450
Flowerdale River (Stream gauging station)	**IF17**	382900	5463750
Flowerdale River at Lapoinya Rd	**IF18**	382050	5460100
Flowerdale River at Ten Foot Track	**IF19**	380600	5455400
Coopers Creek at Ten Foot Track	**IF20**	381100	5454300
Hardmans Creek at Preolenna Rd	**IF21**	376950	5447850
Flowerdale River at Meunna Rd	**IF22**	375900	5446700
Hebe River at Myalla Rd	**IF23**	372600	5453900
Seabrook Creek u/s Bass H'way	**IF24**	396100	5459100
Seabrook Creek at Nunns Rd	**IF25**	395700	5450900
Camp Creek at 'Terra Nova'	**IF26**	392500	5459350
Camp Creek on Deep Ck Rd	**IF27**	392250	5449600

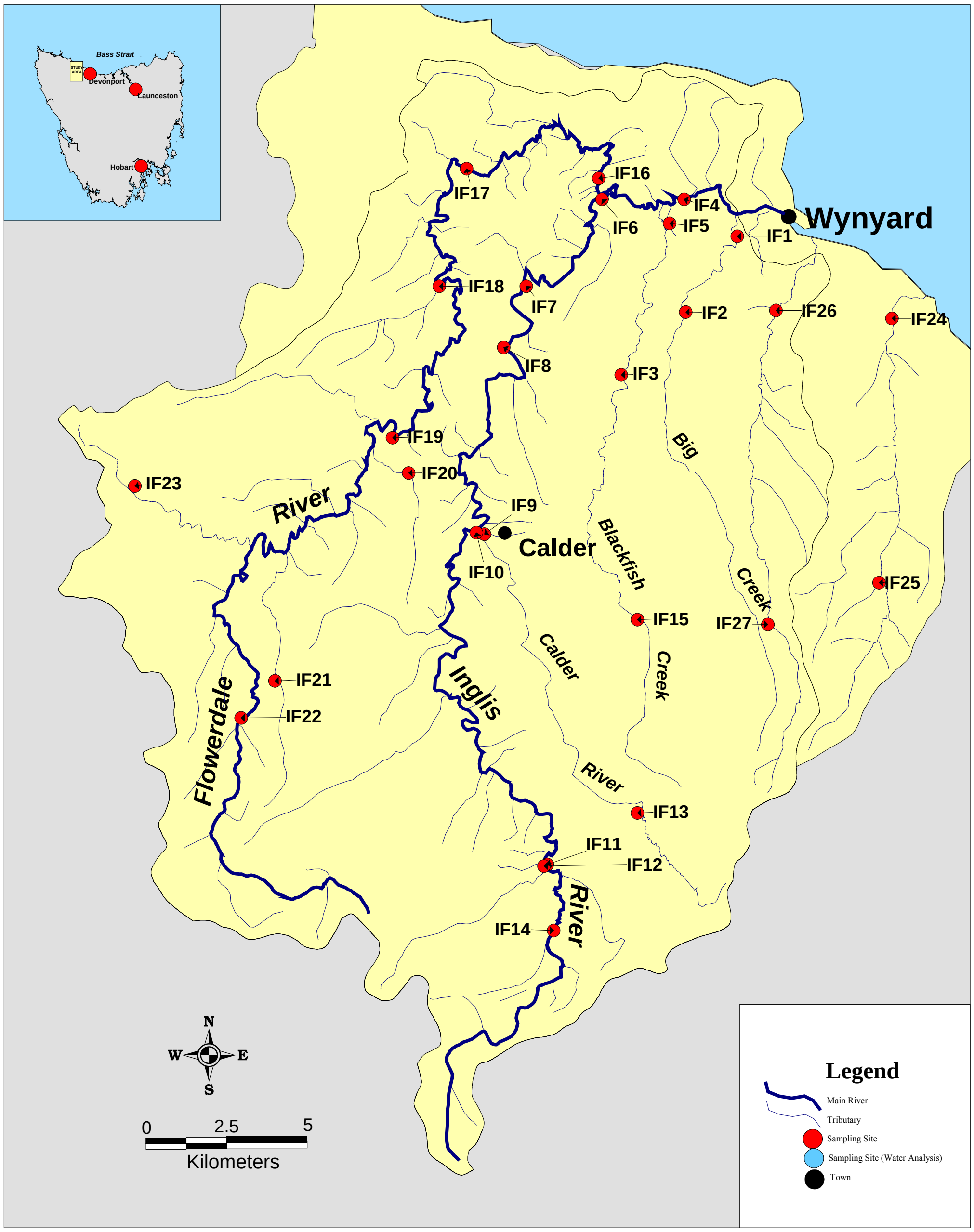

Figure 3.1: Location of all 27 sites monitored in the Inglis - Flowerdale catchment during the 'State of Rivers' investigations (1999-2001), including sites monitored in Seabrook Creek and Camp Creek, to the east of the main catchment.

The second level of sampling involved two catchment-wide 'snapshot' surveys, during which all sites in the main river and its tributaries were more comprehensively sampled. As well as sampling for the normal suite of physico-chemical parameters, sampling also encompassed nutrients, bacteria (Presumptive Faecal Coliform counts) and a number of the main heavy metals. These snapshots were carried out once each in summer and winter and were undertaken during 'stable' hydrological conditions, to avoid potential discrepancies that may have been caused by the patchy or uneven distribution of rainfall. The aim of this technique is to allow comparisons to be made at the catchment level so as to highlight sites or reaches of relative water quality degradation. This technique has been utilised in previous 'State of Rivers' projects (Bobbi, *et al.*, 1996; Bobbi, 1997; Bobbi, 1998; Bobbi, 1999a-d) and has been adapted from earlier work elsewhere in Australia (Grayson, *et al*., 1993).

The third level of monitoring involved the monthly sampling of faecal bacteria at five sites in the catchment between March 2000 to June 2001 at the request of Wynyard-Waratah Council. This council was very conscious of faecal pollution of rivers in their area and the periodic hazards this pollution can cause to human health during the summer months.

The fourth tier of monitoring involved the use of in-stream logging equipment to examine short-term variations in water quality such as dissolved oxygen and pH, which are known to undergo diurnal fluctuations. In-stream monitoring of some water quality variables was also performed in association with river level monitoring in the Inglis River at IF6 (Railway Bridge). At this site, temporary equipment was installed to record turbidity, conductivity and temperature on a continuous basis. It was hoped that the data from this source could be used in combination with nutrient sampling during flood events, to accurately estimate nutrient export loads for the catchment. However this equipment was damaged by willow debris during the flooding that followed willow removal in 1999, and only water level and temperature could be re-instated.

The physico-chemical parameters tested in the field included pH (compensated for temperature), electrical conductivity (corrected to reference temperature 25 ^{o}C), water temperature, turbidity (as nephelometric turbidity units standardised against Formazin) and dissolved oxygen. Bottled water samples were taken and analysed in a NATA registered laboratory for the following nutrients; ammonia nitrogen (NH_3-N), nitrate nitrogen (NO_3-N), nitrite nitrogen (NO_2-N), total nitrogen (TN), dissolved reactive phosphorus (DRP) and total phosphorus (TP). General ions analysis, tested quarterly, included the following variables;

Laboratory pH	
Laboratory Conductivity (@ 25^{o}C)	μS/cm
Colour (Apparent)	Hazen Units
Total Dissolved Solids	mg/L
Total Suspended Solids	mg/L
Hardness (calc. as $CaCO_3$)	mg/L
Total Alkalinity (to pH 4.5 as $CaCO_3$)	mg/L
Chloride (Cl)	mg/L
Flouride (F)	mg/L
Sulphate (SO_4)	mg/L
Iron (Fe)	mg/L
Manganese (Mn) - Total	mg/L
Calcium (Ca)	mg/L
Magnesium (Mg)	mg/L
Potassium (K)	mg/L
Sodium (Na)	mg/L
Silica (SiO_2) (Molybdate Reactive)	mg/L

3.1 Monthly Monitoring

Monthly monitoring of water temperature, pH, dissolved oxygen, conductivity and turbidity was carried out at all 23 sites in the Inglis–Flowerdale catchment, as well as at additional sites in the Camp Creek and Seabrook Creek sub-catchments to the east of Wynyard. The following boxplots show the range and statistical features of the data (for a full explanation of boxplots, see the Glossary), and allow a visual comparison between sites to be made. For details of the names and locations of sites, refer to Table 3.1 and Figure 3.1 above.

3.1.1 Water Temperature

Water temperature data from the 27 monitoring sites is presented graphically in Figure 3.2 below. It shows that temperature at most sites varies between a low of about 6-7 ^{o}C to a high of around 18-20 ^{o}C. Sites where a noticeable deviation from this pattern was recorded were at IF14 (Inglis River u/s Takone) and IF23 (Hebe River), where there was a significant restriction to the range of water temperature and median temperature was markedly lower, and at IF13 (Calder River at Takone Rd) and IF24 (Seabrook Creek), where a lack of riparian cover has clearly resulted in an enlarged range. Good riparian cover and heavy shading at the former sites (IF14 and IF23) is responsible for the smaller range of water temperatures recorded at these two sites. In the Flowerdale River there is a clear trend for cooler conditions towards the upper reaches of the river (IF16 – IF22). This trend is less evident in the Inglis River.

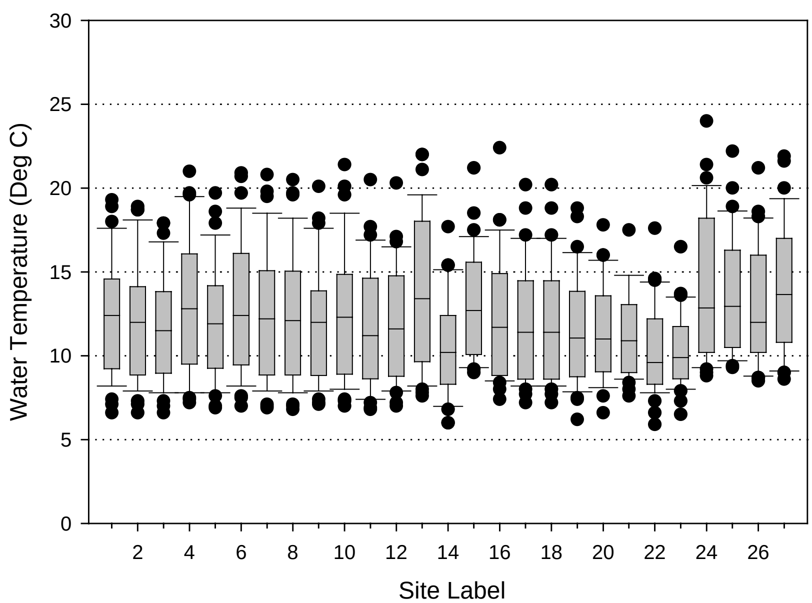

Figure 3.2: Statistical plot of water temperature at sites in the Inglis-Flowerdale catchment, Seabrook Creek and Camp Creek, recorded during monthly monitoring between February 1999 and December 2001.

As expected, there is also a distinct seasonal change in water temperature at all sites, and this is illustrated by the time series plots for water temperature at selected sites in Figure 3.3. While this figure shows that peak temperature tends to occur in January-February each year, the plot also shows that sites with greater exposure (eg. less riparian vegetation – IF13) tend to have much higher water temperature than sites where there is sufficient shading of the river (IF14).

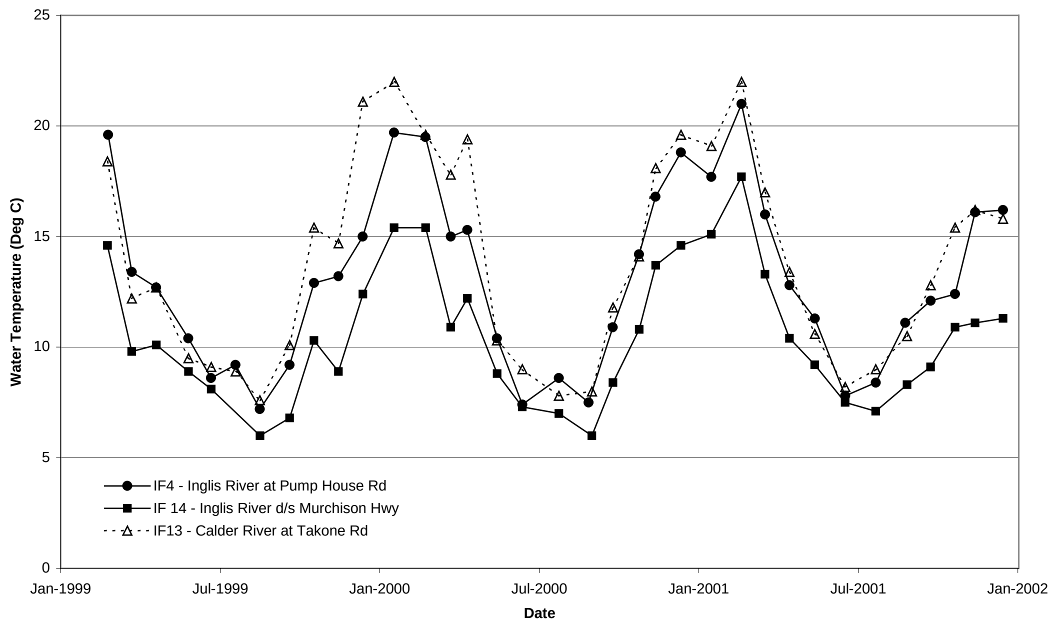

Figure 3.3: Seasonal change in water temperature at selected sites in the Inglis River and Calder River, recorded during monitoring between February 1999 and December 2001.

3.1.2 In-stream pH

The pH of river water at most sites in the catchment is near to neutral, with median pH at most being between 6.5 and 7 (Figure 3.4). The only exception to this was IF23 (Hebe River), where median pH was less than 6 and the minimum value recorded was 4.09. These data, along with that of apparent colour, suggest that the button grass swamps that are located some distance upstream of the monitoring site strongly influence water quality in this stream.

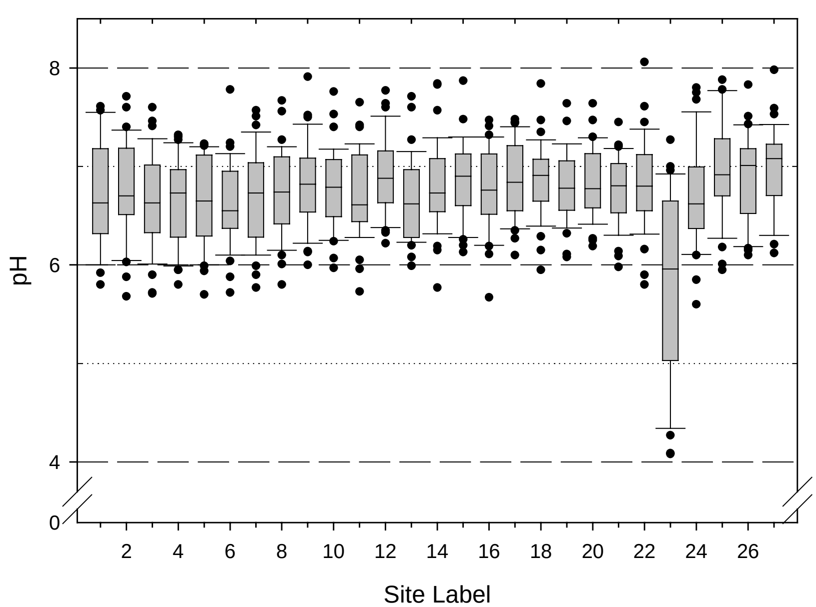

Figure 3.4: Statistical plot of water pH at sites in the Inglis-Flowerdale catchment, Seabrook Creek and Camp Creek, recorded during monthly monitoring between February 1999 and December 2001.

3.1.3 Conductivity

The median conductivity of sites in the catchment varies from about 60 µS/cm at sites high in the catchment to just over 100 µS/cm at sites lower in the catchment (Figure 3.5). The gradual reduction in conductivity with distance from the coast that is characteristic of coastal rivers is most clearly illustrated by the data from the Flowerdale River (IF16 to IF22), with median conductivity decreasing from 104 μS/cm to 61 μS/cm. The range of variation is also markedly less at sites higher in the catchment. No significant issues are highlighted by these data and conductivity throughout the catchment is within the range normally found in coastal rivers and streams on the north coast of Tasmania (Fuller & Katona, 1993).

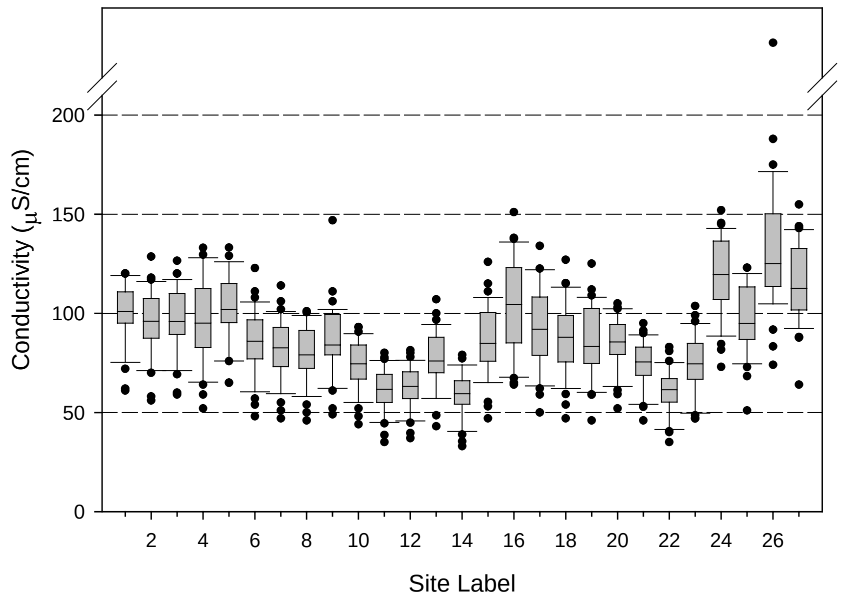

Figure 3.5: Statistical plot of conductivity at sites in the Inglis-Flowerdale catchment, Seabrook Creek and Camp Creek, recorded during monthly monitoring between February 1999 and December 2001.

3.1.4 Turbidity

Turbidity in flowing water is an indicator of the amount of suspended material being transported by the river at the time of sampling. In agricultural areas or in areas where there is a high level of instream and streamside disturbance, turbidity tends to be higher. In the Inglis-Flowerdale catchment, the baseline turbidity as represented by median values from monthly monitoring (Figure 3.6) is generally low (<7 NTU), and the median at most sites falls within the normal range for lowland rivers as defined by ANZECC (2000), although turbidity is occasionally high at sites lower in the Inglis River sub-catchment. Median turbidity was highest at IF15 (Blackfish Creek at Lowries Rd), and at all sites in Seabrook and Camp Creeks (IF24-26). Median turbidity at these sites was between 10-15 NTU. All three of these small catchments have significant levels of disturbance (eg. forestry, agriculture, grazing, etc) and this obviously has some impact on turbidity in these systems.

Lowest turbidity was consistently recorded from sites in the Flowerdale River sub-catchment, and turbidity at sites in this river tended to be less variable, reflecting the lower level of general disturbance in this sub-catchment. The frequent high values that were recorded at other sites appears to be due to a number of factors, the main ones being the presence of gravel quarries and unsealed roads, where runoff is virtually instantaneous and delivers dirty water directly to rivers and streams. This was most apparent at sites IF8 and IF9. During sampling in February 1999, visits to both of these sites 10-20min after a short thunderstorm revealed dramatic increases in turbidity (see Table 3.2) that were directly attributable to runoff from the gravel pits and unsealed roads in the vicinity of these two sites.

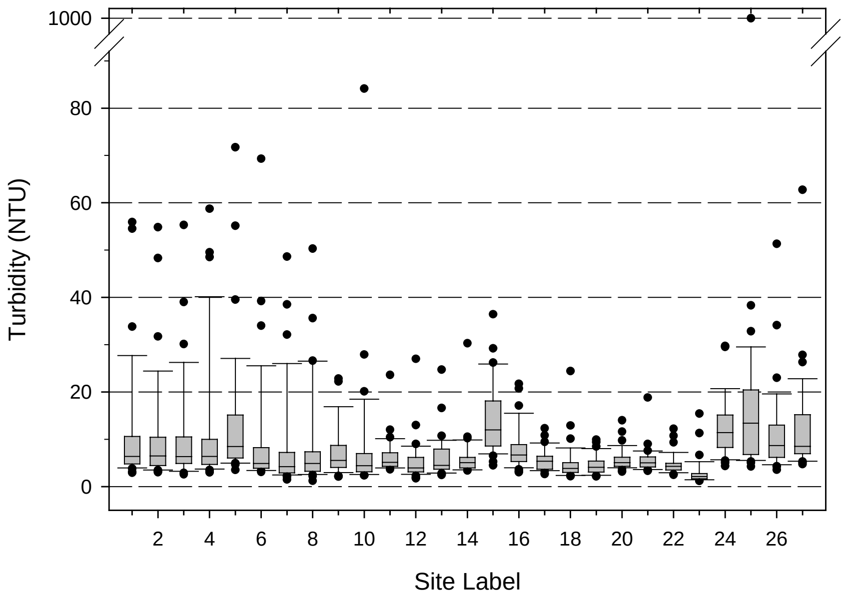

Figure 3.6: Statistical plot of turbidity at sites in the Inglis-Flowerdale catchment, Seabrook Creek and Camp Creek, recorded during monthly monitoring between February 1999 and December 2001.

In comparison, recent forest harvesting operations in the Calder sub-catchment upstream of IF9 were found to have no immediately detectable influence on turbidity levels following the storm event. While unsealed roads also occur in these catchments, the consistently elevated turbidity that was recorded in Blackfish, Seabrook and Camp creeks (IF15 and IF24-27) appears to be influenced more by stock access and poor riparian zone management along these two streams.

Table 3.2: Turbidity data collected during monitoring of the Inglis and Calder Rivers following a short thunderstorm in February 1999.

Site	Turbidity (NTU)
Inglis River at Ingleford Rd (IF8)	26.6
Inglis River at West Calder (IF10)	4.4
Calder River downstream Zig-Zag Rd Bridge (IF9)	108
Calder River upstream Zig-Zag Rd Bridge	5.95
Calder River downstream forest harvesting	4.58

3.1.5 Dissolved Oxygen

Biological processes such as organic decomposition and primary productivity are the major factors that influence the level of dissolved oxygen in environmental waters. In waters that are not subject to human-induced pollution or disturbance, these processes are in balance and vary in a cyclical fashion on a daily and seasonal basis. Unnatural organic enrichment of waterways or increased exposure to sunlight through the removal of riparian vegetation often creates an imbalance to the system that produces extremes in dissolved oxygen. These daily and seasonal extremes in dissolved oxygen concentrations can have a severe impact on the ability of aquatic biota to survive in these environments. The range of dissolved oxygen data at a site can therefore be used as a basic indicator of 'environmental imbalance' in the local ecosystem.

A summary of the monthly data from sites in the Inglis-Flowerdale catchment is displayed in Figure 3.7, where the size of the boxplots indicates the range of oxygen concentrations measured at each site. This plot shows that at the majority of sites, 75% of the oxygen measurements (as represented by the shaded boxes) tend to fall within a 2 mg/L range, with median values of between 9-11 mg/L. These sites can be broadly classified as 'healthy', despite having outliers that may be below the commonly accepted 'unhealthy' concentration limit of 6 mg/L (ANZECC, 1992). The outliers at these sites are likely to indicate periodic 'stress' events caused by extreme climatic events such as very warm weather.

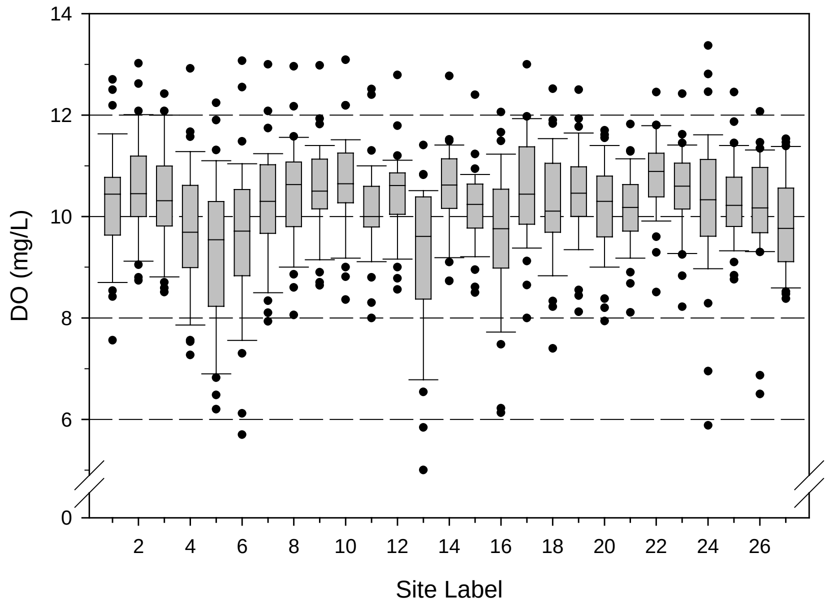

Figure 3.7: Statistical plot of dissolved oxygen concentration at sites in the Inglis-Flowerdale catchment, recorded during monthly monitoring between February 1999 and December 2001.

Sites that show signs of oxygen 'imbalance' are sites IF5 (Blackfish Creek at Stennings Rd), IF6 (Inglis River at Railway Bridge), IF13 (Calder River at Takone Rd) and IF16 (Flowerdale River at Preolenna Rd). Although the median oxygen concentration at all four of these sites is within the range normally found in healthy river ecosystems, at each of these sites there were periods when the oxygen concentration fell near to or below 6 mg/L. This was particularly notable at site IF13 high up on the Calder River. The degree of oxygen 'imbalance' at this site is more clearly illustrated when the oxygen saturation data (rather than concentration) is plotted (Figure 3.8).

Recent revisions to the National water quality guidelines have seen the adoption of a 90% saturation level as the 'trigger' below which there is likely to be some stress to aquatic life (ANZECC, 2000). Using this as a criterion to assess sites in the Inglis-Flowerdale catchment, it is clear that oxygen levels at IF5 and IF13 are most impacted. Both of these sites are located on small tributary streams that have been significantly altered by land-use practices, which have resulted in the total removal of native riparian vegetation and consequent invasion of these streams by weed species (Crack Willow and Cumbungi). At IF13, the stream is totally exposed to sunlight, has almost unrestricted access by cattle, is heavily enriched by nutrients (see Section 3.4 – Catchment Surveys) and during the summer is choked by the water weed Cumbungi (*Typha* spp). This has produced a depositional aquatic environment that is highly modified and likely to suffer substantial oxygen 'sags' due to plant respiration and decomposition (Wilcock, *et. al.*, 1995). This is likely to cause significant stress to aquatic biota and reduce the biodiversity in this stream. Data on diurnal changes in oxygen concentration at this site is presented and discussed in Section 3.5, but shows that nighttime dissolved oxygen levels below 50% saturation occur during the summer months.

Conditions are not as degraded at IF5 (Blackfish Creek), where shade from willows and generally better streamflow prevents oxygen levels falling quite as low as at IF13. Despite being lower in the catchment, this site is much less depositional that IF13, and there is likely to be less instream decomposition and hence less oxygen demand. However, the exposure to sunlight at this site is still high and during the summer there is prolific growth of willow and aquatic weeds, which obviously causes an imbalance in the system resulting in lower overall oxygen levels. Indeed the median oxygen saturation at this site is the lowest of all sites in the catchment (Figure 3.8).

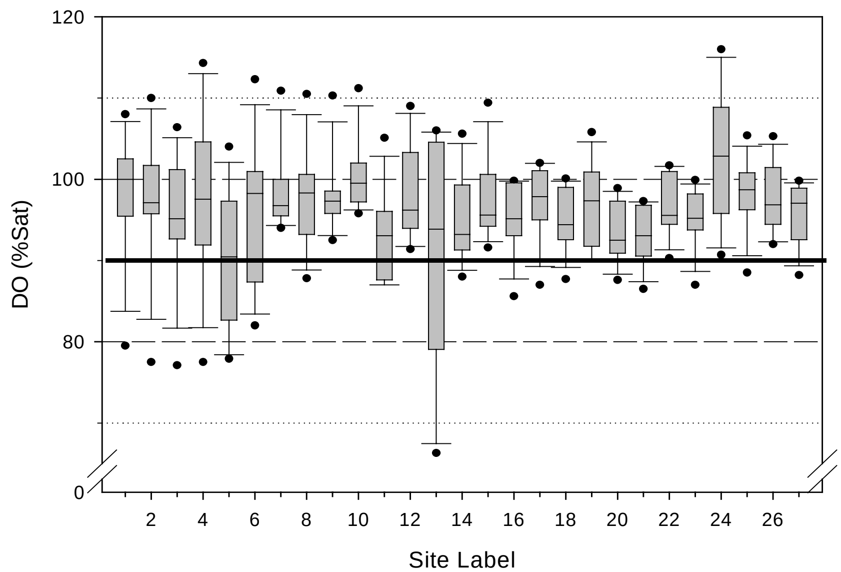

Figure 3.8: Statistical plot of dissolved oxygen (as percent saturation) at sites in the Inglis-Flowerdale catchment, recorded during monthly monitoring between February 1999 and December 2001. #Bold line denotes lower trigger level for ecosystem protection as recommended by ANZECC, 2000.

Despite this highly modified condition, IF5 displays a seasonal pattern of change much like other sites in the catchment (Figure 3.9). During the first year of monitoring there was a clear and progressive seasonal change at all sites, with maximum dissolved oxygen concentrations being recorded in August and minima being measured during February 2000.

This pattern was repeated to some degree the following year (2000-01), however during the autumn of that year extensive willow removal took place in the lower Flowerdale and Inglis Rivers and while this did not affect oxygen levels during the winter of 2000, their removal did cause a marked increase in oxygen variability during the summer and autumn of 2001.

Overall summer-time levels were also higher in these two rivers, but especially in the Flowerdale River, where previously the river was very densely infested with willows. The impacts of willows on riverine oxygen levels and water quality have been investigated during previous 'State of Rivers' studies (Bobbi, *et al.*, 1996), and although their wholesale removal poses other environmental hazards, it does have the benefit of lifting daytime oxygen levels in rivers.

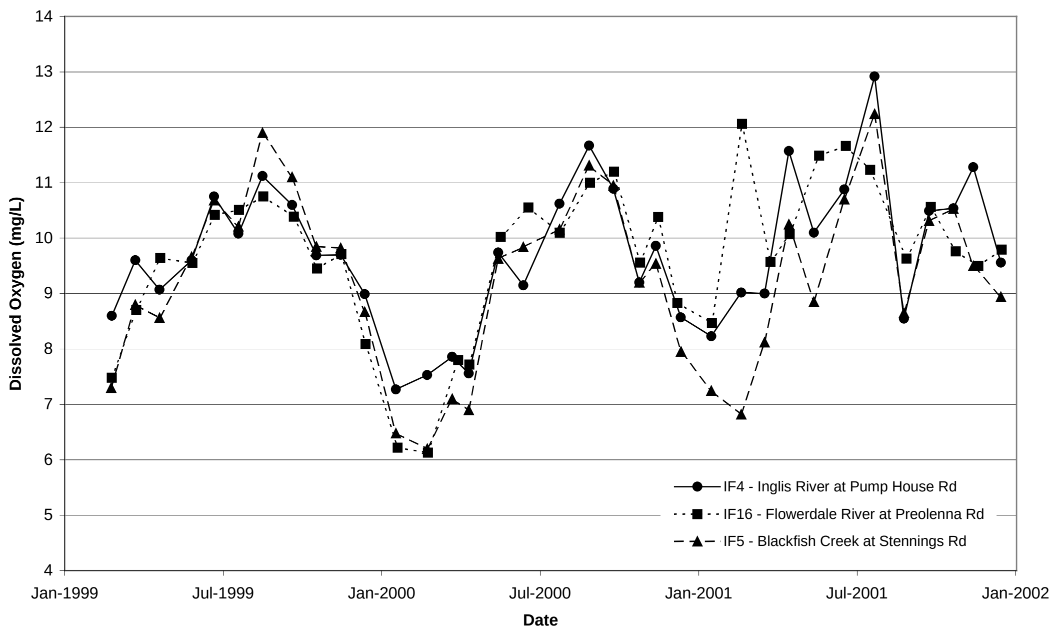

Figure 3.9: Time series plot of dissolved oxygen concentration at three sites in the Inglis-Flowerdale catchment between February 1999 and December 2001.

3.2 General Ionic Composition

Samples for characterising the ionic composition of waters in the catchment were collected on a quarterly basis from a subset of sites. These are listed in detail below and referred to by their labels in the following graphs.

Site Label	**Site Name**
IF1	Big Creek at Wynyard
IF4	Inglis River at Pump Station Rd
IF5	Blackfish Creek at Stennings Rd
IF6	Inglis River at Railway Bridge
IF8	Inglis River at Ingleford Rd
IF14	Inglis River 2km south of Takone
IF16	Flowerdale River at Preolenna Rd
IF17	Flowerdale River at Moorleah
IF23	Hebe River at Myalla Rd
IF24	Seabrook Creek u/s Bass Hwy
IF26	Camp Creek at 'Terra Nova'

The boxplots summarise selected parameters that are normally used to characterise the ionic composition of water, and is only a subset of all parameters that were actually tested. Many of these are influenced primarily by the composition of local soils, vegetation and geology, though some may be influenced by land use and other catchment activities (such as mining). The following brief comments can be made from these data.

The apparent colour of water gives some indication of the level of dissolved and fine organic material in water. Colour can also be affected by the presence of natural minerals such as iron hydroxides. The waters in the Inglis-Flowerdale catchment generally contain little colour, with the exception of the Hebe River (IF23) (Figure 3.10) where the median value for colour was 350 Hazen units. As was discussed earlier in this report, the Hebe River drains a small patch of buttongrass swamp at very western extremity of the catchment, and this has the dual impact of causing highly coloured and moderately acidic water in the Hebe River (a pH of less than 5 was frequently recorded in the Hebe River). These characteristics are more typical of rivers draining the west and southwest coast of Tasmania.

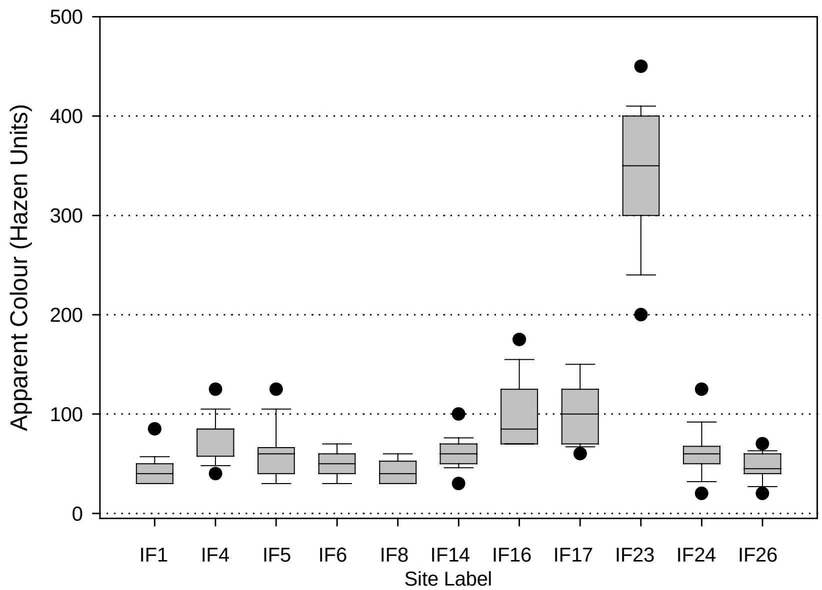

Figure 3.11: Statistical plot of apparent colour sampled quarterly (n = 13) at sites in the Inglis-Flowerdale catchment, between February 1999 and December 2001.

The alkalinity of water in the catchment can broadly be classified as 'soft', having concentrations less than 40mg $CaCO_3$/L (Figure 3.12). Calcium concentrations are also quite low (Figure 3.13). High alkalinity in environmental water generally indicates the presence of limestone or dolomite in the underlying geology, and this generally buffers the water against large pH variations and prevents the generation of low pH values. The low alkalinity and calcium concentrations in the Hebe River means that acidic water generated from the organic rich, peaty soils of the buttongrass swamp upstream has a larger impact on pH than might otherwise be the case.

Alkalinity and calcium concentrations are also low in the upper reaches of the Inglis River at site IF14, however as no buttongrass occurs in this part of the catchment, the pH of the river at this site is not noticeably different to other sites in the catchment (refer to Figure 3.4 presented earlier).

Sulphate is naturally present in surface waters as SO_4^{2-}, and generally originates from ocean aerosols or geological sources such as leaching from sulphite minerals or sedimentary rocks (UNESCO, 1992). Previous 'State of Rivers' studies have shown that many Tasmanian rivers generally contain sulphate in concentrations less than about 5 mg/L ((Bobbi, *et al.*, 1996; Bobbi, 1999c; and Bobbi, 1999d). The concentration of sulphate in the Inglis-Flowerdale catchment is generally within this range, although slightly elevated concentrations were recorded at IF1 (Big Creek) at the catchment outlet. It is likely that the higher levels occasionally found at this site reflect the impact by ocean mists brought inland by sea breezes and northerly winds.

Iron concentration throughout the catchment is relatively high, with median concentration at most sites between 0.5 and 1.0 mg/L. This is higher than many other rivers along the north coast of Tasmania, but is similar or slightly less than was recorded in the Duck and Montagu catchments during monitoring over the same period. The presence of iron at these concentrations has some implications for domestic use, as high levels of iron can affect the taste of drinking water and can stain laundry (ANZECC, 1992).

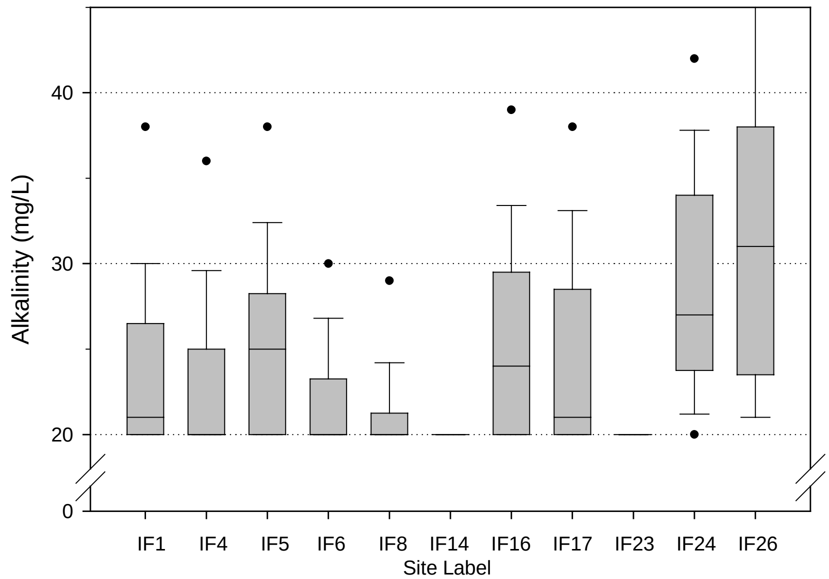

Figure 3.12: Statistical plot of alkalinity (as $CaCO_3$) sampled quarterly (n = 13) at sites in the Inglis-Flowerdale catchment, between February 1999 and December 2001.
Detection limit for this analysis was 20 mg/L.

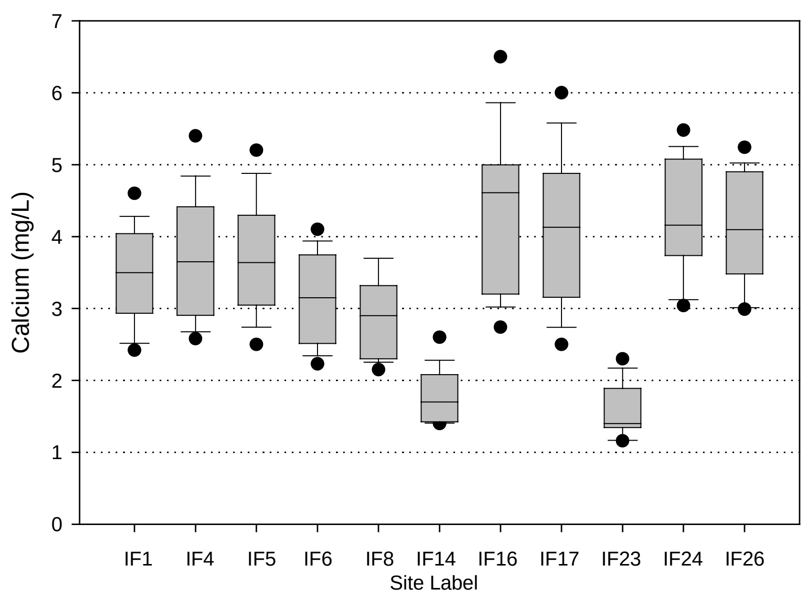

Figure 3.13: Statistical plot of total calcium concentration sampled quarterly (n = 13) at sites in the Inglis-Flowerdale catchment, between February 1999 and December 2001.

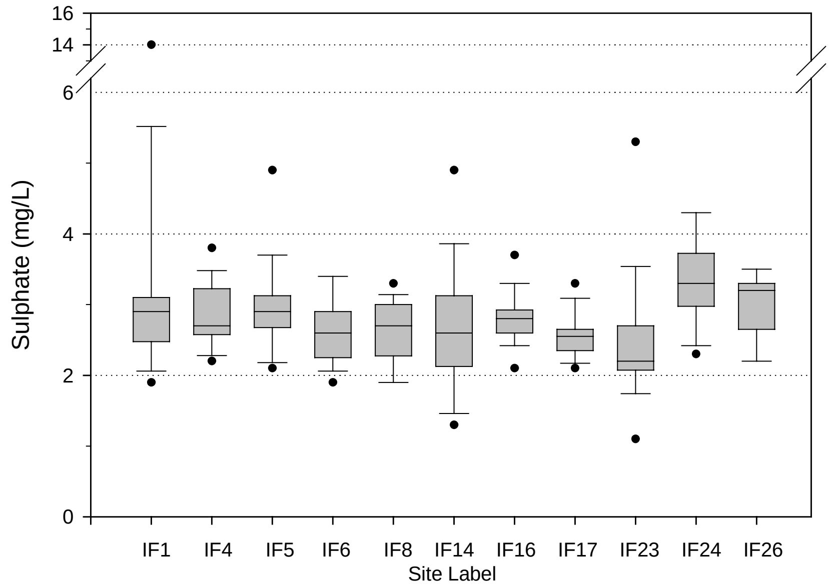

Figure 3.14: Statistical plot of sulphate concentration sampled quarterly (n = 13) at sites in the Inglis-Flowerdale catchment, between February 1999 and December 2001.

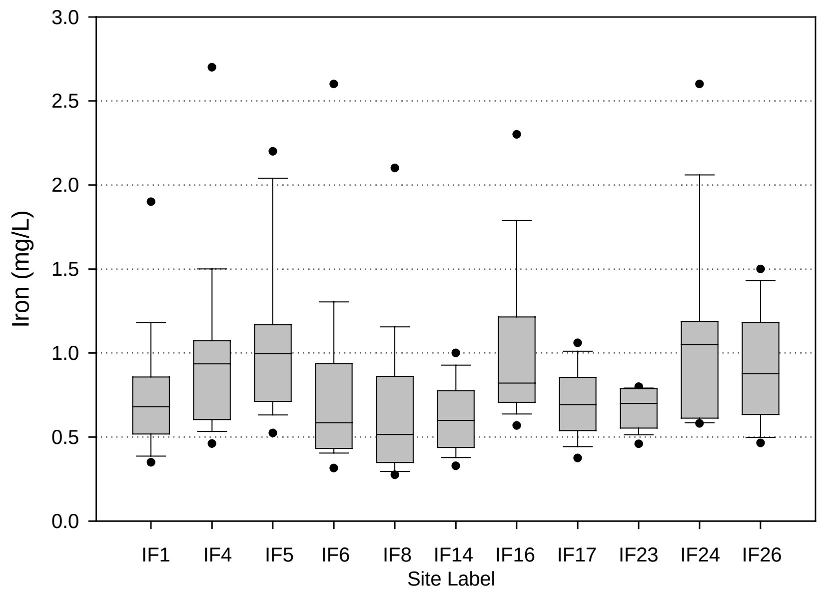

Figure 3.15 Statistical plot of iron concentration sampled quarterly (n = 13) at sites in the Inglis-Flowerdale catchment, between February 1999 and December 2001.