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Botanical, invertebrate and hydrological monitoring 1991-1995 - Final Report

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Chippenham Fen NNR
Botanical, Invertebrate and Hydrological Monitoring
1991 – 1995

Final Report

S.C. Shaw, B.D. Wheeler, P. Kirby & P. White

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Report to:

English Nature
Northminster House
Peterborough
PE1 1UA

Prepared by:

Environmental Consultancy
University of Sheffield
343 Fulwood Road
Sheffield S10 3BQ
United Kingdom
TEL 0114-266-9292
FAX 0114-266-7707

Chippenham Fen NNR
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Project Team:

B.D. Wheeler
S.C. Shaw
P. Bradley
P. Eades
R.P. Money
R. Edmunds
S. Power
P. Kirby
D.P. Butcher
P. White
L. Townend

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1. Background

Chippenham Fen and Snailwell Poor's Fen SSSI (Cambs; NGR TL 648697) together comprise a site considered to be of national importance for the wide range of wetland habitats and associated birds and insects (NCC, 1988). The whole site covers an area of nearly 115 ha, of which 103 ha is currently managed by English Nature as an NNR. The site comprises a wide variety of habitats, including grassland, herbaceous fen, sedge beds, mature woodland and scrub, resulting in a very diverse flora. A number of uncommon species and communities are represented, including the EU-MOLINION alliance, for which the site is a proposed Special Area of Conservation (SAC site), together with the nearby Wicken Fen and Woodwalton Fen. The site is also of national significance for its rich invertebrate fauna.

The hydrological regime of the site is complex (see Section 2). The main water input is probably from rainfall, but chalk springs are evident in some of the dykes. Water moves around the site through a controlled dyke system (which divides the site into a series of compartments), draining into the Chippenham River. The water regime within the compartments is generally characterised by low water levels during the summer, with levels just below, or slightly inundating the peat surface in winter.

The fen is situated in a relatively dry region of Britain (mean rainfall *c.* 600 mm a^{-1}) in which public water supply is largely derived from groundwater abstraction. In order to meet the predicted increase in demand for water in the area to the east of Cambridge, the Lodes-Granta scheme was proposed by NRA to provide abstracted water and to support river flows in times of low flow. Preliminary studies suggested that groundwater levels within the vicinity of the fen would be lowered by proposed abstractions and that the spring flows to the fen, and hence discharge to the Chippenham River, could be detrimentally affected. More detailed investigations by the NRA (Mason 1990), suggested that it would be possible to compensate losses of water inputs to the fen from a supplementary water source. A nearby redundant public water supply borehole was brought back into service specifically to supply piped water to the fen.

Although the supplementary water source is apparently of suitable chemical composition for introduction into a fen ecosystem that is intrinsically of quite low productivity (Wheeler & Shaw, 1987), it was difficult to predict whether the quality and amount of this water, or its method of introduction would be able to sustain the present vegetation and invertebrate resource. With this in mind, a programme of vegetation and invertebrate monitoring was put in place in 1991. There has been some hydrological monitoring on the site since 1976 (see Mason 1990), but the programme was broadened in 1991 in conjunction with the vegetation and invertebrate monitoring programmes. The work described here provides an assessment of the hydrological data, gives details of the 1995 monitoring of vegetation and invertebrates, and draws together the information from the previous years, in an attempt to assess whether the water supply augmentation scheme has been (and will be) adequate to prevent any detrimental changes to the flora and fauna caused by water abstraction.

The main text of this report provides a summary of the assessments of the hydrological, vegetation and invertebrate monitoring programmes. The detailed reports on each topic are given as Appendices, which are available as separate documents. Reports from previous years' monitoring are also available from English Nature.

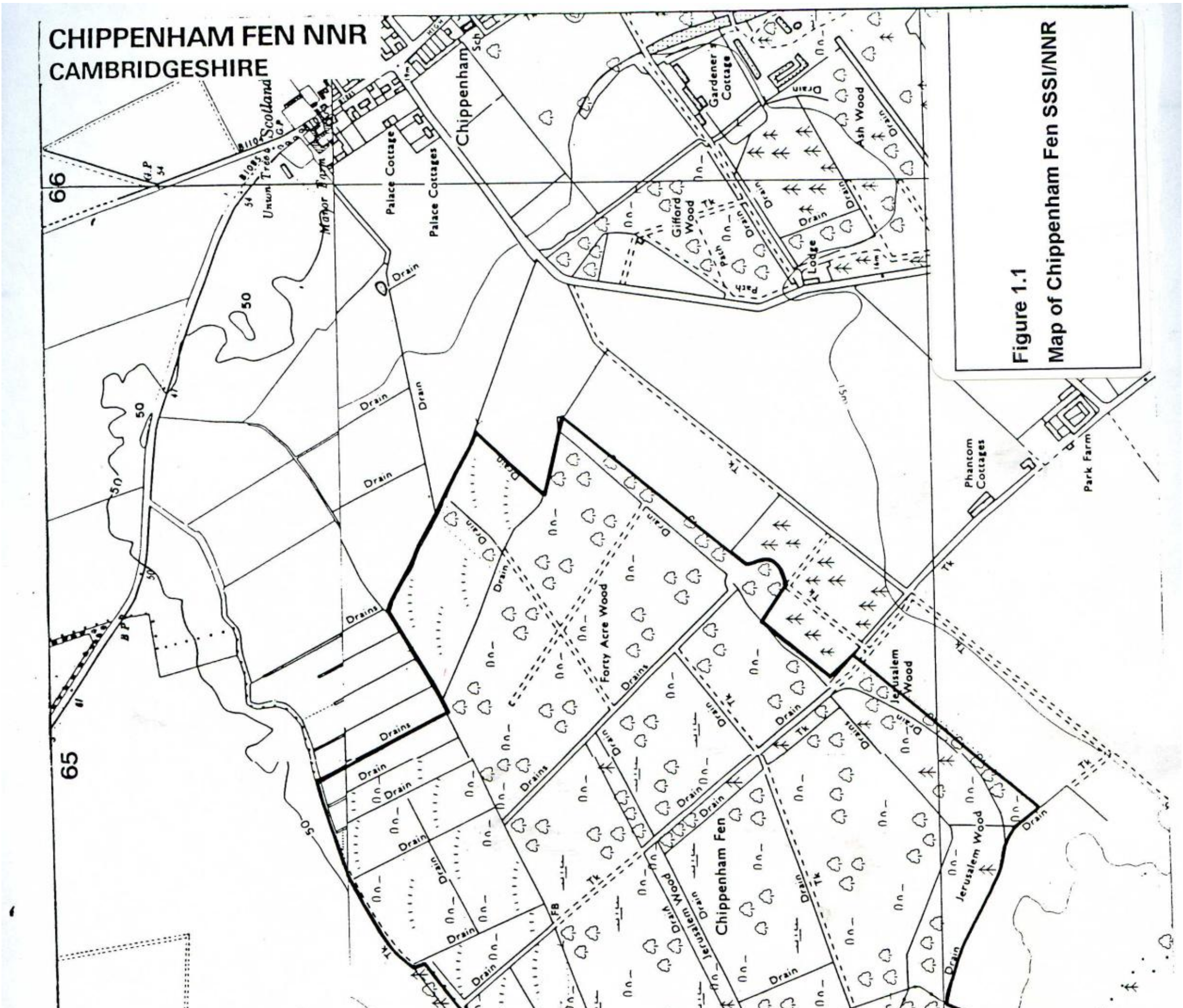
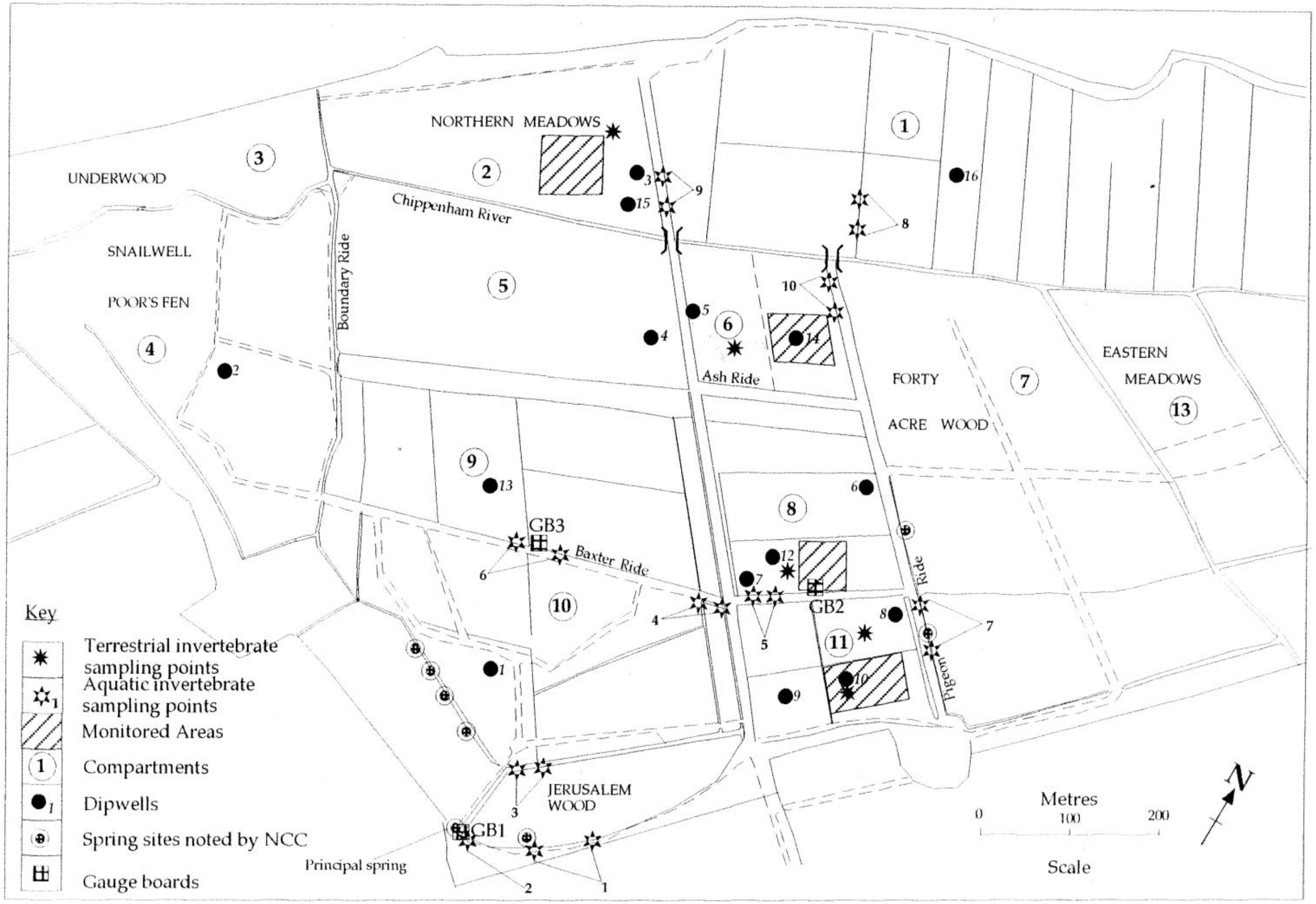


Figure 1.1
Map of Chippenham Fen SSSI/NNR

Figure 1.2 Summary map showing locations for hydrological, botanical and invertebrate monitoring at Chippenham Fen



2. Hydrological assessment

2.1 Introduction

The assessment of the hydrological data provided for Chippenham Fen has been carried out as a separate exercise by the Centre for Water and Environmental Management, University of Huddersfield. A summary is given here; the full report is provided as a separate document (Appendix 1).

The aim of this report has been to review hydrological conditions at Chippenham Fen NNR as monitored by a variety of devices over a five to ten year period. Analysis of available data has been carried out in order to:

1. assess any trends in hydrological conditions over the site during the period of record. This has involved the control of occlusions and impulsive noise within the data so that climatic and management effects may be evaluated;
2. assess, in particular, the impact of local water abstraction on the site;
3. evaluate the application and effectiveness of the supplementary water supply scheme;
4. make recommendations for future adjustments to the supplementary water scheme;
5. make recommendations with regard to a future monitoring strategy.

2.2 Site characteristics

Chippenham Fen is located *c.* 6 km north of Newmarket in a predominately low-lying arable setting (Figure 1.1). The main water input is probably from rainfall, but chalk springs are evident in some of the dykes. Water moves around the site through a controlled dyke system (which divides the site into a series of compartments), draining into the Chippenham River (Figure 2.1). The local geology, vegetation and management practices are described below, and are largely adapted from Mason (1990) and DCEUB (1988), which provide more detailed descriptions.

Geological data suggest that the rocks underlying Chippenham Fen consist of Lower and Middle Chalks, Chalk Marl and Gault Clay dipping gently NW-SE. Chalk Marl outcrops in the Fen as an inlier within the Totternhoe Stone. This latter rock is well jointed and acts as a source of springs within the fen. Pleistocene drift deposits consisting of flint/chalk/clay matrix of variable proportions and size distributions occur across the fen. Overlying this drift (Head) material is a dark brown peat with occasional silt-clay layers. The depth of the peat ranges from between 0.45 m and 2 m.

In hydrological terms, the site is not as intensively regulated as some other lowland peat remnants, as its main use has been as a supply of sedge rather than for the peat itself. The fen was drained by 1800 as a result of the cutting of a network of deep dykes and shallower land drains, after which much of the current woodland was planted. It is reported by Mason (1990) in his review of the site's history that this drainage resulted in a lowering of the water table by *c.* 1.5 m, and sluices were installed to prevent drought damage. Many of the shallower drains became silted up by the early 1900s, although a restoration program was undertaken in each of the World Wars.

The larger dykes carrying water around and through the fen are controlled by a number of bund-dams installed between 1985 and 1987 to replace old wooden sluices (Figure 2.1). Each dam is culverted by a pipe angled at 90° on the 'upstream' side, so that water levels in the dyke higher than the top of the pipe spill through the dam and into the next section. The overspill end is capable of being adjusted by adding or removing additional lengths of pipe ('collars'), and water levels are usually lowered in this way before some site management operations are undertaken.

An additional sluice gate exists on the Chippenham River below the site that can be closed in summer to maintain water levels in the fen.

In addition to hydrological controls on site, external support for water levels in the Chippenham river *via* the fen is supplied by three inflow points in the fen (Figure 2.2). The majority of the pumped support is supplied by pipeline to the Principal Spring, the other two pipes supply water to points in the boundary dyke at the south-eastern margin of Forty Acre wood. The scheme was implemented in order to ameliorate possible impacts from increased groundwater abstraction in the region (see Section 1).

2.3 Hydrological monitoring history

Monitoring at the site has been undertaken at a variety of locations and using a number of methods. Locations of monitoring points within the fen are shown in Figure 2.3.

Dipwell recording

A total of 15 dipwells have been installed across the site, 9 in 1976 and a further 6 in 1991. Readings are taken fortnightly. A Casagrande drive-in piezometer has been installed at the Principal Spring to the depth of the underlying Totternhoe Stone in order to monitor groundwater pressure from the aquifer at one of the main site inflows.

Water level gauging

A total of three gaugeboards (GB1–GB3) have been installed at the Principal Spring and at two locations within the site to monitor water levels in the dykes. These have been surveyed to Ordnance Datum and are monitored fortnightly.

Borehole and river discharge monitoring

In addition to measurements within the site, two measures of local conditions are taken outside the fen. River discharge has been monitored using current metering at the fen over a number of years, but the most reliable data consist of readings recorded by a gauging station immediately downstream of the sluice gate. Daily readings from this gauge exist from 1991 to present.

Readings are also available from an automatic logger at the Chippenham Observation Borehole, which records the level of the water table above Ordnance Datum at 15 minute intervals. These data have been collected since 1991, and have been converted to daily mean values for the purpose of this report.

Rainfall

Rainfall is recorded by three gauges at or near the site: one at Isleham pumping station, and two at Chippenham Fen – an autographic gauge and a tipping bucket raingauge. It is interesting to note that despite the relatively close proximity of the gauges (particularly the two Chippenham gauges), there are marked differences in average and total rainfall values (Table 2.1).

Table 2.1 Mean monthly rainfall totals (mm) for raingauges at or near Chippenham Fen (1991–1995)

Month	Isleham	Chippenham	Chippenham Tipping Bucket	Average
January	13.58	65.15	49.33	**52.91**
February	31.98	33.32	26.70	**32.35**
March	39.66	46.85	22.80	**40.09**
April	42.96	42.60	33.70	**42.89**
May	36.14	43.15	43.20	**35.93**
June	53.60	44.13	54.27	**49.12**
July	47.15	53.00	40.70	**43.02**
August	44.37	51.40	27.05	**35.67**
September	64.67	75.53	67.40	**65.78**
October	64.55	88.10	63.60	**55.40**
November	52.72	51.43	51.30	**52.75**
December	44.02	53.03	52.67	**45.26**
Total	**570.57**	**644.86**	**533.35**	***551.22***
Mean	**47.283**	**53.02**	**45.89**	***45.83***
Standard deviation	**20.16**	**21.81**	**21.86**	***21.40***
Minimum	**6**	**10**	**4.6**	***4.6***
Maximum	**84.3**	**98.8**	**91.4**	***90.33***

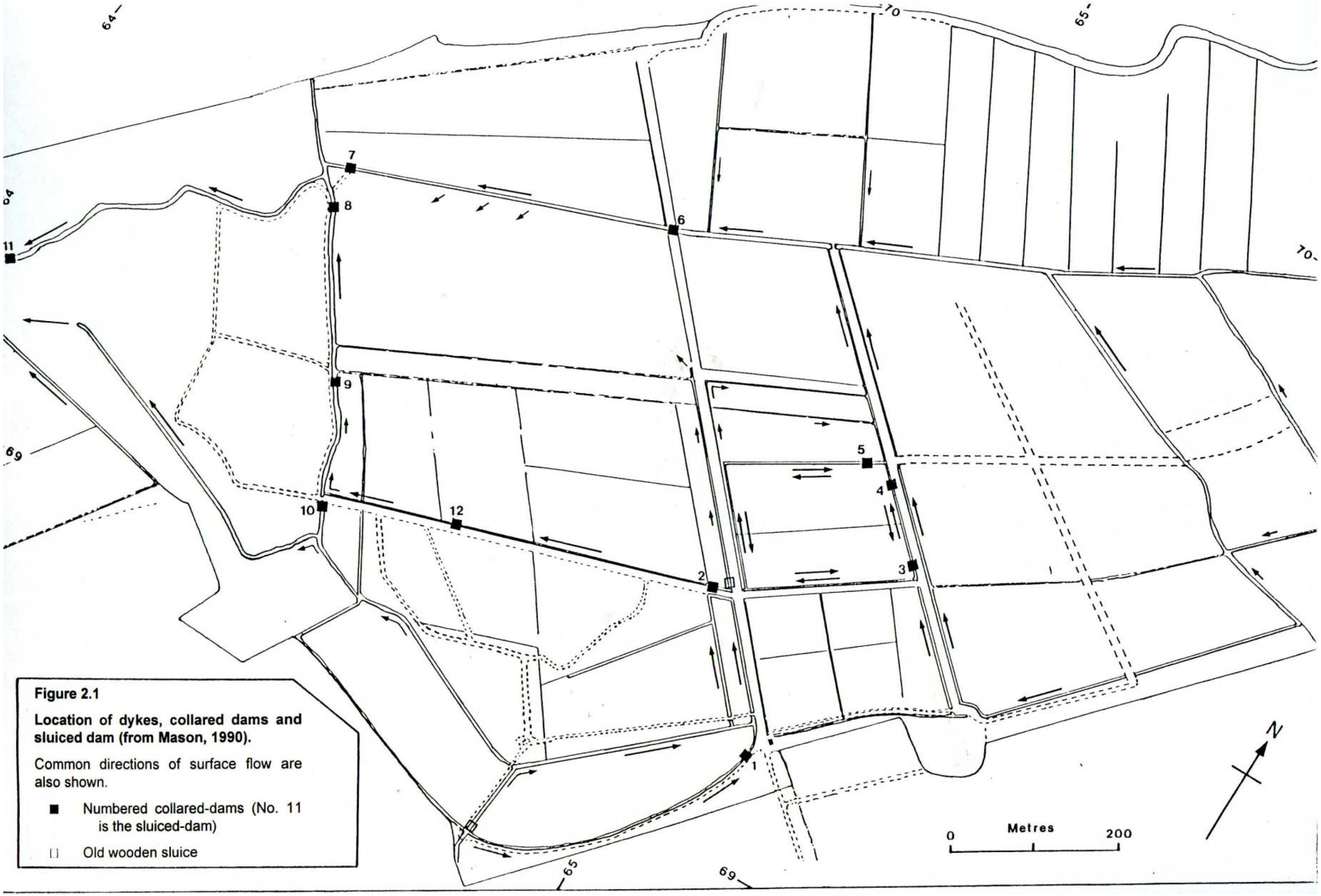


Figure 2.1

Location of dykes, collared dams and sluiced dam (from Mason, 1990).

Common directions of surface flow are also shown.

- ■ Numbered collared-dams (No. 11 is the sluiced-dam)
- □ Old wooden sluice

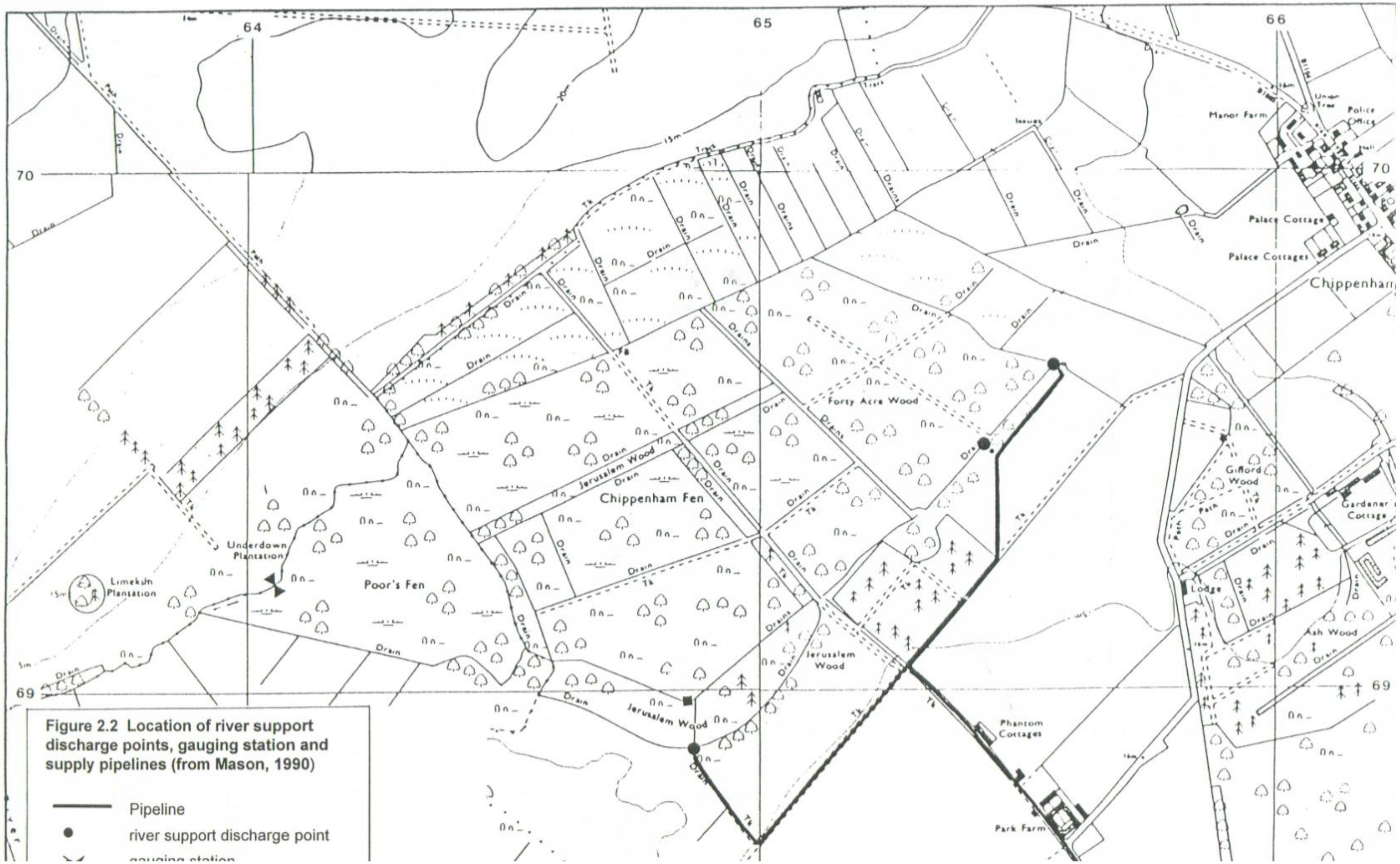
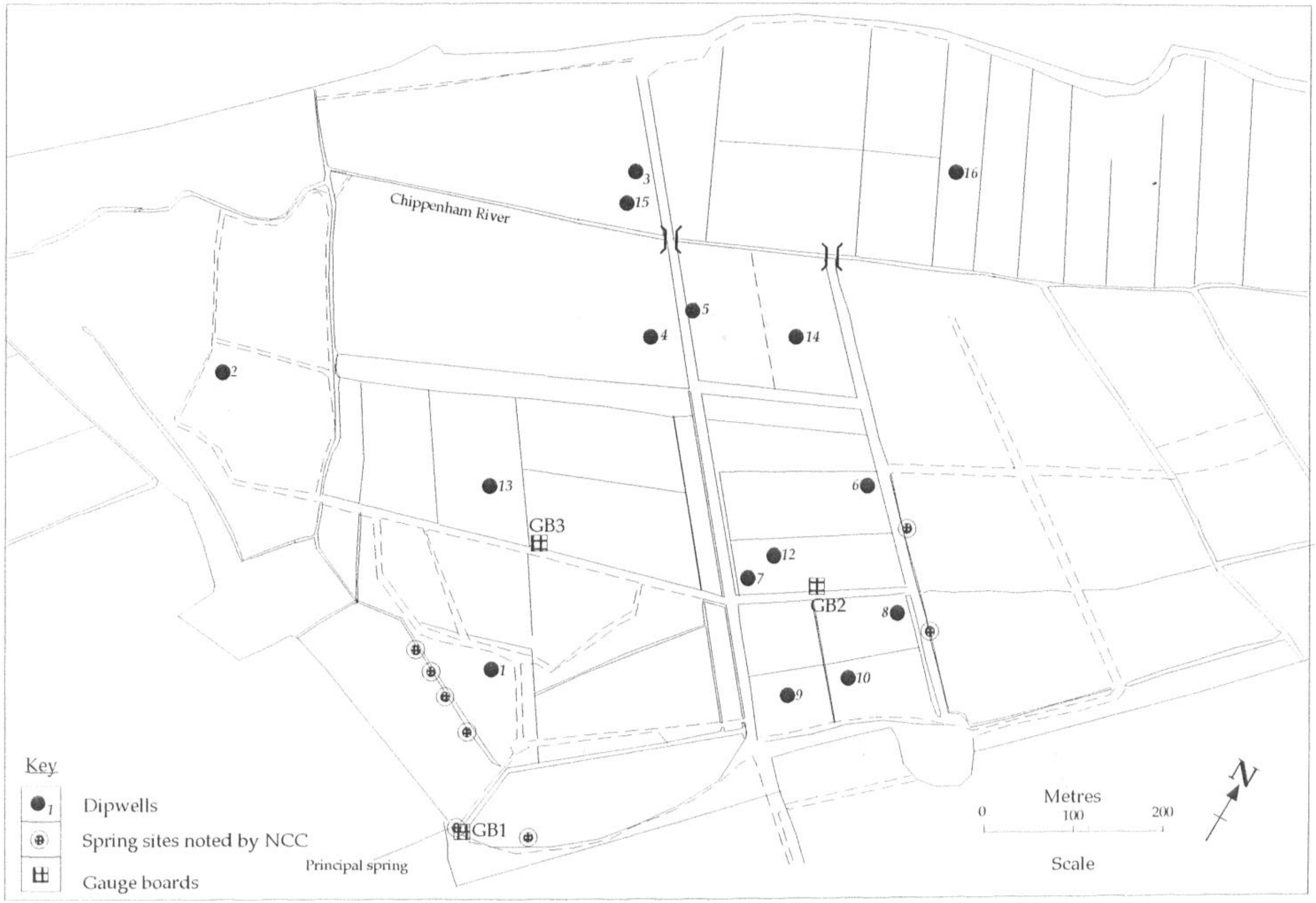


Figure 2.2 Location of river support discharge points, gauging station and supply pipelines (from Mason, 1990)

Figure 2.3 Location of dipwells, gauge-boards and springs



2.4 Results and discussion

As a result of the variety of monitoring approaches employed at Chippenham Fen (2.3) a wealth of data has been collected concerning the hydrological behaviour of the fen and its immediate environs. These data can be considered in a number of ways, namely:

a) examination of the overall behaviour of individual recording instruments;

b) examination of general temporal trends over the whole of the recording period;

c) comparison of specific sets of temporal records within the overall recording period.

An attempt has also been made to compare the readings obtained from the different recording methods.

Detailed results and discussion are provided within Appendix 1.

2.4.1 Dipwell records

The dipwell data collected in the period 1986–1995 have provided an excellent record of the medium to long term variation in water table depths at Chippenham Fen. Overall data suggest that the water table is –18.99 cm below the ground surface on average. While all areas monitored exhibit surface ponding at some point over the recording period, and for much of the period of record water may be found within 30 cm of the ground surface, each dipwell exhibits a considerable degree of variability (Table 2.2 and Figure 2.4). Data from across the site also show considerable variation, with some areas clearly much wetter than others (dipwell 5 shows the highest water tables and dipwell 16 the lowest). The site is clearly prone to drought stress despite the existence of hydrological controls, and water depths may reach in excess of 1 metre below the surface in prolonged dry periods. Thus, in some locations the

Table 2.2 Summary data for water table depth above/below ground surface recorded by dipwells at Chippenham Fen (see Figure 2.3 for locations)

Dipwell Number	Mean (cm)	Median (cm)	Standard Deviation (cm)	Minimum (cm)	Maximum (cm)	Range (cm)
1	-23.5	-16	23.72	-87	2	89
2	-17.049	-12	18.83	-86	7	93
3	-31.73	-16	30.44	-130	4	134
4	-8.81	-3	17.46	-98	8	106
5	4.25	10	23.94	-126	32	158
6	-24.53	-17	25.54	-135	6	141
7	-16.80	-8	22.81	-104	9	113
8	-11.52	1	29.08	-102	18	120
9	-17.73	-12	19.08	-97	3	100
10	-21.40	-6	34.74	-135	12	147
12	-23.91	-15	21.23	-103	-5	98
13	-28.14	-23	14.33	-88	-11	77
14	-18.28	-4	29.65	-119	7	112
15	-27.80	-17	23.65	-91	0	91
16	-45.72	-41	27.06	-107	-2	105
Overall	***-18.99***	***-11***	***26.51***	***-135***	***32***	***105.25***

water table falls below the base of the peat, into the underlying clay or head – detailed examination of the implications of this for the interpretation of the dipwell data was outwith the scope of the present study, but there seems to be no consistent trend evident to suggest that this has a major impact on water table behaviour. However, this may be an important consideration in the assessment of movement of water around the fen, particularly in the summer, when, for example, recharge of the main body of the fen from the dykes may depend more on the transmissivity of the underlying substrata than that of the peat.

There are two features to dipwell records over time, depending on whether the data are reviewed in terms of their relation to the ground surface or in relation to ordnance datum. Firstly, there is an apparent cyclical trend in the minimum levels attained by the water table in successive summers that is less apparent in winter. This may be attributable to normal, medium-term variation in hydrological inputs to the fen, and the lack of a similar cycle in winter maxima can be attributed to the loss of water from the site as surface flow. This loss may then be manifested as higher discharge readings in the Chippenham River. The second trend is an apparent drop in base levels in the early 1990s, where winter and summer readings are obviously (and significantly) lower than in the years before and after (see Figure 2.5). This may again be related to normal climatic variation but it could also be attributable to some as yet undetermined anthropogenic influence on site hydrological regime in these years.

The data suggest that there is a distinct separation of trends over the recording period, with three zones of concern:

a) an initial period of relative stability lasting from the start of recording until c.1989, with winter water table depths stable, but with apparently regular variations in summer water table depths. [April 1986 – March 1990]

b) a transitional period commencing at the end of period (a) and ending c.1992, with winter water table levels apparently markedly lower than those in the previous period. [April 1990 – March 1992]

c) a second period of relative stability, with a suggestion that winter water table depths are initially lower than in period (a) but gradually rising over successive winters. [April 1992 – October 1995]

Examination of the data presented above suggest that in all cases, as would be expected, water depths below the surface show the sequence: Winter<Autumn<Spring<Summer[1]. Within that general pattern, the seasonal difference seems broadly similar for most dipwells. The exceptions to this general rule appear to be dipwells 10 and 3, where the difference between summer and winter extremes are the largest, and dipwells 2, 4 and 13, where the winter–summer difference is the smallest.

As noted in Section 2.2, water flow around the fen is regulated by a number of dams, with water levels manually controlled using a system of collars fitted to a pipe which passes through the dam. Data for the dipwells considered most likely to be affected by alterations in the collars are presented in Figure 2.6, and suggest that the raising and lowering of water levels in ditches around the fen does produce a corresponding change in water table depths in the fen itself. These changes are, however, relatively localised and are manifested only in readings taken close to the dams involved – i.e. there is apparently no general effect on water levels across the fen.

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[1] *Winter*: Dec – Feb; *Autumn*: Sept – Nov; *Spring*: Mar – May; *Summer*: June – Aug.

2.4.2 Chippenham River discharge

Discharge data from the Chippenham River suggest that mean daily flow has varied significantly over time in a manner consistent with changes found in borehole and dipwell readings. Analysis of river discharge data in terms of the periods identified in the dipwell records (see above), where there is a marked change in water table base level, suggest that there is a significant difference in discharge in the period before and after 1/4/1990 (periods 'a' and 'b' above). In this case, readings in the period where dipwell water table depths were much lower (period b) are significantly lower ($p<0.001$) than in the final period, with mean daily discharges of 0.0348 and 0.1007 cumecs respectively. However, correlation analyses suggest that while dipwell readings are significantly related to levels at the Principal Spring, and borehole readings are significantly related to discharge, flow rates show no significant links to dipwell levels. This would suggest that while all three are maintained by regional changes in groundwater levels, the routeing of water supplied to the Principal Spring through the fen reduces the direct relationship between fen and river, particularly as flow to the fen is augmented by pumping through the spring, and flow through the fen is controlled by a series of regulated dams. The unusually low correlations between rainfall and discharge would seem to confirm that direct local inputs to the fen are less important than regional ones except in relatively high magnitude storms.

2.4.3 Dyke water levels

Data from gauge boards GB2 and GB3 show that water levels in the dykes monitored by them are extremely stable, suggesting a relatively constant relationship between inputs to the dykes and losses to the fen. However, given the rapid fall in water table depths in the fen in dry periods, it could be argued:

(a) that this stability is attributable to the use of water management controls to limit water loss from the dykes to the river, with some inputs from pumped support discharge and localised springs;

(b) that the rapid fall in water table depths in the fen dipwells is a result of net loss of water through evapotranspiration exceeding combined inputs from rainfall and seepage into the fen from the dykes (and springs, if present). It should be noted that during the summer, water levels can fall below the base of the peat, and thus recharge from the dykes into the fen may depend on the permeability of the substratum beneath the peat, rather than the peat itself;

(c) that the fen is a significant contributor to this relatively constant water level in the dykes, so that while water levels in the dykes remain stable, in dry periods they may do so at the expense of fen storage.

The latter seems unlikely, unless there are some inputs from springs directly into the fen (rather than just to the dykes), although there is some evidence that in terms of water table elevation (m.a.o.d.), there is an hydraulic gradient from the fen to the dykes for most of the year, water levels in the fen only rarely falling below those in the dykes (see Appendix 1). A specific study would be required to elucidate patterns of water movement between the dykes and the peat within the fen compartments, with careful attention paid to measurement of elevations (m.a.o.d.).

Water levels at gaugeboards GB2 and GB3 show a good relationship between each other but show relatively weak relationships with other monitoring data, suggesting that while these gauges are useful in indicating the hydrological regime of their respective ditches they are less useful as a means of inferring hydrological regimes in other parts of the fen.

2.4.4 Observation borehole

Records from the observation borehole show a consistent annual range. However there is an apparent change in base level after the first year of recording that is consistent with a rise in water table at the dipwells. It would be unwise to attach too great a significance to this feature, given that interpretation is based on a change after only one year of borehole recording.

The data suggest that there is a significant relationship between observation borehole readings and readings taken at the Principal Spring, although the strength of the relationship between the two variables is not clear. Relatively large changes in borehole levels are needed to produce small changes in levels at the principal spring.

2.4.5 General comments

The data illustrate the buffering effect of the fen and its associated extended drainage system, with water entering the system distributed around the fen and 'lost' to the peat mass. It would be expected that in periods where the fen is largely saturated, additional water inputs would be channelled through the fen with minimum loss to storage, while in drier periods the fen would act as a hydrological input to the Chippenham River for as long as water levels in the fen are above those of the River. However, the extent of the relationship between the fen inputs and the output to the Chippenham River should be examined in more detail in order to assess the validity of these statements.

The data would suggest that there is a marginal difference in rainfall totals between specific periods of monitoring, but there are technical limitations to the statistical tests that make this suggestion suspect. It is also questionable whether the relatively small difference in rainfall between the transitional and final periods identified above can be held to be responsible for the relatively large differences in dipwell, borehole and river discharge readings in the periods identified above.

2.4.6 Supplementary water supply

The operation of the river support pumping into the fen in order to compensate for groundwater abstracted for water supply at nearby boreholes has been examined, although the extent of this pumping has proved difficult to establish, as records suggest that the amount of pumped supply has suffered operational difficulties, so that actual amount supplied has not been monitored on all occasions. The longest period for which information is available is 1.7.92 to 26.11.92, when support pumping occurred more or less continuously to Chippenham Fen and Chippenham Park Lake, at a rate of between 13.2 and 25.7 $l.s^{-1}$. Mean dipwell data, gauge board data, and discharge data from 1992 for the months before pumping, three months of pumping and three months after cessation of pumping are illustrated in Figure 2.7 to Figure 2.9. Rainfall over the same period is shown in Figure 2.10. All data illustrated are summarised in Table 2.3. (Principal Spring piezometer data are not available for the period in question).

Table 2.3 Mean values for dipwell and dyke water levels, river discharge and rainfall before, during and after pumped inflows at Chippenham Fen, 1992

	Before pumping	During pumping	After pumping
Dipwell water table depth (cm)	-37.84	-11.65	-6.37
River discharge (cumecs)	0.0228	0.0466	0.1361
GB1 (m.a.o.d.)	12.845	12.846	12.885
GB2 (m.a.o.d.)	12.476	12.442	12.389
GB3 (m.a.o.d.)	12.311	12.261	12.290
Rainfall total (mm)	113.9	315.0	140.7
Mean daily rainfall (mm)	1.252	2.218	1.481

Mean dipwell data (Figure 2.7) show an obvious and rapid response that may be attributable to the additional influx of water, with a *c.* 35 cm decrease in water table depth shown in early July (although this may also be attributable to the sluice gate operations). This new level is maintained throughout the pumping period, although small fluctuations may be explained by alteration of the quantities supplied. For example in mid-October the discharge rates decreased from a total of 25.2 $\mathrm{l.s^{-1}}$ to 13.2 $\mathrm{l.s^{-1}}$, and this apparently coincides with an increase in water table depth. Water tables apparently continue to remain relatively stable after pumping ceased in November. Mean values also show a decrease in water table depth during pumping but in the three months after pumping ceased water table depths decrease further.

Gauge board data (Figure 2.8) on the other hand show minimal change over the three periods. It would be expected that, as the gauge boards monitor water levels in the water distribution network within the fen, they would exhibit greater change, particularly in the case of GB1, which is adjacent to one of the inflow points for pumping at the principal spring. It is possible to identify a decline in readings towards the end of support pumping but its significance is doubtful given that it apparently commences before this support ended. It could be argued that the stability exhibited by gauge board readings is a result of a successful pumping strategy, with inflows maintained at levels sufficient to maintain a stable water level in the drains. If water is seeping from the drains and into the fen, then it is possible that the extra water is arriving at a rate equivalent to the maximum seepage rate of the fen. More information on water table depths closer to the drains and on local hydraulic conductivities (within the peat and underlying substrata) would be needed to examine this suggestion further.

River discharge data (Figure 2.9) suggest a small increase as pumping commences but flows throughout August and September are extremely low. The increase in discharge in late September pre-dates the cessation of pumping and thus it is difficult to identify the exact impact that pumping may have had. Because discharge over this period has been recorded daily, there are sufficient readings available to test the three periods using analysis of variance. The analysis indicates that there is a significant difference between the periods before during and after support pumping ($p<0.001$), but this may be attributable to the influence of much higher discharges recorded in the third period, rather than to the pumping operations. Given that it is implied above that much of the extra inflow may be lost from the drains, it is possible that most of the water has been lost to storage within the fen. If this is the case then the amounts supplied to the fen by pumping may need to be increased in order to maintain river discharge levels.

There is thus a strong suggestion of a negative relationship between water supply abstraction and discharge in the Chippenham River, although the link may be related to the impact of fluctuations in rainfall on both datasets rather than causal. The use of pumped storage to compensate for this abstraction has had relatively little impact on fen water table depths and Chippenham River discharge, with readings falling to very low levels despite this additional water supply. However, detailed examination of the available data suggest that discharge levels in the Chippenham River and water table depths within the fen may respond positively to support pumping, but the exact magnitude of any effects may be masked by variations in rainfall and evapotranspiration. Extrapolations from existing data suggest that without support discharges directly to the fen, river discharges would effectively cease, although results from this data manipulation should be treated cautiously. It would be reasonable to argue that, given the level of licensed abstraction possible, the amount of compensation water pumped into the Principal Spring may need to be re-evaluated.

2.5 Recommendations for future monitoring

The present study has highlighted some of the limitations of the data which have been collected. It is recommended that the data collection is rationalised, monitoring points added and studies carried out in order to address specific questions. Some suggestions for future work are made below.

While the elevation relative to ordnance datum of the dipwells and gaugeboards was checked in 1992, it is possible that as ground levels fluctuate over time as soil water stores expand and contract, the assumed elevations of the monitoring equipment have changed, with obvious consequences on data recorded relative to the original datum. This has clear implications for the interpretation of data, for example, the elucidation of patterns of water movement around and through the fen, and it is recommended that elevations relative to ordnance datum are re-surveyed. It would be a useful addition to the dataset if the water level in the Chippenham River were also recorded to datum, as this would then allow a direct comparison of water levels in the fen with those at its principal outlet.

While numbers of dipwells and gauges are certainly adequate, the majority of them are concentrated in a particular part of the site. In order to achieve a more spatially representative dataset, additional dipwells and gaugeboards should be installed in the western half of the site. Consideration should also be given to ensuring that dipwells are distributed evenly between locations close to and distant from drains and dykes, and in relation to the dam/collar system controlling flow within the fen.

It was noted above that in certain parts of the fen during dry periods, the water level can fall below the base of the peat, into the underlying clay or 'head' – any possible recharge into the centre of the fen compartments by water from the dykes in summer may therefore depend on the transmissivity of the underlying substratum, rather than the peat. A specific examination of the implications of this for general data interpretation and assessment of water regimes within the fen was outside the scope of the present study, and it is recommended that this should be looked at in more detail, if possible.

The data suggest that the operation of the collared dam system and of the sluice at the fen outflow have some impacts on water table depths within the fen, but that the impact of such operations appear to be localised and short lived. However, the present location of dipwells in relation to these devices means that interpretation is problematic and limited. It would be an interesting addition to the body of knowledge in general, and of the fen in particular, if any planned alterations to sluice and/or collared dam levels were to be accompanied by a more intensive monitoring program. This increased level of monitoring would consist of a greater frequency of recording, and ideally would involve a series of dipwells in close proximity to the dam or dams concerned, so that the exact magnitude and extent of any change in water table depth could be more accurately determined. This work could be complemented by monitoring the hydrological impacts on the fen of controlled alterations of collar heights at the dams. The current situation of collar adjustment as required for vegetation or other management purposes is ideal for practical site control but makes analysis of the impact of such adjustment difficult. Ideally, each dam should have several dipwells associated with it at a number of distances, and each collar should then be raised in sequence and the change in water level across the site monitored.

Additional monitoring of flow rates and directions within the fen would both add to the information provided by Mason (1990) and give more detail about the current state of the fen's hydrological regime. The monitoring of discharge should also apply to any of the fen's major inputs and outputs, and would help to produce a water balance equation for comparison with that discussed in Mason (1990) and DCEUB (1988).

Water table depths over time have largely been discussed without reference to the control exerted by variations in the clay, marl and peat deposits within the fen, and a number of assumptions have been made regarding the importance of surface water contributions to the fen. There is a possibility that groundwater plays an important role in the fen hydrological regime, but this is difficult to establish given the data available. It is recommended that a suite of Casagrande type piezometers are installed at different depths so that the water pressure in different strata of the fen deposits, and hence the role of groundwater inputs may be assessed.

While dipwell and other data suggest that the fen acts as a buffer between hydrological inputs and discharge outputs, the large fall in water table levels experienced in drier years suggests that this fen storage may be short lived and unable to cope with prolonged droughts. This may result from inadequate control of flow through the fen, and in order to retain water in the fen for longer period it may be necessary to increase the number of adjustable dams, particularly in areas at higher elevations. Alternatively, more complex routeing of flow through the fen would have a similar effect. Both of these options would have obvious consequences for discharge in the Chippenham River, at least in the short term, and thus a more detailed study of the fen hydrological regime using the recommendations made above would be advisable before undertaking them. However, some degree of summer dryness may be natural in a fen system of this type, particularly if spring inputs are not very important, and it is possible that the system of controlled dykes may keep parts of the fen wetter than they would be naturally (see also Section 3). Further consideration needs to be given to the possible adequacy of the supplementary water supply under conditions of maximum abstraction, and whether distribution of the water around the fen should (and could) be improved – the current work has highlighted the need for a thorough re-appraisal of the water management of the site.

Finally, it is recommended that data collection continue, and that where possible data collection dates are rationalised so that consistent data series are available for future analysis. This would include the calculation of daily means for borehole data, and fortnightly means or totals from the daily river discharge, borehole and rainfall data.

Figure 2.4: Seasonal means for water table depths in dipwells at Chippenham Fen, 1986-1995

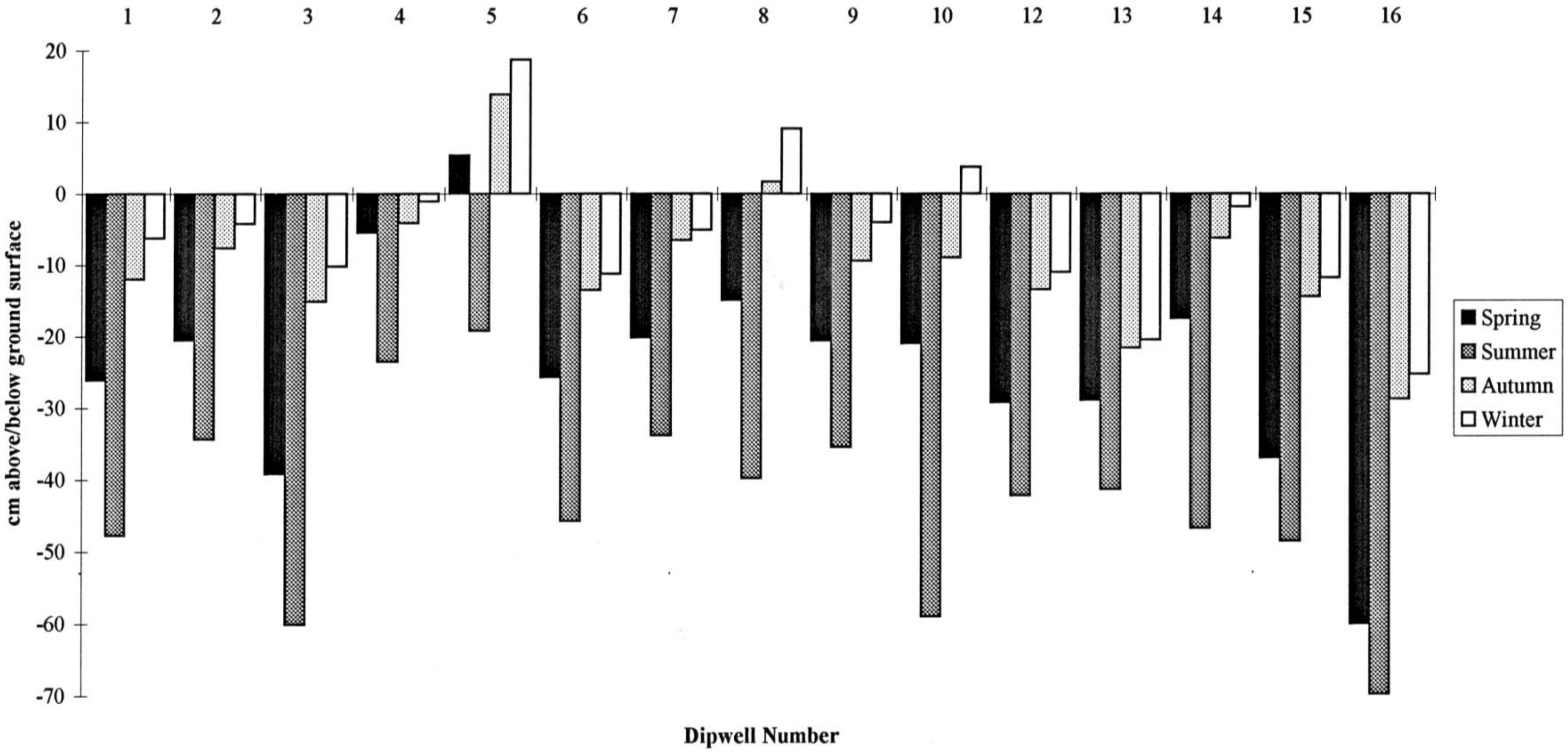


Figure 2.5: Seasonal mean water table depth for all dipwells at Chippenham Fen, 1986-1995

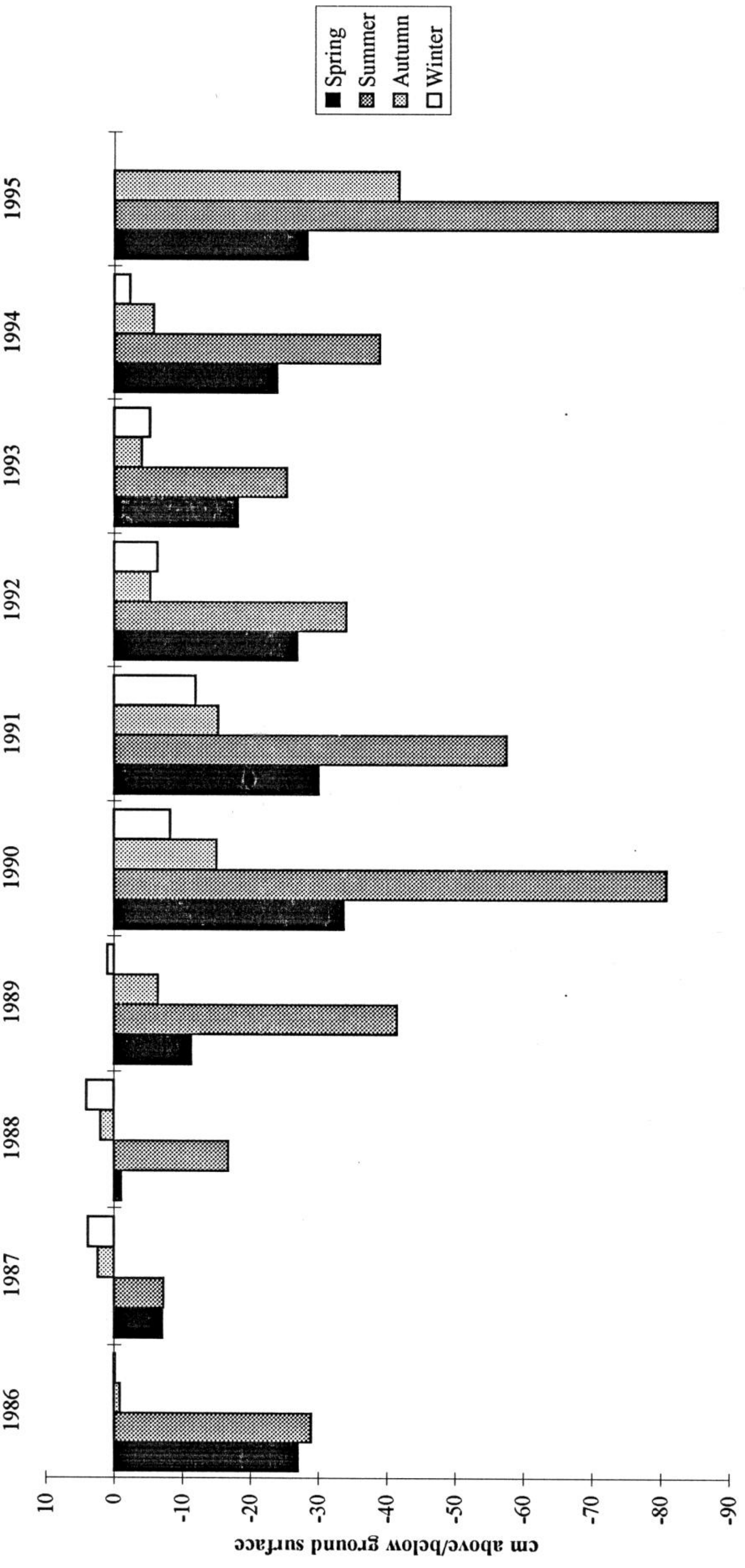


Figure 2.6: Water table depths for dipwells affected by water level adjustments in nearby drains, 1992-1994

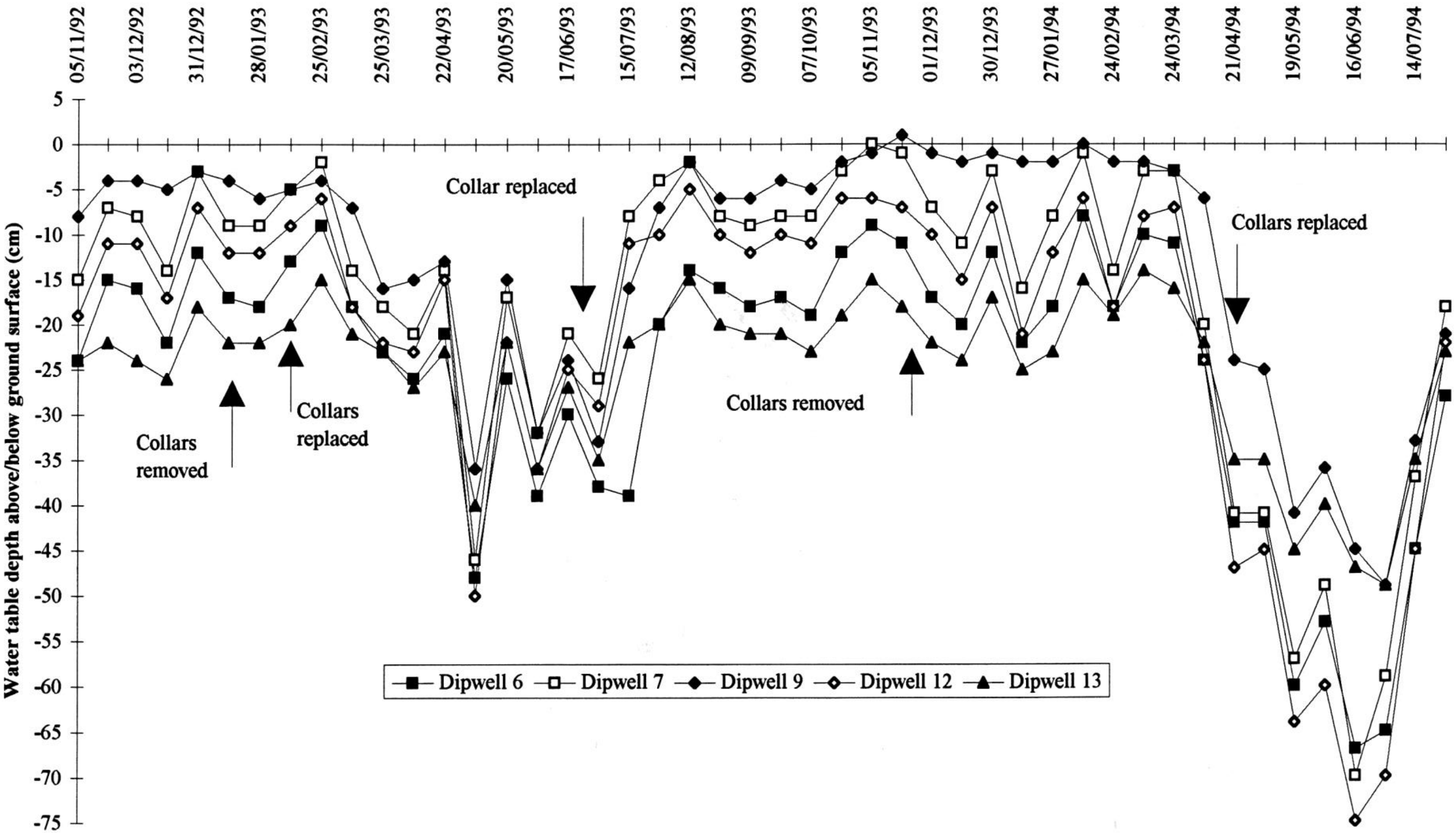


Figure 2.7: Mea[illegible] dipwell water table level before, during and after pumped discharge inflow, Chippenham Fen 1992

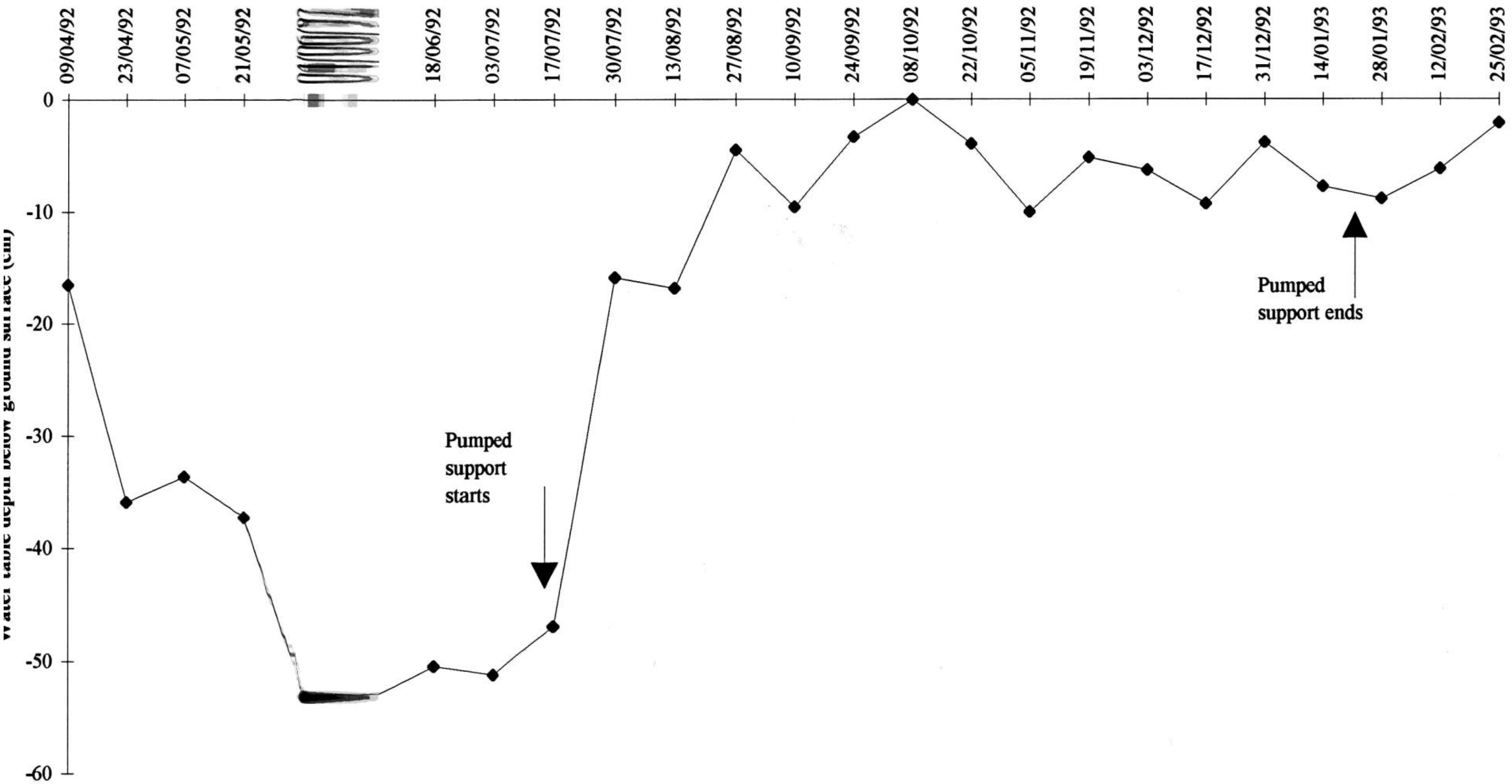
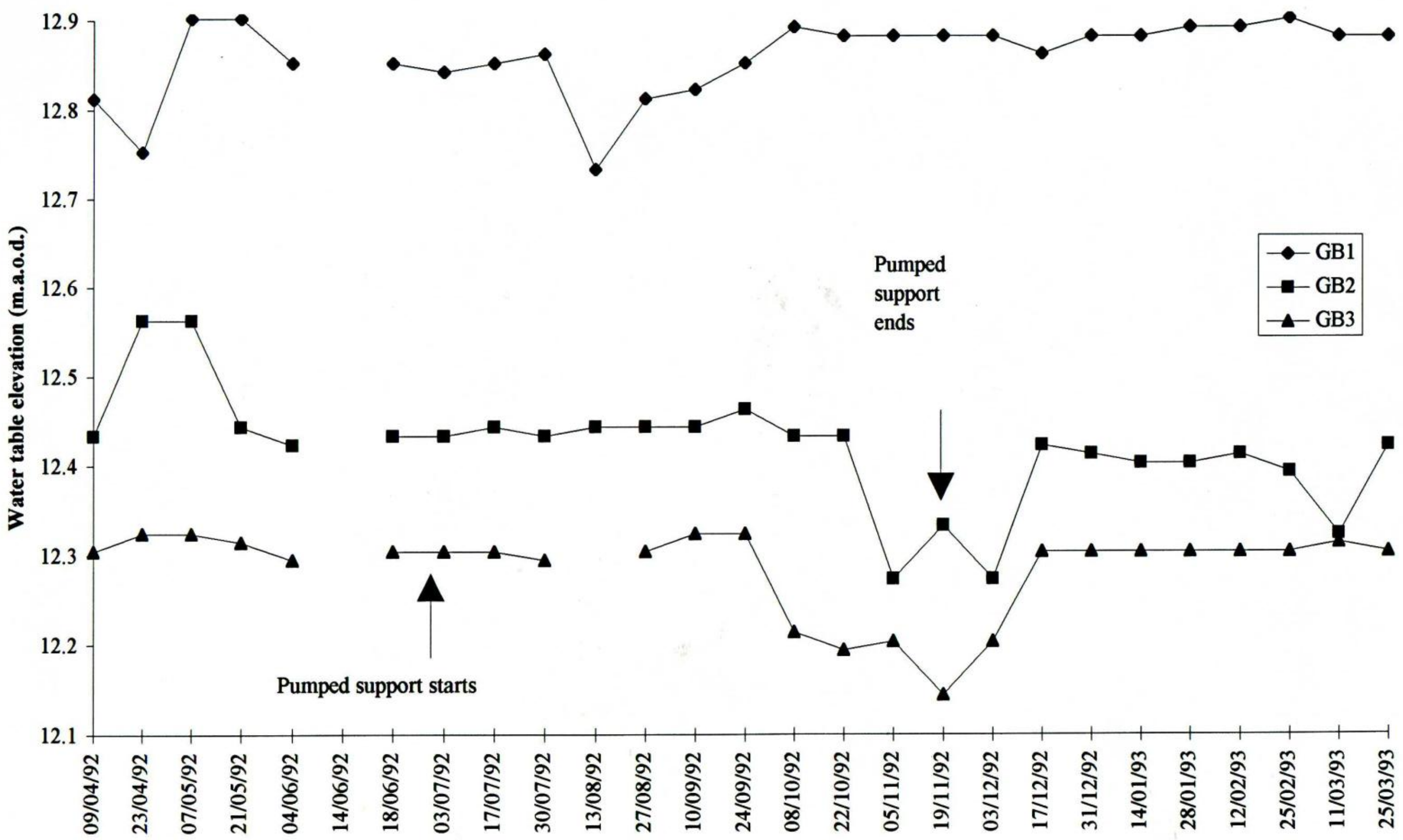


Figure 2.8: Gaugeboard readings above ordnance datum before, during and after pumped discharge to Chippenham Fen, 1992



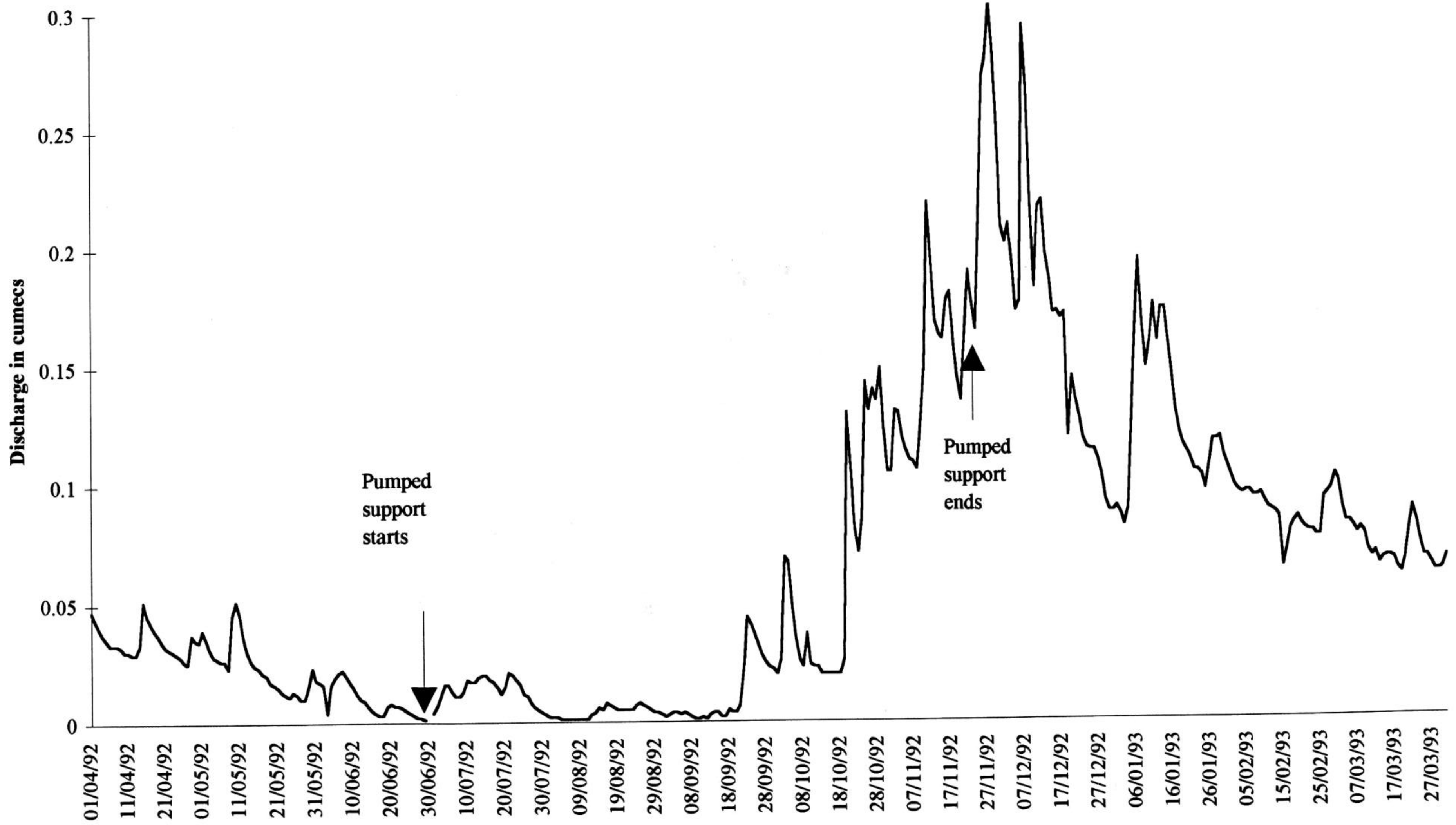
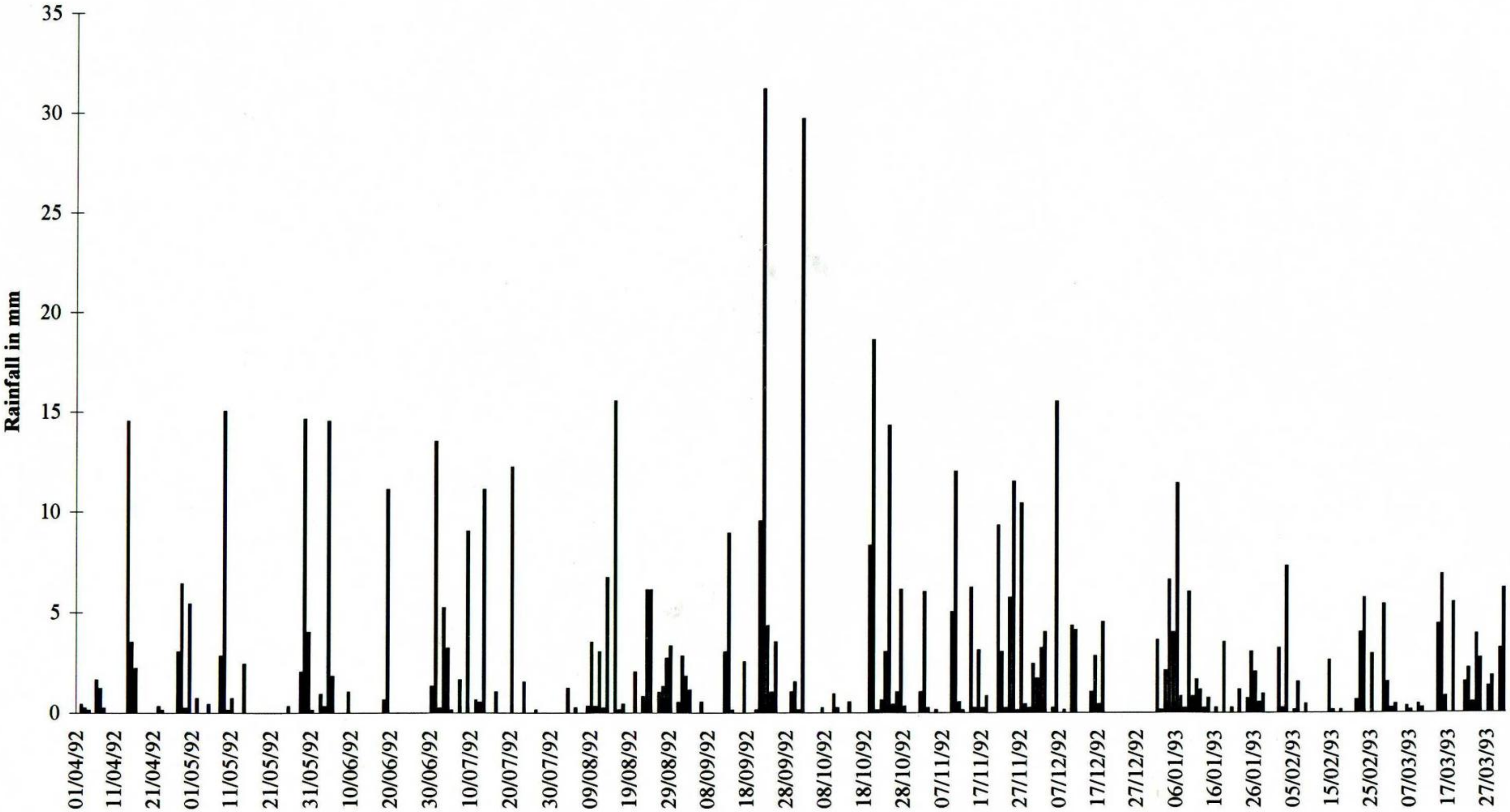


Figure 2.9: Mean daily discharge before, during and after pumped discharges to Chippenham Fen, 1992

Figure 2.10: Daily rainfall recorded at the Isleham raingauge before, during and after pumped discharge to Chippenham Fen, 1992



3. Vegetation monitoring

3.1 Introduction

Although the supplementary water source is apparently of suitable chemical composition for introduction into a fen ecosystem that is intrinsically of quite low productivity (Wheeler & Shaw, 1987), it was difficult to predict whether the quantity and quality of this water, or its method of introduction would be able to sustain the present vegetation and invertebrate resource. With this in mind, a programme of vegetation monitoring was put in place in 1991, with the additional aim of attempting to provide an empirical assessment of the changing hydrochemical regime by long-term monitoring of changes in floristic composition of the vegetation, by the use of a cost-effective monitoring programme.

Five years of monitoring have now been completed, and the results assessed. The full report on vegetation monitoring is provided in Appendix 2.

3.2 Methods

Four compartments were chosen for monitoring, in consultation with staff of English Nature: North Meadow and Compartments 6, 8 and 11 (see Figure 3.1). The constraints upon selection were:

(i) to represent a range of characteristic vegetation-types;
(ii) to represent contrasting hydrological conditions;
(iii) proximity to water-level recording stations;
(iv) a sufficiently large area of visually-uniform, herbaceous vegetation to facilitate extensive sampling.

Within each compartment, an area of visually-uniform vegetation (*c.* 30 x 30 m) was selected for sampling; in one compartment (6), two contrasting vegetation-types were present.

Each year, the monitoring was carried out between the last week in July and second week in August. The dates were chosen as a compromise between the requirement (i) to attain near maximal biomass in the vegetation (for the crop mass determinations) and (ii) to not cause excessive delay to management operations.

Three different techniques were used: random quadrats, permanent quadrats and crop mass estimates. Permanent quadrats can be used to provide a detailed record of compositional changes at particular points within the fen. They can provide clear evidence of temporal change at these points, but do not necessarily reflect changes elsewhere in the compartments, for which random quadrats were used. Crop mass components were estimated in order to assess change in performance (rather than abundance) of selected species and groups.

For the random quadrats, monitoring was based upon estimates of species frequencies, derived from records of species presence in 30 random nested quadrats, each with two 'nest levels: 0.25 m^2 and 2 m^2. Recording was carried out every year.

With the exception of Compartment 6, the permanent quadrat comprised a 5 x 1 m rectangle, subdivided into 5 contiguous 1 x 1 m squares. In Compartment 6 a short transect was set up with five, non-contiguous one metre square quadrats. Permanent quadrats were established in 1991, and subsequently recorded in 1993, 1994 and 1995.

Crop mass was estimated by clipping ten randomly-located 50 x 50 cm quadrats close to the ground. The cut material was sorted into the following components: *Phragmites australis, Cladium mariscus, Molinia caerulea, Juncus subnodulosus,* herbaceous species, bryophytes, other living material and litter, and subsequently air-dried and weighed.

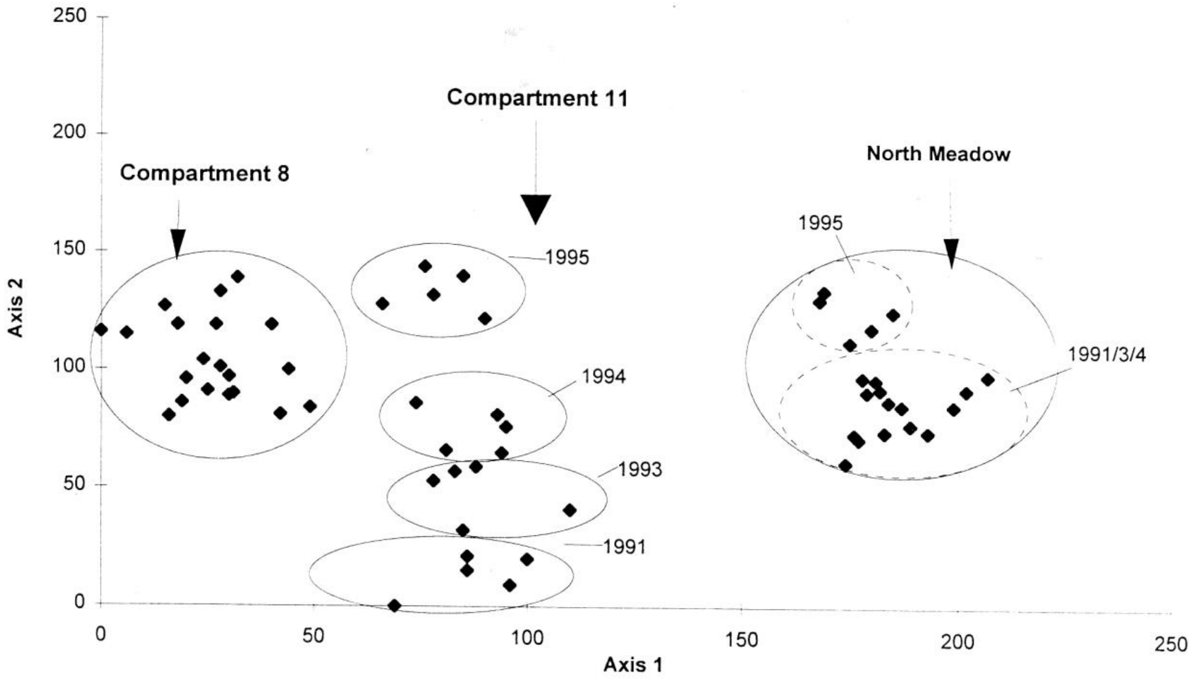


Figure 3.2 DECORANA ordination of permanent quadrat data for North Meadow, Compartments 8 and 11.

3.3 Results

Detailed results of the monitoring are available in Appendix 2. Results for random quadrat data have been presented for each year in terms of:

- mean frequency of individual species in each compartment;
- mean species density (SPD), mean numbers of Principal Fen Species (PFS)[2] and Rare Principal Fen Species (RPFS);
- mean proportion of species in the monitoring area encountered in each quadrat (mean frequency SPD, PFS and RPFS);
- total number of species, PFS, RPFS and non-fen species in each compartment.

Frequency distribution curves have also been plotted, which summarise the trends in changes in individual species frequencies. Results for permanent quadrat data are presented as frequency of individual species in each 'sub-quadrat' and as total frequency for each year. The data have been ordinated using the DECORANA computer programme. The composition of the vegetation in Compartment 6 permanent quadrats was relatively stable over the monitoring period. The ordination for Compartments 8, 11 and North Meadow is shown in Figure 3.2.

A table has been constructed which summarises the overall changes in selected species between 1991 and 1995 (Table 3.1). The 'moisture value' and 'nitrogen value' assigned to each species by Ellenberg (1974) have been included. These provide an indication of the water levels and nitrogen levels associated with particular plant species, based on an intuitive assessment of their preferences in western Central Europe. An indication is also given of the typical water levels and substratum fertilities with which the species were found to be associated in the synoptic survey of British fen vegetation-types reported by Shaw & Wheeler (1991). Although with clear limitations in their extrapolation, (see Wheeler & Shaw, 1995), these figures help to give some idea of the conditions with which the species are typically associated, and thus facilitate the interpretation of the data in terms of the possible ecological significance of variations in species' abundances.

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[2] A list of principal fen species and rare principal fen species is provided in Appendix 2

Table 3.1 Summary of changes in frequency of selected species between 1991 and 1995

1 = random quadrat size 1 (0.25m^2); 2 = random quadrat size 2 (2m^2); P = permanent quadrat. The number of arrows is an indication of the degree of change; ≈ denotes little, or no change; brackets indicate species present at very low frequency, or small change in frequency. Ebg.F = Ellenberg 'moisture value'; Ebg.N = Ellenberg 'Nitrogen value'; Wtab = mean summer water table; Fert = substratum fertility (M=moderate, L = Low) (see below)

	Ebg.F	Wtab	Ebg.N	Fert	Q	North Mead.	Comp. 6	Comp. 8	Comp. 11
Agrostis stolonifera	6~	M	5	M	1	↓↓↓	–	↓↓	↓↓
					2	↓↓↓	(≈)	↓↓	↓↓
					P	↓↓	–	≈	↓↓↓
Anagallis tenella *	–	M	–	L	1	↑	–	↑↑	↑
					2	↑	(≈)	↑↑	↑
					P	–	–	↑	↓↓
Angelica sylvestris *	8	M	X	M	1	↑↑↑	↑↑	↑↑↑	↑
					2	↑↑	↑↑	↑↑	↓
					P	↑↑↑	(↑)	↑↑	↑↑
Cardamine pratensis	7	M	X	M	1	–	–	–	↑
					2	–	–	–	↑↑
					P	–	–	(≈)	(≈)
Carex flacca	6~	M	X	L	1	≈	(≈)	↓	(↓)
					2	≈	(≈)	↓	↓
					P	≈	–	↑↑	↑↑
Carex hostiana **	9	M	2	L	1	(↓)	–	(≈)	–
					2	(↓)	–	(≈)	–
					P	≈	–	–	↓
Carex panicea *	7	M	3	L	1	↓	–	↑↑	≈
					2	≈	(≈)	↑↑	≈
					P	≈	–	↑↑	(≈)
*Carex viridula ssp. brachy.**	8	M	2	L	1	–	(≈)	≈	≈
					2	–	(≈)	↓	≈
					P	≈	(≈)	↑	↑↑
Cirsium dissectum **	–	L/M	–	L	1	↓	(↓)	↑	–
					2	≈	↑	↑	–
					P	↓	(≈)	(≈)	–
Cirsium palustre *	8~	L/M	3	M	1	↓↓	(≈)	↓	↓↓
					2	↓↓	(↓)	↓	↓↓
					P	↓	(≈)	↑	≈
*Cladium mariscus***	10	L/M	3	L/M	1	–	=	(↓)	(↓)
					2	–	=	(↓)	(↓)
					P	–	=	↑	–
Deschampsia cespitosa	7~	M	3	M	1	(≈)	(≈)	(↓)	↓↓
					2	≈	(≈)	≈	↓↓
					P	–	–	≈	↓↓↓
Epilobium hirsutum *	8=	L	9	H	1	–	–	(↓)	–
					2	–	–	(↓)	–
					P	–	–	–	–
Equisetum palustre *	7	M	3	M	1	(≈)	↑↑	≈	↑
					2	(≈)	↑↑	↑	↑↑
					P	–	≈	≈	↑↑
Eupatorium cannabinum *	7	L/M	8	M	1	↑↑↑	(↓)	↑↑	(↓)
					2	↑↑↑	↓	↑↑	↓
					P	↑↑↑	≈	↑↑↑	↑↑↑
Festuca rubra	X	L/M	X	M	1	↑↑	(≈)	≈	(↑)
					2	≈	(≈)	≈	↑
					P	↑↑	(≈)	≈	↑
Filipendula ulmaria *	8	L/M	4	M	1	–	(≈)	(≈)	≈
					2	≈	↑	(≈)	↑↑
					P	–	(≈)	–	–
Fraxinus excelsior	X	–	7	–	1	(≈)	(↑)	≈	↓
					2	(≈)	(↑)	≈	↓
					P	(≈)	(≈)	(≈)	↑
*Galium uliginosum**	8	L/M	X	L/M	1	↑	(≈)	↓	(↓)
					2	↑	(↑)	≈	≈
					P	↑↑	(↑)	↑	≈
Glechoma hederacea	6	–	7	–	1	–	–	–	–
					2	(≈)	–	–	(≈)
					P	(≈)	–	–	↓↓

						Mead.	6	8	11
Hypericum tetrapterum *	8=	L	5	M	1	–	–	–	–
					2	–	–	(≈)	–
					P	–	–	–	–
Juncus subnodulosus **	8	M	X	M	1	(↓)	≈	(↓)	≈
					2	≈	≈	(↓)	≈
					P	↓	↑	≈	=
Lythrum salicaria *	8=	L/M	X	M	1	(≈)	↑↑	↑	(≈)
					2	(≈)	↑	≈	(≈)
					P	–	–	↑	–
Mentha aquatica *	9=	M	4	M	1	↑	(↑)	↑	↑↑
					2	↑	↑	↑	↑↑
					P	↑↑↑	–	↑↑	↑↑↑
Molinia caerulea *	7~	M	2	L	1	≈	↑	≈	≈
					2	≈	↑	≈	≈
					P	=	–	≈	≈
Phragmites australis *	10~	M	5	M	1	≈	(↓)	(↓)	≈
					2	≈	≈	≈	≈
					P	↑	≈	↓	≈
Prunella vulgaris	X	L/M	X	L	1	↓	–	(↓)	↓↓
					2	↓	–	≈	↓↓
					P	↓	–	–	–
Ranunculus flammula *	9~	M/H	2	L/M	1	–	–	–	≈
					2	–	–	–	≈
					P	–	–	–	–
Salix seedlings (cf. cinerea)	(9~)	M	(4)	M	1	↑↑↑	–	≈	↑↑↑
					2	↑↑↑	(≈)	≈	↑↑↑
					P	↑↑↑	–	↑↑	↑↑↑
Samolus valerandi **	8=	–	6	–	1	–	(↓)	≈	≈
					2	–	(↓)	↑	↑
					P	–	–	(↑)	–
Scrophularia auriculata *	–	–	–	–	1	–	(≈)	–	–
					2	–	(≈)	(≈)	–
					P	–	–	–	–
Selinum carvifolia **	7~	–	2	–	1	↑↑	–	–	–
					2	↑	–	(↑)	↑
					P	↑↑↑	–	–	–
Symphytum officinale	8	M	8	M	1	–	–	–	↑
					2	–	–	–	↑↑
					P	–	–	–	–
Valeriana dioica *	8~	M	2	L/M	1	–	–	–	↑
					2	↑	–	≈	↓
					P	↓	–	≈	≈
Vicia cracca	5	L	–	M	1	–	(↑)	↑	↑
					2	↓	↑	↑	≈
					P	↓	–	≈	≈
Brachythecium rutabulum	–	L/M	–	M	1	↑↑	↑	↓	↓
					2	↑↑	↑↑	≈	↓↓
					P	↑	↑	↓↓	≈
Calliergon cuspidatum *	–	M	–	M	1	↓↓	(↑)	↓	↑
					2	↓	(↑)	↑	↑
					P	↓↓	≈	↓	≈
Eurhynchium praelongum	–	L	–	M	1	↓	–	↓↓	↓
					2	↓	(≈)	↓↓	↓
					P	↓	(≈)	↓	(≈)
Fissidens adianthoides *	–	M	–	L	1	≈	(≈)	↑	–
					2	≈	(≈)	↑	–
					P	↑	(≈)	↓	–

* = principal fen species, ** = rare principal fen species

Ellenberg values are taken from Ellenberg (1974). 'Moisture values' range from 1 (occur in extremely dry soils), through 7 (in moist soils which do not dry out) to 12 (submerged plants, usually entirely immersed). X: with broad amplitude, or with different behaviour in contrasting habitats; ~ in fluctuating mosture conditions. = soils that are fairly regularly inundated.

'Nitrogen values' range from 1 (only in soils very poor in mineral nitrogen), through 7 (mostly in soils rich in mineral N) to 9 (only in soils very rich in mineral N).

Water table and fertility values are taken from Shaw & Wheeler (1991). Summer water table: low = -25 to -10 cm; moderate = –9 to +1 cm. Substratum fertility: low = 3–9 mg/seedling; moderate = 10–20 mg/seedling.

Figure 3.1 Location of vegetation monitoring plots

Crop mass

Figure 3.3 provides a summary of the crop mass recorded in 1991 and 1995, with a summary of the changes provided in Table 3.2. The highest crop mass was recorded from Compartment 6, followed by Compartment 8, Compartment 11 and North Meadow. There was some variation in contribution from component groups, but no trend for an overall increase in crop mass, which would be consistent with an increase in fertility, other than perhaps in Compartment 6 (although the apparent increase in total crop mass was not statistically significant).

The greater crop mass recorded from Compartment 8 than Compartment 11 is consistent with the stage of mowing cycle in which they were sampled, *i.e.* the biomass in the former includes an additional years growth. The difference is particularly noticeable in the litter component. The contribution from herbs and *J. subnodulosus* is lower in Compartment 8 than Compartment 11. The latter species is present at high frequency in both compartments, and, as it is deciduous, it could be speculated that less biomass is produced in the second year following mowing than in the first. This difference is also consistent with the possibility that the substratum in Compartment 11 is more fertile than that in Compartment 8.

Table 3.2 Summary of changes in crop mass between 1991 and 1995

	North Meadow	Compartment 6	Compartment 8	Compartment 11
Phragmites australis	(↑)	≈	≈	↑↑
Cladium mariscus	not present	≈	(↓)	≈
Juncus subnodulosus	≈	(↑)	↓	≈
Molinia caerulea	↑↑	≈	≈	(↓)
Herbs	≈	≈	≈	≈
Moss	≈	≈	≈	↑↑
Others	↓	≈	(↑)	≈
Litter	↑↑↑	↑↑↑	≈	≈
Total	(↑)	(↑)	≈	≈

The number of arrows indicates the degree of statistical significance of the change ($p < 0.05$, 0.01 or 0.001). Brackets indicate an apparent change, although not statistically significant.

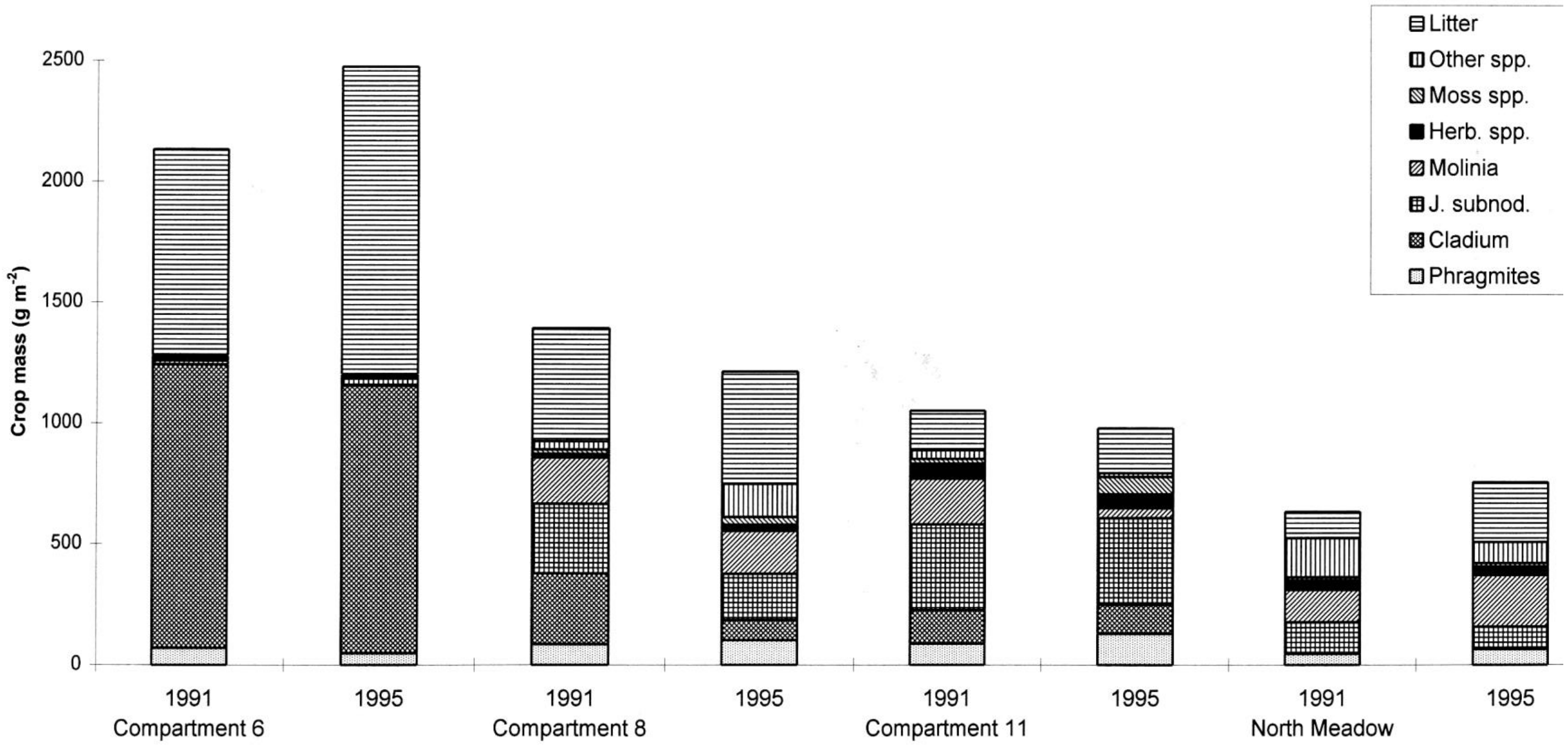


Figure 3.3 Chippenham Fen: crop mass components in 1991 and 1995

Hydrological regime

An important part of the assessment of variation in vegetation composition in the different compartments is to consider the hydrological regime during the monitoring period. Water level data were collected for each monitoring area from one dipwell (see Appendix 1), which for the present purposes, has been assumed to be representative of the monitoring area, although not actually within it. Figure 3.4 provides a compilation of the dipwell data taken for these compartments from the hydrological assessment; these data are summarised in Table 3.3. The 'duration lines' shown in Figure 3.4 can be used to illustrate the number of sampling occasions over a given period on which a given water level was exceeded (e.g. Grootjans & Ten Klooster 1980). For example, a convex duration line represents the water regime of a site in which the water table remains mainly in the upper half of its fluctuation range. Of the four compartments, the water regimes in Compartment 8 and North Meadow show the most similarity, with water levels generally lower, but more stable than in Compartments 6 and 11.

In the compartments where vegetation was monitored, dipwells were only installed at the start of the monitoring period (*i.e.* in 1991), and there are therefore no data for a comparable earlier period. This is particularly problematic for the comparison of crop mass data, which was only sampled at the beginning and end of the monitoring period. It may be possible to make some inferences from the longer-standing dipwell records, but time constraints mean that it has not been possible to do this yet. Comparisons of duration lines drawn for different periods could also be useful in looking at changes in the water regime through time.

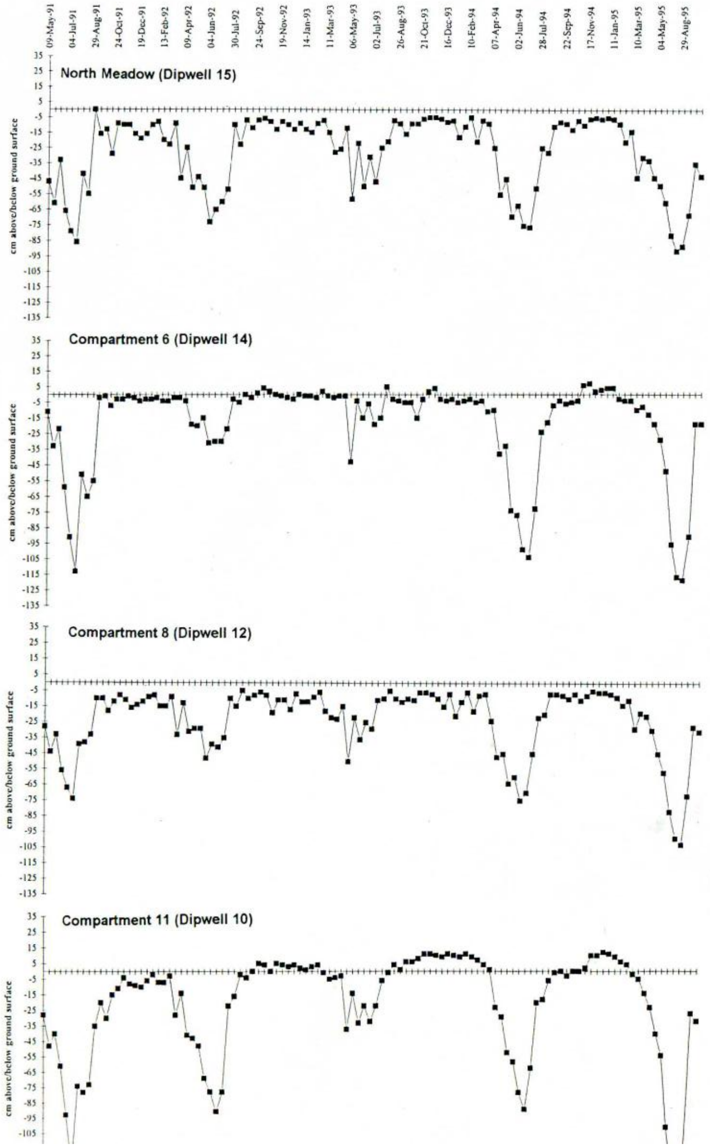
Table 3.3 Variation in water level in the dipwells closest to the vegetation sampling areas

(Measurements in cm above/below ground surface)

	North Meadow	**Compartment 6**	**Compartment 8**	**Compartment 11**
Dipwell No.	15	14	12	10
Elevation (MAOD)	12.3	12.6	12.7	12.92
Mean	-27.8	-18.3	-23.9	-21.4
Median	-17	-4	-15	-6
St. Deviation	23.7	29.7	21.2	34.7
Minimum	-91	-119	-103	-135
Maximum	0	7	-5	12
Range	91	126	98	147
Spring	-37.1	-17.5	-29.3	-21.0
Summer	-48.7	-46.9	-42.3	-59.1
Autumn	-14.4	-6.3	-13.5	-9.0
Winter	-11.8	-1.9	-11.1	3.7

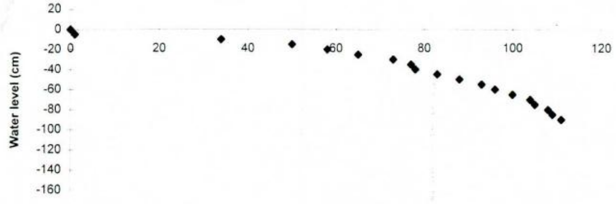
igure 3.4 Variation in dipwell water levels in North Meadow and Compartments 6, 8 & 11 for the period 9.5.91 to 9.10.95

. Water level in dipwell (relative to ground surface)

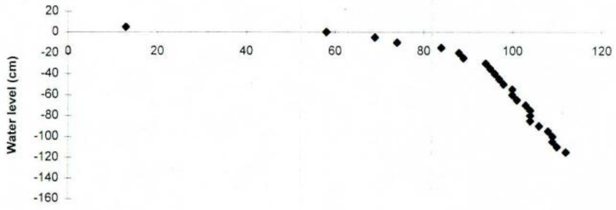


B. Duration lines (Showing no. of occasions on which given water level was exceeded)

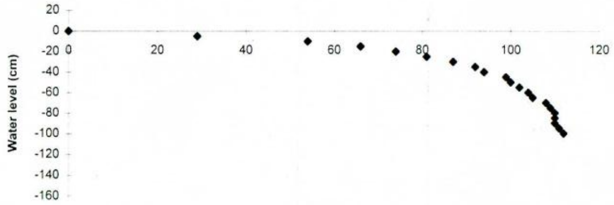
(a) North Meadow (Dipwell 15)



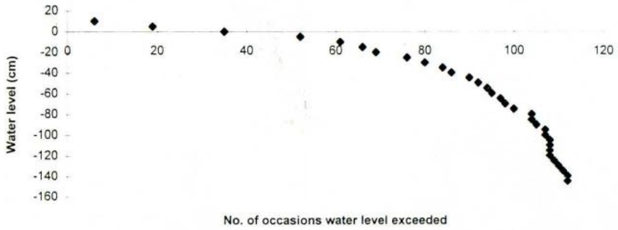
(b) Compartment 6 (Dipwell 14)



(c) Compartment 8 (Dipwell 12)



(d) Compartment 11 (Dipwell 10)



3.4 General trends in each compartment

North Meadow

The vegetation of the North Meadow is quite different to that of the other compartments, comprising a relatively low-growing sward of vegetation, with *Molinia caerulea* and *Juncus subnodulosus* as some of the most important component species, but with a well-developed sward of associates, giving a diverse stand. This area was the most species rich in terms of mean species density, but supported fewer species in total, and fewer principal fen species than both Compartments 8 and 11. However, interestingly, it did support the highest number (8) of rare fen species of the four compartments. The vegetation supports a number of notable species including *Anagallis tenella, Carex hostiana, Cirsium dissectum, Gymnadenia conopsea* and *Selinum carvifolia*, together with a quite large population of marsh orchids.

The hydrological regime experienced in the western part of North Meadow was similar to that in Compartment 8 in terms of the range of values experienced, the relatively high variability during winter periods and the depths to which the water table declines during summer. The mean water table depth (–27.8 cm) was the lowest of the four areas.

The three main species (*Juncus subnodulosus, Molinia caerulea* and *Phragmites australis*) were found at or near 100 % frequency throughout the monitoring period, although there was a trend for a slight decrease in *J. subnodulosus*. The fluctuating and generally sub-surface water table is likely to favour the growth of species such as *Molinia caerulea*. This species showed an increase in biomass over the period monitored. However, this does not necessarily suggest an increase in substratum fertility, as the sampling was carried out one-year and two-years after mowing, and therefore a straight comparison cannot be made between the two samples. However, the trend for an increase in frequency of *Angelica sylvestris, Eupatorium cannabinum* and *Mentha aquatica* could also be suggestive of an increase in nutrient supply. The *Molinia* is clearly kept in check by the current management regime of grazing and mowing. The present intention to maintain higher water levels, particularly in winter (a bank at the west end of the Compartment has recently been repaired) should help to dis-favour *Molinia* and maintain species diversity. However, extended inundation should be avoided. The decline in *Calliergon cuspidatum* and increase in *Brachythecium rutabulum* may reflect the relatively dry conditions, as may the sudden influx of *Salix* seedlings in 1995. It would be interesting to monitor the overall effect of the recent raising the water levels (the site was inundated in winter 1995/6).

The general increase in frequency over the monitoring period of both *Anagallis tenella* and *Selinum carvifolia* is of note, as these species are of particular interest. The latter showed a particularly strong increase in frequency at the smaller random quadrat size (from 33% to 53%), which suggests that it has become generally much more frequent within the monitored area, now occurring in over half of the quadrats sampled. For *Anagallis*, the increase was from 3.3 to 7%, which is probably of significance, although may just be an expression of the generally low frequency of this species. Further monitoring would help to determine whether this was a general trend.

Selinum carvifolia and *Angelica sylvestris* may be damaged to some extent by grazing, and it is of interest to note that in both species there was apparently an increase in frequency of these species following mowing of the sward. It is possible that for such species (which are fairly short-lived perennials), that it is the dynamics of recruitment of individuals which has been monitored, rather than response to environmental conditions.

Recent measures have been taken to increase winter water levels in the North Meadow, by repair of a dam. However, it is possible that winter inundation could in fact be detrimental to the current floristic interest of these meadows as Eu-Molinion.

Compartment 6

It is difficult to make an assessment of trends for this compartment as there is no previous management period with which to compare, having only been mown once during the present monitoring period considered. However, a few general observations can be made.

Cladium mariscus retained its dominance and crop mass throughout the monitoring period, with fairly minor changes in the infrequent associated species. The patchy nature of the vegetation is apparent from both the permanent and random quadrat data, and make it particularly difficult to discern any general trends over one monitoring period.

Compartment 6 supports only few rare fen species, but as two of these formed the major components of the vegetation, this Compartment showed the highest mean frequency of RPFS in most years. The apparently large increase in mean frequency RPFS between 1991 and 1992 can be explained by the fact that in 1992 *Cladium mariscus* and *Juncus subnodulosus* were the only two rare fen species recorded.

Compartment 6 was the wettest of the four, having the highest mean and median water levels. Lying alongside the river, it is possible that it receives some water inputs from this source. However, although autumn/winter water levels were fairly stable and close to the ground surface (sometimes above), summer water levels can fall to more than a metre below surface level, giving a range of 126 cm over the 5-year period. The wet conditions in 1993 were reflected in records of algae on the peat surface, which were not apparent in other years, other than in one of the permanent quadrats in the first year of monitoring (1991).

The increase in mean species density, and total number of species recorded in the random quadrats in 1994, including massive invasion of *Betula* seedlings in 1994, may have been a result of the early drop in water levels in comparison with the previous two years. However, most of the *Betula* seedlings had disappeared by 1995 (possibly drowned by the winter inundation?), and this species does not appear to offer a management threat at present.

There were no trends in vegetation composition which could be clearly related to the mowing regime, where it might be expected that the initial opening-up of the canopy would promote an influx of species, followed by a reduction as the *Cladium* becomes more dense. However, random quadrat data showed a sharp rise in frequency of a number of species in 1994 (*i.e.* in the second year following mowing), many of them having been unsampled or at very low frequencies prior to this, including *Anagallis tenella*, *Fissidens adianthoides* and *Lycopus europaeus*. The low frequencies at which they were sampled explains the slight decline of mean frequency of species density and number of principal fen species.

There was a marked decline in frequency of *Juncus subnodulosus* in 1993 (the year following mowing), which is perhaps surprising as it might be expected that this species would benefit from the opening up of the canopy. The marked increase in frequency of *Fraxinus* seedlings in the two years following mowing with subsequent decline may also be a result of the mowing regime.

In order to reduce the variability due to the patchy vegetation structure, the samples for crop mass were taken from a restricted area of dominant *Cladium*, and thus the lack of changes in contribution from associated species in comparison with trends noted in the random quadrats is not surprising. Although there was an apparent increase in total crop mass, the only significant difference in crop mass recorded between 1991 and 1995 was an increase in the amount of litter. It is possible that this is related to the generally wet conditions following the mowing in 1992, through to spring 1994, and again in autumn/winter 1994/5, which would help to retard decomposition.

Compartment 8

This Compartment is largely dominated by *Molinia caerulea* and *Juncus subnodulosus*, with some *Cladium mariscus* prominent in patches. It is floristically quite similar to Compartment 11, with similar numbers of species recorded, although Compartment 8 supports more rare fen species. There were no changes noted amongst the main dominant species, other than fairly minor variations in frequencies. However, Compartment 8 had the largest number of species exhibiting some change in frequency. Particularly interesting is that the frequency of eight species in this compartment showed considerable variation, seemingly in accord with the mowing cycle. Two species, *Carex panicea* and *Samolus valerandi*, increased in frequency between years 1 and 2 on both occasions, while six species, including *Lythrum salicaria, Valeriana dioica* and *Cirsium palustre* decreased in frequency between years. Total species numbers recorded in the first year following mowing were slightly lower than in the second. This was evident for principal fen species, rare fen species and non-fen species, and seems to be a result of more species being recorded at low frequency in the second year. Although of interest, it is possible that this effect is just a co-incidence of recording rather than a result of species dynamics, particularly as the same trend was not consistent in Compartment 11. Further monitoring would help to determine this. Three species, *Angelica sylvestris, Mentha aquatica* and *Anagallis tenella,* increased in frequency throughout the whole monitoring period.

There was little significant variation in crop mass between 1991 and 1995, although the decrease in *Juncus subnodulosus* and trend for an increase in contribution from 'other' species (mainly sedges and *Equisetum*) could suggest that conditions have particularly favoured the latter group. Data provided by the random quadrats were suggestive of a decrease in frequency of *J. subnodulosus* (from 100 to 93%) over the last year, and also demonstrated an increase in frequency of *Equisetum palustre* and *Carex panicea.* In the permanent quadrat, *Carex panicea, C. flacca* and *C. lepidocarpa* all increased in frequency.

The water regime in Compartment 8 showed more similarities with that in the North Meadow than in Compartment 11, with sub-surface winter water levels, although summer minima were lower, reaching between *c.* 55–100 cm below ground level. Records showed that the first management period (*i.e.* between mowing in 1991 and 1993) was generally wetter than the second (*i.e.* after mowing in 1993) (see Appendix 1), and this is likely to have influenced some species changes which might have been a response to mowing.

Compartment 11

The vegetation in this Compartment is similar to Compartment 8, though with rather more *Juncus subnodulosus* and less *Cladium mariscus.* There was a similar range of principal fen species, but only four of these were rare: *Cladium mariscus*, *Juncus subnodulosus*, *Selinum carvifolia* and *Samolus valerandi*. The vegetation is mown every two years, alternating with mowing in Compartment 8.

The water regime in Compartment 11 showed more similarities with Compartment 6, than Compartment 8. It is typically inundated in winter to a depth of a few cm, but showed the widest variation in water levels, with a range of 147 cm. Comparison with the data for Compartment 8 show that Compartment 11 was generally wetter in winter, but with lower summer water levels. It is possible that some of the variation may be explained by the different nature of the underlying bedrock (Compartment 11 is underlain by Totternhoe Stone), or the differing proximity of the dipwells to ditches.

There was a slight decrease in mean species density and mean number of principal fen species from 1991 to 1993, followed by an increase to 1995. However, this was also reflected in the total numbers of species recorded. In the permanent quadrat, *Carex flacca* and *Carex lepidocarpa* both increased in frequency, although this was not apparent from the random quadrat data. In contrast with North Meadow and Compartment 8, *Calliergon cuspidatum* increased in frequency over the monitoring period – this could be a result of the generally wetter conditions in this compartment. The inundation in this compartment is of interest as it is lies higher above the river than the other three compartments monitored. It would be of interest to know whether this was a result of flooding from adjacent dykes, or ponding of rainwater, especially as this water may be a source of some nutrient enrichment. The trend for an increase in winter water levels should be monitored, as if it continues, may result in some undesirable floristic changes.

There was some evidence of changes in species frequencies in line with the mowing regime, for example, *Molinia caerulea, Equisetum palustre, Cirsium palustre, Deschampsia cespitosa, Symphytum officinalis, Agrostis stolonifera* all decreased in frequency, while *Mentha aquatica* and *Potentilla erecta* tended to increase in frequency following mowing. However, the only consistent species response to mowing in both Compartments 8 and 11 was shown by *Cirsium palustre.*

There was no significant change in total crop mass between 1991 and 1995, although there was a significant increase in contribution from mosses and *Phragmites australis.* The frequency of *Phragmites* did not change over this period, suggesting that there may be a response to some external factors (such as nutrient supply), although, of course, some natural variation in biomass production cannot be discounted. However, the overall species changes noted would also be suggestive of an increase in nutrient supply, and are also consistent with the observation that there has been a general increase in water levels (see Appendix 1).

3.5 Discussion

Few species appear to have shown a consistent pattern of increase or decrease across the site during the five years of monitoring (Table 3.1). Exceptions include *Mentha aquatica,* which increased in frequency in all compartments, *Angelica sylvestris,* which increased in frequency in Compartments 6, 8 and the North Meadow and *Anagallis tenella,* which increased in North Meadow and both Compartments 8 and 11. There was a reduction in frequency of *Cirsium palustre* and *Agrostis stolonifera* in all compartments except 6 (where they were only present at low frequency). There was a major influx of *Salix* seedlings into North Meadow and Compartments 8 and 11 in 1995.

In attempting to interpret such trends, and others reported here, there are several general points which should be made:

- Conditions seem to have been drier in the period 1989–1991 than in the period through which the vegetation has been monitored (see Appendix 1). It is therefore possible that some of the changes in species abundance recorded may be a response to this.
- The field distribution and abundance of many wetland species are likely to be strongly influenced by environmental variables other than water levels, for example, substratum fertility, base status and availability of toxic metals (*e.g.* iron). The species composition of a sward is also strongly affected by the management regime.
- The natural population dynamics of many species is poorly known, and some of the variation recorded is undoubtedly due to natural population fluxes, although these will be influenced by prevailing environmental conditions. For example, the large invasion of *Salix* seedlings in 1995 was presumably the result of good conditions for seed production in 1994, coupled with subsequent optimum conditions for germination and establishment. Similarly, species are affected differently by management (including disturbance by trampling), and response may depend on their vegetative regenerative abilities, as well as life-history characteristics. For example, *Mentha aquatica* is known to regenerate well from fragments, and it is possible that the general increase in frequency of this species is a result of the management regime, rather than a response to changing environmental conditions.
- The response of plant species to hydrological conditions, or to changes in them, is very poorly known (see Wheeler & Shaw, 1992; 1995). In particular, little is known about the speed of response of species to changing water level conditions, but it is likely that established perennial plants will show substantial inertia against water level change (and that such plants can survive periodic, short-term droughts). The general trend for an increase in frequency of *Anagallis tenella* is of interest, as this is a species which might be expected to be badly affected by low summer water levels. However, recent evidence indicates that in laboratory conditions, *Anagallis tenella* grows better when in soil with a water table maintained at –20 cm than when kept at –10 cm or 0 cm. (P. Eades, *pers. comm.*)

It is thus difficult from the present data to separate natural population fluxes from the response to management and environmental conditions, but there is no consistent evidence that suggests that there have been any substantial general changes in vegetation composition or crop mass throughout the monitoring period which would be suggestive of deterioration in the floristic quality of the site. However, the floristic changes in North Meadow reflected the generally 'dry' conditions, perhaps coupled with a small amount of enrichment, while in Compartment 11 the changes in vegetation were consistent with the increasingly wet, although widely fluctuating, water levels, together with an increase in nutrient supply. Further monitoring would identify whether these are general trends which would be of concern in the future. The present data set provides a good baseline against which future changes in the vegetation can be assessed, and it is recommended that vegetation monitoring is continued, but perhaps on a less frequent basis.

The crop mass sampling has provided some useful information, but it is suggested that continued monitoring of crop mass cannot be justified. Some changes in species composition have been noted, particularly in North Meadow and Compartment 11, and these compartments should be monitored as a minimum. It is recommended that detailed sampling is continued on a two-yearly basis (to fit in with the management regime), if possible. If funding is limited, it may be possible to devise a less intensive monitoring strategy which would help to determine whether adverse changes are taking place. As the permanent quadrats are now marked with transponders, these should be easy to resample as required.

3.6 Conclusions

Compartment 8 and Compartment 11 are both managed on a two-year mowing cycle, thus two full management cycles have been monitored. North Meadow is grazed annually, but mown every 2–3 years and Compartment 6 is mown every four years. For these areas, only one management cycle has been monitored, making it more difficult to assess consistent trends.

Some changes in species abundances have been noted. However, with a relatively short period of monitoring, it is difficult to separate the effects of:

a) natural population dynamics;

b) management cycle;

c) variation in hydrological conditions (water levels and climate).

There is no consistent evidence that suggests that there have been any substantial changes in vegetation composition or crop mass throughout the monitoring period in Compartment 6 or Compartment 8.

In Compartment 11, changes in species frequencies suggested that conditions are becoming wetter and perhaps more nutrient-rich. This is consistent with the trend shown by the dipwell data over the five-year period, for rising winter water levels, but with a substantial fall in water levels during the summer (*i.e.* wide fluctuations). Possible sources of enriched water should be investigated, particularly as the area is inundated in winter.

In North Meadow, the monitoring data suggest that there may have been a some increase in nutrient supply, coupled with summer-dry conditions. It is suggested that damming water in the Chippenham River to produce winter inundation may in fact be detrimental to the current floristic interest in this area.

The present data set provides a good baseline against which future changes in the vegetation can be assessed. It is recommended that vegetation monitoring is continued, but perhaps on a less frequent basis.

4. Invertebrate monitoring

4.1 Introduction

Monitoring of the aquatic and terrestrial invertebrates at Chippenham Fen has been carried out by Dr Peter Kirby over the period 1991 to 1995. The full report is provided as a separate document (Appendix 3).

4.2 Aquatic invertebrates

4.2.1 Introduction

Monitoring of vegetation and invertebrates at Chippenham Fen began in 1991, and aquatic invertebrates have been sampled annually in the autumn since then. In 1991, seven ditches were selected for monitoring by English Nature, these being ones thought particularly likely to show any effects of changes in the quality and quantity of the water supply. In 1992, in addition to the seven stations examined in 1991, a further three stations were sampled, further from the points of input of spring and augmentation water, to provide a wider range of ditch types and comparative data. All ten stations were sampled in 1993–1995. The results of monitoring in 1991–1994 and some analysis have been given in annual reports (Kirby 1992b, 1993, 1994, 1995).

In 1991 a wide range of invertebrate groups was identified. Either very low numbers or very few species were found in many of these groups, and it was thought that most would be unhelpful in indicating deleterious changes in the water supply through a simple monitoring programme. In subsequent years only Mollusca and Coleoptera have been sampled in all years, with Hemiptera also identified in 1993 and 1994.

The specific aims of the 1995 aquatic invertebrate survey were:

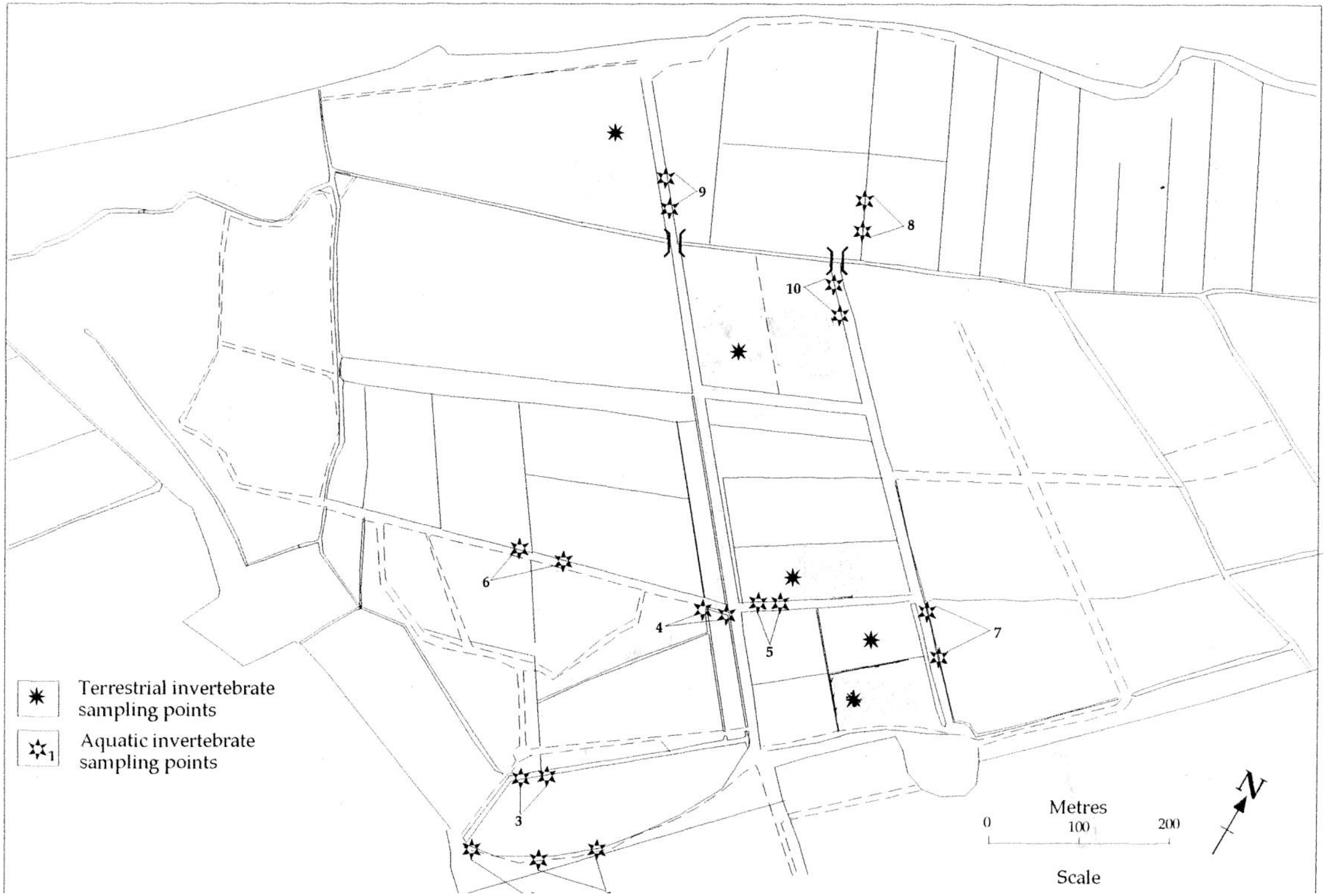
- to sample the water beetles, molluscs and bugs at the ten ditches monitored in previous years;
- to analyse the results over the five year monitoring period, highlighting any changes that /may be ascribed to inadequate water supply to the fen;
- to comment upon the known ecological requirements of the species which have exhibited change.

4.2.2 Methods

Samples were taken in late September or early October in each year of the monitoring period. The locations of the sampling stations have been the same in each year, and are shown on Figure 4.1. Each was sampled over a twenty metre stretch, selected to include the typical features of the ditch. Details of procedures and sample stations are given in Appendix 3.

The abundance of each species in each ditch was estimated on a five-point scale (1 = abundant; 5 = rare), and each species recorded was assigned a status according to its national / local status (*e.g.* Hyman & Parsons, 1992; Kirby, 1992a). Each recorded species has also been assessed according to whether it occurs in still or running water, whether it requires permanent water, and whether it is likely to be sensitive to changes in water quality.

Figure 4.1 Location of sample stations for monitoring terrestrial and aquatic invertebrates



4.2.3 Results and discussion

Detailed results from the monitoring are provided in Appendix 3, and compare the 1995 data with those of previous years, with tables summarising records of individual species, and giving totals year by year and ditch by ditch. Table 4.1 provides a summary of species numbers in various categories from all ditches in all years.

The overall character of the fauna

Although the sample stations are very varied in terms of width, depth, successional stage and extent of shading, and though there is consequently considerable variation in the fauna recorded from them, they nonetheless have much in common. Shared characteristics are a silty bottom (though variously overlain by dead leaves and mud), abrupt margins, and flowing water. The consequence is a fauna which supports species characteristic of both still and flowing water, the balance between the two determined by distance from the springs which supply water to the fen; the density of submerged and emergent vegetation (determined in large measure by the time since last management); and the volume of water entering the fen.

The mix of flowing and still water species, and variation according to amount of flow, are most clearly manifest in the water beetles. The molluscs tend simply to be relatively poor in species, considering the water chemistry of the site. To some extent the same is true of beetles; none of the flowing ditches is rich in either species or rarities. Presumably the 'half-way house' character of the ditches has meant that they do not have the conditions needed to support either a rich fauna, or many of the scarcer representatives, of either fen ditch or flowing water beetle communities. The physical structure and vegetation of the ditches, with abrupt margins and usually dense tall marginal plants, may well be further significant factors in limiting the species richness of the invertebrate fauna. Some groups of Hydrophilid beetles normally associated with dense vegetation near water margins, for example, are scarce or absent in these ditches. This is most obviously the case with the genera *Enochrus*, *Helophorus* and *Cercyon*. Dryopids, also characteristic marginal species, are similarly scarce.

These characteristics are emphasised by the two sample stations, 8 and 9, which do not conform to the generality. Sample station 8 is on an unshaded heavily vegetated ditch with negligible flow between cattle-grazed fields. This sample station has been consistently more species-rich than any other, particularly in a consistently high species count of molluscs. It is especially characterised by a large population of *Planorbarius corneus* and by the consistent presence of the beetles *Noterus clavicornis* and *N. crassicornis*. These species were found in at least small numbers in every year at sample station 8, but never recorded elsewhere. Station 9 is a small drainage ditch with dense growth of *Molinia* and other grassy vegetation, which is dry for a considerable part of each summer, and contained a significant amount of water on only one of the sampling periods. The fauna recorded here varied greatly from year to year according to how wet the ditch was, but was always very different in character from the general run of ditch sampling sites.

The sample stations do not cover the full range of aquatic habitats present on the fen. All are ditches, though one is a very small one which is dry for part of every year. Small pools and areas of saturated ground within fenland compartments and under shade from carr and woodland are not included amongst the sample stations, though they are likely to hold important faunas.

Table 4.1 Summary of records from all ditches in all years

tot spp	number of species of molluscs and water beetles recorded in a single year.
av spp	average number of species recorded per year.
tot F	number of species associated with flowing water.
tot P	number of species believed likely to require permanent water.
tot S	number of species believed likely to be sensitive to declining water quality.
tot N	number of species which are Nationally Scarce or Red Data Book.

For each sample station there are five entries in each column, except the av spp column. These correspond to the five years over which monitoring has taken place. The figures for 1991 are given first.

sample station	tot spp	av spp	tot F	tot P	tot S	tot N
1	2	4.0	0	0	0	0
	7		1	1	0	0
	2		0	1	0	0
	3		1	2	0	0
	6		1	1	0	0
2	24	16.6	2	1	2	2
	21		2	2	2	2
	13		2	0	1	1
	14		1	1	0	0
	11		1	1	1	1
3	7	10.6	1	2	1	0
	10		1	2	1	0
	12		1	1	0	1
	14		1	2	0	0
	10		1	1	1	0
4	26	15.0	0	6	6	3
	11		0	4	1	0
	6		1	1	0	0
	10		0	3	0	0
	22		0	1	3	2
5	26	23.8	1	3	5	3
	16		0	2	2	1
	21		1	2	3	2
	32		0	3	5	3
	22		1	2	5	2
6	19	17.6	1	4	3	2
	18		2	3	2	1
	13		2	2	2	0
	19		1	2	4	2
	19		2	2	5	3
7	15	12.2	1	3	4	3
	14		1	3	3	1
	15		1	2	3	2
	9		0	2	0	0
	8		1	2	0	0

continue

Table 4.1 (continued)

sample station	tot spp	av spp	tot F	tot P	tot S	tot N
8	-	38.5	-	-	-	-
	33		0	8	4	2
	36		0	6	3	2
	44		0	9	5	3
	41		0	8	4	2
9	-	8.3	-	-	-	-
	17		0	0	2	2
	9		0	0	1	1
	4		0	0	0	0
	3		0	0	0	0
10	-	13.0	-	-	-	-
	20		0	3	1	1
	9		0	1	1	0
	14		1	4	0	0
	9		0	2	0	0
total	**58**	**58.6**	**4**	**9**	**13**	**10**
	56		**4**	**6**	**6**	**5**
	59		**4**	**7**	**10**	**8**
	59		**3**	**11**	**8**	**5**
	61		**4**	**10**	**10**	**6**
total all years	**97**		**5**	**14**	**23**	**17**

The effects of wet and dry years

The first survey, in 1991, was undertaken in conditions of extreme drought. It was suggested in the report for that year (Kirby, 1992b) that some of the recorded species were present in the sample ditches only because either their more usual habitats had dried out and they were seeking refuge from drought in the ditches which still held water, or because atypically low water flow had led to normally unsuitable ditches temporarily providing conditions suitable for still-water species. Data from the three subsequent, rather wet, years tend to confirm this. Several scarce species seen in 1991 which would not typically be expected in ditches of the types sampled have not been recorded since. *Enochrus isotae* and *Hydaticus seminiger* are the two clearest examples, with *Limnebius nitidus* and *L. truncatellus* perhaps less certainly so.

1995 was also a drought year, though the effects on the sample ditches were less dramatic. In 1995 the compensation scheme was in operation and water was pumped into the ditches, and also there had been considerable rainfall by the time of survey in 1995, whereas in 1991 the drought was ongoing at the time of survey. Also, 1991 was preceded by other dry years, whereas from 1992 to 1994 summer rainfall was relatively high. Smaller water bodies on the fen must have felt the effects of drought during the summer of 1991, however, and it might be expected, therefore, that the fauna recorded in the ditches might bear at least traces of their use as refuges from drought. However, no such traces can be clearly identified. The high occurrence of *Hydroporus memnonius* could be such a trace: this is more typically a species of small still water bodies with dead leaves than of spring-fed ditches, and has previously been recorded in the seasonally dry sample station 9. *H. memnonius* was not found at all in the 1991 survey, which rather argues against this suggestion. It may be, though, that wet summers in 1992-94 encouraged population increase in this species which was not possible prior to 1991 because of relatively dry summers.

The pattern of wet and dry years during the monitoring period is far from ideal for the purpose of the monitoring project: the situation when the baseline survey was performed was not typical; the following three years saw a good natural water supply to the fen, and only in the last year was augmentation considered necessary. Any effects of this change of water supply on the fauna would probably not be seen until 1996.

The occurrence of nationally scarce species of water beetles

Of the eighteen nationally scarce invertebrate species recorded during monitoring, seventeen are beetles. The remaining species, the bug *Microvelia pygmaea*, is considered below.

A number of species of scarce water beetles have been recorded on only a single occasion from only a single sample station during the course of five year's monitoring. The majority of these have been recorded only as single specimens. It is impossible to be sure how many of these are species which do not 'belong' in the sample area from which they were taken, in the sense that they have not established long-term breeding populations there but were recorded only as wandering individuals or briefly established populations. For example, three *Cercyon* species, *C. convexiusculus*, *C. tristis* and *C. sternalis*, have proved quite frequent in pitfall trap catches of terrestrial invertebrates in several compartments of the fen. It seems almost certain that the terrestrial areas of fen vegetation hold the main populations of these species, and that the few individuals caught by sampling the ditches are wanderers.

A total of 17 notable and Red Data Book water beetle species have been recorded over the five years of survey. Of these, six are listed above as vagrants or refugees. A further two (*Noterus crassicornis* and *Eubrychius velutus*), though well established, have only been recorded from sample station 8. Another two (*Helophorus nanus* and *H. strigifrons*) have been found only in sample station 9, and only in one year when the ditch was unusually wet. This leaves only seven scarce species recorded from the main group of sample stations: *Rhantus grapii, Agabus chalconatus, Hydraena testacea, Haliplus laminatus, Laccobius sinuatus, Graptodytes granularis* and *Scarodytes halensis.* The latter two species were both recorded in several years from several sample stations, and are clearly well-established components of the fauna of the flowing water ditches.

The Hemiptera

The Hemiptera of the ditches were not recorded in all years, and their records have not been analysed in the same detail as the Mollusca and Coleoptera. The recorded species are almost all common or only slightly local, and included *Microvelia pygmaea*, *Notonecta marmorea*, *Corixa dentipes, Cymatia coleoptrata*, *Notonecta maculata, Plea minutissima* and *Ilyocoris cimicoides.* The latter two species are common in parts of the south of England, but somewhat local in Cambridgeshire.

The bug fauna shows no great or informative changes over the monitoring period. Some predominantly still-water specie, such as the backswimmers *Notonecta glauca* and *N. maculata* were, not surprisingly, more frequent in the flowing-water ditches in years of low flow than in years of high flow.

Changes in individual species

Most individual species show no clear trend over the five years of recording to date. A large proportion, indeed, have been recorded so rarely that any trend would be difficult to detect. A few species show consistent changes, and are worth highlighting:

Lymnaea peregra and to a lesser extent *L. palustris*, never common in the samples, were most frequent in 1992 and have since declined. The increase in 1992 was in part the result of the addition of more sample sites, but *L. peregra* did appear in sample stations in 1992 where it was absent in 1991. These species provide the most readily quantifiable component of a general decline in molluscs in the flowing water ditches since 1992. A possible reason for the changes observed is that these predominantly still, warm-water species colonised some ditches during periods of low flow and have since declined as conditions became less suitable. This is supported by the fact that both *Lymnaea* species, and molluscs in general (with the exception of *Physa fontinalis*) have been most frequent, and most consistent in their occurrence, in sample station 8, where the effects of cold flowing water from the springs are not directly felt. The reason for the apparent one-year lag between proposed cause and observed effect in the other ditches is, however, not clear.

Several species of water beetle show a rise in frequency to 1994, then a falling off in 1995. This is true of *Agabus bipustulatus*, *Anacaena globulus*, *Hydroporus planus*, *Ilybius fuliginosus*, *Laccobius minutus*, and possibly *Gyrinus substriatus*. The changes are for the most part not especially large, though the increase in *Hydroporus planus* in 1994 as compared with previous years is relatively dramatic. There is a contrasting set of species which, though they do not necessarily show a clear trend through the first four years of survey, have been fairly regularly recorded, did comparatively poorly in 1994, and have seen a revival in 1995. The flowing-water species *Stictotarsus duodecimpustulatus* and *Elmis aenea* were not seen at all in 1994, but both were found again in 1995, the latter in higher numbers than ever before. Other species showing a high frequency in 1995 were *Hydraena riparia*, *Hydroporus memnonius*, *Limnebius papposus* (though the second highest frequency for this species was in 1994) *Dytiscus semisulcatus* and *Anacaena lutescens*.

It is by no means certain that all these changes in the survey results represent real changes in the ditch faunas: the numbers of species and, especially, of individuals is small. Other species show a wide range of patterns of variation from year to year. Random variation, perhaps due to species with small populations being missed during sampling, may have played a part in generating the results obtained.

An interesting feature of the two groups of species contrasted above is that those which have declined after 1994 are all widely distributed and nationally common species tolerant of a wide range of water conditions; whereas those which appear to have increased in 1995 are more specialised and local species, including two which are nationally scarce. If the trends seen are true, the implication is that, in the sample ditches used for this monitoring exercise, years of drought favour less common species, whereas years of abundant rainfall favour common generalists. This in part fulfils a prediction made after the 1991 survey that, since most of the scarcer species recorded were primarily associated with still water, reduction in water supply to the fen and consequent reduction of flow would lead to an increase of scarce species in the flowing water ditches, even if the quality of the fauna over the fen as a whole were declining. However, the effect of reduction in wetter years is seen even amongst species specifically associated with flowing water. It is not easy to see how drought might favour such species.

It was not predicted in 1991 that wet years would result in an absolute increase in common and relatively generalist species. It is possible that in some cases increased populations of such common species in the countryside as a whole as a result of increase in number and extent of breeding sites led to more individuals taking up residence in relatively poor sites such as the flowing water ditches. This is, however, not a wholly satisfactory explanation in view of the suggestion already made that in drought years water beetles from a wider area seek refuge in the ditches. It is not immediately apparent why the effect of transient colonists in wet years should be greater than that of refugees in dry years for common species. Genuine increase in breeding populations of common species in the sample ditches in wet years must be considered as likely an explanation, even if the reasons are not clear.

Overall species richness

The total number of species of Mollusca and Coleoptera recorded from all sample stations is remarkably similar in each year, varying from a maximum of 61 species in 1995 to 56 in 1992. This is of interest chiefly in demonstrating how misleading overall figures of species richness can be in environmental monitoring. The figure in the first year was boosted by species using the ditches as refugia in time of drought. Loss of these species to their more usual habitat in the second year was compensated by the addition of three further sample stations, two of which supported a rather different suite of species to the original seven, and one of which, station 8, has proved consistently more species-rich than any other. Further, though the overall number of species has remained similar, the particular species involved have varied considerably. Only 27 species have been recorded in all five years of the survey, little more than half the number of species recorded in any particular year and less than one-third of the total number of species of Mollusca and Coleoptera recorded in total during monitoring.

Changes at individual sample stations

Details of changes in the fauna, or the lack of them, at individual sample stations since 1991 are provided in Appendix 3. None of the sample stations has been immune to natural change through succession, though its effects have varied considerably from station to station. Only sample station 5 has been managed during the course of the monitoring exercise.

4.2.4 Recommendations for future monitoring

After examining the records from the wide range of groups identified from the monitored ditches in 1991, it was decided that water beetles and molluscs would be the most useful groups to retain in the monitoring programme, and that other groups could add relatively little to any interpretation which might be given.

Molluscs were included in the monitored groups first because the water chemistry and location of the site suggest that it has potential for a high mollusc diversity, and second because molluscs include a large proportion of species which require permanent water. It was therefore felt that molluscs would be severely affected if ditches showed any increased tendency to dry out. In fact, rather few species of mollusc have been recorded in most of the sample ditches. Molluscs have declined during the monitoring period in the face of increased water flow, presumably because of increased water flow and/or decreased water temperature. It seems likely that conditions of drought sufficient to kill all or any species of mollusc in the main group of sample stations surveyed, close to the main spring, would occur only in such extreme conditions that monitoring of the invertebrates of the ditches would be unlikely to be needed to inform of impending disaster.

It seems likely, therefore, that as with the beetles the effects of reduced flow are likely, counter-intuitively, to be marked by an increase in the species richness of the mollusc fauna of the flowing ditches. The case for including molluscs in monitoring work is weakened by this: there is every chance they would add little or no information to that given by beetles alone. Though on average molluscs are less mobile than beetles, and should therefore be more site-faithful and less prone to coming and going as refugees and wanderers which can obscure trends in the breeding species of ditches, in practice relative site-faithfulness is not well shown by molluscs in the results obtained by monitoring to date.

In spite of the limited usefulness of molluscs in achieving the aims of the survey so far, any continued monitoring programme should probably continue to use them. Recording them adds little time and effort to that which would be needed to cover the water beetles alone, and the relatively high numbers of species and individuals at sample station 8 suggests that, over the fen as a whole, the mollusc fauna may be both considerable and sensitive to long-term hydrological change.

Interpretation of the data from the sample ditches is still hampered to some extent by the lack of a thorough knowledge of the aquatic fauna of the fen. Terrestrial invertebrate survey has been of assistance in the interpretation of some of the records, by revealing the high frequency of some *Cercyon* spp. away from the ditches and reinforcing the suggestion that those recorded in ditch samples are likely to be vagrants from their main centres of population. More widespread survey of the aquatic habitats would be of further assistance in the interpretation of records. This could be usefully coupled with an investigation of relationships between the aquatic fauna and the physical conditions of temperature and flow rates within the ditches, which may help to elucidate the significance of groundwater inputs, and the impacts of the use of the supplementary water supply.

A general survey to establish the distribution and status of at least the water beetles of the fen would not only assist in the interpretation of the data from the ditches, but could provide useful baseline data for more widespread monitoring. Annual monitoring of a small range of ditches should provide indication of any significant long-term change. When such evidence appears, there may be justification for repeating a more widespread survey to determine the extent of change over the fen as a whole. If a fen-wide baseline survey is done, then at least such large-scale monitoring will be possible. Without it, there may be no possibility of determining detailed effects of hydrological changes in the future.

The total number of ditches so far monitored seems likely to be adequate to monitor long-term changes. Clearly, though, the more sample stations there the more confidently results can be interpreted. This is the more true because variation within individual ditches as a result of management, succession and other factors must be taken into account in interpretation. Certainly no fewer sample stations should be used in any future monitoring programme.

Though the inclusion within the sample set of ditches well-removed from the water inputs to the fen, for comparison and contrast, has proved worthwhile, the small number of such stations may limit the level of interpretation that can be given to long-term changes. It is possible that occasional fen-wide survey, suggested above, could replace the inclusion of sample stations well-removed from the springs in annual survey.

Of the sample stations monitored, arguably the least useful has been station 10. Its location suggested that it might be interesting as representing ditches close to the limits of the direct influence of flowing water from the springs. In fact, it has been poor in species and individuals of invertebrates, and its fauna seems so heavily governed by the extent of shade from nearby trees that it may be of limited value. This station could usefully be replaced by another better-situated to reflect hydrological change in any continued monitoring programme.

Annual monitoring of at least some sample stations would seem essential if any long-term effects due to changed hydrology are to be separated from year-to-year variations on fauna resulting from succession, management and other factors.

4.2.5 Conclusions

The results of monitoring of the aquatic invertebrates of the ditches of Chippenham Fen NNR over the period 1991–1995 suggest that the quality of the established fauna, in terms of representation of scarce species and those of restricted habitat requirements, though it has varied, has not shown any consistent decline or increase over the monitoring period.

Variation within individual sample stations has mostly been interpretable in terms of changes in the condition of individual ditches or their use as refuges from drought. Changes not readily interpretable in these terms have proved spontaneously reversible and do not reflect a general trend.

Periods of low water flow in the ditches close to the springs are characterised by an increase in scarce species usually associated with still waters. Two factors are thought responsible: species seeking refuge from drought; and species finding the changed conditions of the ditches suitable for their establishment.

Reduction in flow which is likely, if continued in the long term, to lead to decline of fen and ditch communities elsewhere on the site, would probably result in an increase in species richness and mean species quality in the flowing water ditches.

A reduction in the number and frequency of species specifically associated with flowing water would be expected to result from long-term flow reduction. However, within the range of flows experienced during the monitoring period such species have actually been recorded somewhat more frequently in years of low flow, though the reasons are not clear.

Even without the effects of species moving into the flowing ditches at times of low flow, the data suggest a change in the fauna in response to flow rates. In periods of high flow relatively scarce species, even if established long-term in the ditches, appear to decline, while relatively common species increase. The results are not clear-cut or definitive, and could be an artefact of the data.

At station 4 species-richness follows a U-shaped curve bottoming in 1993. The reasons for the change are not clear, but the scale of the change makes it likely that it was a response to ecological change and not a sampling error. Its localisation precludes any overall change in the water entering the fen being responsible. Though it does not directly help in the monitoring aims, the change shows that the invertebrate fauna of the ditches is capable of large and quantifiable change.

Molluscs have proved themselves of less value for monitoring purposes than was expected. Their removal from the monitoring programme would probably have little effect on the usefulness of the data. However, collection of mollusc data adds little time to what would be needed to cover water beetles alone. Since they have been recorded each year to date, it is probably advisable to continue recording them in any future monitoring programme.

A full survey of at least the water beetles (and preferably also of the molluscs) of the fen would provide useful material for the interpretation of samples from the sample stations currently in use, and could provide baseline data for more widespread monitoring surveys in the future.

Ten sample stations seems adequate to monitor for long-term changes in the invertebrate fauna. However, the number of sample stations well-removed from the spring may prove limiting in interpreting data from these sample stations in the future. Occasional fen-wide monitoring could possibly replace annual monitoring of these sample stations. Sample station 10 has proved relatively uninformative, and could usefully be replaced.

If monitoring were continued, annual sampling would seem essential if allowance is to be made for variation seen in the sample stations as a result of successional, management and other changes.

4.3 Terrestrial invertebrate monitoring

4.3.1 Introduction

The work described continued a programme of annual monitoring of vegetation and invertebrates begun in 1991. The overall aim was to assess whether the water supply augmentation scheme at Chippenham Fen is adequate to prevent any detrimental changes to the flora and fauna caused by water abstraction from the chalk aquifer. Though vegetation and aquatic invertebrates have been monitored annually since 1991, terrestrial invertebrate survey was not undertaken in 1992, 1993 or 1994.

The specific aims of the terrestrial invertebrate monitoring exercise in 1995 were:

- building upon the results of 1991 sampling, to sample for selected groups of terrestrial invertebrates following an amended sampling regime
- to describe any major differences in the fauna between the two sampling periods and, if possible, to relate them to hydrological changes
- to produce recommendations for future monitoring.

The 1991 sampling of terrestrial invertebrates was not considered particularly successful, and to provide a poor basis for future monitoring. The inclusion of terrestrial invertebrates in the 1995 programme was with the intention of developing a more sustainable basis for future monitoring of terrestrial invertebrates on the site.

4.3.2 Methods

Invertebrates at Chippenham Fen NNR were sampled between 14-28 July 1995 using pitfall and water traps at five trapping stations in Compartments 2, 6, 8 and 11 (2 stations) (Figure 4.2). Except in Compartment 6, which had not previously been trapped, the traps were placed in the same positions as were used in a similar survey in 1991.

The following statistics and indices were calculated from the data: for each run of pitfall traps and for each run of water traps:

- the number of traps in which each species was caught
- the number of individuals caught in total
- the number of individuals of each species caught per trap
- an overall frequency of capture rating for the trap run as a whole. Four levels of frequency were employed, identified by letters in order to make clear the distinction from actual numbers captured:

  O = occasional; F = frequent; C = characteristic; A = abundant.

A wide range of groups was identified from the trapped material, but interpretation and analysis has used Araneae; Coleoptera (Cantharidae, Carabidae, Dryopidae, Hydrophilidae, Staphylinidae), Diptera (Dolichopodidae, Sciomyzidae, Stratiomyidae, Syrphidae, Tipulidae) and Hemiptera (Auchenorhyncha).

Several of these groups, specifically Dryopidae, Hydrophilidae and Syrphidae, are additions to the groups proposed for analysis at the outset of the 1995 sampling. They seem likely to be of value in monitoring, and are recommended for inclusion in any future monitoring programme.

Within target groups (Araneae; Coleoptera: Cantharidae, Carabidae, Dryopidae, Hydrophilidae, Melyridae, Staphylinidae; Diptera: Dolichopodidae, Sciomyzidae, Stratiomyidae, Syrphidae; Hemiptera-Auchenorhyncha - a "wetland indicator score" has been calculated for each species. Any species not specifically associated with wetland scores zero irrespective of its rarity. For the remainder, a common wetland species scores 1, a local species 2, a notable or notable B species 4, a notable A species 6, a Red Data Book 3 species 8, a Red Data Book 2 species 10 and a Red Data Book 1 species 12.

The national status of each species was selected to determine the significance given to it compared with other wetland species because, given that all are wetland-specific species, it is likely that restricted requirements within the wetland habitat provide the chief reason for the scarcity of some species relative to others.

For each trapping station a "combined wetland indicator score" has been calculated by summing the wetland indicator scores for all species in target groups. These scores are enhanced for species which were trapped in relatively large numbers: thus one is added to the score for "frequent" species, two for "characteristic" species, and three for "abundant" species. The 1995 target groups are listed above. A second combined score was calculated for comparison with 1991 results, using as target groups only those recorded in both years (Araneae, Carabidae, Staphylinidae, Sciomyzidae, Stratiomyidae, Syrphidae, Tipulidae).

4.3.3 Results and discussion

Comparison of 1991 and 1995 data

There have been only two terrestrial invertebrate surveys of the fen during the monitoring period, in 1991 and 1995. Comparing any two samples separated by several years in a habitat with complex ecology and attempting to single out the effects of a single factor is difficult. Specific problems in this case are:

- the likely effects of climate: the 1991 survey was undertaken in drought conditions, but after a period of relatively high water tables. Subsequent years have seen lower, but until 1995, gradually recovering water tables, and relatively high summer rainfalls. The interactions between water tables and summer rainfall in determining the invertebrate fauna are not known. Any long-term recovery in the fauna from the 1991 drought might well mask any adverse effects of water abstraction.
- the extent of natural fluctuation in the invertebrate communities of the fen, and in the population sizes of individual species, in the absence of ecological and habitat change, are not known. This is particularly a concern because both invertebrate surveys have taken place in unusually dry years, when the weather at the time of sampling may have greatly influenced the invertebrate catches in traps. A number of further years' sampling would be needed to determine the magnitude of such natural changes.

It is improbable at the outset, therefore, that comparison of the 1991 and 1995 data will enable a satisfactory interpretation of any ecological change which might underlie any differences seen. Comparison is chiefly of interest in determining whether any changes have taken place, whatever their cause, and in trying out the method of comparison using wetland indicator species and scores.

Overall comparisons of the trapping results from the two years have been carried out, comparing the numbers of wetland-associated species, the combined wetland indicator scores, and the scores per species for all compartments recorded in both years (see Table 11, Appendix 3).

It can be seen that for Compartment 2 the combined wetland indicator score and the score per species were markedly higher in 1995 than in 1991; in all other compartments both scores were lower in 1995 than in 1991. The difference between years is relatively slight in trap run A of Compartment 11, but is considerable in the other cases.

Examination of the results from 1995 suggests that a change in score per species up to 10% of its value cannot be taken as indicative of real change. However, the differences between 1991 and 1995 considerably exceed 10 % of the value of the score per species in all cases but 11A, and are probably real.

Though the total score and score per species is generally lower in 1995 than in 1991, the total numbers of wetland species recorded is roughly similar in the two years. Indeed it is, on average, higher in 1995 than in 1991 for the compartments recorded in both years.

Examination of trends in individual groups and species elucidates the nature of the changes to a small extent, but most of the changes in species seen between the two years are too erratic to be easily interpreted. The overall character of the fauna in 1991 and 1995 was very similar. Many individual species were captured too infrequently for any clear-cut differences to be seen and interpreted.

Hygrophilous ground beetles tend to be more frequent in 1995 than in 1991. Thus *Pterostichus gracilis* was found in large numbers and in more compartments in 1995 than in 1991, while *P. anthracinus*, not recorded at all in 1991, was quite frequent in Compartment 11 in 1995, though found nowhere else. Other species recorded in 1995 but not 1991 include *Acupalpus dorsalis*, *Agonum obscurum*, *Bembidion biguttatum*, *B. guttula*, *Pterostichus rhaeticus* and *Stenolophus mixtus*. On the other hand, *Agonum fuliginosum* was recorded in a number of traps in 1991, but not at all in 1995, and a number of wetland species recorded in both years were trapped in larger numbers in 1991. A number of Staphylinidae show no clear trends, but the nationally scarce wetland species *Philonthus fumarius* and *Platystethus nodifrons* were recorded in 1995 but not in 1991. In other words, though the combined wetland scores and scores per species for most compartments were lower in 1995 than in 1991, some wetland species nonetheless increased, and indeed the clearest trends visible in the data are amongst groups which did increase.

The higher wetland indicator scores and scores per species are not merely the result of higher capture rates in 1991, a possibility given the method of calculation employed, with frequently captured species being given enhanced scores. Recalculation of the scores without weighting for frequency of capture (Table 4.2) shows that the differences between the two years remain the same.

Table 4.2 Comparison between 1991 and 1995 combined wetland indicator scores and scores per species calculated without weighting for frequency of capture

Year		Compartment			
		2	8	11A	11B
1991	Combined score	25	42	43	52
	Score per species	0.60	1.05	0.86	0.88
1995	Combined score	34	34	39	36
	Score per species	0.79	0.72	0.65	0.64

The differences between the two years are thus probably real, result from a widespread change in the occurrence of wetland species of a number of groups in the traps, and are in spite of differences in the reverse direction in some species. The reason for the changes, and especially the reason for the change in Compartment 2 being in the opposite direction to those seen in the other Compartments monitored in the two years, is uncertain. Lowered water tables after the 1991 drought are the most obvious possible cause, but it is not clear why this is the case as some groups, notably hygrophilous ground beetles, showed an apparently opposite trend to the overall fauna. The later period of sampling in 1995 may also have made a difference; it was sufficiently late that some species may have been declining. Since the total number of wetland species recorded remained similar, and the downward trend was nor seen in all groups or in all monitored compartments, it cannot be said, in spite of the observed difference, that there is convincing evidence of an overall decline in faunal quality, merely a suggestion of change which would require further work adequately to interpret.

Locations of trapping stations and numbers of traps

In 1991 traps were run only in Compartments 2, 8 and 11. The addition of Compartment 6 to the monitored set in 1995 has shown this to be considerably richer in wetland species than any of the others. It also produced a considerable number of rarities: it was the only location of capture for the spiders *Clubiona juvenis* (RDB2), *Entelecara omissa* (Na) and *Hypomma fulvum* (Na), and of the seventeen nationally scarce and Red Data Book species recorded there, eight were recorded from no other compartment. Moreover, Compartment 6 had overwhelmingly the richest faunas of Dolichopodidae and Sciomyzidae of any of the recorded compartments.

There are potential practical problems in the monitoring of Compartment 6 using traps. It is a relatively wet compartment, and in years of high spring and summer rainfall pitfall traps could easily be lost to flooding. However, water traps should be operable in most years. Water traps were, overall, more effective than pitfalls in recording the characteristic fauna of this compartment of relatively tall vegetation. Future monitoring exercises should include this compartment.

Compartment 6 is presumably distinct in its fauna for three reasons: the different vegetation composition (*Phragmites*-dominated with *Juncus* clumps), the wetter conditions compared to other monitored compartments and the different vegetation and physical structure, with extensive areas of bare mud and wet exposed *Phragmites* litter amongst the taller vegetation. These conditions are ones which would be expected to lead to high invertebrate richness on general habitat grounds, so the findings are not surprising, either in general or in the detail of the groups and species recorded there.

This finding of the importance of Compartment 6 for invertebrates raises a further point in the selection of the location of sample stations. Their current location is close to plots being monitored for vegetation. This is logical, and should enable a degree of integration of monitoring results from vegetation and invertebrates. However, the areas selected for vegetation monitoring are not necessarily those which would be expected to be of particular importance for invertebrates (though they undoubtedly hold rich faunas). There is a possibility of areas which are botanically poor but which are structurally good for invertebrates being neglected, and consequently of important invertebrate species and habitats which might be sensitive to the effects of water abstraction going unmonitored. It is worth pointing to the Sciomyzidae again: a group for which Chippenham Fen is known to be important but which the 1991 selection of monitoring sites proved scarcely to record at all. It would be worthwhile reconsidering the locations of invertebrate monitoring sites to determine whether they could be better chosen to complement, rather than merely be an adjunct to, the botanical monitoring sites.

Recommendations are provided in Appendix 3 on the number and type of traps needed for monitoring. Ten pitfalls seems an adequate number to achieve the set objectives. For water traps, on the other hand, five traps does not seem adequate to fulfil the objectives. It is suggested that in any future monitoring, the number of water traps per sample station is increased to ten. The data show clearly the value of using two different trap types to record different elements of the invertebrate fauna.

Selection of groups for monitoring purposes

Invertebrate groups suitable for use in such a monitoring exercise should:

- be readily identifiable
- be at least moderately well-known in terms of ecology and status
- be readily captured by the trapping methods in use
- have a high proportion of members associated with wetland conditions
- have a reasonable representation of species which are scarce, and therefore by implication of specialised habitat requirements.

The list of groups for identification and analysis in 1991 comprised Araneae, Coleoptera (Carabidae, Staphylinidae), Diptera (Sciomyzidae, Stratiomyidae, Syrphidae, Tipulidae), Hemiptera (Auchenorhyncha, Heteroptera) and Mollusca. On the basis of the records made in 1991, it was suggested that Syrphidae, Heteroptera and Mollusca be dropped. It was also suggested that the beetle families Cantharidae and Melyridae, and the fly family Dolichopodidae be added.

In 1995 a number of additional groups of invertebrates were identified from the trap samples which it was felt might be informative. On the basis of those identifications, the following recommendations are made for future monitoring:

- addition of the Coleoptera families Dryopidae and Hydrophilidae: these families proved to be well-represented and consistently captured in the trap samples and to include a high proportion of nationally rare and scarce species. Since members of both species are dependent on wetland conditions (indeed, the key members of both families are normally regarded as water beetles) they should be useful for monitoring purposes. Since they are rather small and slow-moving insects they provide an interesting contrast to the more active ground beetles also used for monitoring.
- The hoverflies (Syrphidae) recommended for removal from the monitored groups in 1991, have proved rather more useful in 1995, with improved catches.

Staphylinidae have proved one of the least satisfactory groups for monitoring purposes. The proportion of specifically wetland species amongst the catch has been small, a large proportion of the recorded species being general detritivores with no strong habitat preferences, so that a considerable amount of identification time has been taken up with species of little relevance to the monitoring project. Further, the captures of Staphylinidae are rather erratic. Captures of wetland species have been better in 1995 than in 1991, and it is probably as well to retain the group in the monitoring exercise at least for the present, but if trimming of the range of groups identified were found necessary, this should be the first to go.

Other identified groups worthy of mention are the beetle families Chrysomelidae and Curculionidae. The catches of these groups are rather too erratic to be helpful in monitoring; it is generally recognized that they do not trap very well or consistently. Nonetheless, the faunas recorded suggest that these groups fulfil the other characteristics required of groups for monitoring. The records of the weevil *Phytobius muricatus* from Compartment 11 are particularly interesting, being apparently the first post-1970 record of the species from Cambridgeshire (Hyman & Parsons 1992).

4.3.4 Conclusions

Of the four sample stations compared between 1991 and 1995, three (in Compartments 8 and 11) show a lower combined wetland indicator score and score per species in 1995 than in 1991, though a roughly similar number of wetland-specific species were recorded in the two years. Compartment 2 had higher scores in 1995 than in 1991. The differences are of sufficient scale that appear to be real, rather than merely artefacts of the data, but since they are not consistent across all groups or compartments, since the number of wetland species overall has not fallen, and since the extent of natural variation in scores in the absence of ecological change is not known, they cannot yet be interpreted as demonstrating a decline in faunal quality.

The use of traps in Compartment 6, not trapped in 1991, has produced evidence of a richer wetland fauna than that recorded in any other compartment, and it is recommended that this compartment is included in any future monitoring programme.

It is suggested that the locations of invertebrate sample stations be re-considered. Re-location of some to cover a wider range of invertebrate-rich habitats and situations, even if botanically species-poor, might better serve the overall objectives of monitoring than maintaining a close link between invertebrate and plant monitoring areas.

5. Summary and General Conclusions

1. Hydrological, botanical and invertebrate monitoring have been carried out at Chippenham Fen NNR (Cambs; NGR TL 648697), with a view to assessing the impact of a scheme designed to provide a supplementary water supply to the Fen and support river discharges during periods of low flow.
2. The site is subject to wide variation in water levels, and although it is possible to maintain fairly stable levels in the dykes using collared dams and sluices (with some support from the supplementary water supply), water levels within individual Compartments still fall to particularly low levels in the summer (< 130 cm below surface, i.e. below the base of the peat in some places). However, it is not known for how long this regime has prevailed.
3. There was a negative relationship between borehole water abstraction and discharge in the Chippenham River, but there was no clear evidence that abstraction has a major impact in general on the water regime across the fen – rainwater deficits and losses of water through evapotranspiration from the vegetation are undoubtedly also important in causing the summer draw-down. It is probable that the fen has also been affected by changes in the Chippenham River coupled with agricultural land claim and drainage downstream.
4. Active springs are evident in some of the dykes, but it is not clear how important spring water is to the hydrological regime on the site, or to the maintenance of the plant communities (those now present are not particularly characteristic of spring-fed systems). Rainfall may be the main source of water to the surface of the fen, but it is possible that groundwater has more of a 'supporting' role, for example, in helping to reduce downward water losses, while not having a direct impact on the plants. The shallow depth of peat may help to enable base-rich conditions to be maintained.
5. Examination of the data for periods where the supplementary water supply has been in use suggest that this has had relatively little impact on water levels, as discharges and dipwell readings fell to low levels despite the augmented supply. There is some evidence of a positive response in river discharge and dipwells to the support pumping, but the magnitude of the effect may be masked by variations in rainfall. Further consideration needs to be given to the possible adequacy of the supply under conditions of maximum abstraction, and whether distribution of the water around the fen should (and could) be improved.
6. Some changes in plant species abundances over the five-year period have been noted, but there is no consistent evidence which suggests that there have been any substantial changes in vegetation composition or crop mass, in Compartments 6 and 8. In Compartment 11, changes in species frequencies suggest that conditions are becoming wetter and perhaps more nutrient-rich. This is consistent with the trend shown by the dipwell data over the five-year period, for rising winter water levels, but with a substantial fall in water levels during the summer (*i.e.* wide fluctuations). In North Meadow, the monitoring data suggest that there may have been a some increase in nutrient supply, coupled with dry conditions. As the peat is apparently of generally low fertility, the possible sources of external enrichment should be given further consideration, and steps taken to rectify any problem, if possible.

7. It is suggested that the current policy of maintaining high water levels (surface flooding) in the winter should be re-appraised, as this may in fact be detrimental to the current floristic interest of the EU-MOLINION. The water regime experienced in the North Meadow in recent years is probably adequate for the maintenance of examples of this Alliance, and may provide a model for future manipulations of the water table in Compartment 11.
8. The site is considered to be one of the top ten in England for its invertebrate fauna. A total of 17 notable and Red Data Book water beetle species were recorded during the five-year monitoring period. It is important that any modifications to the current conditions on the site should take invertebrates into account (for example, a reduction in the area of open water habitat available would be undesirable).
9. The results of monitoring of the aquatic invertebrates of the ditches of Chippenham Fen NNR over the period 1991–1995 suggest that the quality of the established fauna, in terms of representation of scarce species and those of restricted habitat requirements, though it has varied, has not shown any consistent decline or increase. Variation within individual sample stations has mostly been interpretable in terms of changes in the condition of individual ditches or their use as refuges from drought. Changes not readily interpretable in these terms have proved spontaneously reversible and do not reflect a general trend. Even without the effects of species moving into the flowing ditches at times of low flow, the data suggest a change in the fauna in response to flow rates. In periods of high flow relatively scarce species, even if established long-term in the ditches, appear to decline, while relatively common species increase. The results are not clear-cut or definitive, and could be an artefact of the data.
10. For terrestrial invertebrates, the data suggested some reduction in 'quality' of the wetland faunal, although as the sampling was only carried out on two occasions (1991 and 1995), further monitoring is required to determine if this is a general trend, or due to natural variation.
11. The current work has highlighted the need for a thorough re-appraisal of the water management of the site, including the use of the sluices and the supplementary water supply. It is understood that NRA are intending to commission a Water Level Management Plan for the site, which is to be welcomed.
12. If separate sections of the site could be effectively isolated, it would be of considerable interest to experiment with different water management regimes (including no provision of supplementary water), and to monitor their effects on the flora and fauna.
13. Hydrological, botanical and invertebrate monitoring should continue, subject to the recommendations made above.

6. References

DCEUB (1988). *Water resources, Lodes and Granta investigations: Main Report.* Department of Civil Engineering, University of Birmingham for Cambridge Division Anglian Water.

ELLENBERG, H. (1974). Zeigerwerte der Gefäßpflanzen Mitteleuropas. *Scripta Geobotanika,* **9,** 1–97.

ECUS (1991). *Vegetation Changes at Chippenham Fen NNR: Monitoring Procedures and Base-line Data for 1991.* Unpublished Report to English Nature. Environmental Consultancy, University of Sheffield.

ECUS (1992). *Vegetation Changes at Chippenham Fen NNR (1992 Survey).* Unpublished Report to English Nature. Environmental Consultancy, University of Sheffield.

ECUS (1994a). *Vegetation Changes at Chippenham Fen NNR (1993 Survey).* Unpublished Report to English Nature. Environmental Consultancy, University of Sheffield.

ECUS (1994b). *Vegetation Changes at Chippenham Fen NNR (1994 Survey).* Unpublished Report to English Nature. Environmental Consultancy, University of Sheffield.

GROOTJANS, A.P. & TEN KLOOSTER, W. Ph. (1980). Changes of ground water regime in wet meadows. *Acta Botanica Neerlandica,* **29**, 541–554.

HYMAN, P.S. & PARSONS, M.S. 1992. *A review of the scarce and threatened Coleoptera of Great, Britain, part 1.* Peterborough, Joint Nature Conservation Committee. (U.K. Nature Conservation, No. 3).

KIRBY, P. (1992a). *A review of the scarce and threatened Hemiptera of Great Britain.* Joint Nature Conservation Committee, Peterborough. (U.K. Nature Conservation, No. 2).

KIRBY, P. (1992b). *Chippenham Fen, Cambridgeshire. Aquatic invertebrate monitoring 1991.* Unpublished report to English Nature.

KIRBY, P. (1993). *Chippenham Fen NNR, Cambridgeshire. Aquatic invertebrate monitoring 1992.* English Nature Research Report, no. 33. Peterborough, English Nature.

KIRBY, P. (1994). *Chippenham Fen NNR, Cambridgeshire. Aquatic invertebrate monitoring 1993.* Unpublished report to English Nature.

KIRBY, P. (1995). *Chippenham Fen NNR, Cambridgeshire. Aquatic invertebrate monitoring 1994.* Unpublished report to English Nature.

MASON, G (1990). *The hydrogeology of Chippenham Fen, Cambridgeshire: an assessment of the impact of the Lodes-Granta groundwater scheme.* National Rivers Authority Anglian Region.

NATURE CONSERVANCY COUNCIL (1988). *Chippenham Fen and Snailwell Poor's Fen NNR and SSSI citation.*

WHEELER, B.D. & SHAW, S.C. (1987). *Comparative Survey of the Habitat Conditions and Management Characteristics of Rich-fen Vegetation Types.* Nature Conservancy Council, Peterborough.

WHEELER, B.D. & SHAW, S.C. (1991). *A Review of the Habitat Conditions and Management Characteristics of Herbaceous Fen Vegetation Types in Lowland Britain.* Nature Conservancy Council, Peterborough.

WHEELER, B.D. & SHAW, S.C. (1992). *Biological Indicators of the Dehydration and Changes to East Anglian Fens Past and Present.* English Nature Research Reports 22, English Nature, Peterborough.

WHEELER, B.D. & SHAW, S.C. (1995). Plants as Hydrologists? An assessment of the value of plants as indicators of water conditions in fens. In: *Hydrology and Hydrochemistry of British Wetlands.* Eds J.M.R. HUGHES & A.L. HEATHWAITE. Chichester: Wiley. pp. 63–82

WHEELER, B.D., SHAW, S.C. & COOK, R.E.D. (1991). Phytometric assessment of the fertility of undrained rich-fen soils. *Journal of Applied Ecology,* **29,** pp. 466–475.