NRA - WATER QUALITY 81

National Rivers Authority (Anglian Region)

RIVER NAR EUTROPHICATION STUDIES. - DIATOMS.

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CONTENTS

Summary

Although almost all the monitoring systems classified the sites as moderately to strongly eutrophic, the assessments of pollution varied considerably. Between-site resolution differed markedly according to the system employed, and even with interpretation of the particular system. Evaluation of sites also differed if the ecological tolerance assigned to a particular species varied with author.

Assessment using MEWAM was particularly problematical because in many cases the most abundant taxon was not used by that method. Interestingly, there was agreement between MEWAM and the S&S system on the poor quality of one site (17), which contrasted with the other assessments, but there was no marked deterioration in water quality below Litcham sewage works, as might have been expected. Resolution of the Lange-Bertalot system was poor, only two designations (III and II-III) emerged. The Watanabe index showed least agreement with the other methods, as well as containing internal inconsistencies. Calculation of the "French" indices seems to offer the finest resolution and to integrate all species in the sample. They do however generally suggest that the tributaries are slighty more polluted than the main channel, although this could be related to water depth and flow.

Comparisons with other biotic indices and physico-chemical data on the sites would be useful in assessing the appropriateness of the various methods for British lowland river systems.

Introduction

The contract was undertaken in response to an invitation to tender from the NRA, the objective of which was to collect samples of epilithic diatoms from sites identified by the NRA, to determine the degree of eutrophication or pollution at those sites using a range of methods, and to make recommendations for future monitoring.

Outline of contract

It was agreed that samples of epilithic diatoms from unshaded stones at sites identified by the NRA would be collected. The diatoms would be removed from the stones by scraping and fixed in dilute Lugol's solution to preserve cellular detail. Sketch maps would be drawn at each site to record salient details and collection site; photographs would also be taken.

At least 400 cells per sample would be counted using fixed material with intact protoplasts, to avoid the inclusion of dead cells in the counts. Raw counts would be converted into percentage abundances, with all data being stored on paper and disk. After counting, samples would be cleaned using acid treatment, washed and mounted in Naphrax. Cleaned material would be used to check identifications (following Krammer & Lange-Bertalot, 1986,1988,1991a,b). A set of permanent slides prepared from cleaned subsamples would be presented to the NRA on completion of the contract.

Results would be evaluated in line with MEWAM, A review of methods for the use of epilithic diatoms for detecting and monitoring changes in river water quality (Round, 1993); the Diatom Index of Descy (1979); the C.E.E. Index of Descy & Coste (1988); the Specific Pollution Index of Coste (1982); the Generic Diatom Index of Rumeau & Coste (1988); the Diatom index of pollution (DIApo) devised by Watanabe et al. (1986, 1988); Lange-

Bertalot's (1979) "Differentiating species system and the zone system developed by Steinberg & Schiefele (1988). Results of the different systems would be compared and evaluated. Inter-site differences would be highlighted and recommendations for future monitoring included.

Methodology

Samples of five, unshaded, flat stones were taken from 21 sites on the River Nar by staff of the Natural History Museum in late September 1993. Although 23 sites were identified by the NRA, two of these (NRA 10, NRA 12) proved inaccessible and could not be sampled. After collection, stones were kept cool in polythene bags to minimize drying out. On return to the Natural History Museum, the diatoms were scraped off the stone surface (rinsing with distilled water) and fixed in Lugol's iodine. Appendix I summarizes the site information, NRA codes and OMNIS codes used for analysis with the OMNIDIA programme (see below). Sketch maps of each site were drawn (Appendix XII) to illustrate salient features of the sites and the precise sampling areas. Photographic records were also taken.

After fixation, the diatoms were identified and analysed. At least 400 cells were counted per sample. Only cells with preserved cell contents were counted, to ensure assessment of the community living at the collection sites. Empty cells were ignored for the purpose of the analysis. Data were recorded as raw counts (Appendix II) and converted to percentage abundance values (Appendix III).

After counting, subsamples were cleaned in boiling nitric acid, washed in distilled water and used to prepare permanent slides, mounted in Naphrax. These were used to check identifications of taxa following Krammer & Lange-Bertalot (1986, 1988, 1991a,b). It should however be remembered that these slides contain representatives of all diatoms in the sample at the time of collection, whether dead or alive. The relative proportions of species on the slides may therefore differ from the counts obtained from fixed material. A set of slides accompanied the final report.

Resumé of the monitoring systems

MEWAM

Round (1993) divided rivers into 5 zones, based on the dominant diatom taxa, i.e. those with the highest percentage abundances.

Zone 1: clean water in uppermost reaches (low pH); dominants *Eunotia exigua* and *Achnanthes microcephala*.

Zone 2: nutrient richer and somewhat higher pH; dominants *Hannaea arcus*, *Fragilaria capucina* and *Achnanthes minutissima*.

Zone 3: Nutrient rich (corresponding to pH 6.5-7.3, alkalinity 5.0-23.3 mg/l $CaCO_3$ in Leclercq [1977,1988]); dominants *Achnanthes minutissima* in the upper region, *Cymbella minuta* in the mid-region; *Cocconeis placentula*, *Reimeria sinuata* or *Amphora pediculus* in sequence downstream.

Zone 4: Eutrophic with restricted flora due to detrimental influx of materials; dominants *Gomphonema parvulum*, with relative absence of *Amphora/Cocconeis/Reimeria*.

Zone 5: Flora grossly restricted by detrimental influx of materials; dominants small *Navicula* and *Nitzschia* species.

Diatom index of Descy (1979)

Descy (1979) devised a Diatom index (ID) based on the relative abundances of taxa in a community, taking into account their ecological characteristics. These were described by indices of sensitivity to pollution and indicator value. (Appendix IV includes sensitivity (1-5) and indicator (1-3) values for the species found in this study.) Low sensitivity values indicate a tolerant species, high values a sensitive species; similarly indicator values increase with decreasing ecological amplitude.).

Descy's original index ranged from 1 to 5 and the quality classes were described as follows:

- ID > 4.5 best biological quality, no pollution;
- ID 4-4.5 almost normal quality (slight changes in the community, slight pollution;
- ID 3-4 more important changes in the community, decrease of the sensitive species, moderate pollution or significant eutrophication;
- ID 2-3 resistant species dominant, decrease or disappearance of the sensitive species (reduced diversity), heavy pollution;
- ID 1-2 marked dominance of a few resistant species (many species disappear), very heavy pollution.

Appendix V shows some of the chemical conditions Descy considers representative for the different water quality zones.

When calculated using the OMNIDIA programme (Prygiel, Coste & Lecointe, 1991) Descy's index is on a scale 1-20. The redefined index approximately corresponds to Round's zones as follows:

ID >18	Zone I
ID 16-18	Zone II
ID 12-16	Zone III
ID 8-12	Zone IV
ID 4- 8	Zone V

CEE index of Descy & Coste (1988)

The CEE index is based on a biotic index grid in which taxa are divided into a table, grouped according to their tolerance and indicator value. Taxa are ranked (Appendix VI) in groups of low indicator value against sub-groups of species of greater indicator value. Tolerance increases from left to right and top to bottom respectively. The index is calculated:

$$ID = 12 - (SGM + GM)$$

where SGM = sub-group median, GM = group median, i.e. the group with the highest abundance.

If stenoecious taxa (sub-groups) are very under-represented, with a relative abundance less than 1%, then:

$$ID = 12 - GM \times 2$$

The index is again calculated automatically within the OMNIDIA programme and expressed on a 1-20 scale. Low numbers indicate more polluted conditions.

Specific pollution index (IPS) of Coste (1982)

Coste's (1982) Specific pollution index (IPS) was developed from the Diatom index (ID) of Descy, using similar sensitivity and indicator values, but is converted to a scale of 1-20 in the following way (Prygiel, 1991a):

$$IPS = 4.75 \times ID - 3.75$$

Thus:

ID > 4.5 = IPS >17.6

ID 4-4.5 = IPS 15.3-17.6

ID 3-4 = IPS 10.5-15.3

ID 2-3 = IPS 5.8-10.5

ID 1-2 = IPS 1-5.8

However, Prygiel (1991b) defines his zones slightly differently from Descy, so that the degrees of trophy and pollution for the IPS values are as follows:

IPS	≥ 16.0	pollution / eutrophy absent or weak	Zone I
IPS	13.5-16.0	moderately eutrophic	Zone II
IPS	11.0-13.5	strongly eutrophic / weakly polluted	Zone III
IPS	7.0-11.0	strongly polluted	Zone IV
IPS	< 7.0	very strongly polluted	Zone V

Generic index (GEN) of Rumeau & Coste (1988)

The generic index devised by Rumeau & Coste (1988) is calculated similarly, but with sensitivity and indicator values allocated to entire genera rather than species. Thus *Navicula* has a sensitivity index of 3.4, indicator value 1.9. Examples of other values are: *Achnanthes* - 4.5 and 2.1; *Cocconeis* - 3.5 and 1.8; *Gomphonema* - 3.6 and 1.9; *Nitzschia* - 1.0 and 2.3; *Surirella* - 3.6 and 2.2.

Diatom Assemblage Index of pollution (DIApo)

Watanabe et al. (1986, 1988) used a statistical analysis to develop a diatom index of pollution, assuming that taxa that frequently occurred together had similar ecological tolerances. In developing their index, they assumed that *Nitzschia palea* and *Cymbella minuta* were representative of saprophilous and saproxenic taxa and gave them initial values of D = 0 and 100 respectively. Other taxa were given initial values of D = 50. By a series of calculations final values of D were obtained and, according to their value for D, taxa were designated saprophilous, eurysaprobic or saproxenic.

Saprophilous species .... $0 < D < 29$

Eurysaprobic species .... $30 < D < 74$

Saproxenic species .... $75 < D < 100$

The diatom assemblage index was calculated using the following equations:

(1) $DIApo = 100 - \Sigma_{saprophilous} - 1/2\ \Sigma_{eurysaprobic}$

(Watanabe et al., 1986)

(2) $DIApo = 50 + 1/2\ (\Sigma_{saproxenic} - \Sigma_{saprophilous})$

(Watanabe et al., 1988)

(Σ = sum percentage abundances of all designated taxa from that site.)

Although Watanabe et al. (1986) published the above relationship between the tolerance index and taxon designation, allocation to the different categories is does not seem to be applied strictly according to the index (see Watanabe et al., 1988). Tolerance indices of species encountered in this study are given in Appendix VII.

The relationship between DAIpo, saprobic system and BOD values are as follows (Watanabe et al., 1988):

Saprobic system	DIApo	BOD
Xenosaprobic zone	100 - 85	< 0.25
ß-oligosaprobic zone	84 - 70	0.25 - 1.25
α-oligosaprobic zone	69 - 50	1.25 - 2.50
ß-mesosaprobic zone	49 - 35	2.50 - 5.0
α-mesosaprobic zone	34 - 20	5.0 - 10.0
ß-polysaprobic zone	15 - 5	10.0 - 20.0
α-polysaprobic zone	< 5	> 20.0

Differentiating species system of Lange-Bertalot (1979)

Lange-Bertalot (1978) grouped species into three categories on the basis of their tolerance to organic pollution:

A - sensitive, widespread where water quality is II or better; differentiates against III and IV;

B - indifferent, tolerant of water quality II and III; differentiates against III-IV and IV;

C - occurs over all saprobic levels, tolerant or resistant to polysaprobic conditions; grows well, or even better, under latter conditions.

Subsequently he (Lange-Bertalot, 1979) numbered these categories (in reverse) and identified some of the characteristic taxa:

1. most tolerant (=C) - *Nitzschia palea* or *Gomphonema parvulum*;
2. less tolerant (=B) - such as *Nitzschia paleacea* or *Fragilaria vaucheriae*;
3. relatively sensitive species (=A).

The species placed in these categories by Lange-Bertalot (1979) are given in Appendix IX, and a summary of the water quality categories in Appendix X (taken from Schiefele, 1987).

The formulae by which the water quality classes are identified are as follows:

II (B-mesosaprobic)		A	>50%	B+C	
II-III (B-α-mesosaprobic)	10%	<A	<50%	<B+C	<90%
III (α-mesosaprobic)	10%	>A,B,	<50%	> C	
II-IV (α-meso-polysaprobic)	10%	<A+B	<50%	< C	
IV (polysaprobic)	10%	>A+B		C	>90%

Trophic and pollution zones of Steinberg & Schiefele (1988)

The zone classification scheme presented by Steinberg & Schiefele is a development of the differentiating species system devised by Lange-Bertalot (1978, 1979). It claims to offer finer resolution in less polluted waters than the Lange-Bertalot system, but similarly rests on the relative proportions of taxa of different tolerance categories.

Steinberg & Schiefele (1988) argued that Lange-Bertalot's method, not only failed to discriminate water quality better than II (ß-mesosaprobic), it only considered organic pollution. As the nutrient status of the water was ignored, unpolluted nutrient-poor waters or moderately nutrient-rich streams could not be classified. Schiefele (1987) had already tested Lange-Bertalot's method on other German rivers and suggested modifications. These were taken further (Steinberg & Schiefele, 1988) in recognising five categories of response to pollution and two of response to nutrients:

1. most tolerant towards pollution (mt): species are able to reproduce even under polysaprobic conditions.
2. highly tolerant towards pollution (ht): species are able to inhabit the α-meso-polysaprobic regions.
3. tolerant towards pollution (t): species tolerate α-mesosaprobic conditions.
4. sensitive towards pollution (s): species are insensitive to ß-α-mesosaprobic conditions
5. highly sensitive towards pollution (hs): species avoid conditions worse than ß-mesosaprobic.

oligotraphent (o): species differentiate towards nutrient rich conditions, i.e. they may avoid high nutrients or be outcompeted by eutrophic species under nutrient rich conditions.

FIGURE 1

Showing the changes in water quality (MEWAM, L-B, S&S zones, IPS & DIApo indices) along the River Nar and its tributaries.

NRA 23 - The Warren, Litcham
- II-III P1(P2) 11.7 20.37

NRA 22 - Drury Square Litcham
- III P1 14.4 12.01

NRA 20 - Bridge Farm, Litcham
3 III P1 14.6 5.15

NRA 21 - below Litcham sewage works
3 III P1 14.6 2.94

NRA 19 - Lexham Hall
- III TII/P1 15.5 28.98

NRA 18 - A1065 nr West Lecham
- II-III TII/P1 14.2 20.05

NRA 17 - Church Farm, Newton
5 III P2 13.3 21.70

NRA 16 - Castle Acre South
- III P1 14.6 5.72

NRA 15 - Peddlar's Way Ford, Castle Acre
- III P1 15.3 7.13

NRA 14 - Mill House Ford, South Acre
- III P1 14.5 8.25

NRA 13 - West Acre South
- III TII/P1 13.7 30.35

NRA 11 - Bradmoor Plantation
- III TII/P1 13.9 20.25

NRA 9 - Narborough West
- III P1 15.0 13.24

NRA 8 - Narborough West
- III P1 11.7 29.31

NRA 7 - Ashwood Lodge, nr Pentney
3 II-III TIV/P1 15.5 25.12

NRA 6 - Middleton Common, Blackborough
4/5 II-III P1 13.0 81.82

NRA 5 - Priory, Blackborough
3/4 II-III P1 13.5 11.43

NRA 3 - High Bridge, Blackborough
3? II-III TIV/P1 14.0 18.67

NRA 4 - High Bridge, Blackborough
4? II-III? P1(P2) 12.9 25.50

NRA 2 - Setchey Bridge
3 II-III TIV/PI 14.4 17.05

NRA 1 - King's Lynn
5? II-III PI 12.2 48.88

eutraphent (eu): development of these species is enhanced under nutrient rich conditions.

Abbreviations in brackets are the designations used in the calculations. The differentiating species recognised by Steinberg & Schiefele (1988) are given in Appendix XI.

To obtain an estimate of water quality, the relative proportions of the different species categories are calculated, and according to their contributions trophic zones and degrees of pollution are recognised:

Trophy I:	o ≥ 50%,	hs ≥ 10%,	eu < 10%,	t + ht + mt + s < 10%
Trophy II:	o ≥ 10%,	hs ≥ 10%,	eu < 50%,	t + ht + mt + s < 10%
Trophy III:	o < 10%,	hs ≥ 10%,	eu ≥ 50%,	t + ht + mt + s < 10%
Trophy IV:	o < 10%,	hs < 10%,	eu ≥ 50%	
Pollution 1:	o + hs < 10%,		eu < 50%,	t + ht + mt + s ≥ 10%
Pollution 2:	o + hs < 10%,		eu < 50%,	t + ht + mt + s ≥ 50%
Pollution 3:	o + hs < 10%,		eu < 10%,	t + ht + mt + s ≥ 50%

Results

Unfortunately two sites, NRA10 (Narborough North East) and NRA 12 (Bradmoor Plantation) could not been assessed because access was not obtained.

MEWAM

Because so few species are cited as the basis for zone allocation, more than 50% of the sites could not be unequivocally ranked according to MEWAM (Figure 1, Table 2). Table 3 summarizes the more abundant taxa at all sites and reveals that many sites were dominated by *Navicula tripunctata* which Round does not consider. Other *Navicula* species are abundant in several samples, while *Rhoicosphenia curvata* and *Melosira varians* dominate three samples. These are all commonly found in moderately nutrient rich waters, but are not particularly associated with pollution. (Most are ranked

TABLE 1

Allocation to sites of trophic and pollution indices of Descy, Descy & Coste (CEE), Coste (IPS) and Rumeau & Coste (GEN).

No.	Site designation	DESCY	CEE	IPS	GEN
NRA1	- King's Lynn	16.3	12.2	12.2	12.5
NRA2	- Setchey Bridge	14.7	11.3	14.4	14.1
NRA3	- High Bridge, Blackborough (Nar)	15.1	12.0	14.0	13.7
NRA4	- High Bridge, Blackborough (Trib)	14.3	10.9	12.9	13.6
NRA5	- Priory, Blackborough	19.4	12.0	13.5	12.2
NRA6	- Middleton Common, Blackborough	20.0	0.99	13.0	14.1
NRA7	- Ashwood Lodge, nr Pentney (Nar)	15.8	11.1	15.5	13.8
NRA8	- Narborough West (Trib)	19.9	14.3	11.7	12.9
NRA9	- Narborough West (Nar)	17.7	12.4	15.0	13.8
NRA10	- Narborough North-East	-	-	-	-
NRA11	- Bradmoor Plantation	17.4	13.5	13.9	12.1
NRA12	- Bradmoor Plantation	-	-	-	-
NRA13	- West Acre, South	17.6	14.3	13.7	13.5
NRA14	- Mill House Ford, South Acre	17.5	12.4	14.5	12.9
NRA15	- Peddlar's Way Ford, Castle Acre	18.8	12.4	15.3	13.2
NRA16	- Castle Acre South (Nar)	18.1	12.6	14.6	12.6
NRA17	- Church Farm, Newton	18.0	12.0	13.3	13.1
NRA18	- A1065 nr West Lecham	13.1	11.5	14.2	12.8
NRA19	- Lexham Hall (Nar)	18.0	12.0	15.5	13.7
NRA20	- Bridge Farm, Litcham	16.4	11.1	13.6	12.7
NRA21	- below Litcham Sewage Works	16.2	13.2	14.6	13.2
NRA22	- Drury Square, Litcham	16.1	11.8	14.6	13.3
NRA23	- The Warren, Litcham	15.3	9.9	11.7	13.0

TABLE 2

Allocation to sites of trophic and pollution zones according to Round (MEWAM), Lange-Bertalot (L-B) and Steinberg & Schiefele (S&S) and pollution index (DIApo) of Watanabe et al.

No.	Site designation	MEWAM	L-B	S&S	DIApo
NRA1	- King's Lynn	5?	II-III	P1	48.88
NRA2	- Setchey Bridge	3	II-III	TIV/P1	17.05
NRA3	- High Bridge, Blackborough (Nar)	3?	II-III	P1	18.67
NRA4	- High Bridge, Blackborough (Trib)	4?	II-III?	P1(P2)	25.50
NRA5	- Priory, Blackborough	3/4	II-III	P1	11.43
NRA6	- Middleton Common, Blackborough	4/5	II-III	P1	81.82
NRA7	- Ashwood Lodge, nr Pentney (Nar)	3	II-III	TIV/P1	25.12
NRA8	- Narborough West (Trib)	indet	III	P1	29.31
NRA9	- Narborough West (Nar)	indet	III	P1	13.24
NRA10	- Narborough North-East	-	-	-	-
NRA11	- Bradmoor Plantation	indet	III	TII/P1	20.25
NRA12	- Bradmoor Plantation	-	-	-	-
NRA13	- West Acre, South	indet	III	TII/P1	30.35
NRA14	- Mill House Ford, South Acre	indet	III	P1	8.25
NRA15	- Peddlar's Way Ford, Castle Acre	indet	III	PI	7.13
NRA16	- Castle Acre South (Nar)	indet	III	PI	5.72
NRA17	- Church Farm, Newton	5	III	P2	21.70
NRA18	- A1065 nr West Lecham	indet	II-III	TII/P1	20.05
NRA19	- Lexham Hall (Nar)	indet	III	TII/P1	28.98
NRA20	- Bridge Farm, Litcham	3	III	P1	5.15
NRA21	- below Litcham Sewage Works	3	III	P1	2.94
NRA22	- Drury Square, Litcham	indet	III	P1	12.01
NRA23	- The Warren, Litcham	indet	II-III	P1(P2)	20.37

indet = most abundant taxon not included in zone allocation list in Round (1993).
DIApo calculated using 1988 designations and equation 1 (see text for details).

TABLE 3

Species comprising more than 5% by abundance (to nearest 1%)

SPECIES	NRA1	NRA2	NRA3	NRA4	NRA5	NRA6	NRA7	NRA8	NRA9	NRA11	NRA13
Ach. lanceolata	-	-	-	-	-	-	-	-	-	-	5
Cocc.placentula	-	21	10	6	-	-	36	-	-	-	-
Cymb.caespitosa	-	-	-	-	-	-	-	-	-	-	-
Cymb.lanceolata	-	-	-	-	-	9	-	-	-	-	-
Cymb.prostrata	-	-	-	-	-	-	-	-	-	-	-
Cymb.minuta	-	-	-	-	-	-	-	-	-	9	14
Cymb.silesiaca	-	14	10	12	-	9	6	-	-	-	-
Fragi.capucina	-	-	8	-	-	-	-	-	-	-	-
Fragi.cap. vaucheriae	-	-	9	10	-	-	-	-	-	-	-
Fragi.leptostauron	-	-	-	-	-	-	19	-	-	-	-
Fragi.pinnata	-	-	-	-	-	-	-	-	-	-	-
Fragi.rumpens	-	-	-	-	-	-	-	-	-	-	-
Fragi.virescens	-	-	-	-	-	-	6	10	5	-	-
Gomph.parvulum	-	7	7	-	-	27	6	-	-	-	-
Mel.varians	-	-	-	-	6	-	-	-	19	-	-
Nav.capitatoradiata	15	-	-	9	6	-	-	-	-	-	-
Nav.cryptocephala	-	-	-	-	-	-	-	-	-	-	-
Nav.cryptotenella	9	6	5	-	7	-	-	-	-	-	5
Nav.erifuga	-	-	-	-	-	-	-	28	5	-	5
Nav.gregaria	9	12	6	19	26	9	6	5	-	-	-
Nav.lanceolata	-	-	-	-	-	-	-	-	-	-	-
Nav.menisculus	-	-	-	-	-	-	7	10	9	18	-
Nav.slesvicensis	-	-	-	-	-	45	-	-	-	-	-
Nav.tripunctata	-	-	-	-	41	-	-	38	28	42	42
Nav.trivialis	-	-	-	-	-	-	-	-	-	-	-
Nitz.amphibia	-	-	-	-	-	-	-	-	-	10	5
Nitz.dissipata	30	-	-	-	-	-	-	-	-	-	-
Nitz.palea	7	-	-	-	-	-	-	-	-	-	-
Rhoic.curvata	6	22	21	-	-	-	11	-	9	6	-
Sur.brebissonii	-	-	-	12	-	-	-	-	-	-	-
Syn.ulna	-	-	-	-	-	-	-	-	5	-	-

TABLE 3 (contd.)

Species comprising more than 5% abundance (to nearest 1%)

SPECIES	NRA14	NRA15	NRA16	NRA17	NRA18	NRA19	NRA20	NRA21	NRA22	NRA23
Ach. lanceolata	-	-	-	-	-	-	5	12	-	6
Cocc.placentula	-	5	-	-	-	-	38	31	-	-
Cymb.caespitosa	-	-	-	-	-	-	-	-	-	6
Cymb.lanceolata	-	-	-	-	-	-	-	-	-	-
Cymb.prostrata	-	-	-	-	-	7	-	-	-	-
Cymb.minuta	-	-	-	-	-	-	-	-	-	-
Cymb.silesiaca	-	-	-	-	-	-	-	-	-	-
Fragi.capucina	-	-	-	-	-	-	-	-	-	-
Fragi.cap.v. vaucheriae	-	-	-	-	-	-	-	-	-	-
Fragi.leptostauron	-	-	-	-	-	-	-	-	-	-
Fragi.pinnata	-	8	-	9	-	19	-	-	16	7
Fragi.rumpens	-	-	5	-	-	-	-	-	-	-
Fragi.virescens	-	-	13	-	-	-	-	-	-	-
Gomph.parvulum	-	-	-	-	-	-	-	-	-	6
Mel.varians	10	15	12	-	53	10	7	-	13	7
Nav.capitatoradiata	-	-	-	-	-	-	-	-	-	24
Nav.cryptocephala	8	-	-	19	-	-	18	6	7	-
Nav.cryptotenella	-	-	-	6	13	27	-	-	-	6
Nav.erifuga	-	-	-	5	-	-	-	-	-	-
Nav.gregaria	18	7	6	11	11	5	8	-	7	-
Nav.lanceolata	8	-	-	-	-	8	18	-	-	-
Nav.menisculus	-	6	5	34	-	5	-	-	-	-
Nav.slesvicensis	-	-	-	-	-	-	-	-	-	-
Nav.tripunctata	25	39	39	-	-	-	-	26	-	-
Nav.trivialis	-	-	-	-	-	-	11	-	-	-
Nitz.amphibia	-	-	-	-	-	-	-	-	-	-
Nitz.dissipata	-	-	-	-	-	-	-	-	-	-
Nitz.palea	-	-	-	-	-	-	-	-	-	-
Rhoic.curvata	5	-	-	-	-	11	7	-	-	6
Sur.brebissonii	-	6	-	-	-	-	-	-	-	-
Syn.ulna	-	-	-	-	5	-	6	-	5	20

eutrophic and mesosaprobic by Lowe, 1974.) Allocation of zone 5 to site 1 was based on the assumption that *Nitzschia dissipata* could be considered a small *Nitzschia*; rankings of 4? to site 4, and 3/4 to site 5 were based on the occurrence of *Navicula gregaria* which Round (1993) shows in the corresponding Lange-Bertalot zone. The poor ranking (zone 5) for site 17 rests on the presence of *Navicula menisculus* which would presumably be included in Round's small *Navicula* species, that of 4/5 for site 6 on the presence of *Gomphonema parvulum*. It should be noted that Round (1993) does not really define what he means by "small" *Navicula* or *Nitzschia* species. This requires precise definition, but by no means all small taxa of these genera are pollution tolerant.

Descy, CEE, IPS and GEN indices

Descy's index identified three tributary sites, 4,5 and 6, as particularly high quality, with four more, 15,16,17 and 19, still within his un-polluted zone. Sites 2,3 and 18 however fell in his zone III, indicating moderate pollution or significant eutrophication. In almost all cases however, his index was higher than CEE, IPS and GEN, perhaps bearing out Leclercq & Maquet's (1987) criticism that it over-estimates water quality.

On the other hand, the CEE index was generally the lowest of this group, usually shifting in the same direction as Descy's, except at site 6 for which no index was calculated. The most abundant taxon is not included in the CEE grid, and is also more usually associated with slightly brackish conditions. CEE places the majority of the sites in Descy's zone III, with the exception of site 6 and 23. The latter falls into zone IV, suggesting heavy pollution. Using Prygiel's zonation, sites 8 and 13 would be considered zone II and moderately eutrophic.

FIGURE 2

<u>Showing the variation in Descy, CEE, IPS and GEN indices for sites 1 - 13 along the River Nar</u>.
(Division into zones following Descy.)

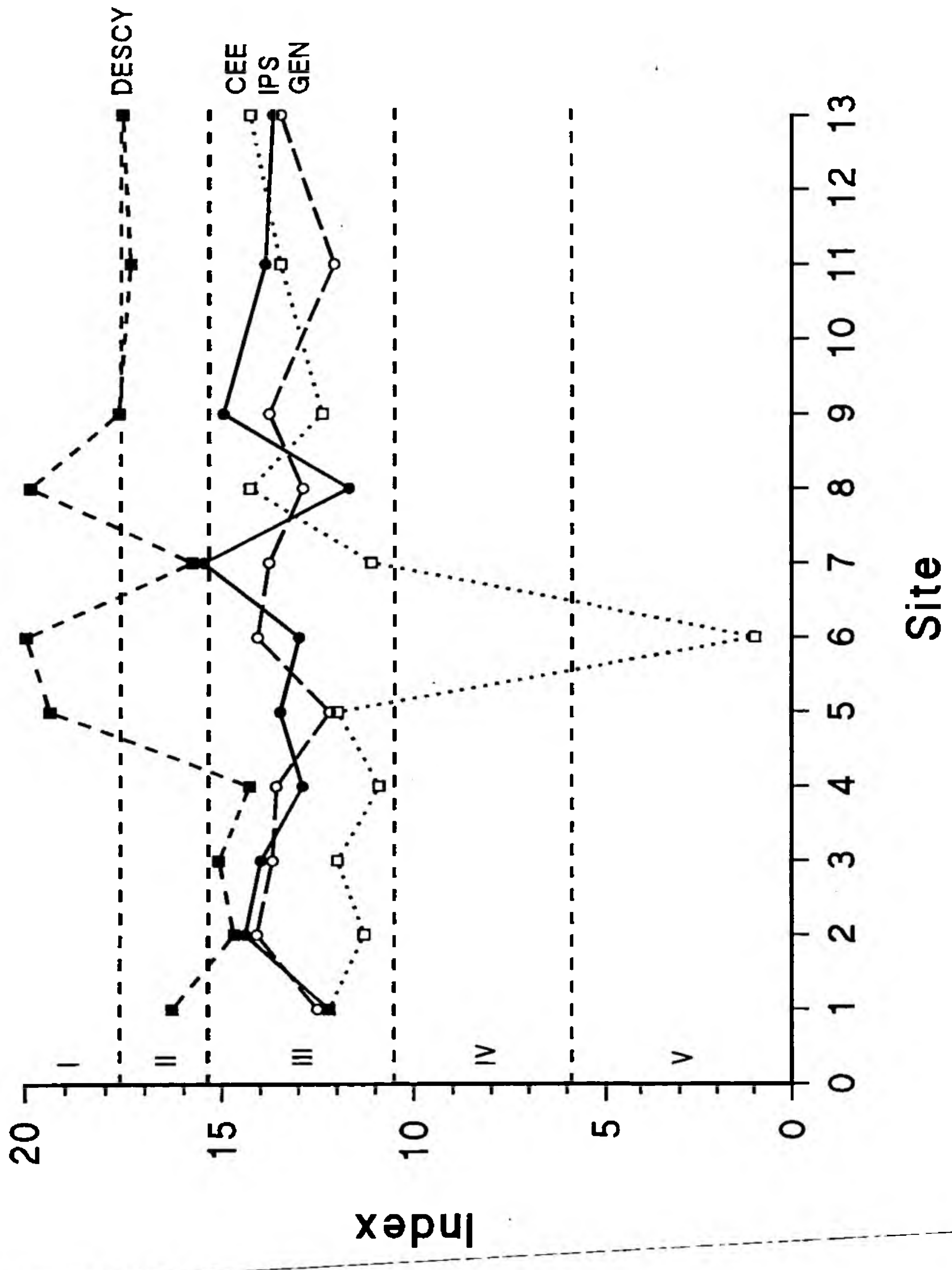


FIGURE 3

Showing the variation in Descy, CEE, IPS and GEN indices for sites 1 - 13 along the River Nar.
(Division into zones following Prygiel.)

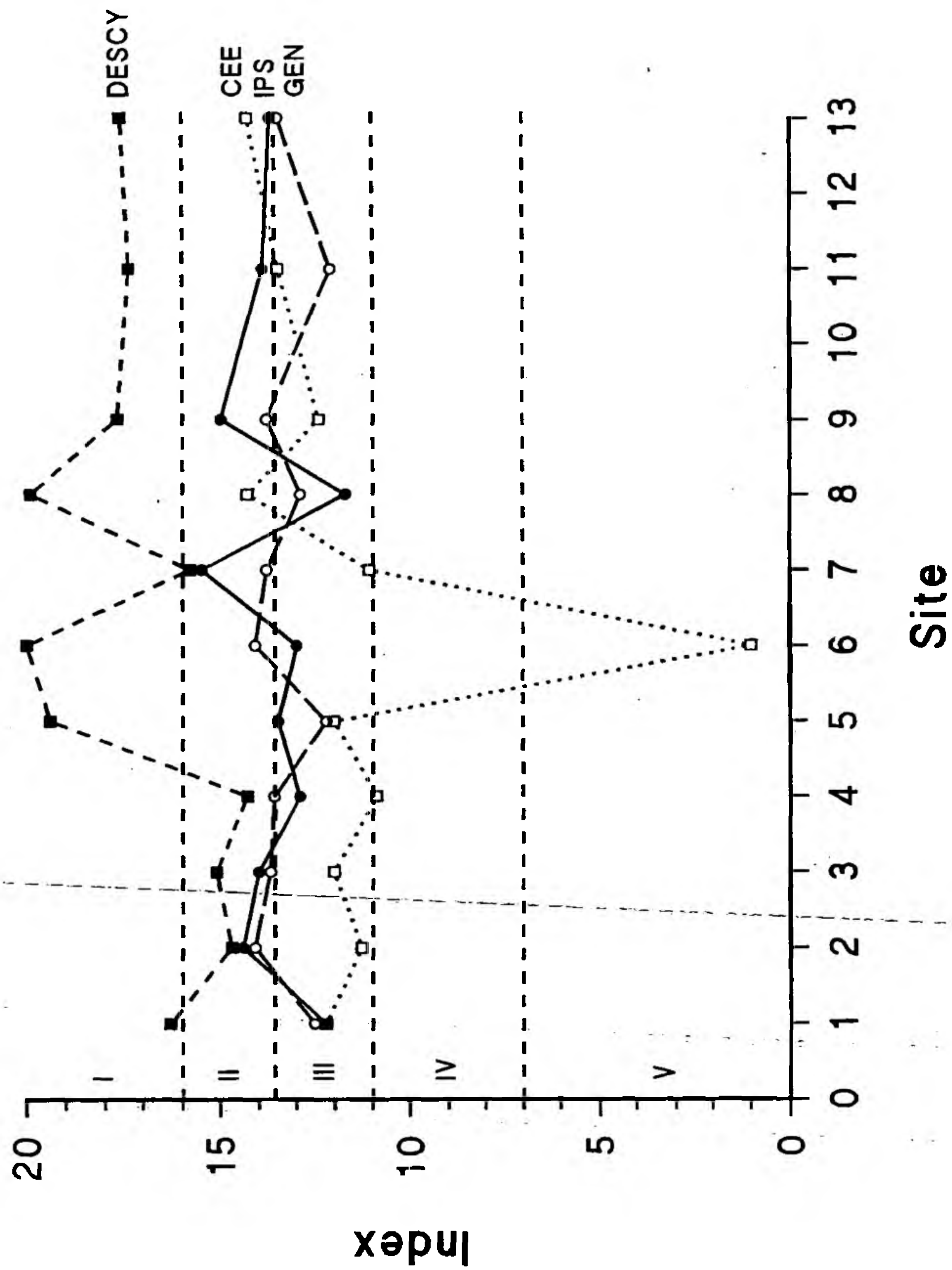


FIGURE 4

Showing the variation in Descy, CEE, IPS and GEN indices for sites 13 - 23 along the River Nar.
(Division into zones following Descy.)

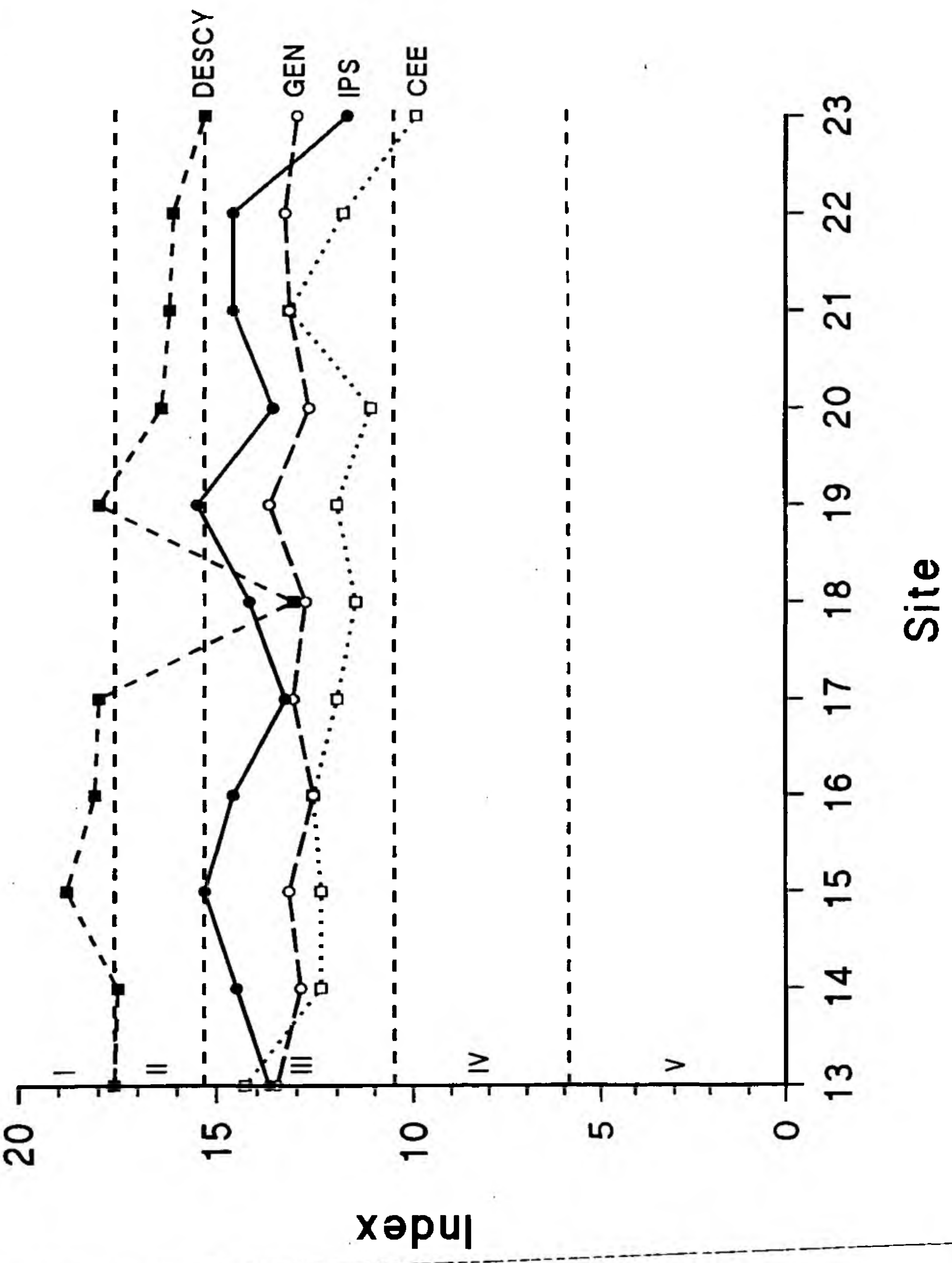
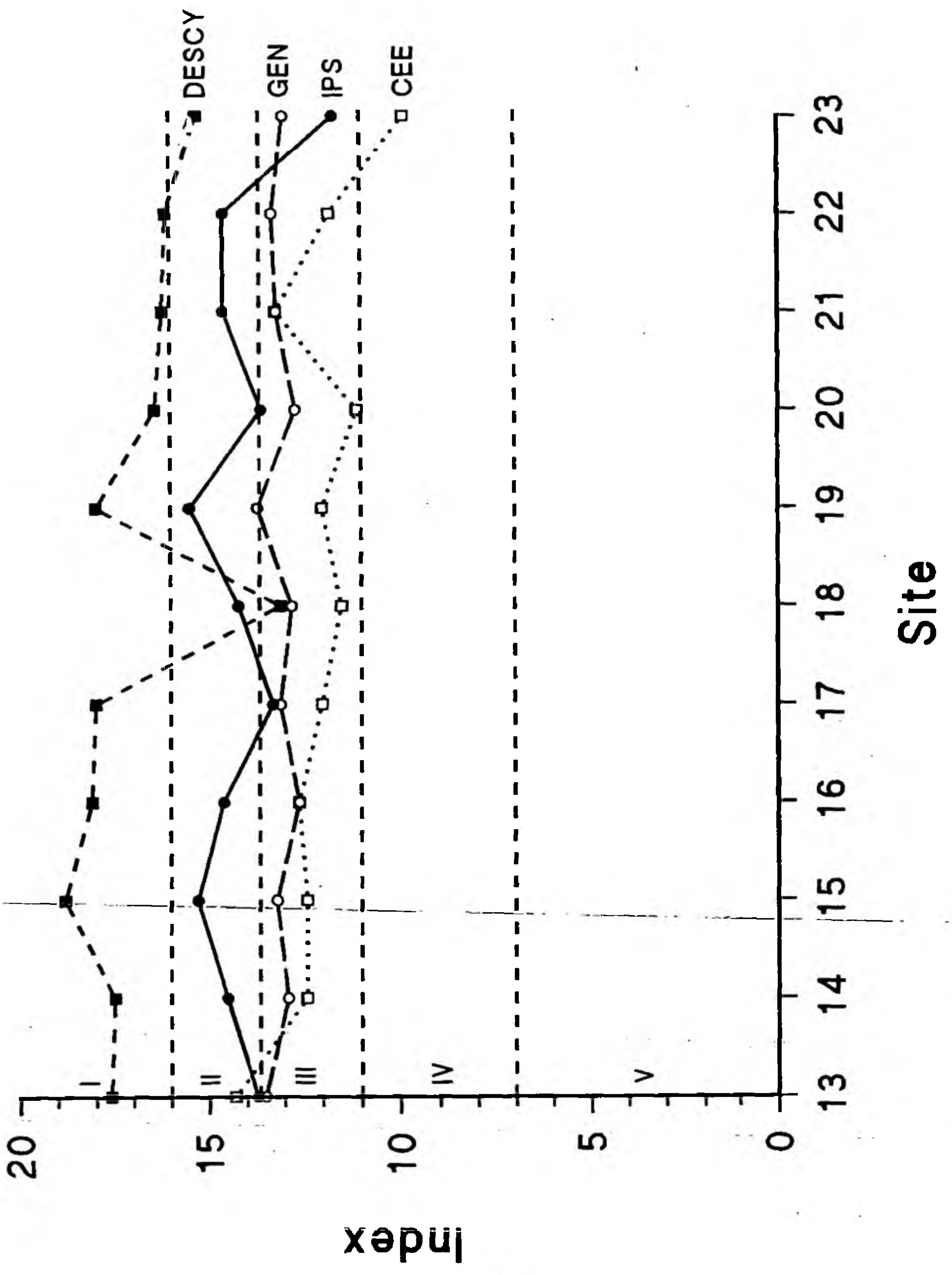


FIGURE 5

Showing the variation in Descy, CEE, IPS and GEN indices for sites 13 - 23 along the River Nar.
(Division into zones following Prygiel.)



IPS and GEN, although differing slightly from each other tended to follow the same trend, except at 5, 7, 13, 14, 17 and 18. Values for both indices were almost entirely within Descy's zone III, IPS 7 and 19 just into zone II. Using Prygiel's scheme and IPS, more sites were in zone II, moderately eutrophic rather than strongly eutrophic.

Trophic and organic pollution zones

Lange-Bertalot's system (Table 2) identifies all sites as zone II-III or III, i.e. ß-α-mesosaprobic to α-mesosaprobic, critically to strongly polluted respectively. According to his system, the upstream sites apart from 23 and 18, are generally more polluted than the downstream ones. However, the criticism that his system cannot distinguish water quality better than zone II should be borne in mind. Furthermore, his system is based on species differentiating against more polluted conditions; taxa may be tolerant of pollution but occur in unpolluted waters.

Steinberg & Schiefele's system (Table 2) makes more distinctions between the sites, with variation in trophic status indicated (11, 13, 18, 19 = TII; 2, 7 = TIV), although all show some degree of pollution. Site 17 is identified as the most polluted (= strongly polluted and cf. MEWAM), with sites 4 and 23 tending towards this.

The diatom assemblage index (DIApo) developed by Watanabe et al. shows the greatest variation in results depending upon the designation chosen (1986 or 1988, verbal designation or designation equivalent to tolerance index) and the equation used (Table 4). Figure 7 shows that the resolution of equation 2 is very poor, but this is due to its reliance on saproxenic taxa which are poorly represented in the samples. Using the 1988 verbal designation and equation 1, the greatest differences between sites are

TABLE 4

Comparison of values of DAIpo obtained using Watanabe's 1986 and 1988 designations and indices with the different equations.

No.	Site designation	A	B	C	D	E
NRA1	- King's Lynn	48.13	48.88	61.63	69.50	60.50
NRA2	- Setchey Bridge	26.50	17.05	48.85	64.98	55.99
NRA3	- High Bridge, Blackborough (Nar)	34.15	18.67	49.75	68.18	56.88
NRA4	- High Bridge, Blackborough (Trib)	39.43	25.50	50.75	71.27	60.70
NRA5	- Priory, Blackborough	56.02	11.43	49.23	59.21	50.86
NRA6	- Middleton Common, Blackborough	63.64	81.82	50.00	95.45	54.55
NRA7	- Ashwood Lodge, nr Pentney (Nar)	27.49	25.12	50.00	68.48	55.92
NRA8	- Narborough West (Trib)	69.95	29.31	50.00	71.55	56.40
NRA9	- Narborough West (Nar)	50.59	13.24	50.00	73.40	57.45
NRA10	- Narborough North-East	-	-	-	-	-
NRA11	- Bradmoor Plantation	61.25	20.25	54.50	54.50	44.38
NRA12	- Bradmoor Plantation	-	-	-	-	-
NRA13	- West Acre, South	77.86	30.35	56.97	64.30	47.39
NRA14	- Mill House Ford, South Acre	40.75	8.25	51.50	61.50	54.00
NRA15	- Peddlar's Way Ford, Castle Acre	45.95	7.13	50.61	63.39	52.83
NRA16	- Castle Acre South (Nar)	51.49	5.72	49.75	64.30	55.47
NRA17	- Church Farm, Newton	18.87	21.70	50.83	61.79	50.94
NRA18	- A1065 nr West Lecham	20.54	20.05	50.25	86.51	50.25
NRA19	- Lexham Hall (Nar)	37.69	28.98	50.00	71.97	52.27
NRA20	- Bridge Farm, Litcham	27.29	5.15	50.22	51.45	46.09
NRA21	- below Litcham Sewage Works	41.18	2.94	50.00	51.47	50.00
NRA22	- Drury Square, Litcham	15.44	12.01	50.37	62.13	50.25
NRA23	- The Warren, Litcham	20.37	20.37	50.00	62.96	49.07

A = 1986 designation + Eq.1; B = 1988 designation + Eq.1; C = 1988 designation + Eq.2; D = 1988 indices + Eq.1; E = 1988 indices + Eq.2.

FIGURE 6

Showing the variation in DAIpo at all sites, according to the designations used with equation 1.
(A,B,D as defined in Table 4)

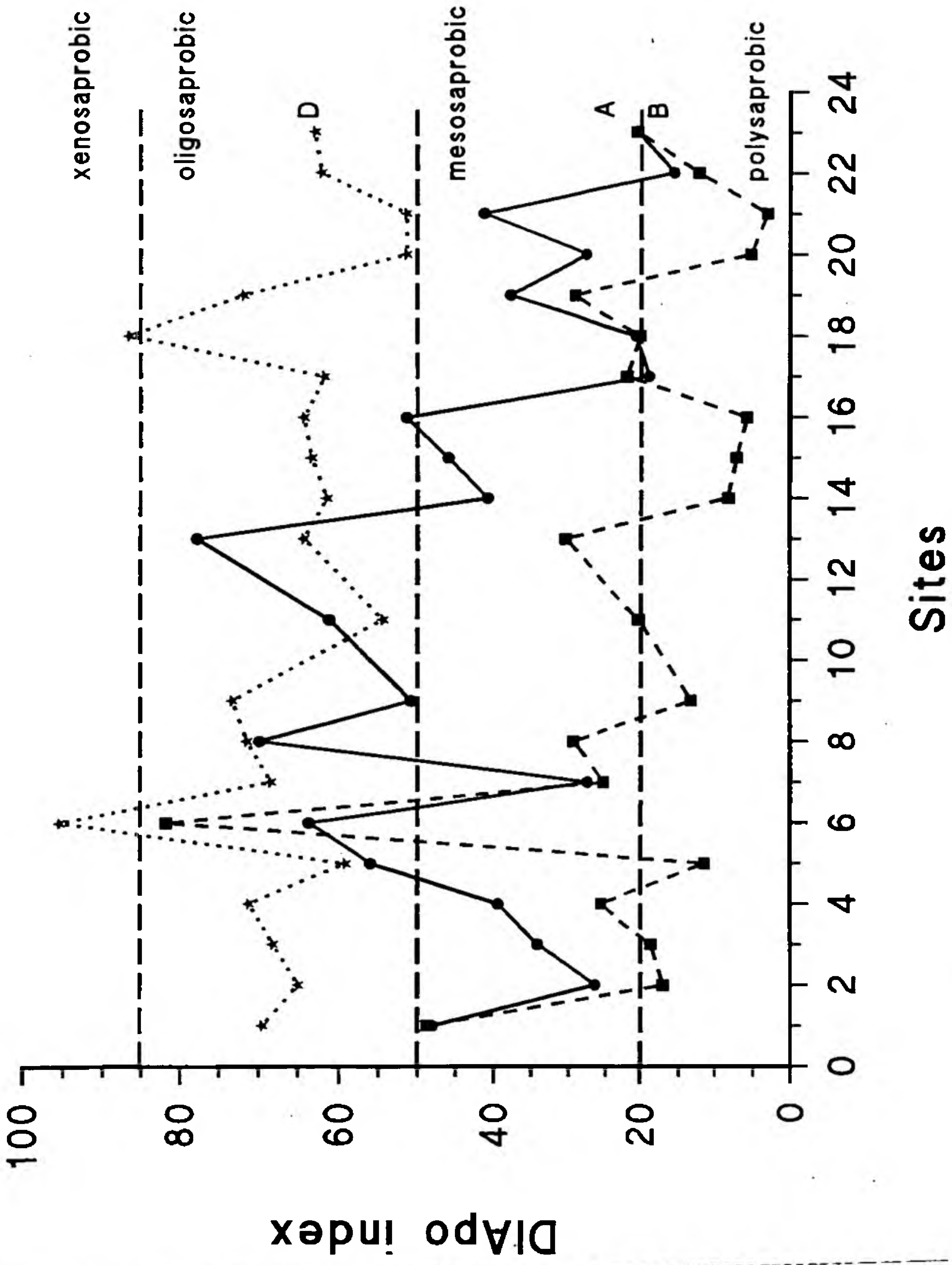
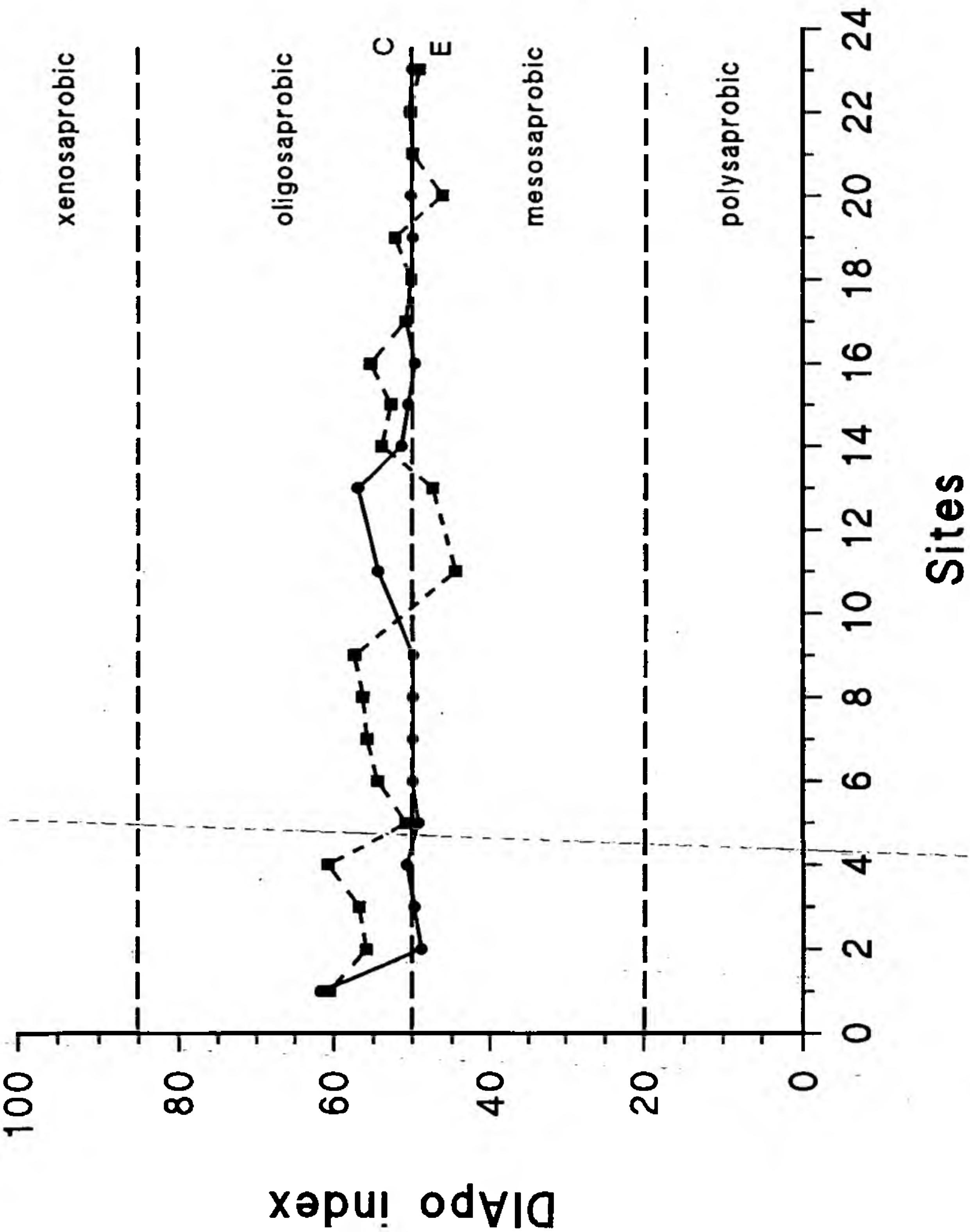


FIGURE 7

<u>Showing the variation in DAIpo at all sites, according to the designations used with equation 2</u>.

(C,E as defined in Table 4)



revealed (Figure 7, line B), several sites falling in the polysaprobic zone (2,3,5,9,14-16,20-23), and one near the upper edge of the oligosaprobic zone. Translating 1988 indices into designations (Figure 7, line C) all sites are oligosaprobic or saproxenic, whereas the 1986 designations (Figure 7, line A) present an intermediate picture, with the majority of sites in the mesosaprobic to oligosaprobic zones and only two polysaprobic sites, 17 and 22. Whereas 17 is also identified as the poorest according to MEWAM and Steinberg & Schiefele, the other systems do not concur. There is a similar marked discrepancy over site 6, which according to Watanabe et al. is better than most other sites, very good according to Descy, yet 4/5 according to MEWAM, pollution 1 for Steinberg & Schiefele and undefinable by CEE.

General conclusions on the water courses

All the sites along the River Nar, and those sampled along its tributaries would be classified as eutrophic, with slight or moderate pollution occurring in places, according to the index used. However, although some systems agree on certain sites, full consensus is lacking. E.g. MEWAM and S&S both give NRA 17 the poorest rating, but the other systems do not give this a particularly low ranking. TIV/P1 (S&S) usually coincides with MEWAM 3 or 3?, although P1 sometimes ranks with MEWAM 3, at other times poorer quality. IPS does not show great variation between the sites although lower values are obtained for the tributaries and show some correlation with drops in other rankings. DIApo values do not show the same trend. The only index change seen between the above and below sewage works sites, where differences might have been predicted, is in the DIApo value, which drops below the works, but was already low above it. On the basis of IPS and MEWAM however, neither site is poor.

It is probably necessary to pay closer attention to the effect of water depth on the different indices; shallow stretches may favour species which are ranked as more pollution tolerant because water velocity is lowered. Some samples were also very poor in material, in reaches where water velocity was higher following recent heavy rainfall and abrasion of the flora had probably occurred.

The ranking of taxa requires further investigation. Much of the variation between the DIApo results was due to species rankings being changed. The various systems do not always rank a single taxon in the same way, and whereas the Descy, CEE, IPS and GEN indices integrate information from all taxa, the other systems tend to pick "indicator" species. If these are absent or few the result is potentially skewed. This difficulty also applies to the MEWAM system which fails if the diagnostic taxa are rare. Although Round (1993) argues that only truly epilithic taxa should be included, it is arguable whether rubbing stones to remove silt will ensure removal of epipelic species and retention of the epilithon. It is as likely that those epilithic taxa which project from the stone surface will also be depleted.

Suggestions for future monitoring programmes

For best resolution of the potential impact of nutrient inflows into the river system, sampling should focus on point sources of contamination (above and below), and should be carried out several times a year (e.g. spring, summer, autumn) to allow for seasonality in the diatom flora.

With access to a copy of OMNIDIA, calculation of the "French" indices is straightforward. Their implementation, together with MEWAM, if its resolution can be improved, and the S&S zone system would offer a reasonable range of methods. Lange-Bertalot's zones do not seem to offer sufficient resolution for English rivers while Watanabe's DIApo index is highly dependent on species designations derived from Japanese waters. It is also possible that slightly different taxa (or physiological races) are involved. Comparison with other biotic indices, e.g. invertebrates, and with physico-chemical measurements would provide useful checks of the above methods, and possibly suggest methods for their improvement.

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Appendices

Appendix I
Sites and codes.

Appendix II
Species counts of samples from the River Nar.

Appendix III
Percentage abundances of species in samples from the River Nar.

Appendix IV
Species list for River Nar, with allocation of sensitivity and indicator values of Coste (1982) and allocation of CEE groups following Coste & Descy (1990).

Appendix V
Ranges of physico-chemical parameters in water quality zones (Descy, 1984)

Appendix VI
Groups of species characteristic of different types of water, as used by Coste (1990).

Appendix VII
Species list for River Nar, with allocation to tolerance categories according to Lange-Bertalot (1979), Steinberg & Schiefele (1988) and indices of Watanabe (1986, 1988).

Appendix VIII
Percentages of different species categories for calculation of water quality zones recognised by Lange-Bertalot, Steinberg & Schiefele and for DIApo of Watanabe.

Appendix IX
Lange-Bertalot's (1979) classification of differentiating species.

Appendix X
Water quality categories as in Schiefele (1987).

Appendix XI
Groups of differentiating species as recognised by Steinberg & Schiefele (1988).

Appendix XII
Sketch maps of sites

APPENDIX I

SITES AND CODES

No.	NRA site designation	Grid reference	OMNIS code
NRA1	- King's Lynn	TF622183	1
NRA2	- Setchey Bridge	TF636134	2
NRA3	- High Bridge, Blackborough (Nar)	TF671136	3
NRA4	- High Bridge, Blackborough (Trib)	TF669136	4
NRA5	- Priory, Blackborough	TF674141	5
NRA6	- Middleton Common, Blackborough	TF679141	6
NRA7	- Ashwood Lodge, nr Pentney (Nar)	TF725121	7
NRA8	- Narborough West (Trib)	TF747133	8
NRA9	- Narborough West (Nar)	TF746134	9
NRA10	- Narborough North-East	not found	
NRA11	- Bradmoor Plantation	TF765144	11
NRA12	- Bradmoor Plantation	not found	
NRA13	- West Acre, South	TF779148	13
NRA14	- Mill House Ford, South Acre	TF788152	14
NRA15	- Peddlar's Way Ford, Castle Acre	TF816145	15
NRA16	- Castle Acre South (Nar)	TF818147	16
NRA17	- Church Farm, Newton	TF827154	17
NRA18	- A1065 nr West Lecham	TF838170	18
NRA19	- Lexham Hall (Nar)	TF870168	19
NRA20	- Bridge Farm, Litcham	TF892172	20
NRA21	- below Litcham Sewage Works	TF892176	21
NRA22	- Drury Square, Litcham	TF893176	22
NRA23	- The Warren, Litcham	TF903179	231

APPENDIX II

Species counts of samples from the River Nar.

species	NRA1	NRA2	NRA3	NRA4	NRA5	NRA6	NRA7	NRA8	NRA9	NRA10	NRA11	NRA12	NRA13	NRA14	NRA15	NRA16	NRA17	NRA18	NRA19	NRA20	NRA21	NRA22	NRA23
Achnanthes lanceolata			4	4	2		10		5				21	10			3	2		22	4	4	3
Amphora pediculus								6									8			4			
Caloneis amphisbaena					2																	4	
Caloneis silicula																				1			
Cocconeis placentula	20	89	39	25			152				1			17	20	7	7	4		4	13	128	1
Cymbella caespitosa	15																						3
Cymbella lanceolata			18			1					11		16				12						
Cymbella prostrata																			35				
Cymbella minuta											36		56				7						
Cymbella silesiaca		62	40	47	13	1	25	7	43					20	5	6				10	1	7	
Fragilaria capucina v. capucina		5	32											14	8								
F.capucina v. vaucheriae			36	41																			
Fragilaria construens v.binodis																		18					
Fragilaria leptostauron		14	5				80	3	9		11		5	5	9	4	13	8				17	
Fragilaria pinnata															34		38		98	19		64	4
Fragilaria rumpens																22							
Fragilaria virescens							27	42	20						18	52							
Frustulia vulgaris		14																					
Gomphonema truncatum			5	8				3			3												
Gomphonema parvulum	10	30	29	17		3	25		10		7				4		15	2	4		1	5	3
Gyrosigma acuminatum		1	1		2																	1	
Hantzschia virgata					11																		
Melosira varians	10	9	17	17	23			4	79				14	39	62	49		214	55	29		54	4
Meridion circulare				15																2		3	
Navicula capitata					3										5				11			8	
Navicula capitatoradiata	60	8	6	36	26			7										12					13
Navicula cryptocephala	7												13	30	5	13	80		1	82	2	28	
Navicula cryptotenella.	35	24	21	6	30		1		15		16		21	10	11	18	25	51	140			8	3
Navicula erifuga								115	20				22	6			20						
Navicula gregaria	35	51	23	75	105	1	25	20			10		15	73	30	25	45	43	25	34	1	27	2
Navicula lanceolata														31					40	80		8	
Navicula menisculus	17	8	10	6	12		30	40	40		73		10	3	26	19	145	16	29	16	1	3	
Navicula reinhardtii			1																				
Navicula slesvicensis						5																	1
Navicula tripunctata		9	7	8	165			155	120		168		170	100	157	156		11	15	16	9	8	
Navicula trivialis																				51			
Neidium dubium																						3	
Nitzschia amphibia	9		13				2				42		21			12					1		1
Nitzschia capitellata																				5		2	
Nitzschia dissipata	120													12	5			2					
Nitzschia dubia																			3				
Nitzschia heufleriana					3																		
Nitzschia palea	27	10	2	9												2							
Nitzschia recta	2			8					2											10		6	
Nitzschia sigmoidea								1					2						1				1
Nitzschia umbonata	4																						1
Pinnularia lundii				4																			
Rhoicosphenia curvata	22	97	85	12	10		45	3	40		22		16	20	6	11	6		60	31			3
Stauroneis phoenicenteron																			5	5			
Surirella minuta	7			13																			
Surirella brebissonii				48																			
Synedra ulna		3	13	3					20					10	2	6		21	6	26	1	20	11
[illegible]	[illegible]	[illegible]	40[illegible]	[illegible]02	[illegible]	[illegible]	422	[illegible]	[illegible]	0	[illegible]	[illegible]	40	[illegible]00	[illegible]	4[illegible]	424	[illegible]	[illegible]	447	[illegible]4	[illegible]	5[illegible]

APPENDIX III

Percentage abundances of species in samples from the River Nar.

species	NRA1	NRA2	NRA3	NRA4	NRA5	NRA6	NRA7	NRA8	NRA9	NRA10	NRA11	NRA12	NRA13	NRA14	NRA15	NRA16	NRA17	NRA18	NRA19	NRA20	NRA21	NRA22	NRA23
Achnanthes lanceolata	0	0	0.983	0.995	0.491	0	2.37	0	1.182	#####	0	#####	5.224	2.5	0	0	0.708	0.495	0	4.922	11.76	0.98	5.556
Amphora pediculus	0	0	0	0	0	0	0	1.478	0	#####	0	#####	0	0	0	0	1.887	0	0	0.895	0	0	0
Caloneis amphisbaena	0	0	0	0	0.491	0	0	0	0	#####	0	#####	0	0	0	0	0	0	0	0	0	0.98	0
Caloneis silicula	0	0	0	0	0	0	0	0	0	#####	0	#####	0	0	0	0	0	0	0	0.224	0	0	0
Cocconeis placentula	5	20.51	9.582	6.219	0	0	36.02	0	0	#####	0.25	#####	0	4.25	4.914	1.741	1.651	0.99	0	0.895	38.24	31.37	1.852
Cymbella caespitosa	3.75	0	0	0	0	0	0	0	0	#####	0	#####	0	0	0	0	0	0	0	0	0	0	5.556
Cymbella lanceolata	0	0	4.423	0	0	9.091	0	0	0	#####	2.75	#####	3.98	0	0	0	2.83	0	0	0	0	0	0
Cymbella prostrata	0	0	0	0	0	0	0	0	0	#####	0	#####	0	0	0	0	0	0	6.629	0	0	0	0
Cymbella minuta	0	0	0	0	0	0	0	0	0	#####	9	#####	13.93	0	0	0	1.651	0	0	0	0	0	0
Cymbella silesiaca	0	14.29	9.828	11.69	3.194	9.091	5.924	1.724	10.17	#####	0	#####	0	5	1.229	1.493	0	0	0	2.237	2.941	1.716	0
Fragilaria capucina v. capucina	0	1.152	7.862	0	0	0	0	0	0	#####	0	#####	0	3.5	1.966	0	0	0	0	0	0	0	0
F.capucina v. vaucheriae	0	0	8.845	10.2	0	0	0	0	0	#####	0	#####	0	0	0	0	0	0	0	0	0	0	0
Fragilaria construens v.binodis	0	0	0	0	0	0	0	0	0	#####	0	#####	0	0	0	0	0	4.455	0	0	0	0	0
Fragilaria leptostauron	0	3.226	1.229	0	0	0	18.96	0.739	2.128	#####	2.75	#####	1.244	1.25	2.211	0.995	3.066	1.98	0	0	0	4.167	0
Fragilaria pinnata	0-	0	0	0	0	0	0	0	0	#####	0	#####	0	0	8.354	0	8.962	0	18.56	4.251	0	15.69	7.407
Fragilaria rumpens	0	0	0	0	0	0	0	0	0	#####	0	#####	0	0	0	5.473	0	0	0	0	0	0	0
Fragilaria virescens	0	0	0	0	0	0	6.398	10.34	4.728	#####	0	#####	0	0	4.423	12.94	0	0	0	0	0	0	0
Frustulia vulgaris	0	3.226	0	0	0	0	0	0	0	#####	0	#####	0	0	0	0	0	0	0	0	0	0	0
Gomphonema truncatum	0	0	1.229	1.99	0	0	0	0.739	0	#####	0.75	#####	0	0	0	0	0	0	0	0	0	0	0
Gomphonema parvulum	2.5	6.912	7.125	4.229	0	27.27	5.924	0	2.364	#####	1.75	#####	0	0	0.983	0	3.538	0.495	0.758	0	2.941	1.225	5.556
Gyrosigma acuminatum	0	0.23	0.246	0	0.491	0	0	0	0	#####	0	#####	0	0	0	0	0	0	0	0	0	0.245	0
Hantzschia virgata	0	0	0	0	2.703	0	0	0	0	#####	0	#####	0	0	0	0	0	0	0	0	0	0	0
Melosira varians	2.5	2.074	4.177	4.229	5.651	0	0	0.985	18.68	#####	0	#####	3.483	9.75	15.23	12.19	0	52.97	10.42	6.488	0	13.24	7.407
Meridion circulare	0	0	0	3.731	0	0	0	0	0	#####	0	#####	0	0	0	0	0	0	0	0.447	0	0.735	0
Navicula capitata	0	0	0	0	0.737	0	0	0	0	#####	0	#####	0	0	1.229	0	0	0	2.083	0	0	1.961	0
Navicula capitatoradiata	15	1.843	1.474	8.955	6.388	0	0	1.724	0	#####	0	#####	0	0	0	0	0	2.97	0	0	0	0	24.07
Navicula cryptocephala	1.75	0	0	0	0	0	0	0	0	#####	0	#####	3.234	7.5	1.229	3.234	18.87	0	0.189	18.34	5.882	6.863	0
Navicula cryptotenella	8.75	5.53	5.16	1.493	7.371	0	0.237	0	3.546	#####	4	#####	5.224	2.5	2.703	4.478	5.896	12.62	26.52	0	0	1.961	5.556
Navicula erifuga	0	0	0	0	0	0	0	28.33	4.728	#####	0	#####	5.473	1.5	0	0	4.717	0	0	0	0	0	0
Navicula gregaria	8.75	11.75	5.651	18.66	25.8	9.091	5.924	4.926	0	#####	2.5	#####	3.731	18.25	7.371	6.219	10.61	10.64	4.735	7.606	2.941	6.618	3.704
Navicula lanceolata	0	0	0	0	0	0	0	0	0	#####	0	#####	0	7.75	0	0	0	0	7.576	17.9	0	1.961	0
Navicula menisculus	4.25	1.843	2.457	1.493	2.948	0	7.109	9.852	9.456	#####	18.25	#####	2.488	0.75	6.388	4.726	34.2	3.96	5.492	3.579	2.941	0.735	0
Navicula reinhardtii	0	0	0.246	0	0	0	0	0	0	#####	0	#####	0	0	0	0	0	0	0	0	0	0	0
Navicula slesvicensis	0	0	0	0	0	45.45	0	0	0	#####	0	#####	0	0	0	0	0	0	0	0	0	0	1.852
Navicula tripunctata	0	2.074	1.72	1.99	40.54	0	0	38.18	28.37	#####	42	#####	42.29	25	38.57	38.81	0	2.723	2.841	3.579	26.47	1.961	0
Navicula trivialis	0	0	0	0	0	0	0	0	0	#####	0	#####	0	0	0	0	0	0	0	11.41	0	0	0
Neidium dubium	0	0	0	0	0	0	0	0	0	#####	0	#####	0	0	0	0	0	0	0	0	0	0.735	0
Nitzschia amphibia	2.25	0	3.194	0	0	0	0.474	0	0	#####	10.5	#####	5.224	0	0	2.985	0	0	0	0	2.941	0	1.852
Nitzschia capitellata	0	0	0	0	0	0	0	0	0	#####	0	#####	0	0	0	0	0	0	0	1.119	0	0.49	0
Nitzschia dissipata	30	0	0	0	0	0	0	0	0	#####	0	#####	0	3	1.229	0	0	0.495	0	0	0	0	0
Nitzschia dubia	0	0	0	0	0	0	0	0	0	#####	0	#####	0	0	0	0	0	0	0.568	0	0	0	0
Nitzschia heufleriana	0	0	0	0	0.737	0	0	0	0	#####	0	#####	0	0	0	0	0	0	0	0	0	0	0
Nitzschia palea	6.75	2.304	0.491	2.239	0	0	0	0	0	#####	0	#####	0	0	0	0.498	0	0	0	0	0	0	0
Nitzschia recta	0.5	0	0	1.99	0	0	0	0	0.473	#####	0	#####	0	0	0	0	0	0	0	2.237	0	1.471	0
Nitzschia sigmoidea	0	0	0	0	0	0	0	0.246	0	#####	0	#####	0.498	0	0	0	0	0	0.189	0	0	0	1.852
Nitzschia umbonata	1	0	0	0	0	0	0	0	0	#####	0	#####	0	0	0	0	0	0	0	0	0	0	1.852
Pinnularia lundii	0	0	0	0.995	0	0	0	0	0	#####	0	#####	0	0	0	0	0	0	0	0	0	0	0
Rhoicosphenia curvata	5.5	22.35	20.88	2.985	2.457	0	10.66	0.739	9.456	#####	5.5	#####	3.98	5	1.474	2.736	1.415	0	11.36	6.935	0	0	5.556
Stauroneis phoenicenteron	0	0	0	0	0	0	0	0	0	#####	0	#####	0	0	0	0	0	0	0.947	1.119	0	0	0
Surirella minuta	1.75	0	0	3.234	0	0	0	0	0	#####	0	#####	0	0	0	0	0	0	0	0	0	0	0
Surirella brebissonii	0	0	0	11.94	0	0	0	0	0	#####	0	#####	0	0	0	0	0	0	0	0	0	0	0
Synedra ulna	0	0.691	3.194	0.746	0	0	0	0	4.728	#####	0	#####	0	2.5	0.491	1.493	0	5.198	1.136	5.817	2.941	4.902	20.37

APPENDIX IV

Species list for River Nar, with allocation of sensitivity and indicator values of Coste (1982) and allocation to CEE groups following Coste & Descy (1990).

	IPS Sens.	Ind.	CEE
Achnanthes lanceolata (Brébisson) Grunow	4	1	g 3
Amphora pediculus (Kützing) Grunow	4	1	g 2
Caloneis amphisbaena (Bory) Cleve	2	3	g12
Calo. silicula (Ehrenberg) Cleve	5	3	sg10
Cocconeis placentula Ehrenberg	4	1	sg10
Cymbella caespitosa (Kützing) Brun	4	2	g 3
Cymb. lanceolata (Ehrenberg) Van Heurck	4	2	sg10
Cymb. minuta Hilse ex Rabenhorst	4	2	g 2
Cymb. prostrata (Berkeley) Cleve	4	3	g 3
Cymb. silesiaca Bleisch	5	2	sg 9
Fragilaria capucina Desmazières	4	1	g 2
Fragi. capucina v vaucheriae (Kützing) Lange-Bert.	3	1	g 4
Fragi. construens v binodis (Ehrenberg) Grunow	4	1	sg10
Fragi. leptostauron (Ehrenberg) Hustedt	4	1	sg11
Fragi. pinnata Ehrenberg	4	1	sg11
Fragi. rumpens (Kützing) Carlson	4	1	g 2
Fragi. virescens Ralfs	5	2	sg 3
Frustulia vulgaris (Thwaites) De Toni	4	3	sg10
Gomph. parvulum Kützing	2	1	g 6
Gomph. truncatum Ehrenberg	4	1	sg10
Gyrosigma acuminatum (Kützing) Rabenhorst	4	3	sg10
Hantzschia virgata (Roper) Grunow	1	3	-
Melosira varians C.A.Agardh	4	1	g 4
Meridion circulare (Greville) C.A.Agardh	5	2	g 1
Navicula capitata Ehrenberg	4	1	-
Nav. capitatoradiata Germain	3	2	sg11
Nav. cryptocephala Kützing	4	1	-
Nav. cryptotenella Lange-Bertalot	4	1	sg10
Nav. erifuga Lange-Bertalot	2	3	-
Nav. gregaria Donkin	3	1	sg11
Nav. lanceolata (C.A.Agardh) Kützing	5	2	-
Nav. menisculus Schumann	4	1	sg10
Nav. reinhardtii Grunow	5	3	sg 9
Nav. slesvicensis Grunow	3	3	sg12
Nav. tripunctata (O.F.Müller) Bory	4	2	sg10
Nav. trivialis Lange-Bertalot	2	3	sg12
Neidium dubium (Ehrenberg) Cleve	4	2	-
Nitzschia amphibia Grunow	2	2	sg12
Ni. capitellata Hustedt	1	3	g 8
Ni. dissipata (Kützing) Grunow	4	3	g 2
Ni. dubia W.Smith	2	3	sg12
Ni. heufleriana Grunow	4	1	sg11
Ni. palea (Kützing) W.Smith	1	3	g 8
Ni. recta Hantzsch ex Rabenhorst	3	2	sg10
Ni. sigmoidea (Nitzsch) Ehrenberg	3	2	sg11
Ni. umbonata (Ehrenberg) Lange-Bertalot	1	3	g 8
Pinnularia lundii Hustedt	5	3	-
Rhoicosphenia curvata (Kützing) Grunow	4	1	g 4
Stauroneis phoenicenteron (Nitzsch) Ehrenberg	5	2	-
Surirella brebissonii Krammer & Lange-Bertalot	3	2	g 5
Sur. minuta Brébisson	3	1	g 5
Syn. ulna (Nitzsch) Ehrenberg	3	1	sg11

Abbreviations and codes explained in text.

APPENDIX V

Ranges of physico-chemical parameters in water quality zones (Descy 1984).

Water type	akl. mg/l $CaCO_3$	pH	cond. µS/cm	Cl mg/l	SO_4 mg/l	Ca mg/l	Mg mg/l	Na mg/l	K mg/l
1	0-5	3.4-6.0	47-115	2.8-7.5	1.2-30.0	1.1-7.4	0.7-2.6	2.0-4.8	0.1-1.3
2	6-20	6.0-7.6	63-154	3.7-19.9	2.2-18.4	3.7-12.8	1.7-4.1	1.7-8.8	0.4-2.4
3	21-50	6.4-7.9	95-212	7.4-21.3	5.4-22.4	5.5-23.6	2.4-5.4	0.9-13.9	0.5-3.0
4	51-110	7.1-8.3	189-325	8.9-24.2	7.4-33.1	16.4-55.2	1.8-8.0	4.0-9.0	1.1-2.6
5	130-265	7.5-8.2	370-622	11.5-38.5	21.3-57.2	58.2-105.1	3.6-18.0	2.5-14.1	0.1-9.6

APPENDIX VI

Groups of species characteristic of different types of water, as used by Coste (1990).

Groups G1-G8 are characteristic of clean to polluted waters; subgroups SG1-SG4 are more widely distributed species, broadly representative of clean acidic or alkaline waters, through increasing mineralization to slightly saline waters.

high indicator value

pure waters

G1	G2	G3	G4	G5	G6	G7	G8
AMIN	ALIB	ALAN	FCVA	AMMO	GPAR	AVEN	NGAN
DTCR	AOVA	AROS	MVAR	DITE	NMIN	NACO	NGAT
EPEC	APED	CCAE	NJOU	NACI	NATO	NCOM	NPAL
GANT	CMIN	CPRO	NLAN	NAPI	NIAR	NGOE	NPAD
HARC	DVUL	CSIN	NROM	NIHU	NMLF	NSEM	NZSU
MCIR	FCAP	GMIN	NSOC	NPAE	NMMU	NSMO	NUMB
NSIN	NDIS	GOLI	RABB	SOVA	NSBM	NVEN	

															G1	G2	G3	G4	G5	G6	G7	G8
SG1	AAUS DHME NHAN	ABIO EARC NOBL	ACLE ECUR NPSL	AEXI EEXI NRAD	AFLE ERHO NRHE	APEL FRSA NRHY	APUS FVIR NSPD	AVIT GCLA NSTL	CCES GCLE NTRI	CEHR NACD NTUS	CGRA NCLE PNOB	CSHU NEAF RGIB	CSLE NEAL SLIN	DANC NGPE STAN	SG1	10	9	8	7	6	5	4	3
SG2	AMAR CSTE NACU	ANOR CTGL NCTE	CAFF CYLI NINO	CBAC DOBL NMEN	CCIS ETUR NREC	CCYM FCON NSBH	CELL FCRO NSBL	CHEL FVUL NTPT	CLAN GAFF NVER	CMIC GGRA PGIB	CNAV GNOD PSCA	CPED GOMI PVIR	CPLA GTRU SACU	CSIL GYAC SANG	SG2	9	8	7	6	5	4	3	2
SG3	ACON NCPR NSLE	AEXG NEXI NTRD	ASAX NFIL NTRL	AUGA NGRE NVIR	AUGR NHEU NVRO	CDUB NIAN RLON	CPST NIGF SHAN	FBRE NIGR SIDE	FLEP NIRO SPAR	FPIN NITE SPUL	GANG NKOT SROT	GAUG NLAT STKR	GTER NLIN SULN	MAMB NPEL SUOX	SG3	8	7	6	5	4	3	2	1
SG4	ADEL NCLA NSHR	ASPH NCUS NPYG	BPAX NDUB NRCS	CAMP NHAL NSAL	CATO NIFR NSIG	CCAS NIFT NTEN	CMEN NINT NTRV	CSTR NIPU NTRY	GGLI NMUT PMIC	GSCA NMVE SOVI	NALE NOBT SPAV	NAMC NPHY STAB	NAMP NPRO STTU	NCIN NPUP TBRA	SG4	7	6	5	4	3	2	1	0

low indicator value

increasing tolerance ↓

→ heavily polluted

increasing tolerance

APPENDIX VII

Species list for River Nar, with allocation to tolerance categories according to Lange-Bertalot (1979), Steinberg & Schiefele (1988) and indices of Watanabe (1986, 1988).

	Pollution		Trophy	DAIpo	
	L-B	S&S		1986	1988
Achnanthes lanceolata (Brébisson) Grunow	B	ht		70.9	74.32
Amphora pediculus (Kützing) Grunow	A	s		62.3	75.54
Caloneis amphisbaena (Bory) Cleve					
Calo. silicula (Ehrenberg) Cleve					
Cocconeis placentula Ehrenberg	A		eu	45.3	61.47
Cymbella caespitosa (Kützing) Brun			eu		
Cymb. lanceolata (Ehrenberg) Van Heurck					
Cymb. minuta Hilse ex Rabenhorst	B		o		81.82
Cymb. prostrata (Berkeley) Cleve	A				
Cymb. silesiaca Bleisch	B		eu		83.17
Fragilaria capucina Desmazières	A	s/t?		55.1	57.20
Fragi. capucina v *vaucheriae* (Kützing) Lange-B.	B		eu		75.97
Fragi. construens v *binodis* (Ehrenberg) Grunow	A			28.3	
Fragi. leptostauron (Ehrenberg) Hustedt					
Fragi. pinnata Ehrenberg			eu	53.1	63.62
Fragi. rumpens (Kützing) Carlson					44.55
Fragi. virescens Ralfs				73.9	77.00
Frustulia vulgaris (Thwaites) De Toni	B	s/t		72.2	73.65
Gomph. parvulum Kützing	C	mt		34.8	20.82
Gomph. truncatum Ehrenberg	A				
Gyrosigma acuminatum (Kützing) Rabenhorst	A				
Hantzschia virgata (Roper) Grunow					
Melosira varians C.A.Agardh	B			67.6	74.25
Meridion circulare (Greville) C.A.Agardh					82.50
Navicula capitata Ehrenberg	B	t		66.3	27.93
Nav. capitatoradiata Germain		s		41.6	60.11
Nav. cryptocephala Kützing				62.5	40.52
Nav. cryptotenella Lange-Bertalot		hs			
Nav. erifuga Lange-Bertalot					
Nav. gregaria Donkin	B	t		66.0	50.64
Nav. lanceolata (C.A.Agardh) Kützing		s		67.7	64.25
Nav. menisculus Schumann		t		62.8	66.87
Nav. reinhardtii Grunow					
Nav. slesvicensis Grunow					
Nav. tripunctata (O.F.Müller) Bory	A				73.48
Nav. trivialis Lange-Bertalot					22.84
Neidium dubium (Ehrenberg) Cleve					
Nitzschia amphibia Grunow	B			31.6	21.37
Ni. capitellata Hustedt					
Ni. dissipata (Kützing) Grunow	A		eu		84.61
Ni. dubia W.Smith					
Ni. heufleriana Grunow	A	hs		21.4	10.67
Ni. palea (Kützing) W.Smith	C	ht/mt		26.7	17.71
Ni. recta Hantzsch ex Rabenhorst	A				
Ni. sigmoidea (Nitzsch) Ehrenberg				53.8	
Ni. umbonata (Ehrenberg) Lange-Bertalot	C				44.04
Pinnularia lundii Hustedt					
Rhoicosphenia curvata (Kützing) Grunow	A		eu	45.4	73.34
Stauroneis phoenicenteron (Nitzsch) Ehrenberg	B				
Surirella brebissonii Krammer & Lange-Bertalot		t?			53.41
Sur. minuta Brébisson		t?			
Syn. ulna (Nitzsch) Ehrenberg	C	t/mt		61.5	31.97

Abbreviations and codes explained in text.

Steinberg & Schiefele groups	NRA1	NRA2	NRA3	NRA4	NRA5	NRA6	NRA7	NRA8	NRA9	NRA10	NRA11	NRA12	NRA13	NRA14	NRA15	NRA16	NRA17	NRA18	NRA19	NRA20	NRA21	NRA22	NRA23
oligotraphent	0	0	0	0	0	0	0	0	0	#####	9	#####	13.93	0	0	0	1.651	0	0	0	0	0	0
highly sensitive	8.75	5.53	5.16	1.493	7.371	0	0.237	0	3.546	#####	4	#####	5.224	2.5	2.703	4.478	5.896	12.62	26.52	0	0	1.961	5.556
eutraphent	44.25	57.14	49.14	31.09	5.651	9.091	52.61	2.463	19.62	#####	5.75	#####	3.98	17.25	17.2	5.97	12.03	1.485	36.55	14.32	41.18	48.77	20.37
t+ht+mt+s	37.25	24.65	18.18	48.51	36.36	36.36	21.33	17.98	13	#####	22.5	#####	11.44	21.5	15.97	11.44	50.94	18.56	13.07	17	20.59	11.52	38.89
Schiefele (1987) groups	NRA1	NRA2	NRA3	NRA4	NRA5	NRA6	NRA7	NRA8	NRA9	NRA10	NRA11	NRA12	NRA13	NRA14	NRA15	NRA16	NRA17	NRA18	NRA19	NRA20	NRA21	NRA22	NRA23
sensitive	43.75	27.19	22.6	7.711	7.371	0	36.26	1.478	3.546	#####	13.25	#####	19.15	13.25	10.81	6.219	11.08	14.11	26.52	1.79	38.24	33.33	7.407
less tolerant	18.75	31.11	30.96	58.21	33.17	18.18	21.8	16.5	20.8	#####	31.25	#####	19.9	41.75	17.44	18.66	64.39	15.1	20.08	66	29.41	20.83	11.11
tolerant	10.25	9.908	10.81	7.214	0	27.27	5.924	0	7.092	#####	1.75	#####	0	2.5	1.474	1.99	3.538	5.693	1.894	5.817	5.882	6.127	27.78
Lange-Bertalot groups	NRA1	NRA2	NRA3	NRA4	NRA5	NRA6	NRA7	NRA8	NRA9	NRA10	NRA11	NRA12	NRA13	NRA14	NRA15	NRA16	NRA17	NRA18	NRA19	NRA20	NRA21	NRA22	NRA23
A - sensitive	10.25	9.908	10.81	7.214	0	27.27	5.924	0	7.092	#####	1.75	#####	0	2.5	1.474	1.99	3.538	5.693	1.894	5.817	5.882	6.127	27.78
B - indifferent	13.5	31.34	32.68	57.71	36.36	18.18	14.69	7.635	30.02	#####	22	#####	31.59	35.5	25.06	22.89	12.97	64.11	18.18	22.37	20.59	25.49	18.52
C - tolerant	0.5	1.382	9.337	3.98	0.491	0	0	2.463	0.473	#####	0.75	#####	0.498	3.5	1.966	0	1.887	4.455	0.189	3.132	0	1.716	1.852
Watanabe groups (1986)	NRA1	NRA2	NRA3	NRA4	NRA5	NRA6	NRA7	NRA8	NRA9	NRA10	NRA11	NRA12	NRA13	NRA14	NRA15	NRA16	NRA17	NRA18	NRA19	NRA20	NRA21	NRA22	NRA23
saprophilous	6.75	2.304	0.491	2.239	0	0	0	0	0	#####	0	#####	0	0	0	0.498	0	4.455	0	0	0	0	0
eurysaprobic	48.5	72.35	65.6	59.45	43.98	36.36	72.51	30.05	49.41	#####	38.75	#####	22.14	59.25	54.05	48.26	81.13	77.23	62.31	72.71	58.82	84.56	79.63
saproxenic																							
DIApo (1986)	48.13	26.5	34.15	39.43	56.02	63.64	27.49	69.95	50.59	#####	61.25	#####	77.86	40.75	45.95	51.49	18.87	20.54	37.69	27.29	41.18	15.44	20.37
Watanabe groups (design.1988)	NRA1	NRA2	NRA3	NRA4	NRA5	NRA6	NRA7	NRA8	NRA9	NRA10	NRA11	NRA12	NRA13	NRA14	NRA15	NRA16	NRA17	NRA18	NRA19	NRA20	NRA21	NRA22	NRA23
saprophilous	6.75	2.304	0.491	2.239	0.737	0	0	0	0	#####	0	#####	0	0	0	0.498	0	0	0	0	0	0	0
eurysaprobic	47.75	81.8	81.08	73.38	88.21	18.18	74.88	70.69	86.76	#####	79.75	#####	69.65	91.75	92.87	94.03	78.3	79.95	71.02	94.85	97.06	87.99	79.63
saproxenic	30	0	0	3.731	0	0	0	0	0	#####	9	#####	13.93	3	1.229	0	1.651	0.495	0	0.447	0	0.735	0
DIApo (1986)	48.88	17.05	18.67	25.5	11.43	81.82	25.12	29.31	13.24	#####	20.25	#####	30.35	8.25	7.125	5.721	21.7	20.05	28.98	5.145	2.941	12.01	20.37
DIApo (1988)	61.63	48.85	49.75	50.75	49.63	50	50	50	50	#####	54.5	#####	56.97	51.5	50.61	49.75	50.83	50.25	50	50.22	50	50.37	50
saprophilous (D<29: 1988)	9	2.304	4.914	4.229	1.474	0	0.474	0.739	0	#####	11.25	#####	5.224	0	1.229	3.483	0	0	2.083	11.41	2.941	1.961	1.852
eurysaprobic (D30-74: 1988)	43	65.44	53.81	49	78.62	9.091	62.09	55.42	53.19	#####	68.5	#####	60.95	77	70.76	64.43	76.42	26.98	51.89	74.27	91.18	71.81	70.37
saproxenic (D>75: 1988)	30	14.29	18.67	25.62	3.194	9.091	12.32	13.55	14.89	#####	0	#####	0	8	6.88	14.43	1.887	0.495	6.629	3.579	2.941	2.451	0
DIApo 1986 (1)	69.5	64.98	68.18	71.27	59.21	95.45	68.48	71.55	73.4	#####	54.5	#####	64.3	61.5	63.39	64.3	61.79	86.51	71.97	51.45	51.47	62.13	62.96
DIApo 1988 (2)	60.5	55.99	56.88	60.7	50.86	54.55	55.92	56.4	57.45	#####	44.38	#####	47.39	54	52.83	55.47	50.94	50.25	52.27	46.09	50	50.25	49.07

APPENDIX VIII

Percentages of different species categories for calculation of water quality zones recognised by Lange-Bertalot, Steinberg & Schiefele and for DIApo of Watanabe (1986 and 1988).

APPENDIX IX

Lange-Bertalot's (1979) classification of differentiating taxa

1. most tolerant taxa (can grow in polysaprobic waters) (C)

Amphora veneta Kützing
Gomphonema parvulum (Kützing) Grunow
Navicula accomoda Hustedt
Navicula atomus (Naegeli) Grunow
Navicula cloacina Lange-Bertalot & Bonik
Navicula veneta Kützing
Navicula frugalis Hustedt
Navicula goeppertiana (Bleisch) Grunow
Navicula minima Grunow
Navicula permitis Hustedt
Navicula saprophila Lange-Bertalot & Bonik
Navicula seminulum Grunow
Navicula twymaniana Archibald
Nitzschia communis Rabenhorst
Nitzschia gandersheimiensis Krasske emend. Lange-Bertalot & Simonsen
Nitzschia palea (Kützing) W.Smith
Nitzschia umbonata (Ehrenberg) Lange-Bertalot = *N.thermalis* (Kützing) Grunow
Synedra ulna (Nitzsch) Ehrenberg

2. species which can have high reproduction rates in α-mesosaprobic but not polysaprobic waters (B)

a. *Achnanthes lanceolata* (Brébisson) Grunow
Cymbella ventricosa Kützing
Diatoma elongatum (Lyngbye) C.A.Agardh
Fragilaria vaucheriae (Kützing) Petersen
Melosira varians C.A.Agardh
Navicula avenacea Brébisson ex Grunow
Navicula gregaria Donkin
Navicula halophila (Grunow) Cleve
Navicula phyllepta Kützing
Nitzschia amphibia Grunow
Nitzschia filiformis (W.Smith) Schütt
Nitzschia hungarica Grunow
Nitzschia paleacea Grunow
Nitzschia supralitorea Lange-Bertalot
Surirella ovalis Brébisson
Synedra pulchella Ralfs ex Kützing

b. *Achnanthes hungarica* Grunow
Anomoeoneis sphaerophora (Kützing) Pfitzer
Caloneis amphisbaena (Bory) Cleve
Cymatopleura librile (Ehrenberg) Pantoscek = *C.solea* (Brébisson ex Kützing) W.Smith
Gomphnema pseudoaugur Lange-Bertalot
Navicula cincta (Ehrenberg) Kützing
Navicula cuspidata Kützing
Navicula capitata Ehrenberg
Navicula pupula Kützing
Navicula pygmaea Kützing
Navicula salinarum var. (?) *intermedia* (Grunow) Cleve
Nitzschia acicularis (Kützing) W.Smith
Nitzschia apiculata (Gregory) Grunow
Nitzschia clausii Hantzsch
Nitzschia levidensis W.Smith
Nitzschia microcephala Grunow
Nitzschia sigma (Kützing) W.Smith

Nitzschia tryblionella Hantzsch
Synedra acus Kützing
Synedra parsitica (W.Smith) Hustedt

Ecological position questionable; probably reduced vitality.
Frustulia vulgaris Thwaites De Toni
Gomphonema abbreviatum C.A.Agardh sensu Kützing
Pinnularia microstauron var. *brébissonii* (Kützing) Hustedt
Stauroneis phoenicenteron (Nitzsch) Ehrenberg
Synedra fasciculata (C.A.Agardh) Kützing

2b is more sensitive than 2a.

3. relatively sensitive species - cannot tolerate "critical" pollution (A)

a. *Achnanthes minutissima* Kützing
Amphora ovalis Kützing
Amphora pediculus (Kützing) Grunow
Caloneis bacillum (Grunow) Mereschkowsky
Cocconeis pediculus Ehrenberg
Cocconeis placentula Ehrenberg
Cymbella helvetica Kützing
Cymbella prostrata (Berkeley) Cleve
Diatoma vulgare Bory
Gomphoneis curta (Hustedt) Lange-Bertalot
Gomphoneis olivacea (Hornemann) Dawson
Navicula exilis Kützing
Navicula tripunctata (O.F.Müller) Bory
Navicula gracilis var. *schizonemoides* Van Heurck
Nitzschia dissipata (Kützing) Grunow
Nitzschia frustulum Kützing emend. Lange-Bertalot & Simonsen
Nitzschia romana Grunow emend. Lange-Bertalot & Simonsen
Rhoicosphenia curvata (Kützing) Grunow

b. *Achnanthes clevei* Grunow
Amphipleura pellucida Kützing
Cymbella affinis Kützing
Cymbella cistula (Ehrenberg) Kirchner
Cymbella sinuata Gregory
Cymbella tumida (Brébisson) Van Heurck
Denticula tenuis Kützing
Diploneis oculata (Brébisson) Cleve
Fragilaria capucina Desmazière
Fragilaria construens (Ehrenberg) Grunow
Frustulia rhomboides (Ehrenberg) De Toni
Gomphonema angustatum (Kützing) Rabenhorst
Gomphonema augur Ehrenberg
Gomphonema truncatum Ehrenberg
Gyrosigma acuminatum (Kützing) Rabenhorst
Gyrosigma attenuatum (Kützing) Rabenhorst
Gyrosigma nodiferum (Grunow) G.West
Navicula mutica Kützing sensu strictu
Navicula rhynchocephala Kützing
Nitzschia denticula Grunow
Nitzschia heufleriana Grunow
Nitzschia linearis W.Smith
Nitzschia recta Hantzsch
Nitzschia sigmoidea (Ehrenberg) W.Smith
Nitzschia sinuata (W.Smith) Grunow
Nitzschia sociabilis Hustedt
Nitzschia sublinearis Hustedt

APPENDIX X

Water quality categories as in Schiefele (1987).

Water quality		Contribution of differentiating groups in %
I	oligosaprobic, unpolluted to very slightly polluted; $BOD_5 < 1$ 95%<O_2 saturation<105%	("ü-"s>10 (50≤s<90) (wt + t<40?)
I - II	oligo- to ß-mesosaprobic, slightly polluted $BOD_5 < 2$ O_2 saturation deficit <15%	("ü-"s>10 (50≤s<90) (wt + t<40?)
II	ß-mesosaprobic, moderately polluted $BOD_5 < 4$ (6) O_2 saturation deficit <30%	("ü-"s≤10) s≥50) wt = t <50
II-III	ß-α-mesosaprobic, critically polluted $BOD_5 < 7$ (10) O_2 saturation deficit <50%	10<s<50 50≤wt + t <90
III	α-mesosaprobic, strongly polluted $BOD_5 < 13$ O_2 saturation deficit <75%	s≤10 wt≥50 t<50
III-IV	α-meso-polysaprobic, very strongly polluted $BOD_5 < 22$ O_2 saturation deficit <90%	10<s + wt<50 t≥50
IV	polysaprobic extremely polluted $BOD_5 > 22$ (15) O_2 saturation deficit >90%	s + wt≤10 t≥90

"ü-"s = "over" sensitive; s = sensitive; wt = less tolerant; t = most tolerant

[illegible]

[illegible]

[illegible] (Grunow) [illegible]

[illegible]

C.cesatii (Rabenhorst) Grunow
C.delicatula Kützing
C.microcephala Grunow
C.minuta Hilse
Diatoma tenue Agardh (fine areolated form)
Diploneis elliptica (Kützing) Cleve

Eutraphent (eu)
(Development of these species is enhanced under nutrient rich conditions.)
Achnanthes conspicua Meyer
Cocconeis placentula Ehrenberg
Gomphonema olivaceum (Hornemann) Brébisson
Cymbella caespitosa (Kützing) Brun
C.silesiaca Bleisch
Diatoma tenue Agardh (coarse areolated form)
D.vulgare Bory
Fragilaria pinnata Ehrenberg
F.vaucheriae (Kützing) Lange-Bertalot
Nitzschia dissipata (Kützing) Grunow
Rhoicosphenia abbreviata (Agardh) Lange-Bertalot

Classification scheme for assessing trophy and pollution

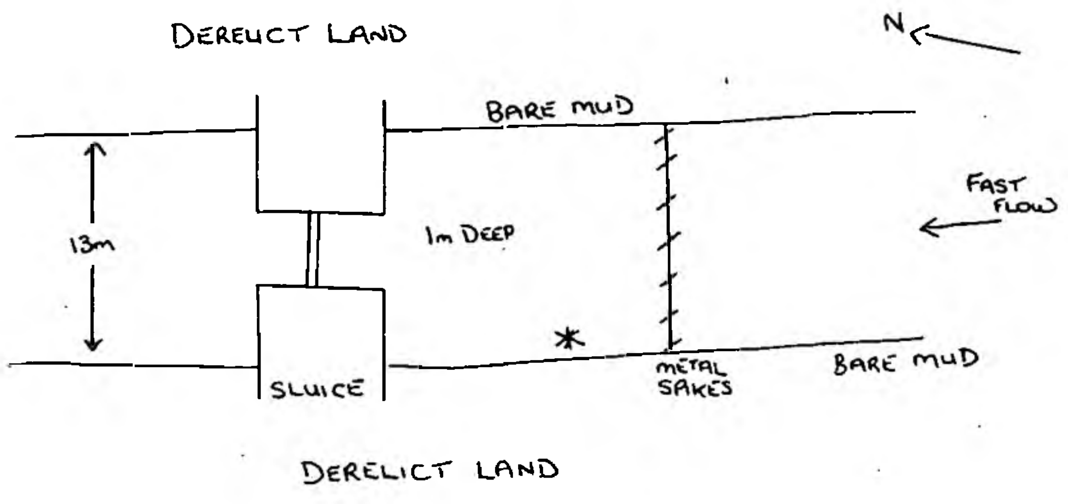
Trophy I:	$o \geq 50\%$,	$hs \geq 10\%$,	$eu < 10\%$,	$t + ht + mt + s < 10\%$
Trophy II:	$o \geq 10\%$,	$hs \geq 10\%$,	$eu < 50\%$,	$t + ht + mt + s < 10\%$
Trophy III:	$o < 10\%$,	$hs \geq 10\%$,	$eu \geq 50\%$,	$t + ht + mt + s < 10\%$
Trophy IV:	$o < 10\%$,	$hs < 10\%$,	$eu \geq 50\%$	
Pollution 1:	$o + hs < 10\%$,		$eu < 50\%$,	$t + ht + mt + s \geq 10\%$
Pollution 2:	$o + hs < 10\%$,		$eu < 50\%$,	$t + ht + mt + s \geq 50\%$
Pollution 3:	$o + hs < 10\%$,		$eu < 10\%$,	$t + ht + mt + s \geq 50\%$

APPENDIX XII

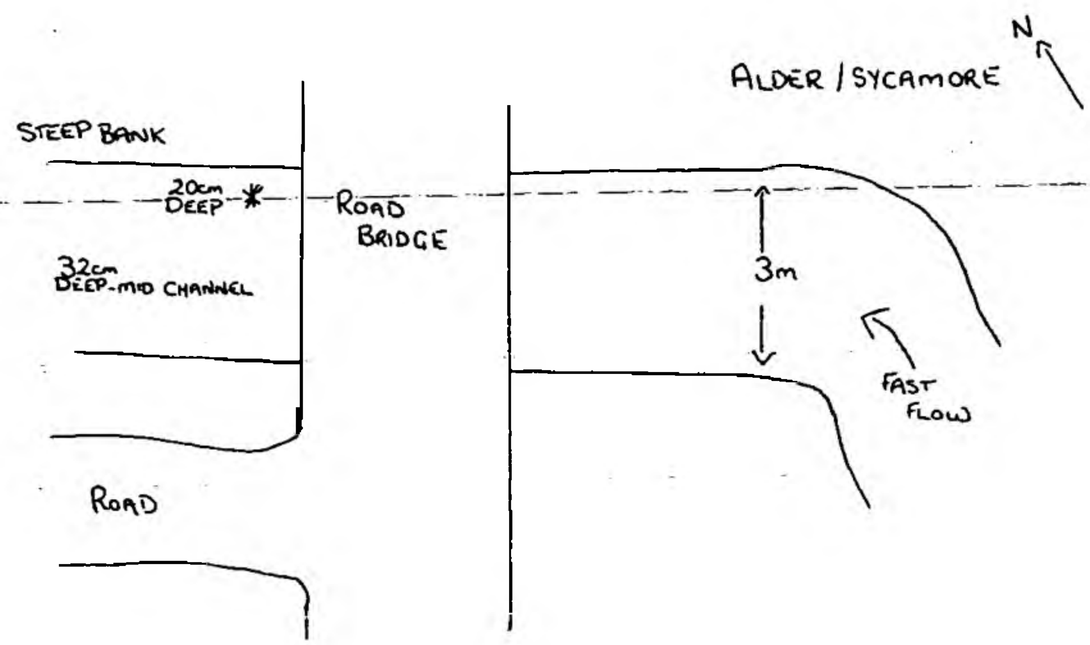
Sketch maps of sites

Asterisks show location of sample

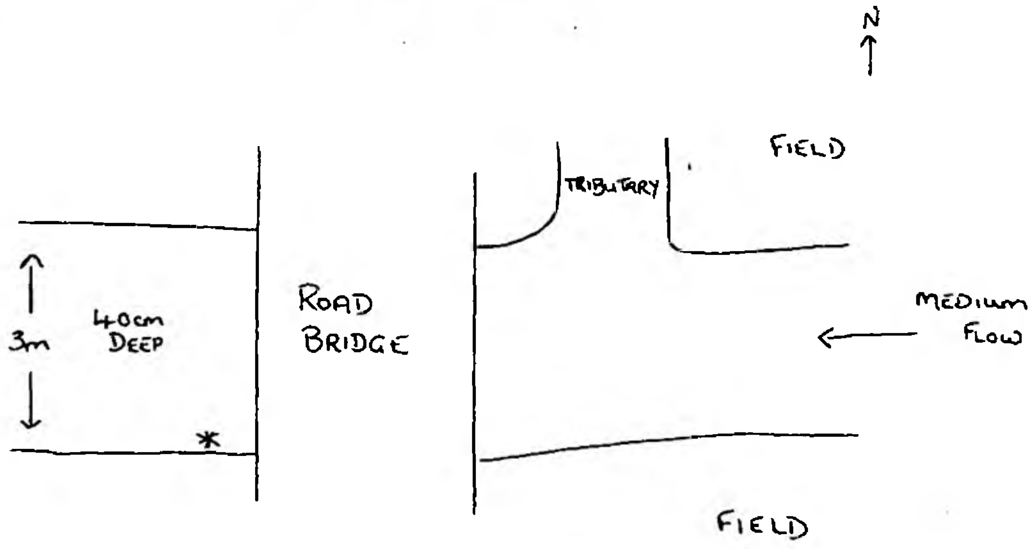
SITE 1 - KING'S LYNN TF622183



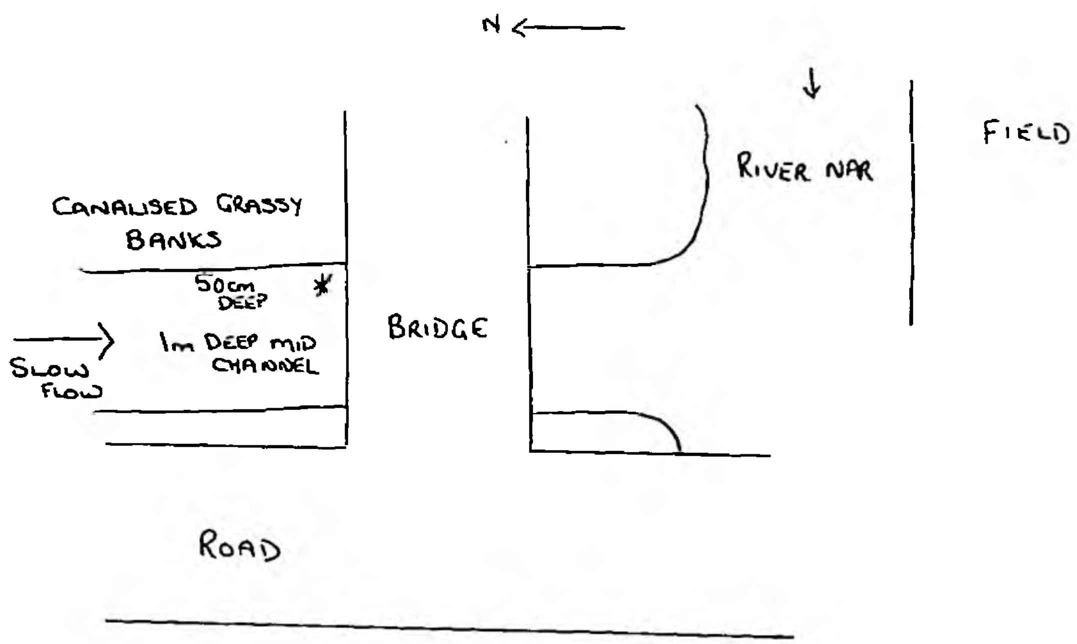
SITE 2 - SETCHEY BRIDGE TF636134



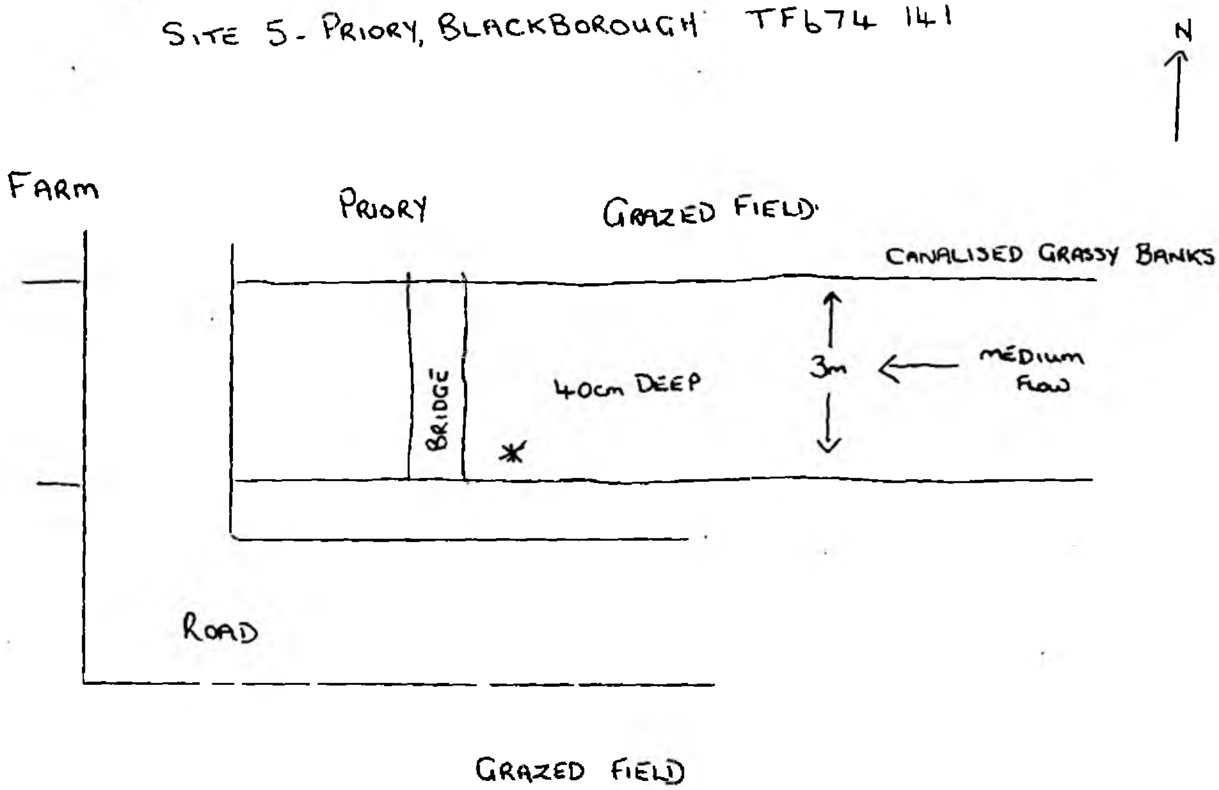
SITE 3 - HIGH BRIDGE, BLACKBOROUGH (NAR) TF669136



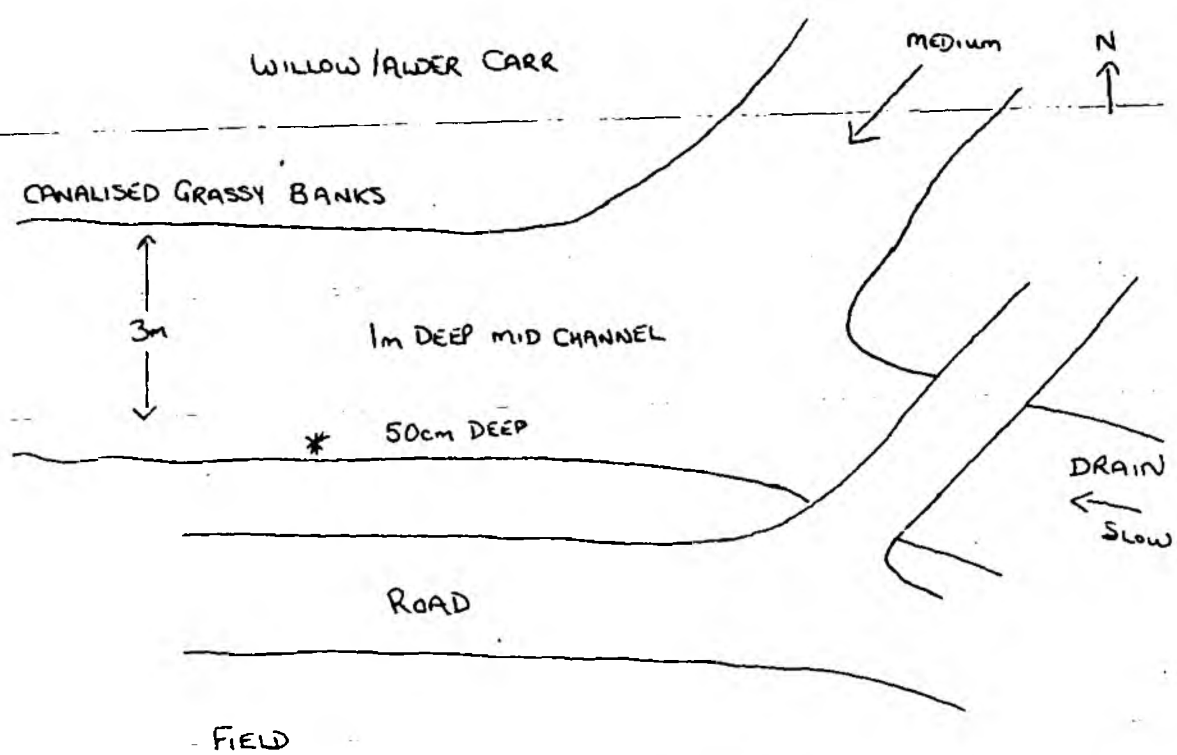
SITE 4 - HIGH BRIDGE, BLACKBOROUGH (TRIB) TF671136



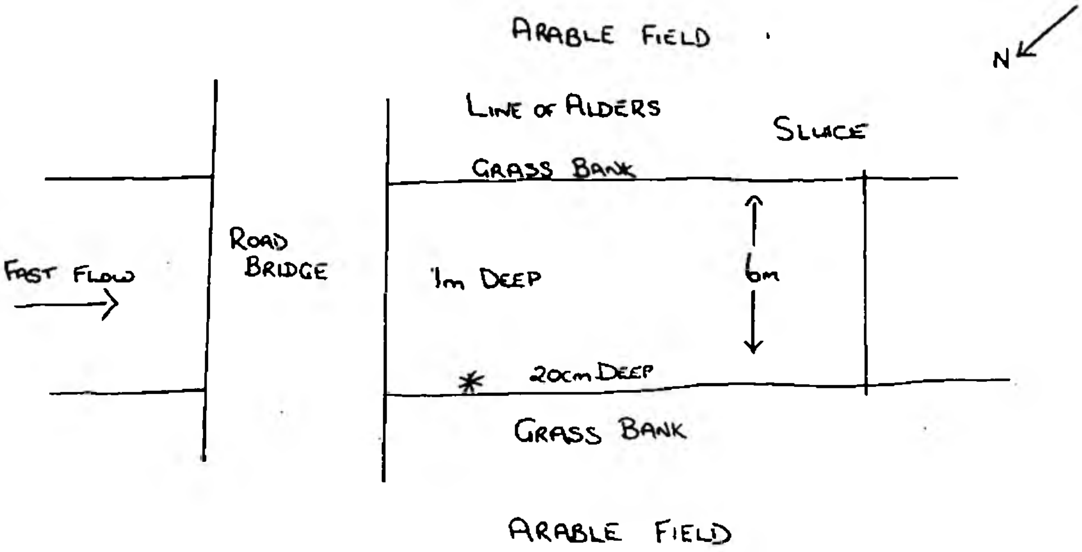
SITE 5 - PRIORY, BLACKBOROUGH TF674 141



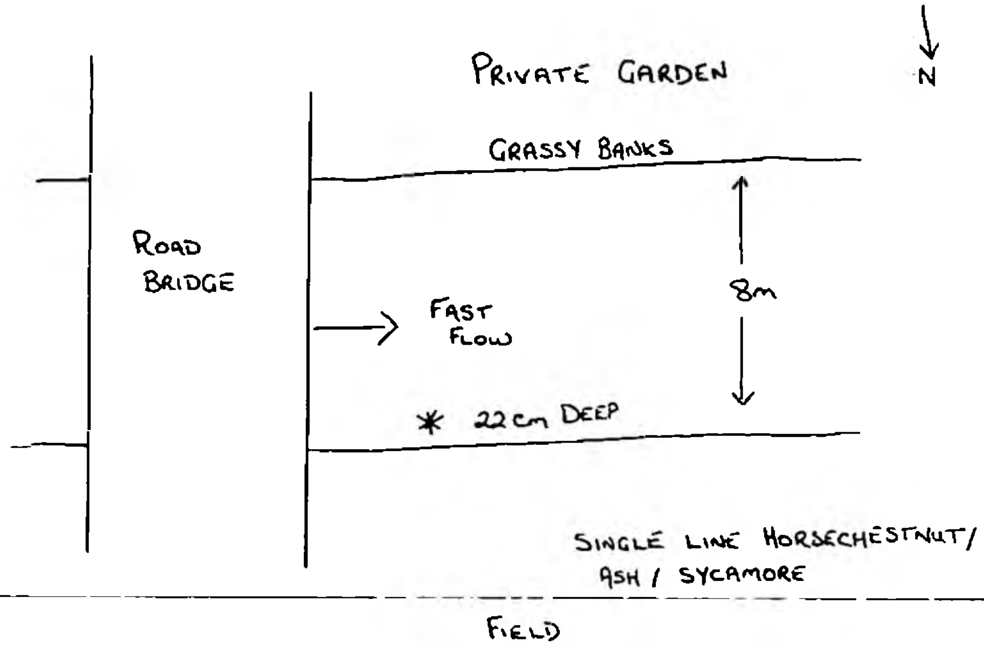
SITE 6 - MIDDLETON COMMON, BLACKBOROUGH TF679 141



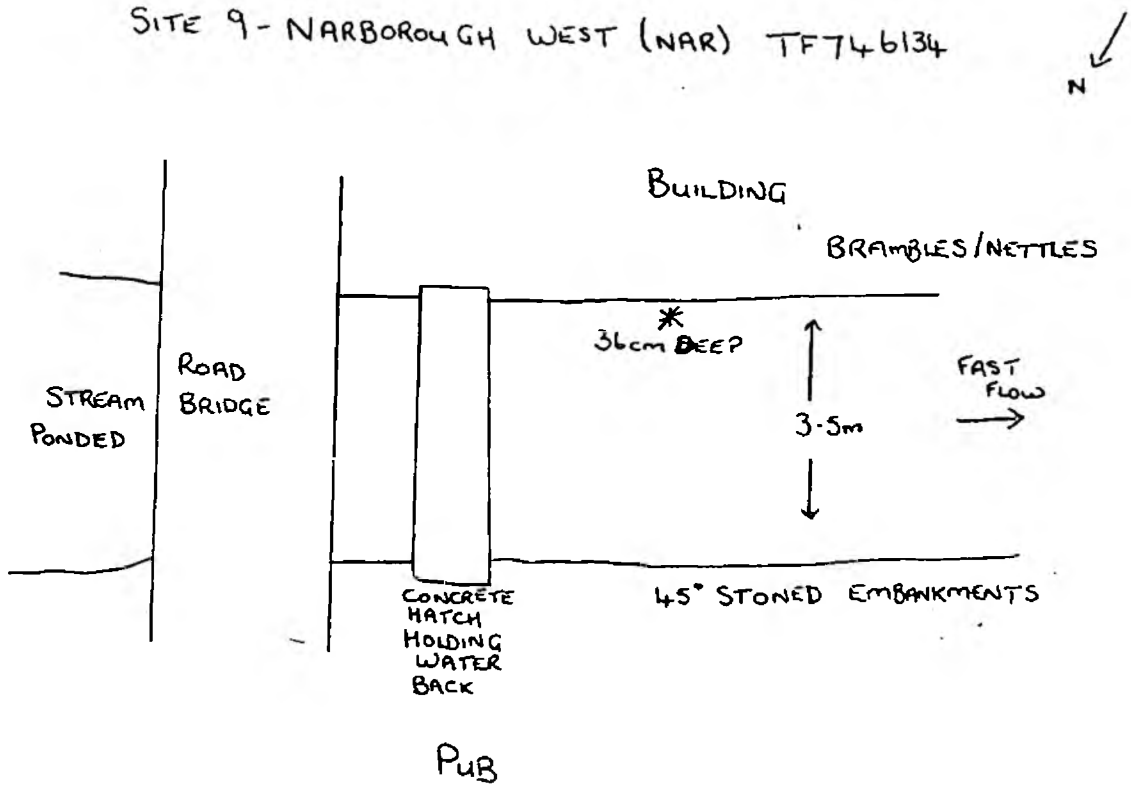
SITE 7 - ASHWOOD LODGE TF 725 121



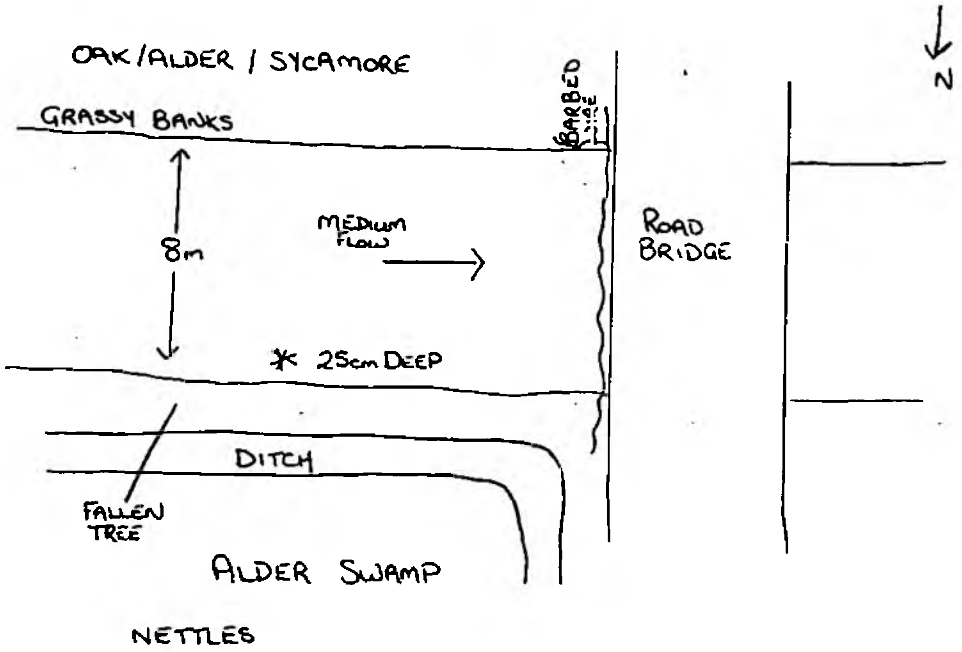
SITE 8 - NARBOROUGH WEST (TRIB) TF 747 133



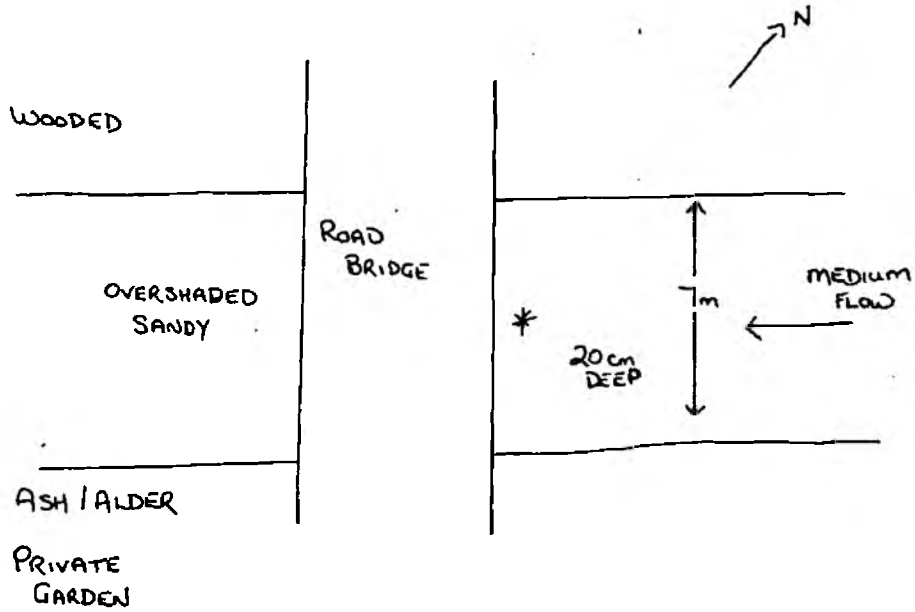
SITE 9 - NARBOROUGH WEST (NAR) TF746134



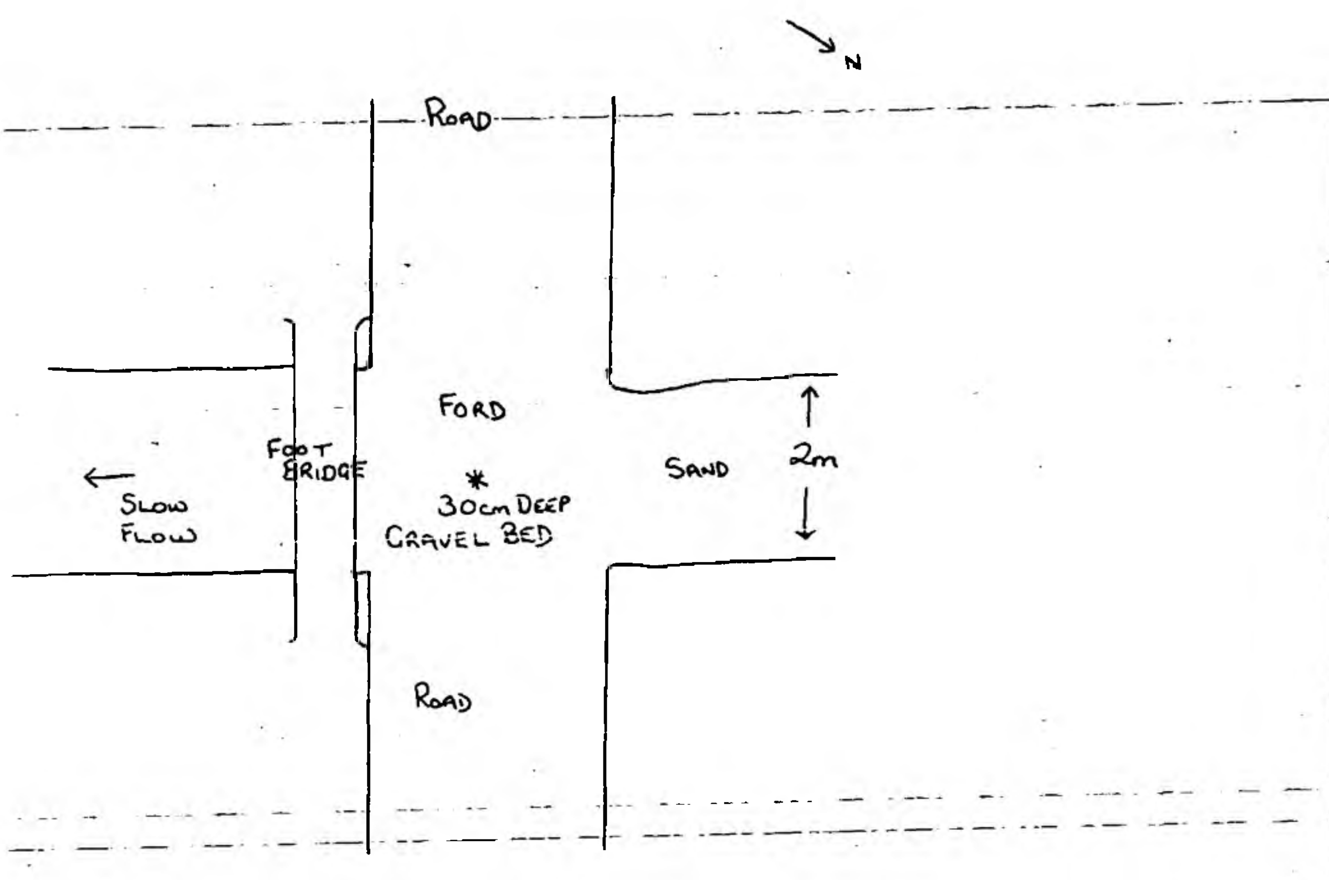
SITE 11 - BRADMOOR PLANTATION TF 765144



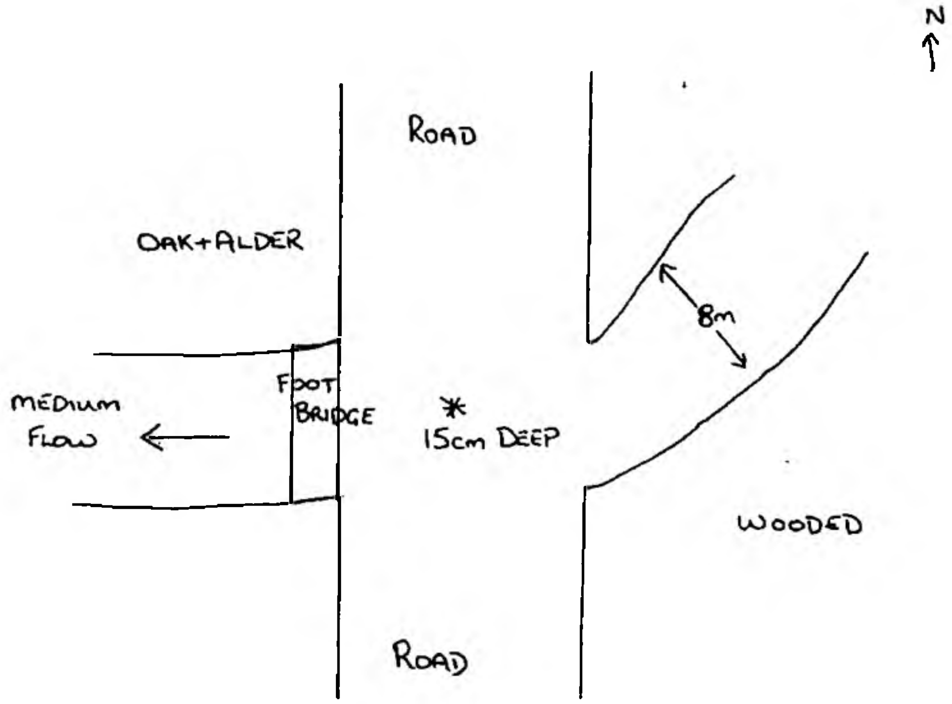
SITE 13 - WEST ACRE, SOUTH TF779 148



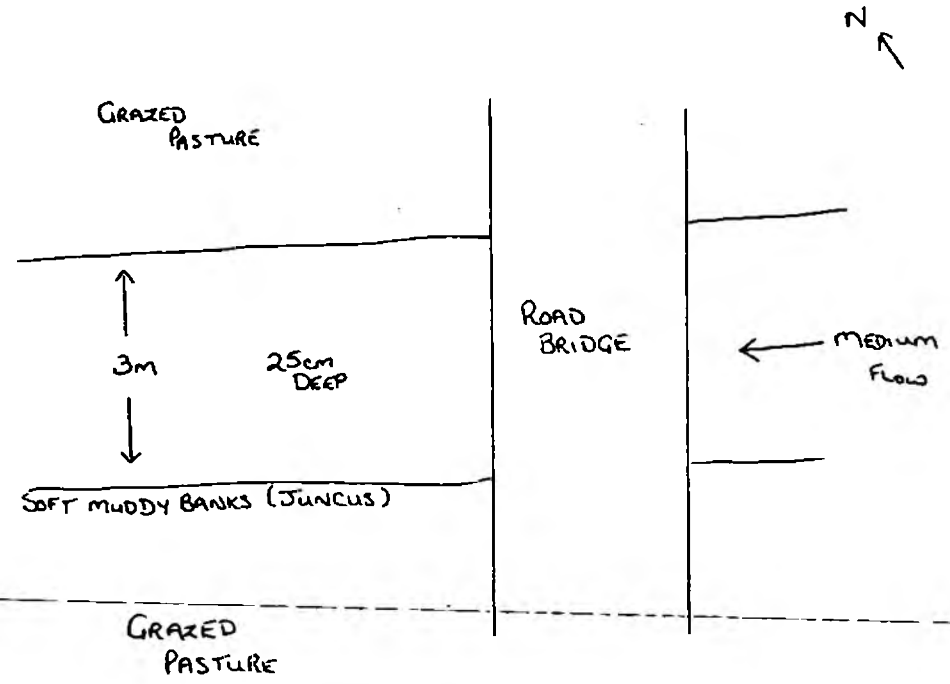
SITE 14 - MILL HOUSE FORD, WEST ACRE TF788152



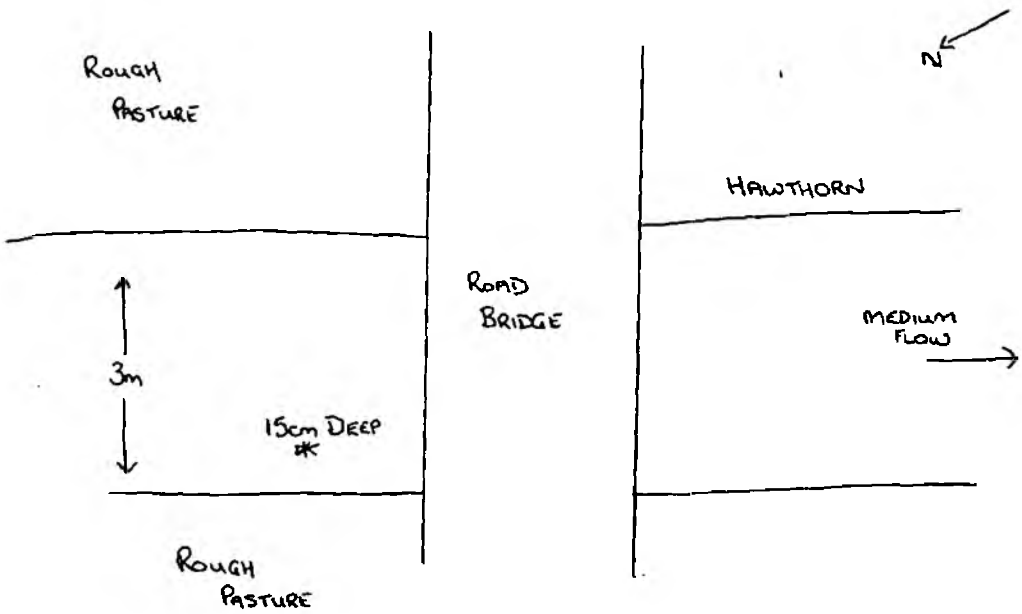
Site 15 - Peddar's Way Ford, Castle Acre TF816 145



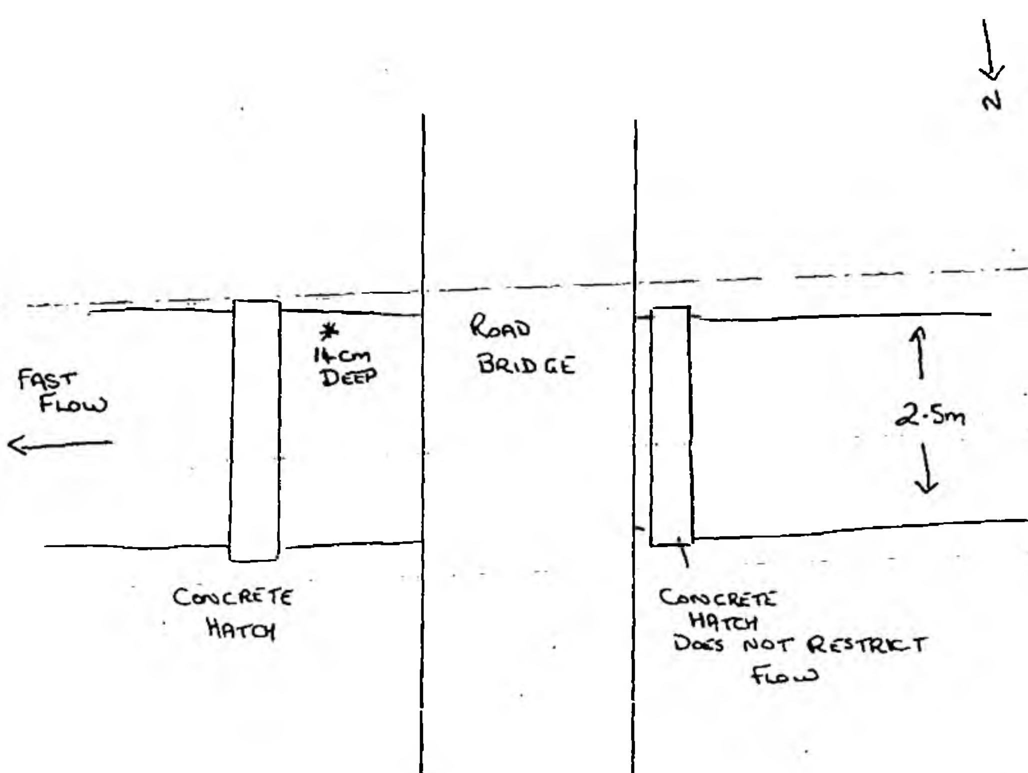
Site 16 - Castle Acre South (Nar) TF 818 147



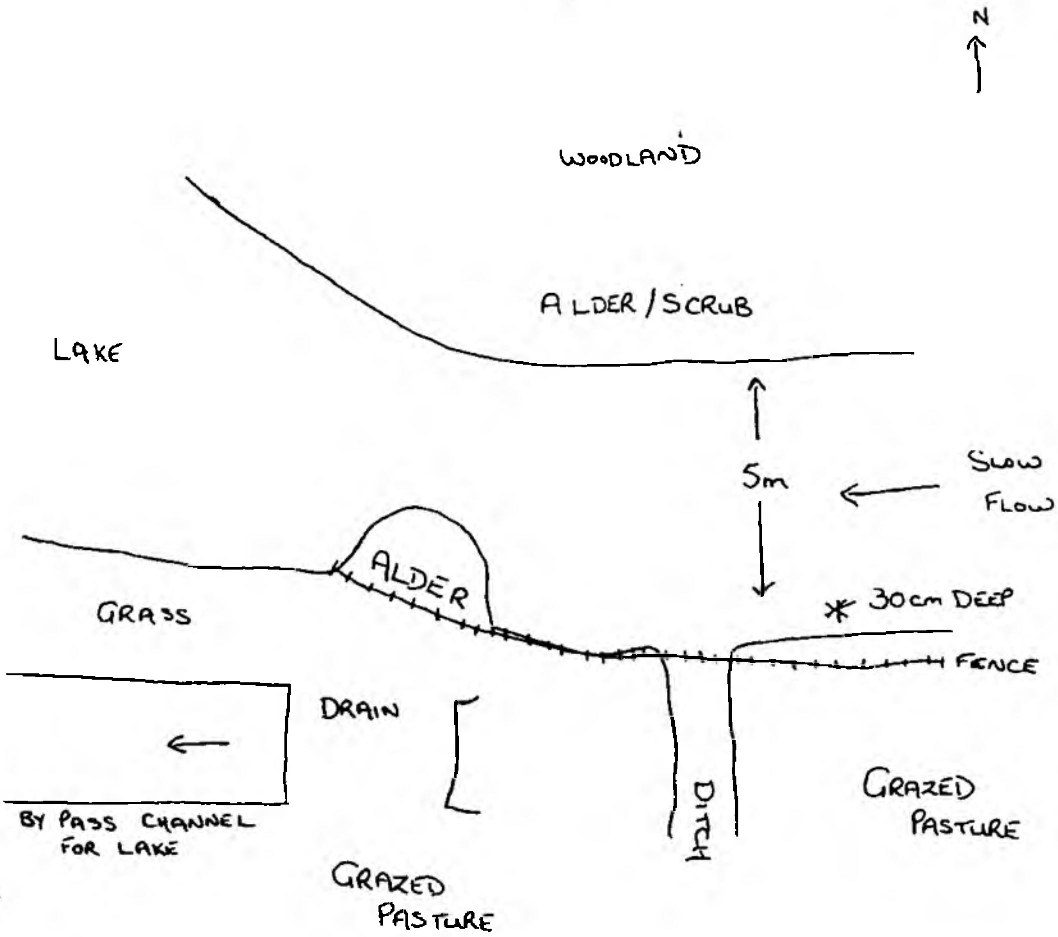
SITE 17 - CHURCH FARM - NEWTON TF827 154



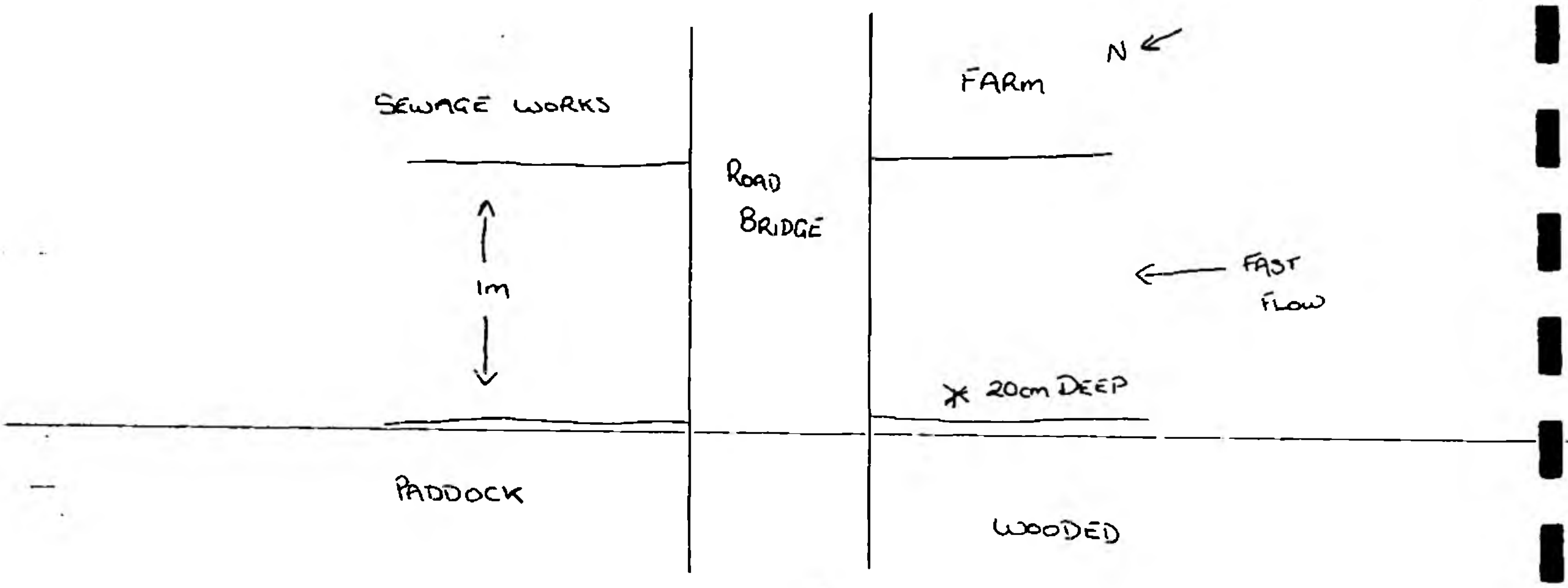
SITE 18 - A1065 Nr. WEST LEXHAM TF838170



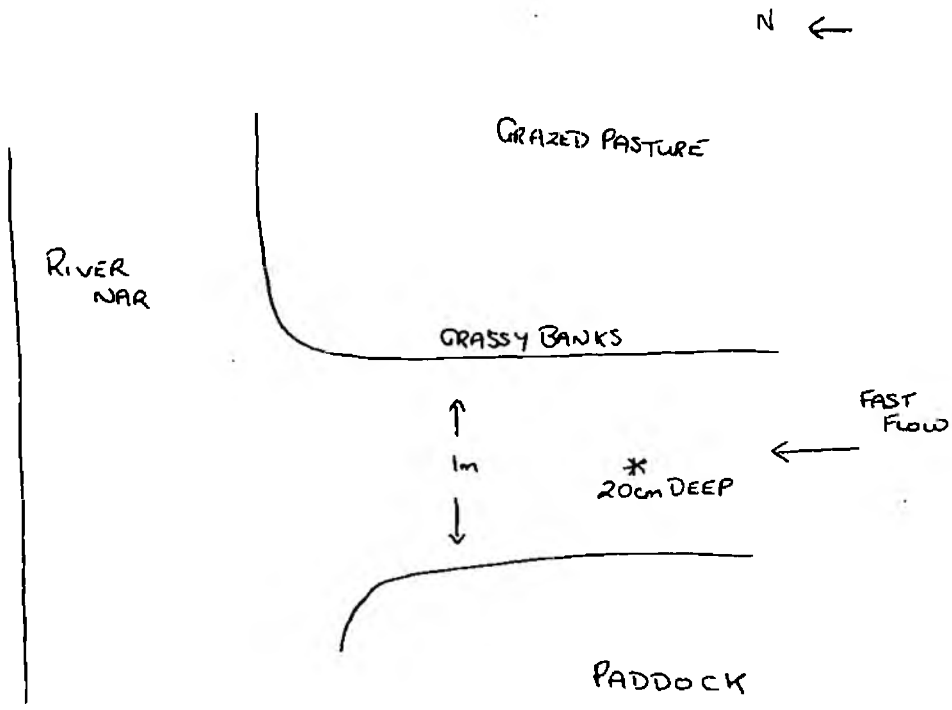
SITE 19 - LEXHAM HALL (NAR) TF 870 168



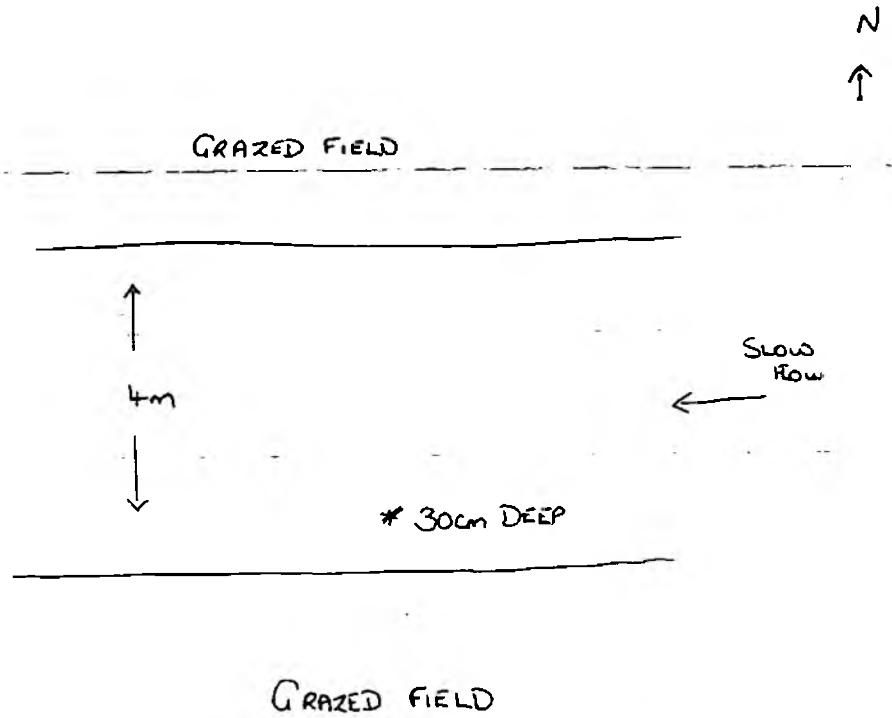
SITE 20 - BRIDGE FARM, LITCHAM TF892 172



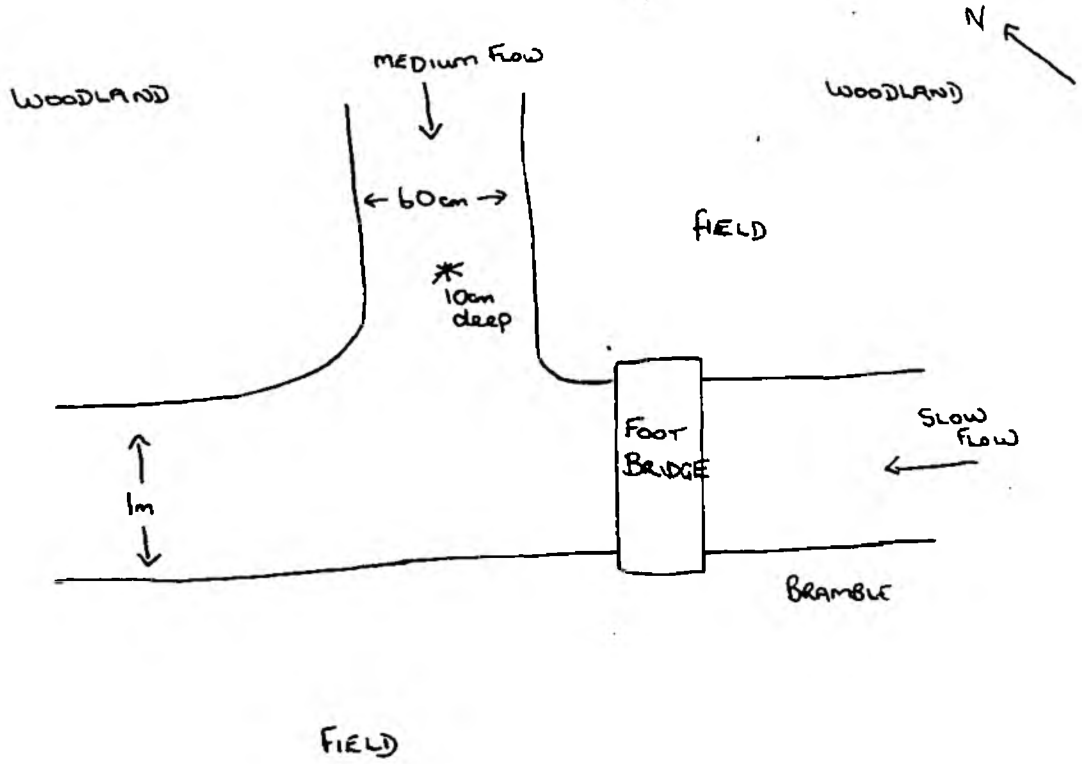
SITE 21 - BELOW LITCHAM SEWAGE WORKS. TF892175



SITE 22 - DRURY SQUARE, LITCHAM TF 893 176



SITE 23 - THE WARREN, LITCHAM TF 903 179



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16 June 1994

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For the Attention of Mr T Clough

Dear Sir

MSC PROJECT PLACEMENT SEVERN TRENT NRA - River Nar Eutrophication Studies - Diatoms

Thank you for the loan of the draft report on the River Nar Eutrophication Studies utilising diatoms. It has provided essential background information on existing methodologies for diatom analysis which will help to form the basis of my project.

Thank you for your time.

Yours faithfully

Innes Urbanski

Innes Urbanski

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