Institute of Freshwater Ecology

Water Quality Monitoring on the Rivacre Brook, Cheshire

FINAL REPORT

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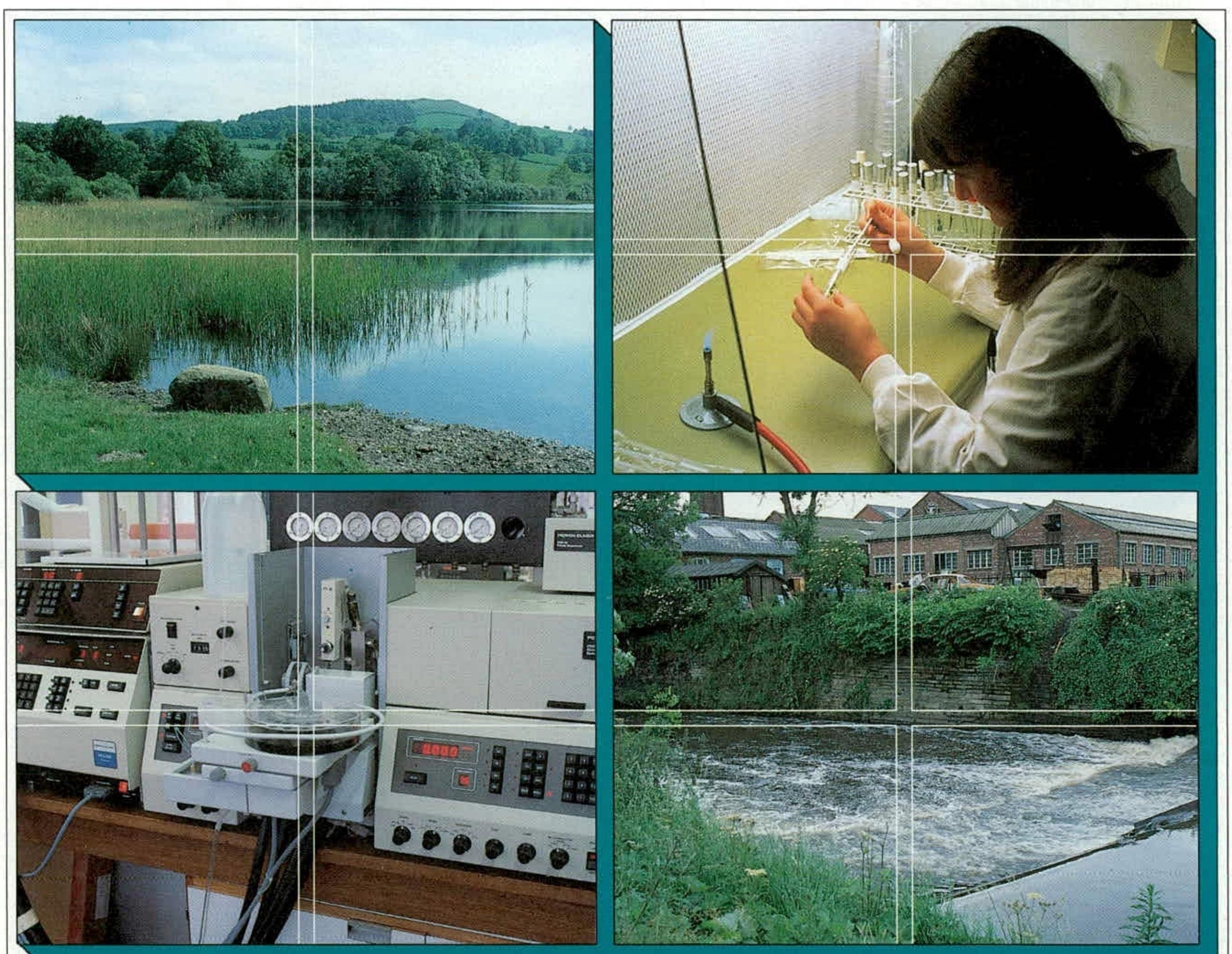
September 1993



Natural Environment Research Council

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Monitoring of water quality using macroinvertebrate animals at selected sites on the Rivacre Brook, The Wirral, Cheshire.

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Contract start date: September 91
Report date: September 93
Report to: British Nuclear Fuels plc, Capenhurst
TFS Project No: T11053q1
IFE Report Ref No: ERL/T11053q1/4

CONTENTS

1. Summary

The report describes the invertebrate freshwater fauna at five sites on the Rivacre Brook system. Three sites (stations 1-3) are immediately downstream from BNFL Capenhurst, one (station 6) is on an adjacent stream, the last (station 9) is below the confluence of these streams, in an urban area. The invertebrate communities are compared with predictions based on chemical and physical attributes at each site.

This report refers extensively to previous work on water quality and freshwater invertebrates, undertaken for BNFL at the same (and adjacent) sites (Gledhill,1990).

Over the duration of the monitoring period (1989-1993) the invertebrate communities (all stations) showed no clear trend that could be attributed to improving or worsening conditions in the Rivacre Brook system.

Lack of habitat diversity is considered to limit faunal diversity, particularly at stations 1-3. Some possible modifications to enrich and broaden the freshwater invertebrate fauna are suggested.

It is recommended (under current circumstances of reduced industrial activity at Capenhurst) that:

1) any future monitoring resumes prior to major new discharges to Rivacre Brook from BNFL.

2) careful consideration is given before reducing the release of pumped water from the R.Dee by BNFL, as the downstream sampling point (in an urban area) is considered to be at risk from sources of pollution beyond BNFLs control, or responsibility.

2. Introduction

2.1. Background to the project.

The Institute of Freshwater Ecology was contracted by British Nuclear Fuels (BNFL), Capenhurst, to investigate aspects of water quality in the Rivacre Brook system (Gledhill, 1990). The tributary of the brook draining the BNFL site has four main sources:

a) industrial effluent from the Capenhurst site.

b) effluent from an on-site sewage treatment plant.

c) surface water run-off from the site.

d) River Dee water, which is pumped to, and held on site.

(The above components are combined prior to discharge from the site.)

The initial investigation (Gledhill,1990) followed local complaints of an unpleasant odour from the Rivacre Brook some distance downstream of the Capenhurst site. It was established that although water quality was generally poor at all sampling stations, a deterioration associated with inputs downstream from the Capenhurst site was the most likely source of odour problems.

2.2 Aims of the project.

In April 1991 at the Windermere Laboratory (Institute of Freshwater Ecology) it was agreed that a continued, but reduced, programme of water quality monitoring using freshwater macroinvertebrates was desirable. At the same time data on a number of physical and chemical parameters would be obtained. This second phase of monitoring was to cover the period autumn 1991 to spring 1993.

OBJECTIVES

1) to provide a continued biological assessment of water quality (using freshwater invertebrates) in the Rivacre Brook system, at stations 1,2,3,9, (and a new station 6)(Figure 1).

2) to assess and interpret any temporal changes detected in invertebrate communities.

Interim reports (1-3) were submitted after each of the first three sampling occasions, their tabulated data is combined in this final report with results from spring 1993.

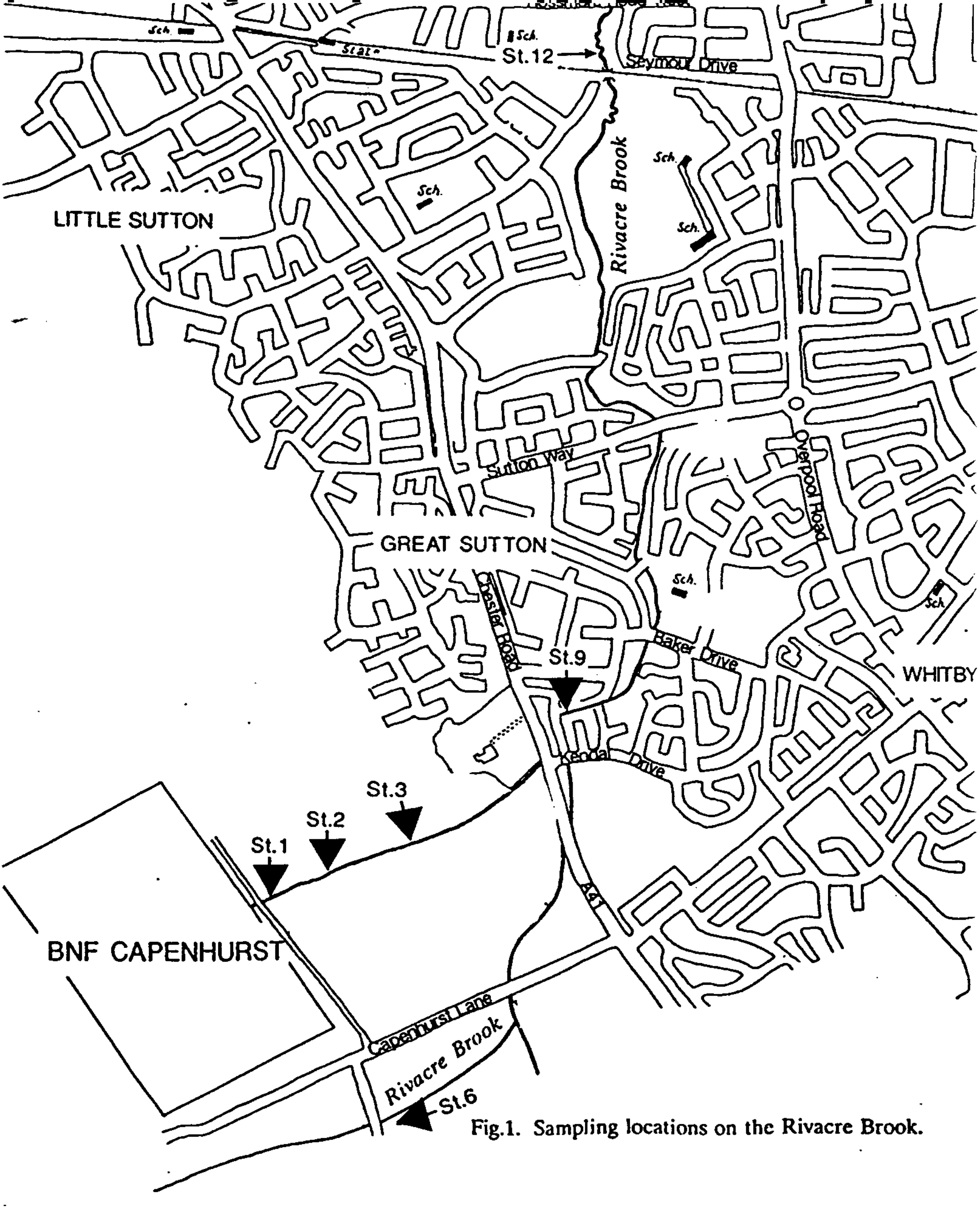

Fig.1. Sampling locations on the Rivacre Brook.

3). Methods

3.1 Sampling sites.

The following grid references for the sampling stations were obtained from Ordnance Survey Sheet SJ 27/37, Pathfinder 756, Ellesmere Port (West) 1:25000.

Station 1.	SJ 370.50/745.75
Station 2.	SJ 373.00/746.50
Station 3.	SJ 374.50/746.75
Station 6.	SJ 374.00/739.00
Station 9.	SJ 379.00/749.50

Stations 1-3 are in a steep-sided channel (ca. 2.5 m deep), crossing open arable fields. These sampling points are heavily shaded by overhanging trees and brambles along the channel margin. Water depth is predominately shallow (10-25cm). Substrates range from the occasional large stone, some gravel and coarse sand to fine sand, silt and clay in the slowest flowing areas. Organic detritus, derived from decomposing leaves, is frequently present, while aquatic plants are generally absent.

Station 6 was relocated at the start of the monitoring programme, as the original site beside Capenhurst Lane (location map, Gledhill,1990) was subject to drying out. The new station 6 (Figure 1) is situated upstream beside the next road bridge (National Grid Reference SJ 374 739). The site is shaded by oak trees, the stream bed is predominately covered with fine sediment and dead leaves with some discarded scrap metal and plastic acting as surrogate boulders.

Station 9, below the confluence of Rivacre Brook (station 6) and the stream from the Capenhurst site (stations 1-3), is situated in an urban area (Figure 1). At the sampling point the stream emerges from a roadside culvert, with associated discharge pipes. Partial shading is provided by a garden hedge to the south, while the banks are reinforced with paving slabs and some aquatic vegetation has become established since the initial survey (Gledhill, 1990). The presence of unpleasant odours and turbid discharges from a pipe were observed on most sampling occasions.

3.2 Sampling technique.

Prior to the disturbance caused by invertebrate sampling, a one litre water sample was obtained for subsequent chemical analysis. A 3 minute kick sample of invertebrates was taken at each station using a pond net of 1 mm mesh. Sampling time was subdivided between habitats in proportion to their extent at each site. The cumulative sample at each station was transferred to a labelled polythene bag. In the laboratory, each sample was washed thoroughly through two sieves (1000 and 250 µm, respectively) and the fractions retained on the sieves sorted in a white tray of water. All invertebrates were removed and preserved in 70 % alcohol prior to identification and counting.

3.3 Sampling frequency.

As some animals are not present at a site throughout the year it is advantageous to take at least two series of samples per year. The present monitoring exercise repeated the six monthly visits undertaken by Gledhill (1990). Samples were obtained from the Rivacre Brook system in spring and autumn (September 91, March & September 1992 and March 1993).

3.4 <u>Physical and chemical parameters</u>.

On each sampling occasion and from each site, the following physical variables were estimated:-

Stream width in sample area.

Water depth at 1/4, 1/2 and 3/4 width.

Surface velocity in the channel (as cm sec^{-1}).

Substratum composition e.g. percentage boulders, cobbles, pebbles, gravel, sand and silt.

Water clarity.

Presence of and percentage cover given by algae, moss and higher plants.

The water samples were analysed for ammonia, soluble reactive phosphorus, total oxidised nitrogen, total alkalinity (as calcium carbonate), dissolved organic carbon, conductivity, chloride and pH.

Some of these physical and chemical variables have been used for the prediction of taxa which would occur at each site, given "pristine" conditions (section 4.5).

4. Results and interpretation

4.1 Chemistry

General Comments

Wide variations in the chemical data occurred during the monitoring period and, more significantly, between the closely adjacent sampling stations, 1,2 and 3. The initial monitoring investigation (Gledhill,1990) interpreted some between-station differences as indicative of additional inputs (between stations 3 and 4), but it is now apparent that rapid changes in some ionic components occur in the BNFL effluent. Consequently it is not appropriate to interpret trends in water quality, without reference to more frequently collected data. It also follows that these single, spot samples cannot be assumed to describe the average conditions pertaining. This should be borne in mind when the values are compared.

For the new station 6, no earlier comparisons are possible.

Table 1 shows the results of chemical analyses of water samples taken from each site on each sampling occasion [including the directly comparable initial data set, (Gledhill,1990)].

Ammonia

At most stations concentrations of ammonia (as N) rose after 1990 (Table 1). The un-ionised form is considered toxic to fish and invertebrates (Alabaster & Lloyd,1980), but generally not at the highest recorded values from stations 1,2,3 and 9. At station 6 (Fig. 1), the ammonia concentrations were considerably higher

Table 1. Water chemistry data* for Rivacre Brook over the period 1989-1993. (Location of numbered Stations - see Figure 1; Sp - spring, Au - autumn; concentrations expressed as milligrams per litre, except pH (pH units) and conductivity (microsiemens per centimeter).

Station - Date	Ammonia NH3.N mg l^{-1}	Total Oxidised Nitrogen mg l^{-1}	Soluble Reactive Phosphorus mg l^{-1}	Chloride Cl mg l^{-1}
1 - Sp 93	<.005	5.34	0.143	61.1
1 - Au 92	0.237	3.77	0.153	38.6
1 - Sp 92	0.256	5.81	0.677	120.5
1 - Au 91	0.336	3.34	0.532	64.8
1 - Sp 90	0.092	3.96	0.457	62.0
1 - Au 89	0.162	3.31	0.356	50.9
1 - Sp 89	0.007	3.70	0.593	67.2
2 - Sp 93	0.053	5.27	0.194	49.3
2 - Au 92	0.153	3.36	0.188	93.2
2 - Sp 92	0.198	5.39	0.682	33.7
2 - Au 91	0.135	2.44	0.348	81.7
2 - Sp 90	0.081	3.72	0.470	59.9
2 - Au 89	0.090	3.89	0.400	53.0
2 - Sp 89	0.006	2.87	0.515	74.1
3 - Sp 93	0.031	4.41	0.108	49.0
3 - Au 92	0.274	3.67	0.108	299.4
3 - Sp 92	0.204	5.98	0.637	32.2
3 - Au 91	0.330	3.69	0.511	75.2
3 - Sp 90	0.069	3.49	0.450	61.0
3 - Au 89	0.051	4.33	0.416	53.1
3 - Sp 89	0.008	3.13	0.504	77.5
6 - Sp 93	2.835	4.17	6.383	73.8
6 - Au 92	1.054	4.74	8.939	59.5
6 - Sp 92	0.063	23.58	1.403	62.5
6 - Au 91	0.032	4.99	10.060	67.3
9 - Sp 93	0.247	3.77	0.342	43.3
9 - Au 92	0.132	2.84	0.292	172.3
9 - Sp 92	0.154	4.63	0.408	27.2
9 - Au 91	0.471	3.25	0.678	66.5
9 - Sp 90	0.228	3.09	0.630	201.2
9 - Au 89	0.050	2.63	0.586	261.0
9 - Sp 89	0.085	2.90	0.656	46.7

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Table 1 (conti.)

Station - Date	Alkalinity as $CaCO_3$ mg l^{-1}	Dissolved Organic Carbon mg l^{-1}	Conductivity uS cm^{-1} at 25oC	pH units
1 - Sp 93	60.45	4.09	552	7.2
1 - Au 92	40.40	3.29	410	7.1
1 - Sp 92	72.00	4.23	702	9.2
1 - Au 91	45.95	3.55	460	7.3
1 - Sp 90	77.35	3.26	-	-
1 - Au 89	56.90	-	-	-
1 - Sp 89	-	3.35	-	-
2 - Sp 93	73.55	4.77	533	7.4
2 - Au 92	43.75	3.33	572	7.2
2 - Sp 92	49.20	3.16	372	7.4
2 - Au 91	43.70	3.79	490	7.3
2 - Sp 90	78.85	3.43	-	-
2 - Au 89	56.30	-	-	-
2 - Sp 89	-	3.43	-	-
3 - Sp 93	72.95	4.22	519	7.4
3 - Au 92	37.20	3.38	1100	7.1
3 - Sp 92	48.00	3.35	370	7.4
3 - Au 91	43.45	4.00	487	7.3
3 - Sp 90	80.60	3.51	-	-
3 - Au 89	53.75	-	-	-
3 - Sp 89	-	3.44	-	-
6 - Sp 93	206.35	14.86	753	7.6
6 - Au 92	150.95	9.65	668	7.4
6 - Sp 92	135.70	10.72	833	7.4
6 - Au 91	137.30	9.55	722	7.6
9 - Sp 93	80.70	4.29	462	7.6
9 - Au 92	48.70	3.61	737	7.4
9 - Sp 92	60.80	4.71	369	7.5
9 - Au 91	52.35	4.45	465	7.5
9 - Sp 90	81.75	3.97	-	-
9 - Au 89	66.25	-	-	-
9 - Sp 89	-	4.38	-	-

on two occasions (Table 1), this is considered to be indicative of intermittent pollution from sources other than the BNFL Capenhurst site.

Total Oxidised Nitrogen

Very similar concentrations were recorded between stations and sampling dates, with the exception of station 6 (spring 1992), when an exceptionally high value was recorded. Other contemporary determinands were not exceptional. No explanation is apparent.

Phosphorus

The values for solouble reactive phosphate in Table 1 should be compared with "Phosphate-P" rather than "Total Phosphate", in Gledhill's (1990) report. Concentrations in general were similar with the new station 6 clearly comparatively "enriched" to a much greater extent.

Chloride

The most recent values for chloride have been more variable but are within a range of concentrations that can be tolerated by most freshwater invertebrates.

Calcium Carbonate

No clear changes over time are apparent, but comparatively high values were recorded from station 6 and a generally higher value was recorded in spring samples. No explanation is apparent.

Dissolved Organic Carbon

Concentrations were generally similar between stations 1,2,3 and 9, but station 6 had higher and more variable DOC concentrations.

Conductivity

Measurements confined to the recent monitoring period. Fairly wide fluctuations were noted, with a maximum of 1100uS at station 3 (corresponding with a chloride maximum).

pH

Measurements were confined to the recent monitoring period. Generally, pH was remarkably stable at all stations, with a single high value (9.2) at station 1 in spring 1992. This coincided with maxima for DOC, conductivity, phosphorus, TON and chloride at this station.

4.2 Faunal composition.

The invertebrate data from the current monitoring period are presented in Appendices 1-20. The following interpretation also draws on the data from the previous report (Gledhill,1990).

The common and widespread taxa.

Changes in the numbers of some common and widespread taxa recorded in the Rivacre Brook system are presented in Table 2.

Oligochaeta (worms)

- The changes in numbers of worms recovered at each station

Table 2. Trends in invertebrate numbers in Rivacre Brook (for the most numerous taxa) over the period 1989-1993. Data for each site derived from three minute pondnet samples, utilising all major habitats present.

Taxa	Spring				Autumn		
	1989	1990	1992	1993	1989	1991	1992
Oligochaeta (worms)							
Station 1	277	44	73	108	81	2615	411
Station 2	122	15	21	117	20	394	210
Station 3	103	16	74	78	10	16	80
Station 6	-	-	69	47	-	57	19
Station 9	174	30	92	37	324	6	95
Asellus aquaticus (hoglouse)							
Station 1	0	0	24	243	0	1118	403
Station 2	2	5	21	322	12	1395	384
Station 3	2	4	74	656	21	910	440
Station 6	-	-	866	598	-	3812	6204
Station 9	178	19	1134	538	411	1732	1079
Crangonyx pseudogracilis (shrimp)							
Station 1	13	0	8	229	13	148	579
Station 2	10	29	2	222	53	116	78
Station 3	19	29	31	290	40	31	83
Station 6	-	-	1	4	-	26	9
Station 9	35	16	158	34	101	25	39
Snails (combined)							
Station 1	7	19	0	3	150	1	19
Station 2	47	31	0	1	99	0	1
Station 3	313	11	1	4	84	2	0
Station 6	-	-	0	66	-	0	0
Station 9	124	15	44	1	82	4	1107*

* 1100 - a single species - (*Potamopyrgus jenkinsi*)

Taxa	Spring				Autumn		
	1989	1990	1992	1993	1989	1991	1992
Chironomidae (non-biting midge larvae)							
Station 1	9	6	99	97	2	30	107
Station 2	66	25	128	161	3	16	33
Station 3	145	13	88	151	3	14	17
Station 6	-	-	272	385	-	167	195
Station 9	115	20	266	143	38	52	22

followed no clear pattern during the monitoring period. Interpretation of changes in total numbers is also hampered by the possibility of wide fluctuations in species composition, an investigation of which was outside the remit of this study.

Asellus aquaticus (Hoglouse or slater)

- this was the most common invertebrate species recorded in the latter period of monitoring and showed a consistent increase in numbers at all stations. This may reflect a long-term improvement in conditions favouring this species, or it could be the result of reduced predation pressure (eg loss/reduction of some leeches).

Crangonyx pseudogracilis (a shrimp)

- Crangonyx pseudogracilis, is a widespread and increasingly common freshwater shrimp, introduced from N.America (Gledhill, Sutcliffe and Williams,1976). Comparatively low numbers were present at station 1, while populations increased in size at other stations. It is possible that a limited upstream migration of this active swimmer, has occurred.

Mollusca

- A combined range of species showed an overall decline in numbers during the whole of the monitoring period (Table 2), although numbers were erratic at some stations. This decline could not be attributed to any detected changes in water quality and no between-species interactions could explain the decline.

Flatworms

There has been a shift in dominance from Dugesia sp, in 1989/90 and October 1991, to Polycelis sp in some recent samples. No explanation for this is apparent, though changes in prey availability may favour Polycelis sp.

Leeches

Initially a more restricted range of species was present, with Glossiphonia complanata rarely found. At station 1 leeches were frequently absent. The increase in G. complanata may similarly be caused by changing prey availability.

Gastropod molluscs

Lymnaea peregra, a generally widespread and common pond snail, was numerous at all stations in 1989/90, but absent or present in low numbers on later sampling dates.

Potamopyrgus jenkinsi, a species prone to rapid population changes, was absent at stations 1-3 on the last 3 sampling dates, but present on the first three dates.

Ancylus fluviatilis (freshwater limpet), was common in 1989 but declined in 1990 and was absent in 1991. Single individuals were recorded at two stations in spring 1993.

Physa fontinalis, was present in small numbers at most stations in 1989 but absent through 1990, 1991, and from stations 1-3 in 1992.

Chironomidae (non-biting midge larvae)

- A large number of short-lived, chironomid species is known to occur in small streams. The comparatively stable numbers recorded are likely to be masking rises and falls in the numbers of particular species (see 3., seasonal trends).

The taxa of restricted occurrence.

A range of insects with winged adults, including beetles and bugs, have occurred infrequently at each site (Table 3). This intermittent presence causes instability in BMWP scores used in water quality assessment. However, the occasional presence of such species is indicative of the potential for successful colonisation by these mobile taxa, when water quality permits.

The intermittent occurrence of other freshwater invertebrates (Appendices 1-20) may be attributal to downstream drift, active upstream migration or transportation by other mobile fauna, depending on the particular characteristics of the taxon in question.

Interpretation of changes in faunal composition (inc. Gledhill,1990).

1) General changes, in addition to those discussed above and shown in Table 2. Data for station 6 are restricted to autumn 1991 onwards.

Table 3. Infrequent and site-restricted taxa, recorded from the Rivacre Brook system (1989-1993). Stations and number of times taxon recorded indicated (max 4 for station 6, max 7 for other stations).

Taxon	station (occasions recorded)				
Baetidae (mayfly)					9(2)
Caenidae (mayfly)				6(1)	
Dytiscidae (water beetle)	1(1)			6(2)	9(3)
Haliplidae (water beetle)					9(1)
Corixidae (water boatmen)	1(1)				9(1)
Velidae (water cricket)					9(1)
Tinodes waeneri (caddis larva)		2(2)	3(1)		9(3)
Limnephilidae (caddis larva)		2(1)		6(1)	9(1)
Simuliidae (black fly)			3(2)		9(5)
Tipulidae (true fly)		2(2)	3(2)		9(2)

Bivalve molluscs

Numbers of Pisidium species (pea mussels) fell in spring 1992, there was some recovery at stations 1 & 2 (autumn 1992 & spring 1993). Identification to species level was available for the last 4 dates and the broadest range of species was noted at station 1 (Table 4). This pattern of species distribution is suggestive of colonisation via the R.Dee water supply (see site specific changes).

2) Site-specific changes

Station 1

Increased siltation is evident at this site, resulting in the temporary loss (burial) of the relatively small area of pebbles and gravel. No changes to the fauna can be attributed solely to this, but some taxa such as leeches, are frequently associated with the underside of stones.

Colonisation by Asellus may have occurred downstream, via the R.Dee supply or upstream by active migration against the flowing water.

The changing broad range of Pisidium (pea mussel) species (Table 4) at this most upstream site indicates transfer from the R.Dee (pumped on site for dilution/supply purposes). This is supported by the observation that P.henslowanum generally occurs in large rivers and lakes, rather than small streams. Also, Pisidium are incapable of active upstream migration against a significant flow of water.

Table 4. Pisidium spp (Pea mussels): general distribution between stations (in sequence - Autumn 91, Spring 92, Autumn 92, Spring 93), with contrasting numbers found at stations 1 and 2. For other stations, presence/absence (+/-) is recorded.

Pisidium spp -	subtr-uncatum	hensl-owanum	caser-tanum	perso-natum	nitidum
Station 1	34,0,50,12	6,1,0,0	0,0,5,8	2,0,7,7	49,0,13,3
Station 2	0,0,11,2	0,0,0,0	0,0,4,2	0,0,0,1	1,0,6,0
Station 3	-,-,-,+	-,-,-,-	+,-,-,-	-,-,-,-	-,-,-,-
Station 6	-,-,-,-	-,-,-,-	-,-,-,-	+,?,-,-	-,-,-,-
Station 9	-,+,-,+	-,-,-,+	-,-,-,-	-,-,-,-	-,-,-,+

In common with the pea mussels, the oligochaeta are largely confined to fine sediments. The comparatively high percentage cover of sand, silt and clay at this station (Table 5) may account for correspondingly high numbers of these taxa.

Station 2

Of the most common taxa recorded, the Chironomidae (midge larvae) were more numerous than at station 1 (Table 2), in spring samples, while bivalve molluscs were fewer in number and species (Table 4). Other taxa showed similar variations to those observed at other stations.

Station 3

There were no striking contrasts with station 2, in terms of macroinvertebrates. These three sites (stations 1,2 & 3) generally had a smaller range of taxa, when compared with station 9, downstream.

Station 6

The data are limited to the current monitoring period (four occasions, autumn 1991-spring 1993). The fauna was strongly dominated by large numbers of Asellus. Snails were absent except in spring 1993. The range of fauna was as restricted as that noted for stations 1-3.

Station 9

Of the common taxa, the gastropod molluscs (snails) showed a similar decline to that noted for stations 1-3 (with the exception of a very large number of Potamopyrgus jenkinsi, in

Table 5. Percentage cover of stream bed substrate types and plant cover for Rivacre Brook sampling stations, over the period 1989-1993. Cover was estimated over about 10m at each site.

Substrate and vegetation cover (%).

STATION	DATE	Boulder/ Cobble	Pebble/ Gravel	Sand	Silt/ Clay	Algal cover	Macro- phyte
1.	Sp. 93	-	-	60	40	70	-
	Au. 92	-	5	5	90	-	-
	Sp. 92	-	5	20	75	-	-
	Au. 91	-	10	70	20	-	-
	Sp. 90	-	10	60	30	-	-
	Au. 89	-	10	60	30	-	-
	Sp. 89	-	10	60	30	-	-
2.	Sp. 93	5	85	5	5	90	-
	Au. 92	-	80	10	10	-	-
	Sp. 92	-	30	20	50	-	-
	Au. 91	-	60	30	10	-	-
	Sp. 90	-	65	25	10	3	-
	Au. 89	-	65	25	10	-	-
	Sp. 89	-	70	20	10	20	-
3.	Sp. 93	5	70	5	20	40	-
	Au. 92	10	30	50	10	-	-
	Sp. 92	5	15	30	50	-	-
	Au. 91	10	50	20	20	-	-
	Sp. 90	-	60	30	10	40	-
	Au. 89	-	60	30	10	-	-
	Sp. 89	-	80	10	10	-	-
6.	Sp. 93	20	-	5	75	-	-
	Au. 92	15	-	-	85	-	-
	Sp. 92	20	-	-	80	20	-
	Au. 91	20	-	20	60	-	-
9.	Sp. 93	35	45	35	5	30	15
	Au. 92	30	50	30	10	15	15
	Sp. 92	30	50	10	10	10	5
	Au. 91	20	-	20	60	10	10
	Sp. 90	2	75	18	5	40	-
	Au. 89	2	80	10	8	10	-
	Sp. 89	2	80	10	8	50	-

spring 1993. A number of taxa that were absent, or infrequent, at other stations regularly occurred at station 9. This is considered to be the result of greater habitat diversity, with the presence of submerged plants and large stones, providing contrasting substrata and water velocities. There is also less shading by trees at station 9, promoting more extensive growths of algae which are both a refuge and food source for some macroinvertebrates. A greater overall stability within the fauna is noteworthy at station 9, despite the obvious presence of additional pollutants (see 3.1, site description).

3) Notable seasonal differences (Table 2)

Asellus aquaticus (Hoglouse or slater)
There is a trend to lower numbers in spring samples, possibly caused by cessation of reproduction through the winter and an increased rate of washout in flood events.

Chironomidae (non-biting midge larvae)
Fairly consistent maxima in spring at all stations. The family includes many short-lived species which have several generations each year. Those characteristic of small streams graze algae from substrate surfaces and the most abundant food sources are available in early spring, before the stream becomes heavily shaded by trees.

4.3 Diversity indices

Diversity indices can provide a measure of the breadth of community structure in relation to the numerical balance between the individual taxa present. The application of the indices proposed by Simpson (1949) and Shannon and Weaver (1949) were described in the earlier report (Gledhill,1990). Their use was continued in this study and the trends through both monitoring periods are presented in table 6.

The values for the two indices show generally similar trends for each station, with some notable exceptions (Table 6). Station 1 had closely similar values on all but the first sampling date (spring 1989). Stations 2,3 and 9 had strikingly higher values on the first three sampling dates (spring 1989, spring and autumn 1990), when compared with later results. Station 6, with data from just four visits, showed large variations.

The major changes observed in the values of the indices are driven primarily by the instability of numbers of animals recovered at each station and the relatively small range of taxa present. This may be illustrated by reference to A.aquaticus (Table 2), which was very abundant in the latter part of the study, while the small number of coexisting taxa were often present in very low numbers (Appendices 1-20). It follows that the use of these diversity indices, as indicators of water quality, is not appropriate in the Rivacre Brook system, as they are excesively sensitive in the prevailing conditions. It might

Table 6. Macroinvertebrate diversity indices and BMWP average score per taxon (ASPT) for Rivacre Brook sampling stations, over the period 1989-1993 (for calculation of indices and ASPT - see section 4.3).

RIVACRE BROOK.

STATION	DATE	SIMPSON INDEX	SHANNON-WEAVER INDEX	ASPT
1.	Spring 93	0.73	1.50	3.00
	Autumn 92	0.73	1.56	3.25
	Spring 92	0.63	1.66	3.33
	Autumn 91	0.55	1.56	3.40
	Spring 90	0.66	1.77	2.40
	Autumn 89	0.67	1.92	3.00
	Spring 89	0.26	0.83	2.50
2.	Spring 93	0.72	1.31	3.71
	Autumn 92	0.66	1.43	3.90
	Spring 92	0.53	1.37	3.04
	Autumn 91	0.48	1.37	3.25
	Spring 90	0.86	2.93	3.64
	Autumn 89	0.85	2.99	3.45
	Spring 89	0.81	2.60	3.50
3.	Spring 93	0.88	0.91	3.55
	Autumn 92	0.46	0.89	2.50
	Spring 92	0.69	1.90	3.87
	Autumn 91	0.33	1.02	3.22
	Spring 90	0.81	2.59	3.25
	Autumn 89	0.85	3.00	3.42
	Spring 89	0.77	2.58	3.69
6.	Spring 93	0.60	1.12	3.60
	Autumn 92	0.07	0.18	2.86
	Spring 92	0.48	1.32	3.25
	Autumn 91	0.15	0.56	3.75
	Spring 90	-	-	-
	Autumn 89	-	-	-
	Spring 89	-	-	-
9.	Spring 93	0.64	1.24	3.70
	Autumn 92	0.61	1.19	3.87
	Spring 92	0.54	1.68	3.54
	Autumn 91	0.17	0.68	4.06
	Spring 90	0.86	2.88	3.56
	Autumn 89	0.74	2.42	3.64
	Spring 89	0.83	2.81	3.75

be argued that this instability provides a crude measure of stress. However the occurrence of single individuals of two or three extra taxa, which could be purely a matter of chance, have a large effect on the values of diversity indices.

4.4 Biotic indices

As stated by Gledhill (1990), the use of macroinvertebrate animals for monitoring water quality has a major advantage over intermittent chemical water sampling in that the animals are continuous monitors of the quality of the water flowing over and around them.

As part of the earlier monitoring programme, the advantages of different indices were considered and the BMWP (Biological Monitoring Working Party)(Chesters,1980) system was adopted as the most suitable and widely used.

In contrast to diversity indices, the BMWP total score and the derived ASPT (average score per taxon), utilise presence or absence rather than numbers of animals. It relies on the proscribed equal effort expended between samples to permit valid comparisons to be made between stations and dates.
"Families" of invertebrates are allocated scores ranging from 1-10, according to their known tolerance to organic pollution. Each family represented in a sample scores only once - irrespective of the number of component genera or species that

are present. Addition of the scores for all scoring families at a site gives the BMWP total score. The actual scores accorded to different "families" are shown in Table 7. Dividing the BMWP score by the number of scoring families gives the Average Score Per Taxon or ASPT (Table 5).

The trends in BMWP score (Table 8) and ASPT (Table 5) for all stations are, in general, more stable than the values derived from diversity indices (Table 5). However, in the case of the BMWP score, the presence/absence of one or two taxa does have a major effect when the total number of different taxa is so low.

There is a seasonal effect on the BMWP total score, with an overall mean of 30.1 in spring and 35.5 in autumn (all stations, all dates), though this is reversed at stations 3 and 6. Over the duration of the monitoring period (1989-1993) the mean BMWP total score (all stations) showed no clear trend that could be attributed to improving or worsening conditions in the Rivacre Brook system, as a whole.

4.5 Prediction of taxa, BMWP score and ASPT

The development of the classification scheme for unpolluted sites on British rivers, using macroinvertebrates (Wright et al, 1985), known as RIVPACS (River Invertebrate Prediction And Classification System), utilises the environmental features of a large number of sites and a data base of information on their macroinvertebrate communities. This is used to predict the probability of capture of species at unsampled sites using their

FAMILIES	SCORE
Siphlonuridae Heptageniidae Leptophlebiidae Ephemerellidae Potamanthidae Ephemeridae Taeniopterygidae Leuctridae Capniidae Perlodidae Perlidae Chloroperlidae Aphelocheiridae Phryganeidae Molannidae Beraeidae Odontoceridae Leptoceridae Goeridae Lepidostomatidae Brachycentridae Sericostomatidae	10
Astacidae Lestidae Agriidae Gomphidae Cordulegasteridae Aeshnidae Corduliidae Libellulidae Psychomyiidae Philopotamidae	8
Caenidae Nemouridae Rhyacophilidae Polycentropodidae Limnephilidae	7
Neritidae Viviparidae Ancylidae Hydroptilidae Unionidae Corophiidae Gammaridae Platycnemididae Coenagriidae	6
Mesoveliidae Hydrometridae Gerridae Nepidae Naucoridae Notonectidae Pleidae Corixidae Haliplidae Hygrobiidae Dytiscidae Gyrinidae Hydrophilidae Clambidae Helodidae Dryopidae Elmidae Chrysomelidae Curculionidae Hydropsychidae Tipulidae Simuliidae Planariidae Dendrocoelidae	5
Baetidae Sialidae Piscicolidae	4
Valvatidae Hydrobiidae Lymnaeidae Physidae Planorbidae Sphaeriidae Glossiphoniidae Hirudidae Erpobdellidae Asellidae	3
Chironomidae	2
Oligochaeta (whole class)	1

Table 7. The BMWP scoring system for freshwater invertebrate families (low scoring families are the most pollution tollerant).

Table 8. RIVPACS predictions of mean Total Scores (BMWP), error limits and observed Total Scores for each Rivacre Brook station, from 1989-1993 (Au. - autumn, Sp. - spring, sd - standard deviation, lcl - lower confidence limit, ucl - upper confidence limit).

		BMWP Total Scores				
		predicted				
Stn.	**date**	**mean**	**sd**	**lcl**	**ucl**	**OBSERVED BMWP**
1.	Spring	122	21.54	79.48	164.22	
	Autumn	115	20.67	74.48	155.52	
	Sp. 93					21
	Au. 92					26
	Sp. 92					20
	Au. 91					34
	Sp. 90					12
	Au. 89					24
	Sp. 89					15
2.	Spring	114	18.63	77.49	150.51	
	Autumn	96	17.97	60.78	131.22	
	Sp. 93					26
	Au. 92					39
	Sp. 92					17
	Au. 91					26
	Sp. 90					40
	Au. 89					38
	Sp. 89					35
3.	Spring	122	20.07	82.67	161.33	
	Autumn	107	18.72	70.31	143.69	
	Sp. 93					32
	Au. 92					15
	Sp. 92					31
	Au. 91					29
	Sp. 90					26
	Au. 89					41
	Sp. 89					48

Table 8 (conti.)

BMWP Total Scores

Stn.	date	mean	sd	lcl	ucl	OBSERVED BMWP
		--------- predicted -----------				
6.	Spring	105.8	18.42	69.74	141.95	
	Autumn	90.4	17.31	56.46	124.30	
	Sp. 93					36
	Au. 92					20
	Sp. 92					26
	Au. 91					30
	Sp. 90	-	-	-	-	-
	Au. 89	-	-	-	-	-
	Sp. 89	-	-	-	-	-
9.	Spring	158	20.37	118.07	197.93	
	Autumn	156	20.95	114.94	197.06	
	Sp. 93					37
	Au. 92					62
	Sp. 92					46
	Au. 91					61
	Sp. 90					32
	Au. 89					51
	Sp. 89					45

specific environmental features (Moss et al. 1987). Because of the wide use of the BMWP score system and ASPT in the biological surveillance of lotic (flowing water) sites the technique was extended to include prediction of <u>families</u> of macroinvertebrates for unsampled sites with known environmental features.

The RIVPACS predictions for each sampling station on the Rivacre Brook generated % probabilities of family occurrence in descending order. Moss et al (1987) described the methods used to quantify the relationship between predicted and observed values. The sums of the predicted probabilities of taxon capture were used to set a target for the number of taxa, total score or ASPT to be expected and these were then compared with observed values. The comparison can be represented by the ratio:-

Observed number : Predicted number

- this is equal to 1.0 if the observed number matches the predicted number.

Wright et al (1988) suggest that the three indices be termed Environmental Quality Indices such that:-

EQI_T = Environmental Quality Index (Number of taxa)

EQI_S = Environmental Quality Index (BMWP score)

EQI_A = Environmental Quality Index (ASPT)

All three indices reflect changes due to pollution and at the same time, by taking account of the expected values for each site, provide a means of assessing the degree to which the faunal communities of the river have deviated from the norm or unstressed state (Wright <u>et</u> <u>al</u>, 1988).

Wright et al (op. cit.) considered the indices in relation to an existing standard, that of the National Water Council river classification scheme (NWC, 1981) in which rivers are classified on a 5-point scale with emphasis on their degree of organic pollution (Table 9). It was noted by Gledhill (1990) that Wright et al (1988) were unable to include NWC class 3 and 4 (polluted) sites and only a few class 2 sites in their banding exercise and it was emphasized that boundaries between bands were provisional. These have since been revised (NRA, 1991) following further evaluation. The ASPT (EQI_A) banding provided a standard to derive equivalent bands for EQI_S (BMWP score) and EQI_T (number of taxa) and the current, revised bands are given in Table 10.

Observed BMWP total scores were considerably lower than those predicted at all stations (Table 11). This also applied to the number of scoring taxa and ASPT on all sampling occasions.

The poor performance ratings were the result of a universal absence of a range of high scoring families, with high predicted probability of occurrence, . Some of these families, such as stoneflies, some caddisflies and mayflies may be disfavoured by the temperature regime imposed by the release of impounded R.Dee water (stations 1,2,3 & 9). All will be excluded/eliminated by the presence of elevated nutrients, as noted at station 6.

Some of these high scoring families require specialised egg-laying sites or food resources that are not available on the Rivacre Brook system.

It should be noted that faunal predictions are generated using largely unpolluted natural streams. In consequence the canalised form of Rivacre Brook with its lack of structural diversity, will

Table 9. Water quality classification, present quality classes, a proposed new system (NRA, 1991) and the corresponding ranges of Environmental Quality Indices (EQIs).

Current water mean quality classes		Proposed grading system	Corresponding EQI ranges
1A	"excellent"	A	0.90 -
1B	"good"	B	0.65 - 0.99
2	"fair"	C	0.60 - 0.85
3	"poor"	D	0.40 - 0.65
4	"Bad"	E	- 0.55

Table 10. Water quality classification, a proposed new system (NRA, 1991) and the corresponding ranges of Environmental Quality Indices (EQIs).

General Ecosystem class		EQI (ASPT)	EQI (Taxa)	EQI (BMWP)
1	Good	>0.89	>0.79	>0.75
2	Fair	0.77-0.88	0.58-0.78	0.50-0.74
3	Poor	<0.77	<0.58	<0.50

Table 11. Environmental quality index (EQI) expressed as, ASPT (= EQIa), total of scoring taxa (= EQIt) and BMWP score (Observed/Predicted = EQIs)and median EQI. Data for the period 1989-1993 are compared.

Environmental Quality Index		stn.1	stn.2	stn.3	stn.6	stn.9
EQIa						
	Sp 1992	0.53	0.65	0.60	0.67	0.57
	Au 1992	0.59	0.75	0.45	0.56	0.61
	Sp 1992	0.62	0.58	0.70	0.60	0.56
	Au 1991	0.62	0.62	0.58	0.75	0.74
	Sp 1990	0.42	0.64	0.55	-	0.55
	Au 1989	0.55	0.66	0.62	-	0.58
	Sp 1989	0.44	0.61	0.62	-	0.58
EQIt						
	Sp 1993	0.56	0.51	0.69*	0.51	0.54
	Au 1992	0.64*	0.72*	0.46	0.39	0.86+
	Sp 1992	0.48	0.36	0.61*	0.41	0.70*
	Au 1991	0.80+	0.58*	0.69*	0.44	0.81+
	Sp 1990	0.40	0.80+	0.72*	-	0.49
	Au 1989	0.32	0.43	0.61*	-	0.38
	Sp 1989	0.48	0.72*	0.96+	-	0.65*
EQIs						
	Sp 1993	0.17	0.23	0.26	0.34	0.23
	Au 1992	0.23	0.41	0.14	0.22	0.40
	Sp 1992	0.16	0.15	0.25	0.26	0.29
	Au 1991	0.30	0.27	0.27	0.33	0.39
	Sp 1990	0.10	0.35	0.21	-	0.20
	Au 1989	0.21	0.40	0.38	-	0.33
	Sp 1989	0.12	0.31	0.39	-	0.28
median EQI						
	Sp 1993	0.53	0.51	0.60	0.51	0.54
	Au 1992	0.59	0.62	0.45	0.39	0.61
	Sp 1992	0.48	0.41	0.61	0.41	0.56
	Au 1991	0.62	0.58	0.58	0.44	0.74
	Sp 1990	0.40	0.66	0.62	-	0.49
	Au 1989	0.32	0.43	0.61	-	0.43
	Sp 1989	0.35	0.55	0.66	-	0.58

+ - value above range for water quality class 2 (Fair), override system upgrades to class 1 (Good).
* - value within range for class 2 (Fair).
The remaining EQI values fall within the range corresponding to class 3 (Poor). The median of the three values is used to confirm the designation of site quality, on nearly all occasions this coincided with the new class 3 (Poor).

result in the absence of certain niches required by the more specialised freshwater invertebrates.

5.Conclusions and recommendations.

5.1 <u>Conclusions</u>.

<u>Water Chemistry</u>.

1) Analyses of water samples indicate that rapid changes in some ionic components occurs in the BNFL effluent and the Rivacre Brook system.

2) It follows that these spot-samples, taken at six month intervals, cannot be assumed to describe the average conditions pertaining.

3) Within the range of chemical variables monitored, there were no occasions when the invertebrate fauna appeared at risk from BNFL discharges.

4) Water quality was impaired on another tributary (station 6).

5) On all sampling occasions, it was also noted that the most downstream station (9) was receiving polluting effluent from a pipe immediately upstream from the sample point.

<u>Macroinvertebrate Fauna</u>.

Over the whole monitoring period (1989-1993) two major changes in the fauna were evident and other features of community structure are noted :

1) There was a striking increase in the numbers of <u>Asellus</u>

aquaticus (hoglouse or slater), which had a depressing effect on the values of diversity indices.

2) There was a general reduction or loss of all gastropod molluscs (pond snails). The reason for this is unclear.

3) The intermittent presence of some macroinvertebrates caused instability in BMWP scores, used to assess water quality. This was accentuated by the small range of taxa.

4) The occasional presence of certain taxa indicates there is clear potential for successful colonisation by mobile species, when water quality permits.

5) Adoption of these diversity indices is inappropriate in the Rivacre Brook system, as they are over-sensitive in the prevailing conditions.

6) While faunal instability provides a crude measure of stress, the presence of single individuals of two or three extra taxa, largely by chance, has a disproportionate effect on the values of diversity indices.

7) Over the duration of the monitoring period (1989-1993) the mean BMWP total score (all stations) showed no clear trend that could be attributed to improving or worsening conditions in the Rivacre Brook system, as a whole.

8) The universally depressed BMWP total score (as compared with RIVPACS predictions) and low diversity, noted at all stations, are the result of an absence of high-scoring families.

9) High scoring families frequently require specialised egg-laying sites, temperature regimes or food resources that are not available on the Rivacre Brook system.

5.2 Recommendations.

Future Monitoring.

On the understanding that industrial activities at BNFL Capenhurst are predicted to fall in the short term, it is recommended that future macroinvertebrate monitoring should be curtailed and restarted prior to the introduction of new processes that may impact the Rivacre Brook system.

Proposals to increase the invertebrate diversity.

The BNFL Capenhurst site discharges a mixture of treatment works effluent, surface run-off and water pumped from the R.Dee. A small open storage reservoir for the R.Dee water contains floating mats of aquatic plants and settled river sediments. It is surmised that some aquatic invertebrates will enter the reservoir via the pumped water while others (notably insects) will colonise through oviposition (egg-laying). Previous checks on the passage of invertebrates from the reservoir to the culvert (Gledhill, 1990) proved negative, but were confined to filtering the outflow for comparatively short periods.

The range of invertebrates recorded in the stream is comparatively narrow. While this may be largely be a reflection of water quality, the absence of gravel riffles, water plants, algae and zones of low water velocity in flood conditions will restrict food sources and refugia (ie., there is a lack of habitat diversity).

Aims

1) Increase habitat diversity within the stream to encourage colonisation by a wider range of invertebrates.

2) Maintain a diversity of aquatic plants, open water and suitable surfaces for egg-laying, aquatic insects in the R.Dee water reservoir (potential stream colonisers by downstream drift).

3) Define conditions to maximise and maintain stream invertebrate diversity, within the constraints imposed by effluent quality.

Possible constraints

1) As the unculverted portion of stream is off the BNFL site, passing through arable crops, such modifications may not prove practical without the full support of the farmer.

2) Variations in water quality will continue to provide a strong constraint towards the development of a "natural" stream community.

3) A seasonal maintenance program would be required to prevent constriction of the stream channel by excessive growth of aquatic vegetation.

4) A reduction in the supply of water from the R.Dee will have implications for downstream dilution of effluents in Rivacre Brook, particularly in dry weather conditions.

Proposals to increase biodiversity

1) Increase light reaching the stream bed by selective removal of riparian vegetation (ie. preserve trees but

remove blackthorn/hawthorn and brambles) over short alternating lengths of stream bank. This would maintain the appearance of a hedge while increasing the light reaching the stream, within its steep sided channel.

2) Provide a small impoundment and/or a series of small marginal bays bounded by emergent aquatic plants, to smooth and attenuate rapid changes in water quality and water velocity. Maintaining the linear field boundary, for ease of cultivation, would most easily be achieved by creating frequent small-scale scalloped edges along the stream bank, reducing the present steep bank gradient at these points, but not encroaching in to the field margins to a significant extent.

6. Acknowledgements.

We would like to record our thanks to IFE colleagues, M.T.Furse (RIVPACS predictions), E.Rigg, J.Lishman and T.R. Carrick (water analysis), A.C.Pinder (invertebrate sample sorting), Dr L.C.V. Pinder (for comments on the report) and Terry Gledhill (initial briefing).

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8. Glossary

ASPT - Average Score Per Taxon (using BMWP score, restricted to BMWP scoring taxa)

Biotic indices - collectively applying (in this report) to the observed/expected indices derived for BMWP total score, BMWP number of scoring taxa, ASPT (see also EQI).

Diversity indices - in this context, the quantitative distribution of individuals among the represented macroinvertebrate taxa.

BMWP - Biological Monitoring Working Party (score) (Chesters,1980). Freshwater invertebrate families have a designated score, scale 1-10, with pollution tolerant families having low scores. The sum of scores for families present gives the BMWP score.

EQI($.._{ast}$) - Environmental Quality Index (Indices based on - ASPT; BMWP score; number of scoring taxa) (Wright et al, 1988)

Family (invertebrate) - taxonomic category for closely related species and genera.

FBA - Freshwater Biological Association

IFE - Institute of Freshwater Biology

Macroinvertebrates - invertebrates that are retained by the net mesh of a standard pondnet.

NWC classes - National Water Council (1981), classes indicating water quality

RIVPACS - River InVertebrate Prediction And Classification System. Utilises an extensive database of largely unpolluted river sites with known invertebrate communities, also certain chemical and physical site attributes. It may be used to generate predictions of invertebrate communities, site by site, using the physico/chemical descriptors, permitting a measure of site performance.

Taxon (pl. taxa) - a group of organisms with variable taxonomic rank (ie may include genus, family, etc)

Appendix 1-20. These appendices list the macroinvertebrate animals found at each site on each sampling occasion from a three-minute kick-sample using a standard pond net. In addition, scoring BMWP families, number of animals, BMWP total score and ASPT, are indicated.

The amphipod Crangonyx pseudogracilis (fam. Crangonyctidae) is included in the Gammaridae in the BMWP score system.

Appendix 1. Invertebrates recorded from Station 1, with numbers of individual taxa, their BMWP score, number of different taxa and the average score per taxon (ASPT).

RIVACRE BROOK St.1 20.9.91

Common name	Scientific name	Number in sample	Family	No. per family	Score (BMWP)
Worms	Oligochaeta	2615	"Oligochaeta"	2615	1
Flatworms	**Dugesia sp.**	9	Planariidae	58	5
	Polycelis sp.	49			
Leeches	**Erpobdella octoculata**	36	Erpobdellidae	36	3
	Glossiphonia complanata	1	Glossiphonidae	1	3
Snails	**Lymnaea peregra**	1	Lymnaeidae	1	3
Bivalves	**Pisidium nitidum**	49	Sphaeriidae	223	3
	P. subtruncatum	34			
	P. henslowanum	26	(sub-sample)		
	P. personatum	2			
Freshwater shrimps	**Crangonyx pseudogr.**	148	Gammaridae	148	6
Water-hoglouse	**Asellus aquaticus**	1118	Asellidae	1118	3
Bugs	**Hesperocorixa sahlbergi**	2	Corixidae	3	5
	H.Linnei	1			
Fly larvae	Diptera sp	3	Diptera	3	-
Midge larvae	Chironomidae	30	Chironomidae	30	2
	Culicidae	10	Culicidae	10	-

Number of different taxa = 12 (10 Scoring taxa)

Total number of specimens N = 4246

BMWP score = 34 ASPT = 3.4

Appendix 2. Invertebrates recorded from Station 1, with numbers of individual taxa, their BMWP score, number of different taxa and the average score per taxon (ASPT).

RIVACRE BROOK St.1 19.3.92

Common name	Scientific name	Number in sample	Family	No. per family	Score (BMWP)
Worms	Oligochaeta	73	"Oligochaeta"	73	1
Pea mussel	**Pisidium henslowanum**	1	Sphaeriidae	1	3
Water-hoglouse	**Asellus aquaticus**	24	Asellidae	24	3
Freshwater shrimps	**Crangonyx pseudogr.**	8	Gammaridae	8	6
Beetle	**Dytiscus marginalis**	1	Dytiscidae	1	5
Midge larvae	Chironomidae	99	Chironomidae	99	2

Number of different taxa = 6

Total number of specimens N = 206

BMWP score = 20 ASPT = 3.33

Appendix 3. Invertebrates recorded from Station 1, with numbers of individual taxa, their BMWP score, number of different taxa and the average score per taxon (ASPT).

RIVACRE BROOK St.1 29.9.92

Common name	Scientific name	Number in sample	Family	No. per family	Score (BMWP)
Worms	Oligochaeta	411	"Oligochaeta"	411	1
Snails	**Lymnaea peregra**	18	Lymnaeidae	18	3
	Physidae	1	Physidae	1	3
Bivalves	**Sphaerium corneum**	1	Sphaeriidae	76	3
	Pisidium nitidum	13			
	P. subtruncatum	50			
	P. casertanum	5			
	P. personatum	7			
Freshwater shrimps	**Crangonyx pseudogr.**	579	Gammaridae	579	6
Water-hoglouse	**Asellus aquaticus**	403	Asellidae	403	3
Bugs	Corixidae	1	Corixidae	1	5
Fly larvae	Diptera sp	1	Diptera	1	-
Midge larvae	Chironomidae	107	Chironomidae	107	2

Number of different taxa = 9 (8 Scoring taxa)

Total number of specimens N = 1597

BMWP score = 26 ASPT = 3.25

Appendix 4. Invertebrates recorded from Station 1, with numbers of individual taxa, their BMWP score, number of different taxa and the average score per taxon (ASPT).

RIVACRE BROOK St.1 17.3.93

Common name	Scientific name	Number in sample	Family	No. per family	Score (BMWP)
Worms	Oligochaeta	108	"Oligochaeta"	108	1
Snails	**Lymnaea peregra**	2	Lymnaeidae	2	3
	Physidae	1	Physidae	1	3
Bivalves	**Sphaerium corneum**	1	Sphaeriidae	20	3
	Pisidium nitidum	3			
	P. subtruncatum	1			
	P. casertanum	8			
	P. personatum	7			
Freshwater shrimps	**Crangonyx pseudogr.**	229	Gammaridae	229	6
Water-hoglouse	**Asellus aquaticus**	243	Asellidae	243	3
Midge larvae	Chironomidae	97	Chironomidae	97	2

Number of different taxa = 7 (7 Scoring taxa)

Total number of specimens N = 700

BMWP score = 21 ASPT = 3.00

Appendix 5. Invertebrates recorded from Station 2, with numbers of individual taxa, their BMWP score, number of different taxa and the average score per taxon (ASPT).

RIVACRE BROOK St.2 20.9.91

Common name	Scientific name	Number in sample	Family	No. per family	Score (BMWP)
Worms	Oligochaeta	394	"Oligochaeta"	394	1
Flatworms	**Dugesia sp**	9	Planariidae	46	5
	Polycelis sp.	37			
Leeches	**Erpobdella octoculata**	39	Erpobdellidae	39	3
	Glossiphonia complanata	1	Glossiphoniidae	2	3
	Helobdella stagnalis	1			
Pea mussels	**Pisidium nitidum**	1	Sphaeriidae	1	3
Freshwater shrimps	**Crangonyx pseudogr.**	116	Gammaridae	116	6
Water-hoglouse	**Asellus aquaticus**	1395	Asellidae	1395	3
Midge larvae	Chironomidae	16	Chironomidae	16	2

Number of different taxa = 8

Total number of specimens N = 2011

BMWP score = 26 ASPT = 3.25

Appendix 6. Invertebrates recorded from Station 2, with numbers of individual taxa, their BMWP score, number of different taxa and the average score per taxon (ASPT).

RIVACRE BROOK St.2 19.3.92

Common name	Scientific name	Number in sample	Family	No. per family	Score (BMWP)
Worms	Oligochaeta	21	"Oligochaeta"	21	1
Water-hoglouse	**Asellus aquaticus**	52	Asellidae	52	3
Freshwater shrimps	**Crangonyx pseudogr.**	2	Gammaridae	2	6
Midge larvae	Chironomidae	128	Chironomidae	128	2
Crane Fly larva	Tipulidae	1	Tipulidae	1	5

Number of different taxa = 5

Total number of specimens N = 204

BMWP score = 17 ASPT = 3.04

Appendix 7. Invertebrates recorded from Station 2, with numbers of individual taxa, their BMWP score, number of different taxa and the average score per taxon (ASPT).

RIVACRE BROOK St.2 29.9.92

Common name	Scientific name	Number in sample	Family	No. per family	Score (BMWP)
Worms	Oligochaeta	210	"Oligochaeta"	210	1
Leeches	**Erpobdella octoculata**	39	Erpobdellidae	39	3
	Glossiphonia complanata	1	Glossiphoniidae	1	3
Snail	**Lymnaea peregra**	1	Lymnaeidae	1	3
Pea mussels	**Pisidium nitidum**	6	Sphaeriidae	21	3
	P. subtruncatum	11			
	P. casertanum	4			
Freshwater shrimps	**Crangonyx pseudogr.**	78	Gammaridae	78	6
Water-hoglouse	**Asellus aquaticus**	384	Asellidae	384	3
Caddisfly	**Tinodes waeneri**	1	Psychomyiidae	1	8
	Limnephilidae	1	Lymnephilidae	1	7
Midge larvae	Chironomidae	33	Chironomidae	33	2

Number of different taxa = 10

Total number of specimens N = 769

BMWP score = 39 ASPT = 3.90

Appendix 8. Invertebrates recorded from Station 2, with numbers of individual taxa, their BMWP score, number of different taxa and the average score per taxon (ASPT).

RIVACRE BROOK St.2 **17.3.93**

Common name	Scientific name	Number in sample	Family	No. per family	Score (BMWP)
Worms	Oligochaeta	117	"Oligochaeta"	117	1
Snail	**Lymnaea peregra**	1	Lymnaeidae	1	3
Pea mussels	**Pisidium personatum**	1	Sphaeriidae	5	3
	P. subtruncatum	2			
	P. casertanum	2			
Freshwater shrimps	**Crangonyx pseudogr.**	222	Gammaridae	222	6
Water-hoglouse	**Asellus aquaticus**	322	Asellidae	322	3
Caddisfly	**Tinodes waeneri**	1	Psychomyiidae	1	8
Midge larvae	Chironomidae	161	Chironomidae	161	2

Number of different taxa = 7 (7 scoring taxa)

Total number of specimens N = 829

BMWP score = 26 ASPT = 3.71

Appendix 9. Invertebrates recorded from Station 3, with numbers of individual taxa, their BMWP score, number of different taxa and the average score per taxon (ASPT).

RIVACRE BROOK St.3 **20.9.91**

Common name	Scientific name	Number in sample	Family	No. per family	Score (BMWP)
Worms	Oligochaeta	16	"Oligochaeta"	16	1
Flatworms	**Dugesia sp.**	16	Planariidae	58	5
Leeches	**Erpobdella octoculata**	1	Erpobdellidae	1	3
	Glossiphonia complanata	1	Glossiphoniidae	1	3
Snail	**Potamopyrgus jenkinsi**	2	Hydrobiidae	2	3
Pea mussels	**Pisidium casertanum**	1	Sphaeriidae	1	3
Water-hoglouse	**Asellus aquaticus**	910	Asellidae	910	3
Freshwater shrimps	**Crangonyx pseudogr.**	119	Gammaridae	119	6
Midge larvae	Chironomidae	14	Chironomidae	14	2

Number of different taxa = 9

Total number of specimens N = 1122

BMWP score = 29 ASPT = 3.22

Appendix 10. Invertebrates recorded from Station 3, with numbers of individual taxa, their BMWP score, number of different taxa and the average score per taxon (ASPT).

RIVACRE BROOK St.3 **19.3.92**

Common name	Scientific name	Number in sample	Family	No. per family	Score (BMWP)
Worms	Oligochaeta	74	"Oligochaeta"	74	1
Leeches	**Glossiphonia complanata**	1	Glossiphoniidae	1	3
Snail	**Lymnaea peregra**	1	Lymnaeidae	1	3
Water-hoglouse	**Asellus aquaticus**	170	Asellidae	170	3
Freshwater shrimps	**Crangonyx pseudogr.**	31	Gammaridae	31	6
Caddisfly	**Tinodes waeneri**	2	Psychomyiidae	2	8
Midge larvae	Chironomidae	88	Chironomidae	88	2
Crane Fly larvae	Tipulidae	2	Tipulidae	2	5

Number of different taxa = 8

Total number of specimens N = 369

BMWP score = 31   ASPT = 3.87

Appendix 11. Invertebrates recorded from Station 3, with numbers of individual taxa, their BMWP score, number of different taxa and the average score per taxon (ASPT).

RIVACRE BROOK St.3 29.9.92

Common name	Scientific name	Number in sample	Family	No. per family	Score (BMWP)
Worms	Oligochaeta	80	"Oligochaeta"	80	1
Leeches	**Glossiphonia complanata**	1	Glossiphoniidae	1	3
Freshwater shrimps	**Crangonyx pseudogr.**	83	Gammaridae	83	6
Water-hoglouse	**Asellus aquaticus**	440	Asellidae	440	3
Midge larvae	Chironomidae	17	Chironomidae	17	2

Number of different taxa = 6

Total number of specimens N = 621

BMWP score = 15 ASPT = 2.50

Appendix 12. Invertebrates recorded from Station 3, with numbers of individual taxa, their BMWP score, number of different taxa and the average score per taxon (ASPT).

RIVACRE BROOK St.3 17.3.93

Common name	Scientific name	Number in sample	Family	No. per family	Score (BMWP)
Worms	Oligochaeta	78	"Oligochaeta"	78	1
Snail	**Lymnaea peregra**	2	Lymnaeidae	2	3
	Physidae	1	Physidae	1	3
	Ancylidae	1	Ancylidae	1	6
Pea mussels	**Pisidium subtruncatum**	1	Sphaeriidae	2	3
Freshwater shrimps	**Crangonyx pseudogr.**	290	Gammaridae	290	6
Water-hoglouse	**Asellus aquaticus**	656	Asellidae	656	3
Midge larvae	Chironomidae	151	Chironomidae	151	2
	Simulium ornatum	2	Simuliidae	2	5
True fly	Diptera	1	Diptera	1	-

Number of different taxa = 10 (9 scoring taxa)

Total number of specimens N = 1184

BMWP score = 32 ASPT = 3.55

Appendix 13. Invertebrates recorded from Station 6, with numbers of individual taxa, their BMWP score, number of different taxa and the average score per taxon (ASPT).

RIVACRE BROOK St.6 20.9.91

Common name	Scientific name	Number in sample	Family	No. per family	Score (BMWP)
Worms	Oligochaeta	57	"Oligochaeta"	57	1
Leeches	**Glossiphonia complanata**	12	Glossiphoniidae	12	3
Pea mussel	**Pisidium personatum**	1	Sphaeriidae	1	3
Freshwater shrimps	**Crangonyx pseudogr.**	26	Gammaridae	26	6
Water-hoglouse	**Asellus aquaticus**	3812	Asellidae	3812	3
Mayfly	**Caenis sp**	1	Caenidae	1	7
Beetles	**Agabus bipustulatus**	3	Dytiscidae	46	5
	Dyticidae larvae	43			
Midge larvae	Chironomidae	165	Chironomidae	165	2
Diptera		1	Diptera	1	-

Number of different taxa = 9

Total number of specimens N = 4146

BMWP score = 30 ASPT = 3.75

Appendix 14. Invertebrates recorded from Station 6, with numbers of individual taxa, their BMWP score, number of different taxa and the average score per taxon (ASPT).

RIVACRE BROOK St.6 19.3.92

Common name	Scientific name	Number in sample	Family	No. per family	Score (BMWP)
Worms	Oligochaeta	69	"Oligochaeta"	69	1
Flatworms	**Polycelis nigra** gp.	32	Planariidae	32	5
Leeches	**Glossiphonia complanata**	14	Glossiphoniidae	14	3
	Erpobdella octoculata	1	Erpobdellidae	1	3
Pea mussel	**Pisidium** sp.	1	Sphaeriidae	1	3
Water-hoglouse	**Asellus aquaticus**	866	Asellidae	866	3
Freshwater shrimps	**Crangonyx pseudogr.**	1	Gammaridae	1	6
Midge larvae	Chironomidae	272	Chironomidae	272	2
Diptera		1	Diptera	1	-

Number of different taxa = 8

Total number of specimens N = 1257

BMWP score = 26 ASPT = 3.25

Appendix 15. Invertebrates recorded from Station 6, with numbers of individual taxa, their BMWP score, number of different taxa and the average score per taxon (ASPT).

RIVACRE BROOK St.6 29.9.92

Common name	Scientific name	Number in sample	Family	No. per family	Score (BMWP)
Worms	Oligochaeta	19	"Oligochaeta"	19	1
Flatworms	**Polycelis sp.**	1	Planariidae	1	5
Leeches	**Glossiphonia complanata**	11	Glossiphoniidae	11	3
Freshwater shrimps	**Crangonyx pseudogr.**	9	Gammaridae	9	6
Water-hoglouse	**Asellus aquaticus**	6204	Asellidae	6204	3
Beetles	Dytiscidae	5	Dytiscidae	5	5
Midge larvae	Chironomidae	195	Chironomidae	195	2
True fly	Diptera	3	Diptera	3	-

Number of different taxa = 8 (7 scoring taxa)

Total number of specimens N = 6447

BMWP score = 20 ASPT = 2.86

Appendix 16. Invertebrates recorded from Station 6, with numbers of individual taxa, their BMWP score, number of different taxa and the average score per taxon (ASPT).

RIVACRE BROOK St.6 17.3.93

Common name	Scientific name	Number in sample	Family	No. per family	Score (BMWP)
Worms	Oligochaeta	47	"Oligochaeta"	47	1
Flatworms	**Polycelis sp.**	18	Planariidae	18	5
Leeches	**Glossiphonia complanata**	7	Glossiphoniidae	7	3
Snail	**Lymnaea peregra**	35	Lymnaeidae	35	3
	Lymnaea truncatula	1		1	
	Physidae	13	Physidae	13	3
	Potamopyrgus jenkinsi	17	Hydrobidae	17	3
Freshwater shrimps	**Crangonyx pseudogr.**	4	Gammaridae	4	6
Water-hoglouse	**Asellus aquaticus**	598	Asellidae	598	3
Caddisfly	Limnephilidae	7	Limnephilidae	7	7
Midge larvae	Chironomidae	385	Chironomidae	385	2
	Chaeboridae	1	Chaeboridae	1	-
	Culicidae	2	Culicidae	2	-

Number of different taxa = 12 (10 scoring taxa)

Total number of specimens N = 1135

BMWP score = 36 ASPT = 3.60

Appendix 17. Invertebrates recorded from Station 9, with numbers of individual taxa, their BMWP score, number of different taxa and the average score per taxon (ASPT).

RIVACRE BROOK St.9 20.9.91

Common name	Scientific name	Number in sample	Family	No. per family	Score (BMWP)
Worms	Oligochaeta	6	"Oligochaeta"	6	1
Flatworms	**Polycelis nigra gp**	1	Planariidae	1	5
Leeches	**Glossiphonia complanata**	5	Glossiphoniidae	8	3
	Helobdella stagnalis	3			
	Erpobdella octoculata	44	Erpobdelliidae	44	3
Snails	**Potamopyrgus jenkinsi**	1	Hydrobiidae	1	3
	Lymnaea peregra	3	Lymnaeidae	3	3
Water-hoglouse	**Asellus aquaticus**	1732	Asellidae	1732	3
Freshwater shrimps	**Crangonyx psuedogr.**	25	Gammaridae	25	6
Mayfly	Baetidae	3	Baetidae	3	4
Bug	Velia sp	2	Mesovelidae	2	5
Lace wing	**Osmylus fulvicephalus**	1	Osmylidae	1	-
Caddis	**Tinodes waeneri**	10	Psychomyiidae	10	8
Diptera	Tipulidae	1	Tipulidae	1	5
Midge larvae	Chironomidae	52	Chironomidae	52	2
Blackfly	**Simulium ornatum**	1	Simuliidae	1	5

Number of different taxa = 16

Total number of specimens N = 1900

BMWP score = 61   ASPT = 4.06

Appendix 18. Invertebrates recorded from Station 9, with numbers of individual taxa, their BMWP score, number of different taxa and the average score per taxon (ASPT).

RIVACRE BROOK St.9 19.3.92

Common name	Scientific name	Number in sample	Family	No. per family	Score (BMWP)
Worms	Oligochaeta	92	"Oligochaeta"	92	1
Leeches	**Glossiphonia complanata**	14	Glossiphoniidae	14	3
	Helobdella stagnalis	1			
	Erpobdella octoculata	16	Erpobdelliidae	16	3
Snails	**Potamopyrgus jenkinsi**	1	Hydrobiidae	1	3
	Lymnaea peregra	38	Lymnaeidae	38	3
	Lymnaea sp.	2		2	
	Anisus vortex	1	Planorbidae	1	3
	Physidae sp	2	Physidae	2	3
Pea Mussels	**Pisidium subtruncatum**	2	Sphaeriidae	2	3
Water-hoglouse	**Asellus aquaticus**	1134	Asellidae	1134	3
Freshwater shrimps	**Crangonyx psuedogr.**	158	Gammaridae	158	6
Mites	Hydracarina	4	"Hydracarina"	2	-
Caddis	**Tinodes waeneri**	3	Psychomyiidae	3	8
Midge larvae	Chironomidae	266	Chironomidae	266	2
Blackfly	**Simulium ornatum**	3	Simuliidae	3	5

Number of different taxa = 13

Total number of specimens N = 1734

BMWP score = 46 ASPT = 3.54

Appendix 19. Invertebrates recorded from Station 9, with numbers of individual taxa, their BMWP score, number of different taxa and the average score per taxon (ASPT).

RIVACRE BROOK St.9 29.9.92

Common name	Scientific name	Number in sample	Family	No. per family	Score (BMWP)
Worms	Oligochaeta	95	"Oligochaeta"	95	1
Leeches	**Glossiphonia complanata**	18	Glossiphoniidae	18	3
	Erpobdella octoculata	8	Erpobdelliidae	8	3
Snails	**Potamopyrgus jenkinsi**	1100	Hydrobiidae	1100	3
	Lymnaea peregra	2	Lymnaeidae	2	3
	Physa sp.	3	Physidae	3	3
Limpet	**Acroloxus lacustris**	2	Ancylidae	2	6
Mite	Hydracarina	1	Hydracarina	1	-
Freshwater shrimps	**Crangonyx psuedogr.**	39	Gammaridae	39	6
Water-hoglouse	**Asellus aquaticus**	1079	Asellidae	1079	3
Mayfly	Baetidae	2	Baetidae	2	4
Water boatman	Corixidae	1	Corixidae	1	5
Beetles	Haliplidae	1	Haliplidae	1	5
	Dytiscidae	6	Dytiscidae	6	5
Diptera	Tipulidae	3	Tipulidae	3	5
Midge larvae	Chironomidae	22	Chironomidae	22	2
Blackfly	**Simulium ornatum**	108	Simuliidae	108	5

Number of different taxa = 17 (16 scoring taxa)

Total number of specimens N = 2489
BMWP score = 62 ASPT = 3.87

Appendix 20. Invertebrates recorded from Station 9, with numbers of individual taxa, their BMWP score, number of different taxa and the average score per taxon (ASPT).

RIVACRE BROOK St.9 17.3.93

Common name	Scientific name	Number in sample	Family	No. per family	Score (BMWP)
Worms	Oligochaeta	37	"Oligochaeta"	37	1
Flatworms	**Polycelis sp.**	18	Planariidae	18	5
Leeches	**Glossiphonia complanata**	6	Glossiphoniidae	6	3
	Erpobdella octoculata	7	Erpobdelliidae	7	3
Snail	Ancylidae	1	Ancylidae	1	6
Pea mussels	**Pisidium subtruncatum**	6	Sphaeriidae	9	3
	Pisidium henslowanum	1			
	Pisidium nitidum	2			
Freshwater shrimps	**Crangonyx psuedogr.**	34	Gammaridae	34	6
Water-hoglouse	**Asellus aquaticus**	538	Asellidae	538	3
Midge larvae	Chironomidae	143	Chironomidae	143	2
	Chaeboridae	1	Chaeboridae	1	-
Blackfly	**Simulium ornatum**	197	Simuliidae	197	5

Number of different taxa = 11 (10 scoring taxa)

Total number of specimens N = 991

BMWP score = 37 ASPT = 3.70

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