REPORT FOR THE TOODYAY LAND CONSERVATION DISTRICT COMMITTEE

RESULTS OF THE JIMPERDING BROOK MONITORING PROJECT

EDITH COWAN UNIVERSITY

PREPARED BY:

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1. PROJECT OVERVIEW

Funding for this project was provided by the National Landcare Program and the National Heritage Trust through the Toodyay Land Conservation District Committee (Project Number NLP 95/W/33) and Edith Cowan University (ECU), with the funds administered via ECU project 2317100. The cash component of the funding was used for the purchase of two hand-held meters (for pH and EC), the employment of a Research Assistant to carry out the in situ measuring and to collect water samples, and for the subsequent analysis of these samples. The pH and EC meters were handed over to the Toodyay LCDC at the completion of the monitoring period.

The results obtained provide a baseline study of water quality in the Jimperding Brook and in some of its tributaries. Water samples were taken on a monthly basis over a three year period from July 1997 to June 2000 and measurements were made of pH, Electrical Conductivity (EC) and Phosphorus concentration to measure acidity, salinity and nutrient level respectively. The samples were taken at nine locations determined by the stream flow characteristics. In this Report we describe the results and discuss their implication for future management of the Jimperding catchment area. These measurements provide a benchmark against which any future water quality changes can be gauged, together with an indication of what parts of the catchment are responsible for the current problems.

2. INTRODUCTION

The Jimperding Valley of Western Australia is an agricultural area located approximately 80km north east of Perth. Jimperding Brook itself is an important tributary of the Avon River and has a catchment area of about 150 square kilometres (15 000 hectares). The Jimperding Brook and some parts of the catchment have an obvious salinity problem. The purpose of this project was to obtain baseline data on the water quality and surrounding tributaries. Between July 1997 and June 2000 pH (acidity), Phosphorus concentration (nutrient level) and Electrical Conductivity (salinity), were recorded on a monthly basis at nine sites. This monitoring followed up a previous project by Lyn Bloom (Bloom and Cross 2001) in which single-site monitoring of salinity and acidity had shown high levels of salinity in the Jimperding Brook just before it entered the Avon River. A closer study was therefore called for to determine which parts of the catchment and associated tributaries might be the major contributors to this problem.

3. GENERAL METHODS

At each of nine chosen sites, measurements were made in situ by hand-held meter for pH, Electrical Conductivity (EC) in mS/cm, as a measure of salinity, and temperature (°C). In addition, samples were taken for laboratory analysis of Phosphorus concentration (ppb) as a measure of nutrient level. The Jimperding Brook, its tributaries and the sampling sites are shown in Figure 3.1. These were chosen to take account of the stream flow characteristics of the catchment.

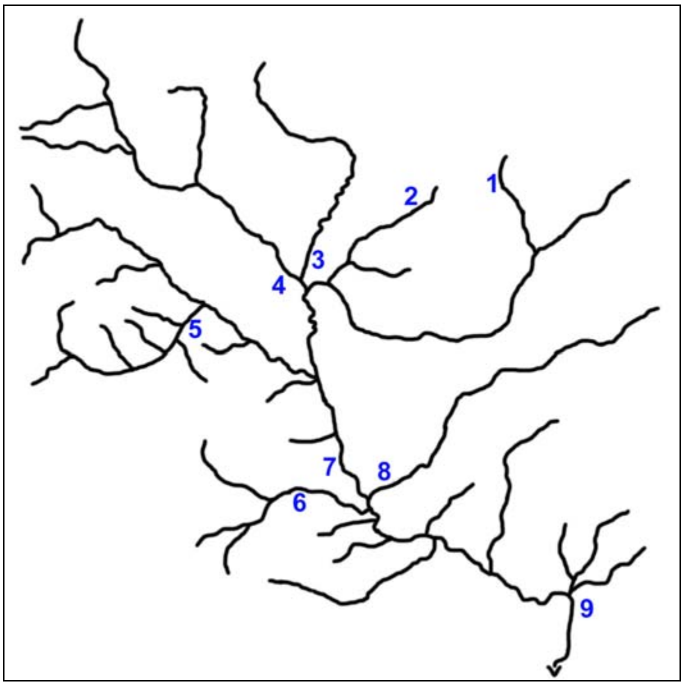

Figure 3.1. Catchment Map showing sampling sites.

4. SITE DESCRIPTIONS

The following subsections show a general photograph (left) indicating the location of the site and one showing the water quality monitoring point (right). Any relevant characteristics of the individual sites are also described. Three time series plots for each of the sites show the water quality parameters. The previous single site sampling (Bloom and Cross 2001) was carried out at Site 9.

4.1 Site 1

Unnamed tributary at Fernie Road. This tributary 'breaks out' close to this site. Water flow is moderate to strong for most or all of the year. This site has the least saline water of all sites.

Figure 4.1a. Photos of Site 1.

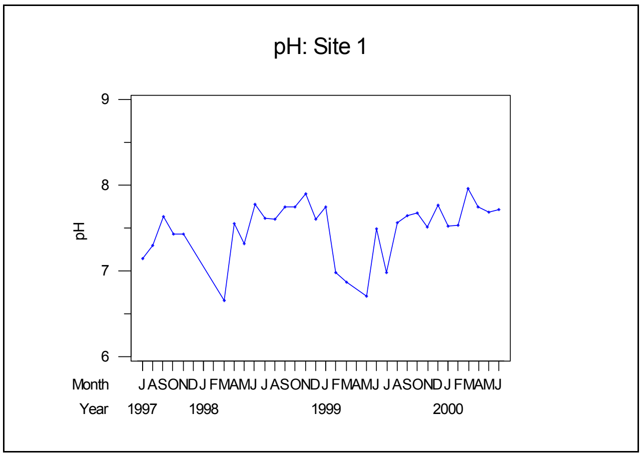

Figure 4.1b. pH for Site 1.

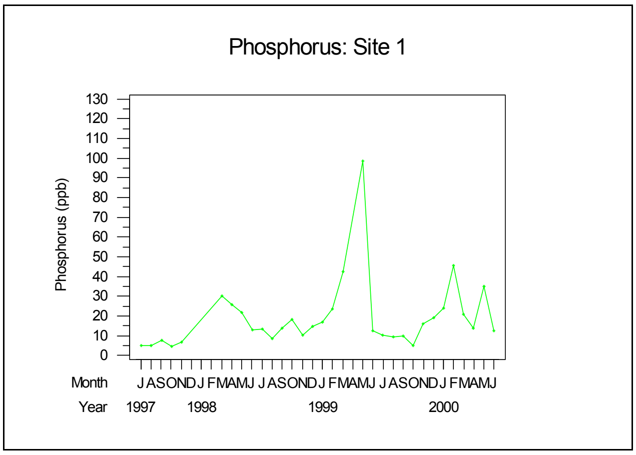

Figure 4.1c. Phosphorus conc. for Site 1.

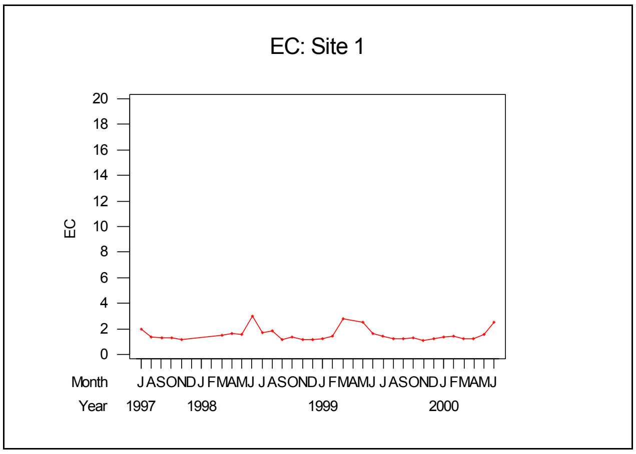

Figure 4.1d. EC (mS/cm) EC for Site 1.

4.2 Site 2

Unnamed tributary at Salt Valley Road. Water flow is moderate and there is significant run-off from a roadside ditch following rain.

Figure 4.2a. Photos of Site 2.

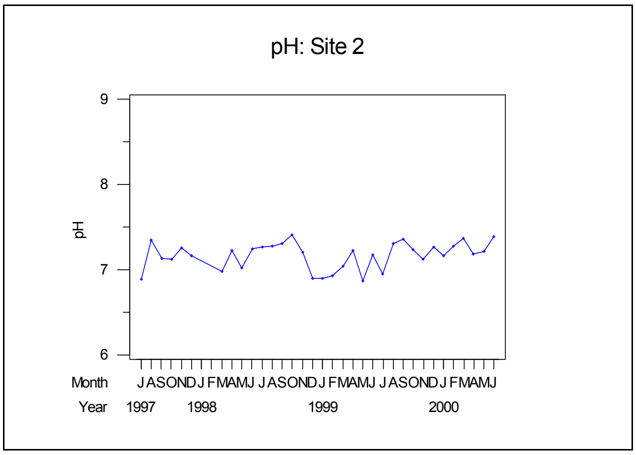

Figure 4.2b. pH for Site 2.

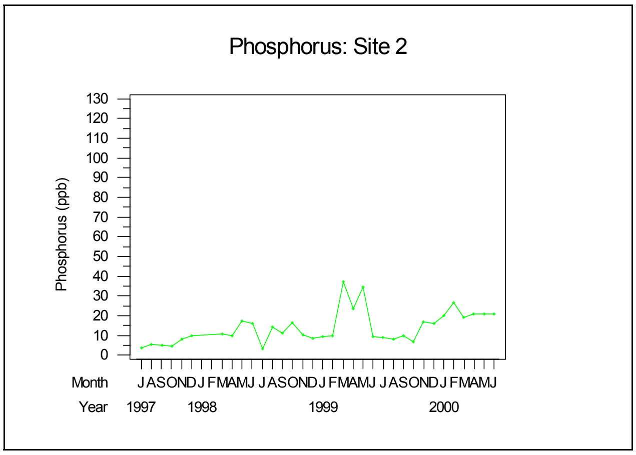

Figure 4.2c. Phosphorus conc. for Site 2.

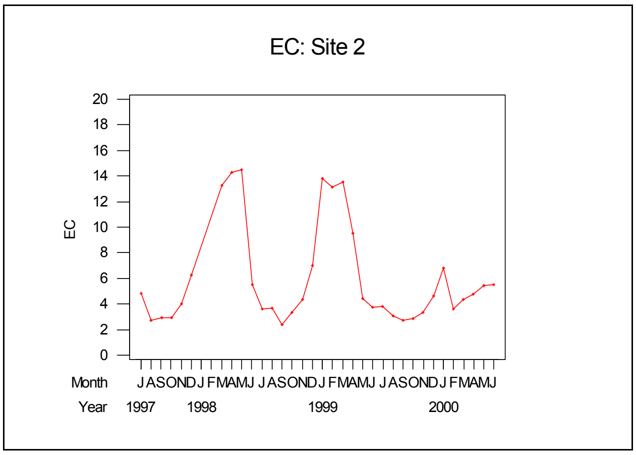

Figure 4.2d. EC (mS/cm) EC for Site 2.

4.3 Site 3

Jim Crow Gully at Salt Valley Road. Water flows strongly for all or most of the year here. Samples were taken from a narrow channel just after the water emerges from under the road and shortly before it joins with the Jimperding Brook. This is one of the most saline sites.

Figure 4.3a. Photos of Site 3.

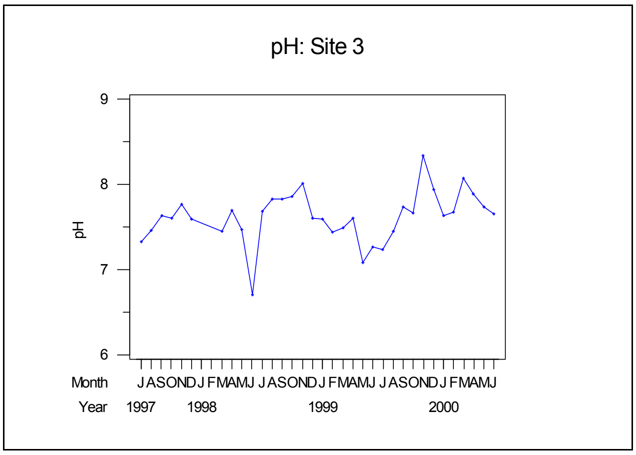

Figure 4.3b. pH for Site 3.

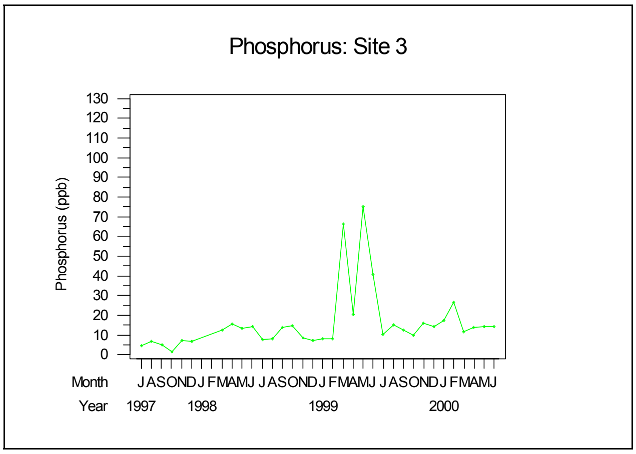

Figure 4.3c. Phosphorus conc. for Site .3

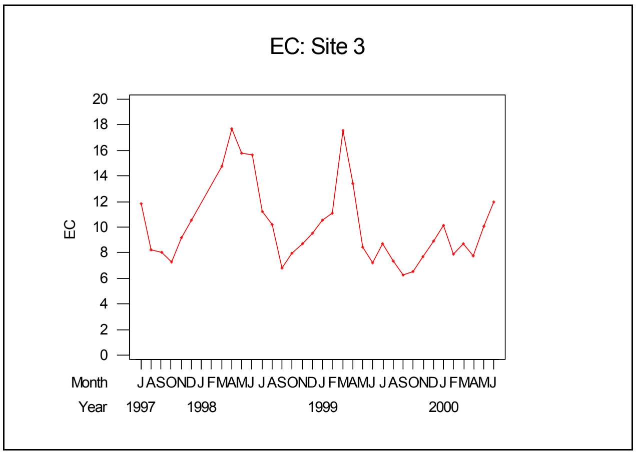

Figure 4.3d. EC (mS/cm) EC for Site 3.

4.4 Site 4

Jimperding Brook at Salt Valley Road at the junction with Chitty Road. Water flow is strong for all or most of the year and was sampled over rocks after crossing under the road. This is also one of the most saline sites.

Figure 4.4a. Photos of Site 4.

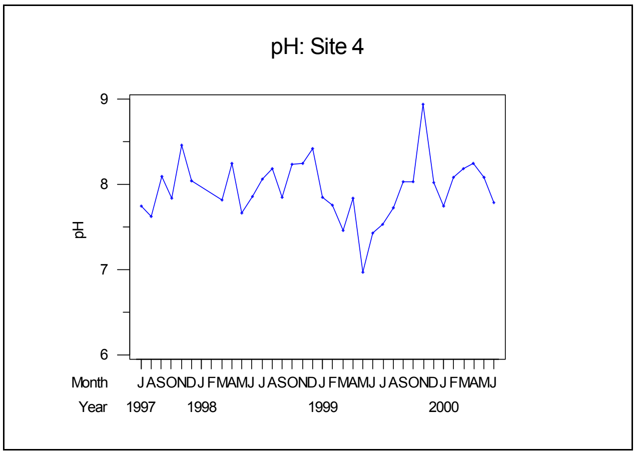

Figure 4.4b. pH for Site 4.

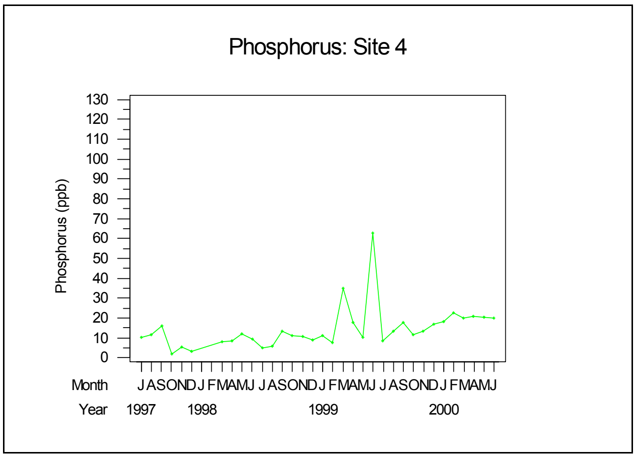

Figure 4.4c. Phosphorus conc. for Site 4.

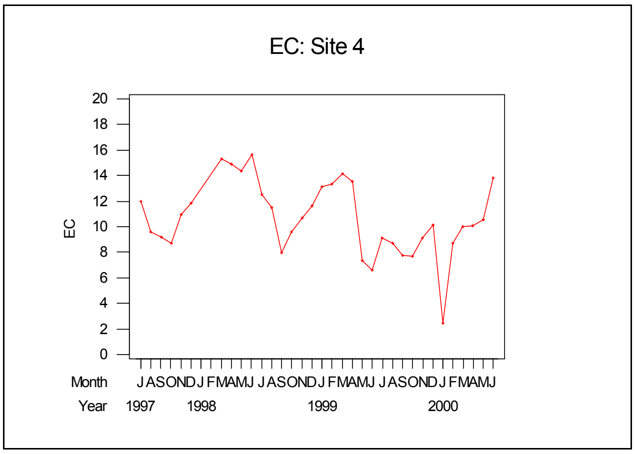

Figure 4.4d. EC (mS/cm) EC for Site 4.

4.5 Site 5

Unnamed tributary at Salt Valley Road. At this site the creek runs parallel to Salt Valley Road through natural bushland. Water was sampled close to a culvert that remained blocked after a heavy January 1999 storm. Water flow is moderate and the creek is often dry.

Figure 4.5a. Photos of Site 5.

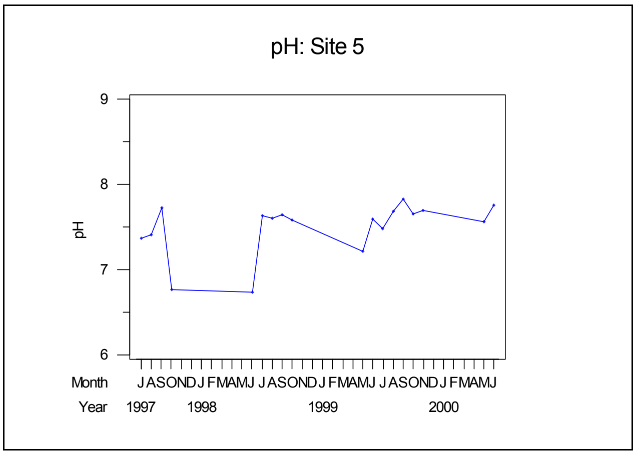

Figure 4.5b. pH for Site 5.

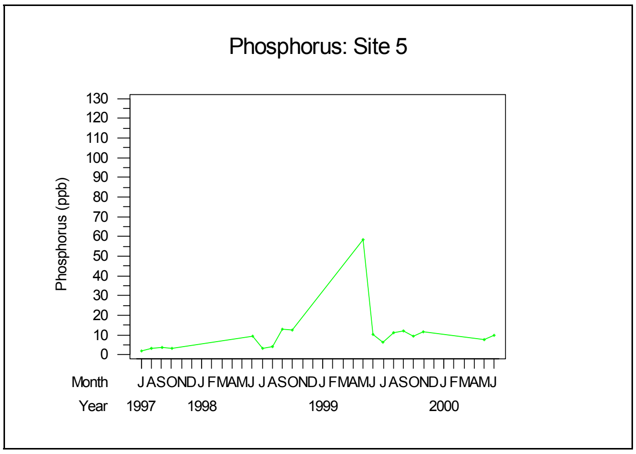

Figure 4.5c. Phosphorus conc. for Site 5.

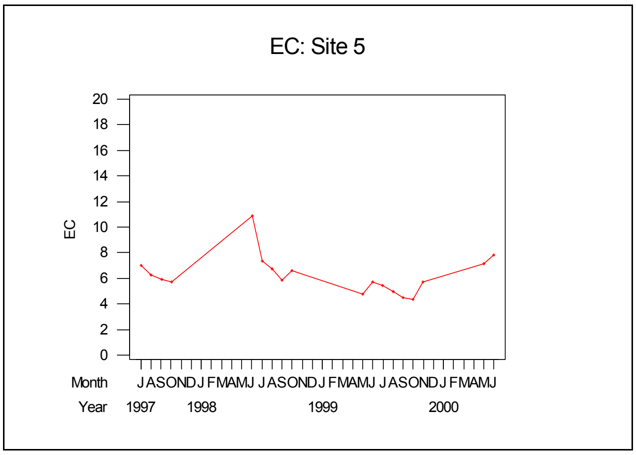

Figure 4.5d. EC (mS/cm) EC for Site 5.

4.6 Site 6

Gabidine Brook at Toodyay Road. Samples were taken from just before the bridge on the old Toodyay Road where the Brook flows through a deep gully with rocks and rock outcrops. Water flow is moderate.

Figure 4.6a. Photos of Site 6.

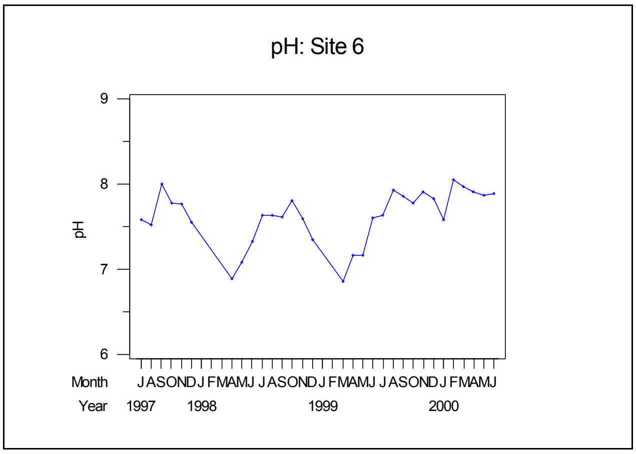

Figure 4.6b. pH for Site 6.

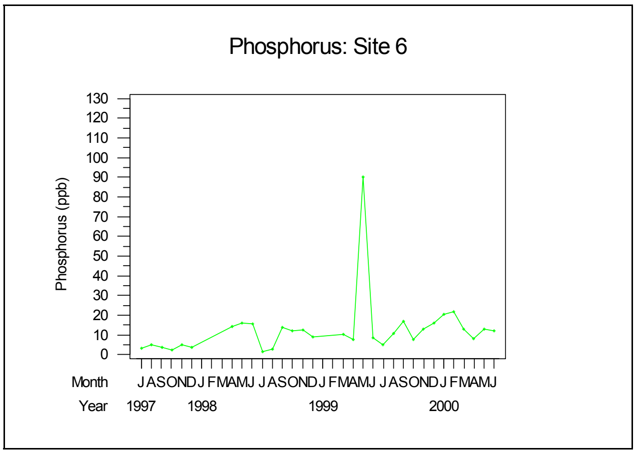

Figure 4.6c. Phosphorus conc. for Site 6.

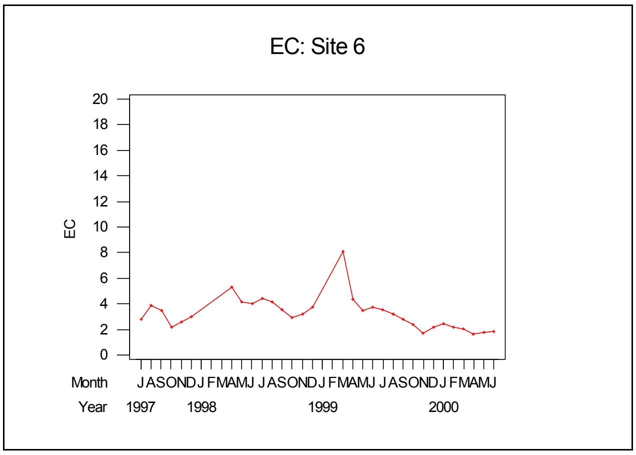

Figure 4.6d. EC (mS/cm) EC for Site 6.

4.7 Site 7

Jimperding Brook at Toodyay Road. At the bridge on the Toodyay Road, the Jimperding Brook is at its widest point. Consequently, water flow is only slight to moderate.

Figure 4.7a. Photos of Site 7.

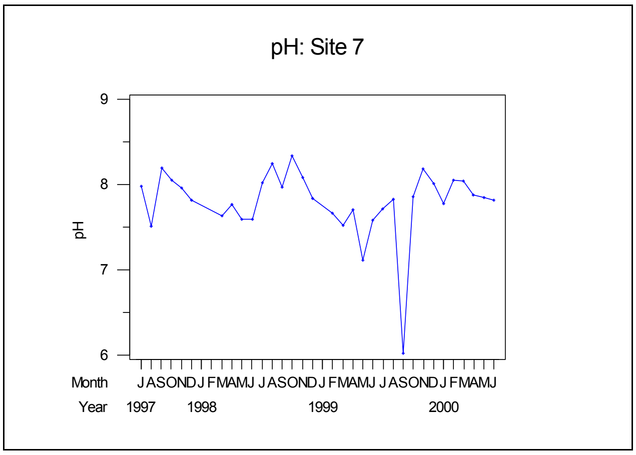

Figure 4.7b. pH for Site 7.

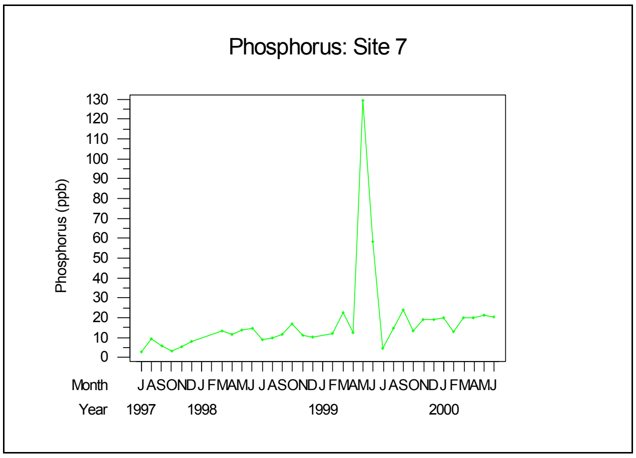

Figure 4.7c. Phosphorus conc. for Site 7.

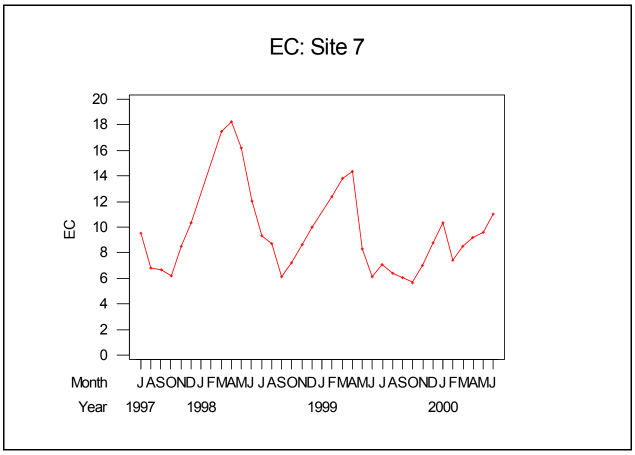

Figure 4.7d. EC (mS/cm) EC for Site 7.

4.8 Site 8

Jingaling Brook at Lovers Lane. Water flows strongly under Lovers Lane, where the samples were taken, and then joins the Jimperding Brook not far from the Toodyay Road.

Figure 4.8a. Photos of Site 8.

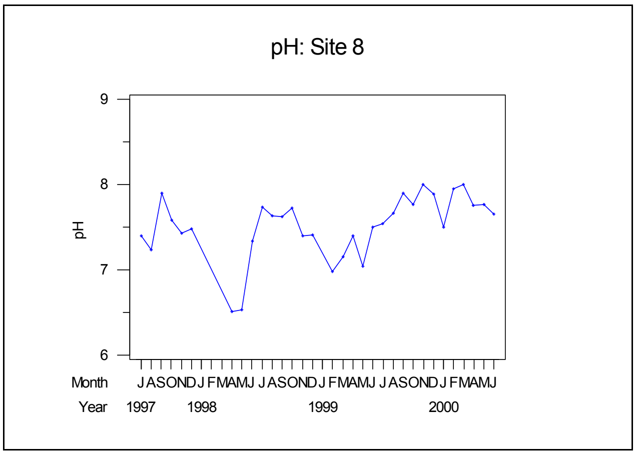

Figure 4.8b. pH for Site 8.

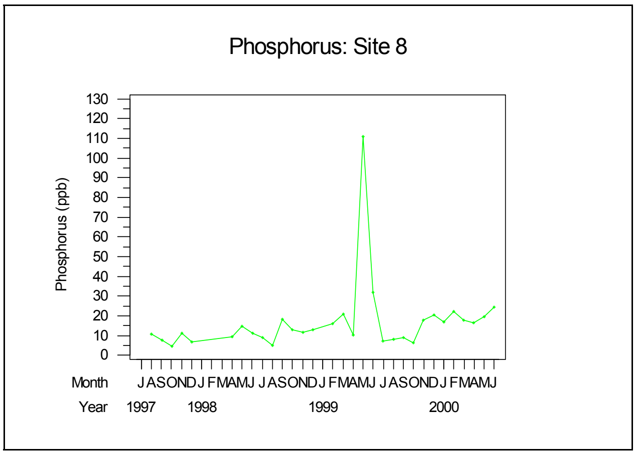

Figure 4.8c. Phosphorus conc. for Site 8.

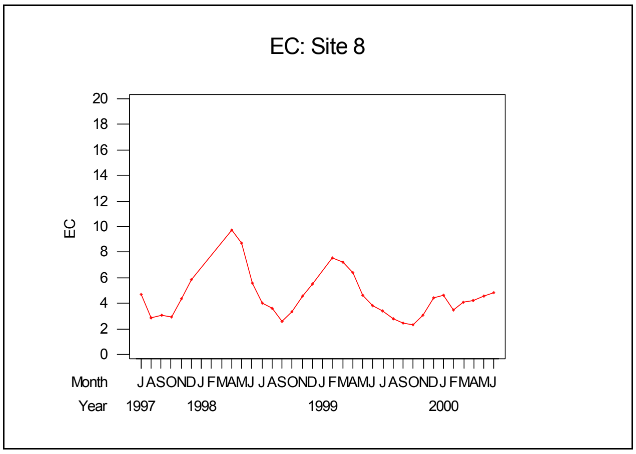

Figure 4.8d. EC (mS/cm) EC for Site 8.

4.9 Site 9

Jimperding Brook at Lovers Lane. This is the last site on the Jimperding Brook before it joins the Avon River. Samples were taken from below the Lovers Lane floodway where flow is usually strong.

Figure 4.9a. Photos of Site

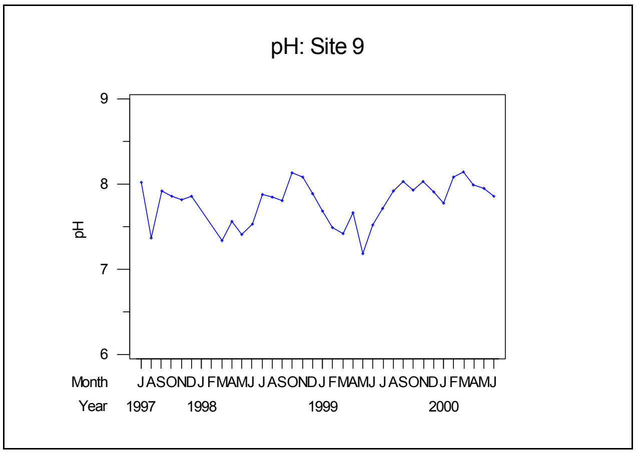

Figure 4.9b. pH for Site 9.

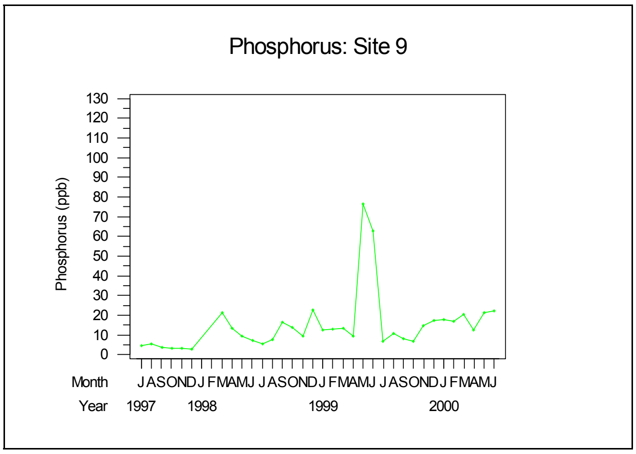

Figure 4.9c. Phosphorus conc. for Site 9.

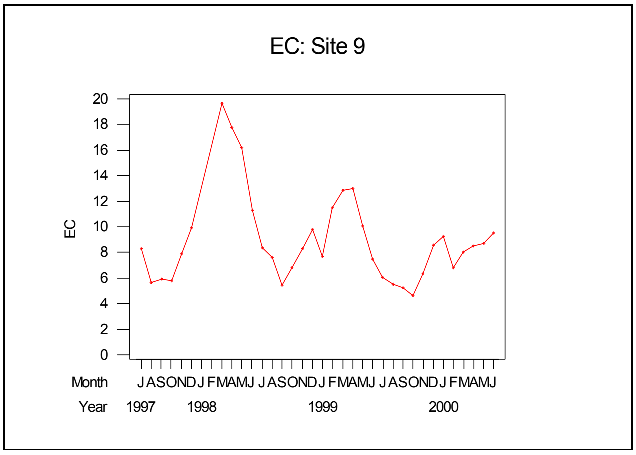

Figure 4.9d. EC (mS/cm) EC for Site 9.

5. THE CATCHMENT AS A WHOLE

Summary means and standard deviations for pH for all sites are given in Table 5.1 and show little variation between the sites, with all having average pH values in the low alkaline range. A Time Series plot for pH at all nine sites is given in Figure 5.1. As expected, the pH values exhibit no obvious seasonal trend.

Table 5.1.
pH Summary Statistics

Site	Mean	Std Dev
1	7.48	0.33
2	7.17	0.16
3	7.62	0.30
4	7.94	0.35
5	7.49	0.31
6	7.62	0.32
7	7.79	0.41
8	7.51	0.37
9	7.83	0.25

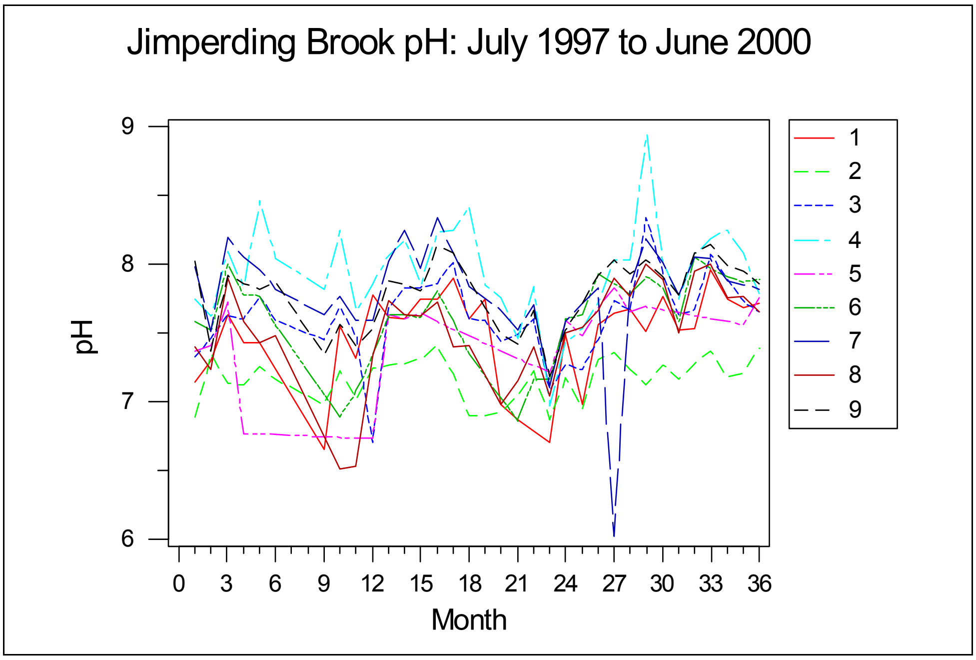

Figure 5.1. Times Series Plot for pH

Comparison boxplots for pH at the nine sites are shown in Figure 5.2. Again, these indicate relatively minor variation between the sites, with the medians all lying in the low alkaline range. The asterisks in Figure 5.2 depict outliers. A notable outlier is the one indicated for Site 7 and occurred (for no apparent reason) in September 1999 (see Figure 5.1).

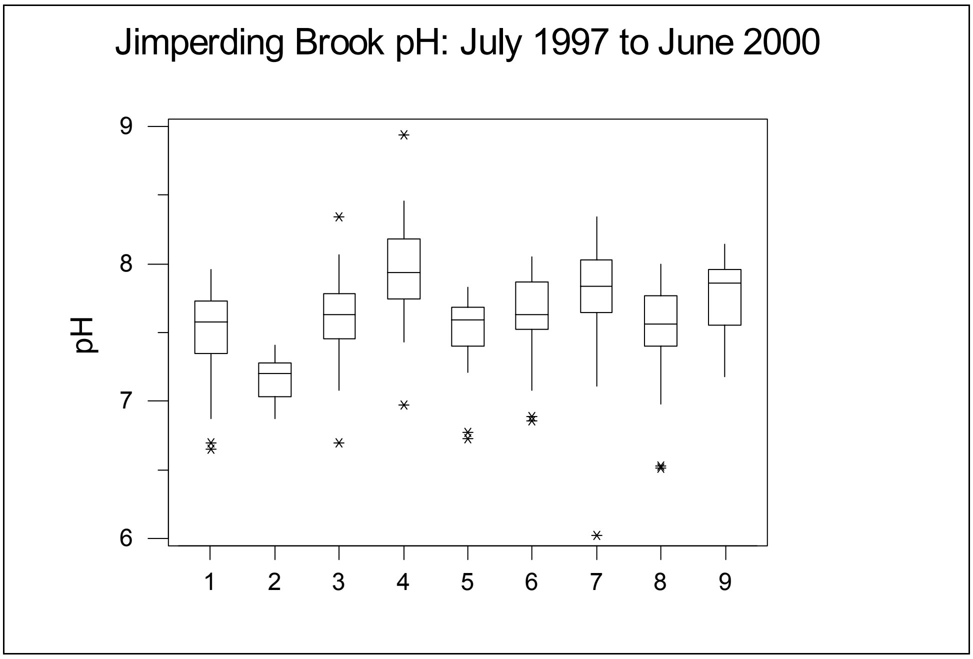

Figure 5.2. Boxplots for pH: All sites.

Summary means and standard deviations for Phosphorus concentration (ppb) are given in Table 5.2. However, these are greatly influenced by high value outliers. The boxplots in Figure 5.3 give a better overall picture and show that there are similar median Phosphorus levels at all sampling sites.

Table 5.2.
Phosphorus (ppb) Summary Statistics

Site	Mean	Std Dev
1	19.10	17.83
2	13.81	8.25
3	15.83	15.61
4	14.31	10.86
5	10.52	12.54
6	12.61	15.35
7	18.15	22.23
8	16.73	18.62
9	14.96	15.23

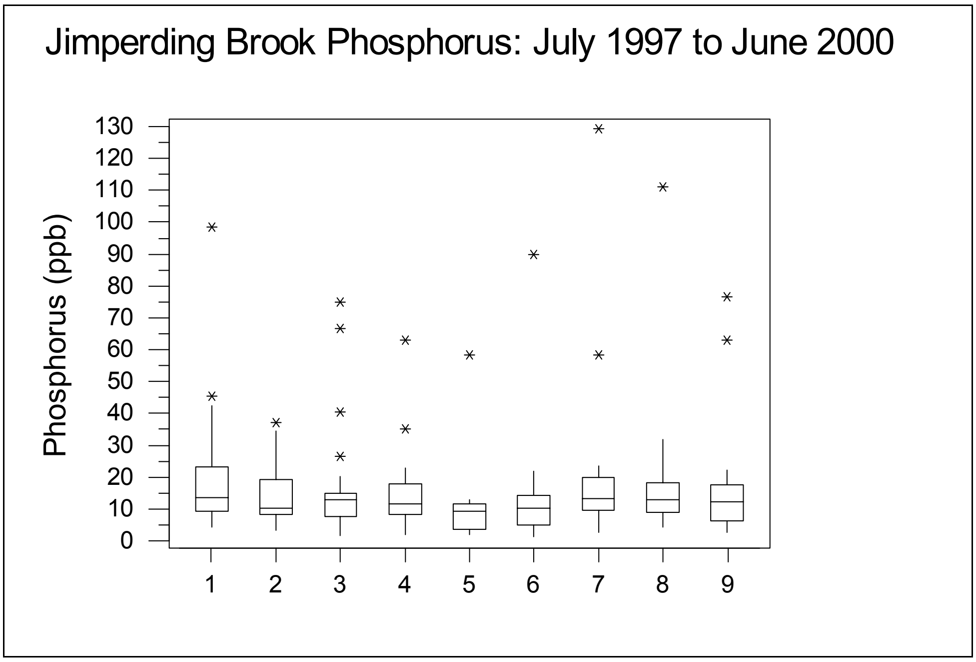

Figure 5.3. Boxplots for Phosphorus: All sites

The Time Series plot for Phosphorus concentration at all sites is shown in Figure 5.4. This shows that the Phosphorous content in the water column was similar at all sites and was characterised by a series of high values occurring after high rainfall. High values were due to sediment becoming suspended as a result of water turbulence. However, despite these obvious peaks, the trend at all sites is one of increasing nutrient levels. The 'spike' in May 1999 corresponded to the first good rain after a dry period following a cyclonic storm in January 1999.

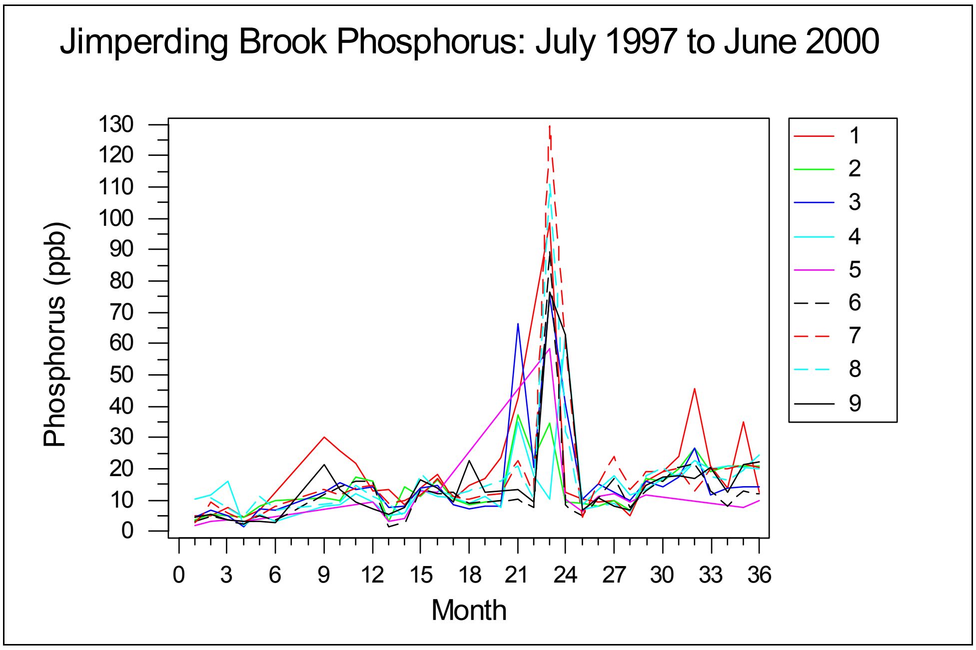

Figure 5.4. Time Series Plot for Phosphorus concentration

Summary means and standard deviations for Electrical Conductivity (EC) in mS/cm for the nine sites are given in Table 5.3.

Table 5.3.
EC (mS/cm) Summary Statistics

Site	Mean	Std Dev
1	1.54	0.49
2	6.02	3.92
3	10.11	3.11
4	10.66	2.87
5	6.27	1.52
6	3.25	1.29
7	9.51	3.34
8	4.55	1.80
9	8.96	3.53

In contrast to pH and Phosphorus concentration, Table 5.3 indicates large differences in average EC values between the nine sampling sites, with Site 1 having a low mean value and Sites 3 and 4 high mean values. The corresponding comparison boxplots for EC are shown in Figure 5.5. Even allowing for outliers, high EC values at Sites 3 and 4 were still apparent, as was the exceptionally low value for Site 1.

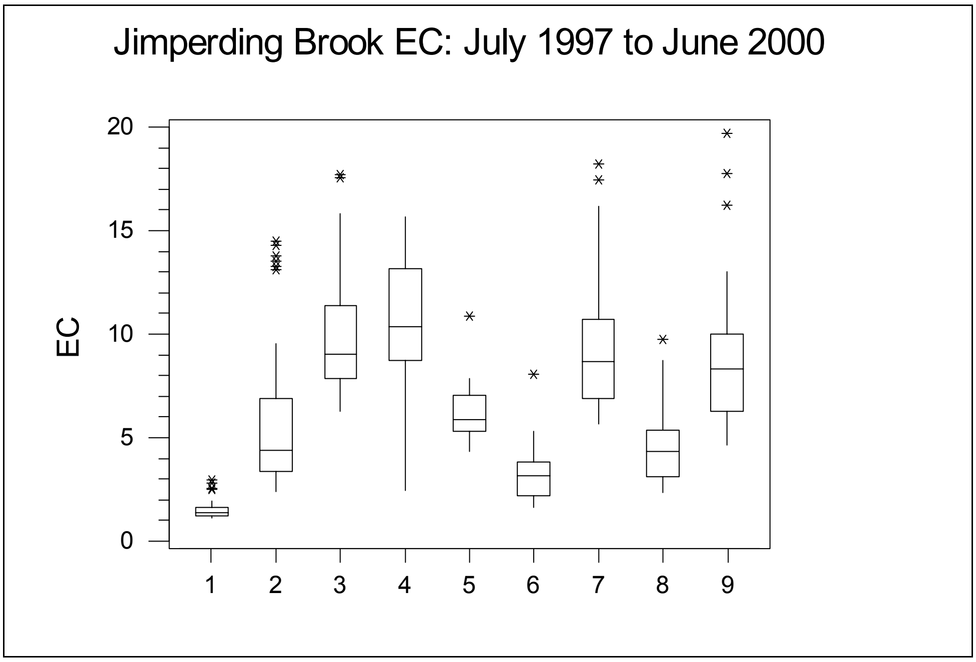

Figure 5.5. Boxplots for EC: All sites

The time series plot for EC is given in Figure 5.6. This shows that electrical conductivity exhibited a seasonal trend, with the amplitude of the variation larger for some sites than for others.

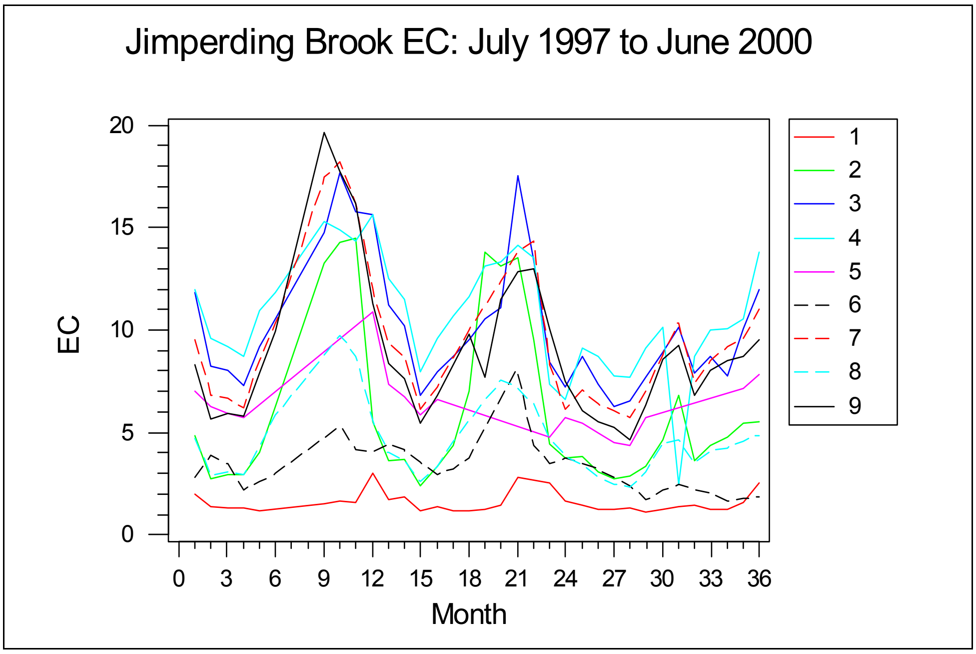

Figure 5.6. Time Series Plot for electrical conductivity

The seasonal variation was a consequence of winter rainfall. The EC values fell during winter and were lowest around October. There is also an apparent trend to lower maximum EC values over the time period considered. Hence the question arises as to whether this is due solely to rainfall variation over the different years. For Site 9, Bloom and Cross (2001) carried out a time series analysis to show that EC varies inversely with rainfall but with a one to two month lag, but that the underlying trend in EC values is not entirely accounted for by rainfall. Because of its location just before the Jimperding Brook joins the Avon River, Site 9 provides a measure of the overall salinity level contributed to the river by this major tributary.

6. CONCLUDING DISCUSSION AND RECOMMENDATIONS

The best overall water quality was found at Site 1. The water here was fresher than at any other site and the water quality varied little throughout the sampling period. This is the only site at which salt content was below the recommended maximum for drinking water. Sites 2, 5, 6 and 8 showed intermediate water quality, while the water quality at Sites 3, 4, 7 and 9 was very poor.

At the intermediate quality sites, particularly Site 6, winter EC values fell to relatively low levels. EC values for Site 2, while generally low in winter, rose sharply during summer making it one of the saltiest sites. Site 3 and Site 4 were the most saline, with high EC levels even in winter and very high EC levels in summer. Sites 7 and 9 (both on Jimperding Brook) were very similar, with maximum EC levels close to those recorded at the worst sites (Sites 3 and 4). This suggests that the contribution of the less saline Jingaling (Site 8) and Gabidine (Site 6) Brooks had little or no mitigating effect on overall water quality. Note that Site 4, which had the highest median EC values, and was therefore the most saline, also had the highest median pH value and also showed the most variability in pH values.

This study has provided essential baseline data against which future changes in water quality can be gauged. There is a clear indication that any real improvement in the quality of the water flowing from the Jimperding Brook into the Avon River must involve a more detailed study of Site 3 and Site 4 and the surrounding catchment area. In addition, further monitoring needs to be carried out to ascertain whether, over time, the salinity and nutrient levels are in fact respectively increasing and decreasing over time.

Recommendation 1
Further investigation is needed into the circumstances contributing to the poor water quality at Site 3 and Site 4. Any remedial measures taken within the catchments should be concentrated on these tributaries since they contribute most of the water and salt content to the brook.

Recommendation 2
Measures should be taken to ensure that there is no deterioration of water quality at Site 1. This site has significantly better water quality than all other sites and can serve as a reference point for remediation measures.

Recommendation 3
Any measures taken to intercept run-off following heavy and possibly unseasonal rainfall will be of great benefit to the brook. This will improve water quality by intercepting the sediment and nutrients before they enter the water course.

7. REFERENCE

Bloom, L. M. and Cross, J. M., (2001). *Salinity and Acidity in the Jimperding Brook in Western Australia.* In MODSIM 2001 International Congress on Modelling and Simulation (eds F. Ghassemi et al) The Modelling and Simulation Society of Australasia, Inc. Canberra, 1961-1965.

APPENDIX 1: pH DATA FOR ALL SITES

Row	Date	pH1	pH2	pH3	pH4	pH5	pH6	pH7	pH8	pH9
1	Jul97	7.14	6.89	7.33	7.74	7.37	7.58	7.98	7.40	8.02
2	Aug97	7.30	7.35	7.46	7.62	7.41	7.52	7.51	7.23	7.37
3	Sep97	7.63	7.13	7.63	8.09	7.72	8.00	8.19	7.90	7.92
4	Oct97	7.43	7.12	7.60	7.84	6.77	7.78	8.05	7.58	7.86
5	Nov97	7.43	7.25	7.77	8.46	*	7.77	7.96	7.43	7.82
6	Dec97	*	7.16	7.59	8.04	*	7.55	7.82	7.48	7.86
7	Jan98	*	*	*	*	*	*	*	*	*
8	Feb98	*	*	*	*	*	*	*	*	*
9	Mar98	6.65	6.98	7.45	7.82	*	*	7.63	*	7.34
10	Apr98	7.55	7.22	7.69	8.24	*	6.89	7.77	6.51	7.56
11	May98	7.32	7.02	7.47	7.66	*	7.08	7.59	6.53	7.41
12	Jun98	7.78	7.24	6.70	7.86	6.73	7.33	7.59	7.34	7.53
13	Jul98	7.61	7.27	7.68	8.06	7.63	7.63	8.02	7.73	7.88
14	Aug98	7.60	7.28	7.83	8.18	7.60	7.63	8.25	7.63	7.85
15	Sep98	7.75	7.31	7.83	7.85	7.64	7.61	7.97	7.62	7.81
16	Oct98	7.75	7.41	7.86	8.23	7.58	7.81	8.34	7.72	8.13
17	Nov98	7.90	7.20	8.01	8.25	*	7.59	8.08	7.40	8.08
18	Dec98	7.60	6.90	7.60	8.42	*	7.35	7.84	7.41	7.89
19	Jan99	7.75	6.90	7.59	7.85	*	*	*	*	7.68
20	Feb99	6.98	6.93	7.44	7.76	*	*	7.66	6.98	7.49
21	Mar99	6.87	7.04	7.49	7.46	*	6.86	7.52	7.15	7.42
22	Apr99	*	7.22	7.60	7.84	*	7.16	7.70	7.40	7.66
23	May99	6.70	6.87	7.08	6.97	7.21	7.16	7.11	7.04	7.18
24	Jun99	7.49	7.17	7.27	7.43	7.59	7.60	7.58	7.50	7.52
25	Jul99	6.98	6.95	7.23	7.53	7.48	7.63	7.71	7.54	7.71
26	Aug99	7.56	7.31	7.45	7.72	7.68	7.93	7.83	7.66	7.92
27	Sep99	7.64	7.36	7.73	8.03	7.83	7.86	6.02	7.90	8.03
28	Oct99	7.67	7.23	7.66	8.03	7.65	7.78	7.86	7.77	7.93
29	Nov99	7.51	7.12	8.34	8.94	7.69	7.91	8.18	8.00	8.03
30	Dec99	7.77	7.27	7.94	8.02	*	7.83	8.01	7.89	7.91
31	Jan00	7.52	7.16	7.63	7.75	*	7.58	7.78	7.50	7.78
32	Feb00	7.53	7.28	7.67	8.08	*	8.05	8.05	7.95	8.08
33	Mar00	7.96	7.37	8.07	8.18	*	7.97	8.04	8.00	8.14
34	Apr00	7.74	7.18	7.89	8.25	*	7.91	7.88	7.76	7.99
35	May00	7.68	7.21	7.73	8.08	7.56	7.87	7.85	7.77	7.95
36	Jun00	7.71	7.39	7.65	7.79	7.76	7.89	7.82	7.65	7.86

Note: The asterisk (*) indicates missing data due to lack of water flow at the relevant site.

APPENDIX 2: PHOSPHORUS CONCENTRATION (ppb) DATA FOR ALL SITES

Row	Date	PHOS1	PHOS2	PHOS3	PHOS4	PHOS5	PHOS6	PHOS7	PHOS8	PHOS9
1	Jul97	4.65	3.50	4.40	10.20	1.85	3.20	2.50	*	4.30
2	Aug97	5.00	5.45	6.60	11.65	3.20	4.90	9.15	10.50	5.10
3	Sep97	7.30	4.65	5.05	16.00	3.70	3.40	5.95	7.55	3.70
4	Oct97	4.40	4.40	1.50	1.90	3.20	2.35	3.20	4.40	3.20
5	Nov97	6.50	8.15	6.90	5.30	*	4.85	5.25	11.10	3.20
6	Dec97	*	9.65	6.65	3.00	*	3.50	7.75	6.80	2.50
7	Jan98	*	*	*	*	*	*	*	*	*
8	Feb98	*	*	*	*	*	*	*	*	*
9	Mar98	30.25	10.80	12.55	8.10	*	*	13.40	*	21.40
10	Apr98	25.80	9.60	15.50	8.40	*	14.30	11.40	9.30	13.19
11	May98	21.85	17.10	13.40	12.15	*	16.05	13.70	14.50	9.25
12	Jun98	12.90	16.10	13.95	9.25	*	15.55	14.80	11.10	7.15
13	Jul98	13.30	3.20	7.55	4.65	3.20	1.30	8.95	9.00	5.10
14	Aug98	8.50	14.25	8.00	5.60	3.80	2.70	9.90	4.65	7.55
15	Sep98	13.50	11.25	13.75	13.25	13.00	13.50	11.50	18.25	16.25
16	Oct98	18.25	16.50	14.50	11.00	12.25	11.75	16.75	13.00	13.50
17	Nov98	10.30	10.05	8.35	10.40	*	12.35	11.20	11.45	9.30
18	Dec98	14.40	8.35	7.10	8.90	*	8.90	10.20	12.95	22.35
19	Jan99	17.00	9.40	7.85	11.15	*	*	*	*	12.25
20	Feb99	23.60	9.65	7.75	7.50	*	*	12.15	16.00	12.65
21	Mar99	42.50	37.00	66.50	35.00	*	10.05	22.75	20.65	13.35
22	Apr99	*	23.50	20.35	17.90	*	7.70	12.35	10.10	9.50
23	May99	98.50	34.50	75.00	10.00	58.50	90.00	129.50	111.00	76.50
24	Jun99	12.40	9.15	40.50	63.00	10.35	8.30	58.50	32.00	63.00
25	Jul99	10.05	8.65	10.10	8.35	6.25	4.90	4.45	7.10	6.45
26	Aug99	9.20	7.85	14.90	13.05	11.20	10.40	14.65	7.95	10.50
27	Sep99	9.65	9.60	12.50	17.50	11.90	16.70	23.70	8.80	8.00
28	Oct99	5.00	6.65	9.80	11.65	9.15	7.65	13.10	6.10	6.45
29	Nov99	15.75	16.60	15.95	13.40	11.35	12.95	18.85	17.70	14.75
30	Dec99	19.05	15.95	14.30	16.60	*	15.95	18.85	20.25	17.30
31	Jan00	24.00	20.00	17.25	18.00	*	20.50	20.00	16.75	17.75
32	Feb00	45.50	26.50	26.50	22.75	*	21.75	12.75	22.00	17.00
33	Mar00	21.00	19.00	11.50	20.00	*	13.00	20.00	17.50	20.50
34	Apr00	13.90	20.95	13.85	20.75	*	7.90	20.00	16.25	12.40
35	May00	34.85	20.70	14.00	20.45	7.50	12.70	21.40	19.30	21.10
36	Jun00	12.45	20.90	14.00	19.75	9.75	11.85	20.45	24.50	22.30

Note: The asterisk (*) indicates missing data due to lack of water flow at the relevant site.

APPENDIX 3: ELECTRICAL CONDUCTIVITY (mS/cm) DATA FOR ALL SITES

Row	Date	EC1	EC2	EC3	EC4	EC5	EC6	EC7	EC8	EC9
1	Jul97	1.96	4.82	11.84	11.97	6.99	2.81	9.50	4.70	8.30
2	Aug97	1.38	2.71	8.26	9.61	6.29	3.85	6.79	2.88	5.67
3	Sep97	1.26	2.93	8.05	9.18	5.94	3.45	6.68	3.04	5.89
4	Oct97	1.31	2.91	7.28	8.68	5.73	2.21	6.21	2.91	5.80
5	Nov97	1.14	3.99	9.19	10.95	*	2.58	8.52	4.38	7.90
6	Dec97	*	6.24	10.55	11.87	*	3.00	10.36	5.84	9.95
7	Jan98	*	*	*	*	*	*	*	*	*
8	Feb98	*	*	*	*	*	*	*	*	*
9	Mar98	1.47	13.25	14.74	15.29	*	*	17.46	*	19.67
10	Apr98	1.65	14.29	17.71	14.89	*	5.32	18.23	9.75	17.75
11	May98	1.58	14.51	15.81	14.38	*	4.16	16.16	8.74	16.21
12	Jun98	2.98	5.51	15.68	15.66	10.87	4.03	12.02	5.59	11.26
13	Jul98	1.67	3.61	11.23	12.51	7.38	4.44	9.33	3.98	8.36
14	Aug98	1.81	3.68	10.22	11.51	6.73	4.12	8.69	3.62	7.62
15	Sep98	1.19	2.40	6.77	7.94	5.82	3.54	6.14	2.58	5.42
16	Oct98	1.33	3.30	7.96	9.57	6.60	2.94	7.20	3.31	6.79
17	Nov98	1.18	4.35	8.74	10.65	*	3.23	8.66	4.58	8.32
18	Dec98	1.18	7.03	9.51	11.63	*	3.74	9.97	5.53	9.77
19	Jan99	1.21	13.80	10.52	13.11	*	*	*	*	7.68
20	Feb99	1.41	13.13	11.10	13.33	*	*	12.40	7.57	11.47
21	Mar99	2.79	13.52	17.54	14.13	*	8.07	13.82	7.21	12.85
22	Apr99	*	9.53	13.42	13.56	*	4.34	14.33	6.38	12.99
23	May99	2.50	4.39	8.41	7.34	4.77	3.50	8.32	4.65	10.10
24	Jun99	1.63	3.72	7.24	6.59	5.73	3.72	6.10	3.82	7.51
25	Jul99	1.41	3.78	8.68	9.10	5.45	3.51	7.08	3.42	6.08
26	Aug99	1.25	3.08	7.38	8.68	4.97	3.17	6.37	2.82	5.51
27	Sep99	1.20	2.74	6.27	7.74	4.52	2.80	6.08	2.45	5.21
28	Oct99	1.26	2.83	6.52	7.71	4.32	2.38	5.68	2.34	4.64
29	Nov99	1.11	3.36	7.71	9.10	5.69	1.69	7.01	3.04	6.35
30	Dec99	1.25	4.64	8.88	10.13	*	2.17	8.77	4.45	8.57
31	Jan00	1.34	6.81	10.17	2.43	*	2.43	10.37	4.61	9.28
32	Feb00	1.44	3.63	7.88	8.74	*	2.21	7.40	3.49	6.78
33	Mar00	1.22	4.32	8.73	9.97	*	2.03	8.50	4.09	8.05
34	Apr00	1.20	4.78	7.74	10.04	*	1.65	9.18	4.25	8.51
35	May00	1.56	5.46	10.06	10.54	7.17	1.79	9.57	4.57	8.73
36	Jun00	2.53	5.48	11.94	13.80	7.85	1.82	11.05	4.86	9.54

Note: The asterisk (*) indicates missing data due to lack of water flow at the relevant site.

APPENDIX 4: TEMPERATURE (°C) DATA FOR ALL SITES

Row	Date	TEMP1	TEMP2	TEMP3	TEMP4	TEMP5	TEMP6	TEMP7	TEMP8	TEMP9
1	Jul97	5.40	5.65	8.43	8.08	7.83	7.28	7.85	7.88	8.70
2	Aug97	8.78	10.00	12.05	10.88	10.15	9.63	10.50	11.48	10.98
3	Sep97	14.10	15.28	16.50	15.80	14.90	13.90	14.43	15.68	14.78
4	Oct97	16.23	16.35	19.85	19.65	19.48	17.30	18.55	19.73	18.28
5	Nov97	17.23	17.13	20.65	20.83	*	18.08	18.53	21.45	19.20
6	Dec97	*	23.60	27.48	28.40	*	23.98	24.80	29.10	24.73
7	Jan98	*	*	*	*	*	*	*	*	*
8	Feb98	*	*	*	*	*	*	*	*	*
9	Mar98	23.73	22.90	23.98	26.18	*	*	22.98	*	25.23
10	Apr98	16.38	16.50	17.35	18.58	*	16.83	17.30	18.08	17.55
11	May98	15.33	15.05	16.00	16.30	*	15.93	16.28	16.48	16.30
12	Jun98	7.45	8.30	9.35	9.73	10.45	9.98	9.53	9.40	9.85
13	Jul98	9.03	10.13	11.95	11.43	10.83	10.20	10.73	10.83	10.68
14	Aug98	12.65	14.00	16.45	15.63	13.93	13.10	14.25	14.63	13.85
15	Sep98	11.38	13.95	15.75	15.00	13.08	12.05	13.75	13.48	12.90
16	Oct98	11.90	13.58	16.30	16.40	15.10	16.63	15.95	16.95	16.03
17	Nov98	19.43	19.23	21.60	2.55	*	20.00	21.08	23.50	21.18
18	Dec98	23.98	24.00	27.13	27.90	*	24.65	25.93	28.55	26.38
19	Jan99	19.93	20.03	21.75	22.70	*	*	*	*	23.73
20	Feb99	22.38	23.40	23.20	26.65	*	*	23.38	24.03	24.73
21	Mar99	19.83	19.70	20.80	20.80	*	20.75	21.00	20.08	21.43
22	Apr99	*	18.63	19.60	22.05	*	19.88	19.80	21.40	20.68
23	May99	15.60	15.73	16.40	16.40	16.55	16.65	16.43	16.68	17.03
24	Jun99	11.85	12.58	13.73	13.03	13.13	13.30	13.23	13.50	13.68
25	Jul99	11.33	11.63	12.95	12.53	12.50	12.80	12.78	13.10	13.28
26	Aug99	8.60	8.63	10.33	9.93	9.83	10.50	10.40	10.43	10.93
27	Sep99	13.58	15.40	19.60	18.00	17.93	16.63	17.10	17.98	17.25
28	Oct99	13.45	13.80	15.38	15.48	15.03	15.70	15.80	16.58	16.95
29	Nov99	19.60	20.15	23.55	22.23	22.58	22.75	22.23	23.00	22.88
30	Dec99	23.70	24.40	28.53	27.00	*	25.58	25.58	25.53	24.03
31	Jan00	20.88	19.85	20.63	20.88	*	22.08	21.85	20.60	22.43
32	Feb00	23.90	23.58	26.38	26.00	*	26.10	25.38	26.85	26.13
33	Mar00	19.88	20.03	22.50	21.98	*	22.05	21.35	22.35	21.53
34	Apr00	16.73	15.88	18.90	18.60	*	17.55	17.15	18.80	17.83
35	May00	12.98	12.45	16.38	15.40	14.73	14.45	14.70	15.73	15.03
36	Jun00	11.30	10.20	13.75	12.63	12.65	12.48	12.55	13.13	13.05

Note: The asterisk (*) indicates missing data due to lack of water flow at the relevant site.