NRA

National Rivers Authority

FERRIC DOSING OF GRAFHAM WATER

REVIEW OF ITS IMPACT ON BENTHIC INVERTEBRATE

1990-1993

Anglian Region

FERRIC DOSING OF GRAFHAM WATER

A REVIEW OF ITS IMPACT ON BENTHIC INVERTEBRATES

1990-1993

BIOLOGY LABORATORY
CENTRAL AREA
NRA, ANGLIAN REGION

CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 INTRODUCTION

1.1 Eutrophication Control

Following the Incidence of severe blooms of blue-green algae in 1989 and 1990 a major phosphate reduction programme was initiated by Anglian Water Services.

Between June 1990 and August 1992 ferric sulphate dosing of Grafham Water was carried out by Anglian Water Services as part of a strategy to lower phosphate levels and thereby reduce the incidence of blue-green algal blooms.

In 1990 dosing was carried out by a combination of methods - discharge from the draw-off (valve) tower, discharge from the aeration (inlet) tower, and from a barge. In 1991 dosing was almost entirely from the aeration (inlet) tower and in 1992 dosing took place only from this source.

The ferric sulphate was discharged as an 11% solution as iron and between June 1990 and August 1992 substantial quantities were used. Up to 1,000 tonnes of ferric sulphate entered the reservoir weekly during 1991 and between May and August 1992 over 800 tonnes were discharged each week.

By the end of August 1992 a total of 30,619 tonnes* of ferric sulphate had been added to the reservoir. Since August 1992 no dosing has been reported by Anglian Water Services. The National Rivers Authority carried out biological monitoring of Grafham Water over this period and for a year after to assess the effect of the dosing programme on the benthic invertebrate communities of the reservoir. Reports were produced for the years 1990, 1991 and 1992. This report describes the results of benthic invertebrate monitoring and sediment iron analyses carried out in 1993 and reviews previous work.

1.2 Grafham Water

The reservoir was formed by damming and flooding the shallow valley of Diddington Brook. It is sited on a continuous mantle of grey Oxford clay covered by chalky boulder clay. Construction began in November 1962 and was completed by early 1966 when it first reached maximum working level.

1.3 Gaynes Cove

The report also describes the results of a specific study of Gaynes Cove, Grafham Water. This investigation included sites within the main reservoir

* Anglian Water Service's figure

and may have implications for the interpretation of data from the Grafham monitoring programme and for any future monitoring strategy.

Grafham Water is an irregular oval in shape with a surface area of 6.35 km^2, a maximum depth of 21 m and a capacity of 59,000 ML. Water is abstracted from the River Great Ouse near Offord, approximately 5 km upstream of Huntingdon.

As in any lake or standing water certain physical and chemical features can determine or influence its ecology and productivity. These include geographical location, latitude, lake size and depth, and the levels of nutrients, particularly phosphorus and nitrogen. Grafham Water can be regarded as a eutrophic lake, fed by abstraction from the nutrient rich River Great Ouse and discharging via the treatment works and to Diddington Brook. Its location, shallowness and surface area enable wind action to maintain a well mixed water column and prevent stratification for most of the year.

It differs in one major respect from lakes though in that the water level in the reservoir can fluctuate greatly. In the past this has led to a loss of marginal vegetation with consequent effects on water nutrient levels, invertebrate diversity and numbers, fish production, and the populations of piscivorous and herbivorous birds.

This project is concerned primarily with the profundal benthos in Grafham Water, a region which is itself subject to a variety of specific influencing factors. These include sediment organic content, river inputs, depth of overlying water, oxygen saturation of the water/sediment interface, and the physicochemical properties of both water and sediment such as pH and the concentrations of certain elements.

2 METHODS

2.1 Sampling Strategy

2.1.1 1990 Survey

Dosing commenced in June with ferric sulphate being discharged from the valve tower, aeration tower and from a barge. To reflect this dosing regime sites were positioned near each tower and also in the main reservoir basin (Figure 1a). Benthic grab samples were taken monthly between July and October.

2.1.2 1991 Survey

Since dosing took place mainly via the aeration tower during this year additional sites were located around this tower (Figure 1b).

Benthic grab samples were taken monthly between May and November.

The monitoring programme in 1990 and 1991 involved an arrangement between the National Rivers Authority and Anglian Water Services whereby invertebrate sampling would be undertaken by the NRA and dissolved iron analysis carried out by Anglian Water from samples taken at two sites.

It was recognised that the 1990 and 1991 surveys represented a 'minimum necessary' approach as staff and resources were limited. It was recommended that monitoring should be extended, covering a greater area of reservoir, using transects, and sampling throughout a year. It was also decided to analyse complementary sediment samples for total iron levels in order to investigate a possible correlation between sediment iron and benthic invertebrate populations found.

2.1.3 1992 and 1993 Surveys

The reservoir was surveyed from August to December 1992 using a grid and general survey approach, sampled alternate months. The grid system of sites centred around the aeration (inlet) tower to give a detailed assessment of the area of likeliest ferric contamination. Sites were also selected to give a general assessment across the whole reservoir (Figure 1c).

In January 1993 the reservoir was surveyed using the grid system and one reference point (site 8) near the valve tower. Since February 1993 an additional site near Savages Creek (Site F) was included and all the sites sampled bimonthly (Figure 1d).

2.2 Sampling Methods

2.2.1 1990 Survey

Duplicate Ekman grabs (0.0225 m^2 surface area) were taken at each of the eight sites (Figure 1a). Samples were returned to the laboratory, sieved (600 μm mesh size), preserved in formalin and sorted by eye in white trays. Results are expressed as numbers per square metre.

2.2.2 1991 Survey

Benthic invertebrates were collected by sampling the substrata with an Ekman grab sampler of 0.0225 m^2 surface area at each of the 11 sites (Figure 1b). Samples were returned to the laboratory, sieved (355 μm mesh size), preserved in formalin and sorted by eye in white trays. Between May and September 2 replicates were taken at sites 2, 3, 4, 5, 6, 7, 8 and 9. In October and November 3 replicates were taken at sites 2, 5, 6, 7, 8, 9, 14, 15 and 16. Results are expressed as numbers per square metre.

2.2.3 1992 and 1993 Surveys

Sites sampled between September 1992 and February 1993 are shown in Figure 1c and sites sampled in the remainder of 1993 are shown in Figure 1d. Benthic invertebrate samples were taken using a modified Ekman grab of 0.0225 m^2 surface area. Duplicate samples were taken at each site. A small sediment core was removed from the surface (top 2 cm) of the sample whilst it remained in the grab using a small plastic tube of approximately 1 cm diameter. This core was analysed for total iron, the results being expressed as mg/g dry weight (total iron). The Ekman grab samples were returned to the laboratory where, after sieving (355 μm mesh size) to remove excess mud, they were sorted live under a binocular microscope at x10 magnification. In cases where the number of individuals of a particular taxa was very high, the sorting method was altered. The sample was thoroughly sieved as normal and then divided evenly into as many petri-dishes as necessary for easy sorting. Invertebrates from all taxa were removed and counted from a proportion of the total sample until 500 individuals of the abundant taxa had been extracted. An estimate of the total number of individuals of each taxa present in the whole sample was then calculated and recorded. Finally, the remainder of the sample was examined to ensure that any other taxa present was accounted for.

Samples that contained an excessive amount of detrital matter were sieved as normal and then transferred to a white tray with equal sub-divisions. It was evenly distributed across the bottom of the tray and a proportion removed, divided amongst a number of petri-dishes and sorted as normal under a binocular dissecting microscope. An estimate of the total number of individuals in each taxa present was calculated and recorded for the whole sample.

The invertebrates were preserved in 70% alcohol and the results expressed as numbers per square metre.

Departures from above method:-

- samples taken in August 1992 were preserved in formalin and had deteriorated in quality by the time they were sorted. These results have not been included in this report.

- In February 1993 limited staff resources only permitted one sample from each site to be sorted.

- In February, March and July 1993 two sediment cores were analysed for total iron at each site.

- In October 1993 two sediment cores were analysed for total iron from each grab sample at depths of 2 and 5 cm from the sediment surface.

- Samples taken in May 1993 and half of the samples taken in July 1993 were sorted in their entirety ie. they were not sub-sampled prior to sorting.

- In October 1993, due to the coarse nature of the sediment at site 6, only partial grab samples were obtained.

3 RESULTS

3.1 Sediment Iron

A total of 237 samples were analysed for total iron (dry weight) during the 1992/93 survey period. The results are shown in Tables 1 and 2 and summarised in Figures 2-6.

The maximum sediment iron level recorded in this period was 396 mg/g dry weight (total iron), whilst the minimum was 19.8 mg/g dry weight.

Mean sediment iron levels ranged from 21-396 mg/g dry weight (total iron). Figures 2 and 3 both show that samples from only two sites (5 and 6) had consistently high sediment iron levels (>90 mg/g dry weight). In samples taken on the 9 September 1992 site 6 had a sediment iron level of less than 50 mg/g dry weight and sites 3 and D had a sediment iron level in excess of 250 mg/g dry weight. It is also noteworthy that iron levels at site 6 have decreased since a peak in October 1992 and that iron levels at site 5 have shown a steady decline over the survey period and were below 90 mg/g dry weight in October 1993. Figures 4-6 show the distribution of iron in the sediments for the months September 1992, July 1993 and October 1993. There appears to be an area of elevated sediment iron (>90 mg/g dry weight) to the south-east of the aeration tower at sites 5 and 6. By October 1993 the area affected by high iron contamination had declined markedly in extent and was restricted to site 6.

3.2 Benthic Invertebrates

The abundance and diversity of benthic invertebrates in Grafham Water between 1990 and 1993 is shown in Tables 3.1 - 3.20 and Tables 4.1 - 4.4.

3.2.1 1990 Survey

Eleven taxa were recorded between July and October 1990 with samples dominated by Oligochaeta, Chironomidae, and, to a lesser extent, Sphaeriidae. The number of taxa found at individual sites ranged from 2 to 6 with generally more taxa being recorded at sites near the valve tower and towards the centre of the reservoir than at sites near the aeration tower. The number of taxa rose steadily between July and September and then rapidly declined in October.

3.2.2 1991 Survey

A reduced faunal diversity was recorded in Grafham Water during 1991 with 9 taxa present in samples taken between May and November. The dominant taxa were Oligechaeta and Chironomidae with Sphaeriidae notably less common than in 1990. Individual sites had a taxa range between 1 and 5 with little overall difference in mean number of taxa between sites near the aeration tower, the valve tower and the main reservoir.

3.2.3 1992 and 1993 Survey

A total of 26 taxa were recorded during the survey period with samples being dominated by Oligochaeta, Chironomidae, Sphaeriidae, Ostracoda, Nematoda and Hydracarina. The maximum number of taxa recorded at any one site was 16 and the lowest was 7. Sites 5 and 6 recorded 10 and 16 taxa respectively in this context.

4 DISCUSSION

4.1 Sediment Analysis

Following the cessation of dosing in August 1992 it might have been expected that settled floc in affected areas would tend to dissipate away from the aeration tower (dosed water inlet) resulting in the area of high sediment iron levels decreasing. Since no discernable layer of ferric floc was present in samples and levels of sediment iron have generally declined in the affected area over the survey period (September 1992 - October 1993) it seems this expected dissipation of floc has occurred.

The extent and rate of the dissipation appears to have been affected by some ferric floc becoming incorporated into the sediment.

During dosing from the aeration tower the distribution of ferric floc would have been determined by the alignment of the water inlet jet and the depth contours of the reservoir. Of the four water inlet gates within the aeration tower only one has been in continuous use and this is orientated to the south-east. A depth contour chart of Grafham Water (Figure 7), and previous depth measurements taken by Central Area staff, reveals a shallow trench extending in a south-easterly direction from the aeration tower. It is possible that as the dosed water entered the main reservoir its velocity would have been rapidly reduced leading to the deposition and subsequent accumulation of ferric floc in this trench. Any floc not deposited here would have continued into the main body of the reservoir to settle over a far wider area depending on the size of the floc particles.

The input of non-dosed water via the aeration tower since September 1992 may have removed some of the surface iron rich sediment or may have deposited a layer of iron-free silt over the affected area, depending on the velocity of the jetted water. Both would have resulted in the observed decline in sediment iron levels, particularly at site 5. It is possible that both processes could be occurring to a varying degree at sites 5 and 6. The coarser sediments at site 6 would suggest that the jetted water so close to the tower is of a sufficient velocity to sort sediment particles by size. The deposition of natural sediments could be as much as a centimetre each year which would certainly influence any long-term effects of sediment ferric contamination.

Account also needs to be taken of the likelihood that the distribution of ferric floc was never uniform due to the uneven profile of the reservoir bed resulting in patches of high and low concentrations in close proximity.

4.2 Benthic Invertebrates

4.2.1 General

Great care is required in the interpretation of data obtained from the 1990 and 1991 surveys because:

1) Paucity of sediment iron data and precise details of the dosing regime for the surveys makes direct correlation of invertebrate abundance and diversity with sediment iron contamination impossible for specific sites.

2) The sorting of preserved samples by eye would inevitably have led to an underestimation of invertebrate numbers and may even have resulted in missing certain taxa altogether. This problem would have been compounded

by sieving samples taken in 1990 through a sieve of a larger mesh size, almost certainly resulting in the loss of small invertebrates and taxa.

It may therefore, be difficult to distinguish between real effects of iron contamination on the invertebrate communities and underestimates caused by the imprecise sorting methods used.

Nevertheless the data can be used to provide a general indication of the status of the benthic invertebrate communities in Grafham Water during the period of dosing. The faunal diversity of Grafham Water in 1990 and 1991 was very low and generally declined between 1990 and 1991.

4.2.2 1990 Survey

During June to December 1990 Grafham Water was mainly dosed from the valve tower. A comparison of the invertebrate communities in this area (sites 2, 3, and 4) with those in the main reservoir (sites 5 and 6) and ones near the aeration tower (sites 7, 8, and 9), shows very little difference. The mean numbers of Oligochaeta and Chironomidae found in samples taken from these three groups of sites varied only slightly with Oligochaeta present at mean densities of 1,944 m^2, 1,837 m^2 and 2,087 m^2 respectively whilst in the same areas mean densities of Chironomidae were 1,299 m^2, 1,136 m^2 and 1,100 m^2.

Generally the number of Chironomidae found in Grafham Water during 1990 were comparable to the numbers found in late 1992. Indeed, the mean number of Chironomidae counted in samples taken in September and October 1990 were greater than numbers found in the same months in 1992, despite a possible underestimation of the 1990 counts.

4.2.3 1991 Survey

In 1991 dosing was carried out almost entirely from the aeration tower between January and November. Changes in the invertebrate communities became apparent in samples taken towards the end of the survey period from an area near the aeration tower, particularly evident at sites 9 and 14.

The reduction in Chironomidae and Oligochaeta populations at site 9 may be as a result of ferric dosing or may be part of the general decline in invertebrate diversity and abundance observed throughout the reservoir during 1991. Samples taken from sites near the aeration tower, the valve tower and from the main reservoir contained fewer invertebrates than samples from the same areas taken in 1990. These results may be associated with high iron levels recorded in the sediments by AWS Survey in 1991.

Similarly the extremely small number of Oligochaeta and the complete absence of Chironomidae at site 14 may be associated with high iron levels in the sediment reported by AWS.

Four taxa present in samples taken in 1990: Erpobdellidae, Glossiphonidae, Gammaridae and Unionidae, were not found in 1991 though 2 additional taxa were present in 1991 survey samples: Lymnaeidae and Hydrobiidae. The presence or absence of the above taxa cannot be considered significant due to their naturally low occurrence in sediments from deeper regions of lakes/reservoirs.

The changes in population densities of Sphaeriidae and Dreissenidae between 1990 and 1991 is notable. In 1990 Sphaeriidae were a very common component of the benthic fauna in Grafham, being recorded in every survey and increasing in abundance in later samples (September/October). Lower numbers were found in samples taken near the aeration tower compared to samples taken from near the valve tower. Deposition of ferric floc in this area might be expected to impact adversely on such filter feeders.

Dreissenidae were recorded at 4 sites during 1990 with a large population found at one site (5) in July. In 1991 this taxa was found only once at a site (perhaps surprisingly) near the aeration tower and since this date has not been recorded in Grafham Water.

4.2.4 1992 and 1993 Surveys

If the invertebrate data is expressed in a number of scatter diagrams (Figures 8-11) it would appear that at a sediment iron level greater than approximately 100 mg/g (dry weight) the invertebrate communities show a reduced abundance. A drawback of such diagrams is that they do not convey any temporal information. Invertebrate numbers have increased dramatically between September 1992 and October 1993. In samples taken on 9 September 1992 none contained more than 2,000 Chironomidae per square metre, on 29 September 1992 only one site exceeded this number, and on 28 October 1992 most sites still contained less than this 2,000. By October 1993, however, no sites contained less than 3,000 Chironomidae per square metre with most containing between 5,000 and 6,000 Chironomidae per square metre. Likewise the number of

Oligochaeta and the total number of individuals found in samples increased greatly towards October 1993.

The scatter diagram plotting the number of taxa found against sediment iron (Figure 9) does not show a clear effect of high sediment iron levels with 10 taxa recorded in a sample contaminated by almost 300 mg/g of iron and 8 taxa present in a sample containing almost 400 mg/g iron.

An indication of this massive increase in invertebrate abundance during the 1992/93 survey period can be seen in Figures 12-15. It was considered that a year after dosing should have been sufficient for signs of a recovery from any immediate effects of iron contamination to have taken place. By examining data from a year apart it was hoped to distinguish between recovery and natural seasonal fluctuations in abundance.

Clearly the number of invertebrates found in samples have increased substantially over the year with some sites showing a 20-fold increase (Figure 12). The number of taxa represented in samples taken in September 1992 and October 1993 (Figure 13) again shows a general increase over the period. It is perhaps noteworthy that in September 1992, within weeks of the cessation of dosing, site 6 supported by far the most diverse fauna. This may, however, be partly attributable to the introduction of invertebrates from the river via the inlet.

A comparison of the number of Chironomidae found in September 1992 and October 1993 (Figure 14) shows a very marked increase over the period with certain sites showing a 100-fold increase in Chironomidae numbers. In September 1992 the maximum number of Chironomidae found at any one site was 3,700/m^2 with most sites supporting less than 1,000/m^2. In October 1993, however, one site contained more than 9,000 Chironomidae, most supported over 5,000/m^2 and none contained less than 2,700 Chironomidae per square metre.

The number of Oligochaeta found at Grafham between the two dates shows a less pronounced increase for most sites and an actual decline in abundance at three sites (Figure 15). The cause of the reduction in numbers at sites 13, 16 and A is unclear but is unlikely to be due to the direct toxic effects of elevated sediment iron contamination since these sites are in areas of low sediment iron levels, ranging from 19.8 to 53.9 mg/g total iron.

The massive increase in the abundance of benthic invertebrates at sites throughout the reservoir a year after ferric dosing ended has perhaps masked any possible effects of high sediment iron levels.

Another way to ascertain whether higher sediment iron levels are deleterious to the benthic fauna is to compare data from a site heavily contaminated with iron with data from a site with sediment iron considered to be of a background level. A comparison was therefore made between site 8, maximum iron 50.7 mg/g, mean iron 46.2 mg/g, and site 6, maximum iron 396 mg/g, mean iron 194.9 mg/g (Figures 16-19).

Site 8 supports a much larger total invertebrate population than site 6 (Figure 16) but a slightly less diverse fauna (Figure 17). A comparison of Chironomidae densities at the two sites (Figure 18) shows that both sites had a low Chironomidae population between September and October 1992, despite the much greater levels of iron in the sediments at site 6. In November 1992 the population at site 8 increased whereas at site 6 the numbers remained low. Although this may indicate an effect of iron on Chironoimidae at site 6 it is more likely that it represents the fluctuation in numbers observed at all the sites with a general pattern common to only a few. In November 1992 only 7 of the sites were sampled resulting in a loss of detail in the timing of any population changes between October 1992 and January 1993 for most sites.

Oligochaeta may be more susceptible to sediment iron, since from Figure 19 it is clear that the populations at site 6 are very much reduced compared to site 8. This may, however, be as a result of factors other than sediment iron.

Sediments in the region of site 6 are noticeably coarser than most other sites, perhaps as a result of larger particles rapidly settling out of the pumped river water as it emerges from the inlet or from the jetted water sorting the sediment by particle size and weight. A coarser sediment, due to its physical properties, is likely to support a lower Oligochaeta population. Sediment at site A is also of a very coarse nature and likewise has a lower Oligochaeta population, despite also having a very low sediment iron level.

Since Oligochaeta were usually the dominant taxa (numerically) in samples a low population, as seen at site 6, would be reflected in the total invertebrate population, and could explain the low number of individuals seen in Figure 16 for site 6.

Further work would be required to investigate the extent that factors such as particle size and sediment organic content could have in influencing benthic invertebrate communities. Work would also needed to assess the contribution of river invertebrates via the inlet to the invertebrate communities around the aeration tower.

Since Oligochaeta and Chironomidae dominate the benthic communities, have been present in every sample taken and are vital components of the reservoir food chain it was decided to examine these taxa in more detail. Early in 1993 the Institute of Freshwater Ecology identified the Chironomidae and Oligochaeta present in samples taken between September 1992 and January 1993 for 16 sites in Grafham Water. It is unfortunate that this period covers such a small part of the seasonal range and that prior to January 1993 the numbers of Oligochaeta and Chironomidae were very low. For such reasons the data is of limited value but may nevertheless give some indication of any adverse effects of high sediment iron loads on the benthic invertebrate communities.

Seven taxonomic groups of Chironomidae were identified, all, with one exception, from the sub family Chironominae (Table 5). An examination of the Oligochaeta present in samples over the period identified fourteen taxonomic groups though several groups were too immature for full identification (Table 5).

A comparison between the mean sediment iron concentration and the total number of Chironomidae taxa recorded at each site over the period is made in Figure 20a. The most diverse chironomid community was found at site 5 with all seven taxa being recorded between September 1992 and January 1993 despite having the highest sediment iron load (mean 264 mg/g, range 141-368 mg/g dry weight). When the data is expressed as a scatter diagram with the number of taxa plotted against sediment iron there is an indication that high sediment iron had some adverse effect on chironomid diversity (Figure 20b).

Since site 5 is situated approximately 60 m from the aeration tower the introduction of invertebrates from the river via the inlet tower is likely to be much less significant. The chironomid taxa found are considered to be mainly characteristic of a lake habitat, further suggesting that river inputs are less likely to be a major factor in determining the invertebrate communities at this site.

Of the fourteen Oligochaeta taxa identified over the period eleven were recorded at site 6 where the mean iron level was 204mg/g dry weight, range 40-396mg/g dry weight (Figure 21a). The scatter diagram (Figure 21b) is inconclusive but does show that even at iron levels of up to 200 mg/g dry weight six Oligochaeta taxa were present. The taxa identified are considered to be characteristic of both lakes and deep, slow flowing rivers though a site so close to the inlet is likely to be greatly influenced by river invertebrate introductions.

5 OVERALL ASSESSMENT

The diversity and abundance of the benthic invertebrate communities has increased markedly between 1990 and 1993 with the most significant increases occurring in 1992-93.

The diversity and abundance of the benthic invertebrate communities in Grafham Water were lowest during 1991. It may be significant that ferric dosing was heaviest and more prolonged during 1991 than 1990 or 1992 and started earlier in the year.

Results from the 1992-93 monitoring programme indicate that the area of Grafham Water affected by high sediment iron levels has declined and that this has coincided with a general reduction in iron levels measured within this affected area.

The observed changes in invertebrate populations since 1990 and particularly since September 1992 suggest that the effects of ferric dosing are not as straight forward as previously believed. Other factors affecting the benthic invertebrate communities in Grafham might be:

a) The effects of toxic contaminants in the ferric sulphate solution that was dosed into the reservoir.

b) The effects of elevated sulphate levels within the sediments due to dosing with ferric sulphate.

c) The alteration of the physical and chemical nature of the sediment eg. changes in particle size and organic content where ferric floc settles and/or becomes incorporated into the sediment.

d) Benthic invertebrate communities undergo significant natural fluctuations between years.

e) The extent that the introduction of invertebrates from the river via the inlet can influence benthic communities, particularly near the aeration tower.

f) The long term effects of draw down on the ecology of the reservoir, particularly the consequences of any alterations to the food chain on certain taxa.

g) The effect of 'clean' sediment accumulating in contaminated areas.

From surveys carried out in 1992-93 it appears that high sediment iron levels are not always associated with significant reductions in invertebrate diversity or even abundance. This may be because iron and/or the contaminants are not toxic to most invertebrate taxa at the levels encountered in Grafham sediments. Alternatively iron and/or the contaminants may be toxic but this toxicity is rapidly reduced by natural sediment processes or that its effects are greatly ameliorated by the physical and chemical properties characteristic of the sediments in Grafham. Any toxic effects could also depend on the timing of dosing in relation to the life cycles of the invertebrate taxa present in Grafham. The life stages of some invertebrates may be more susceptible at certain times of the year. It may be significant that in 1991, when invertebrate abundance was much lower than in 1990 or 1992-93, dosing commenced in January. In January/February 1993 dramatic increases in abundance were observed and so it is possible that the lower abundance in 1991 was, in part, a consequence of the suppression of numbers during the early part of the year. More work, however, would be needed to assess the significance of iron levels on the different stages in the life cycles of invertebrate taxa found in Grafham Water.

If chronic toxicity is significant in delaying the development of certain taxa, its effects may not be accurately detected using only population counts and may not even be immediately apparent, requiring one or more seasons to fully manifest itself.

The smothering effect of the ferric floc may cause more damage to the invertebrate communities than any toxic effects. Since a thick layer of floc has not be recorded in any Grafham samples it is possible that this has allowed relatively high populations to develop.

6 RECOMMENDATIONS

6.1 Monitoring of the reservoir since ferric dosing ceased in 1992 has shown a significant reduction in the area of bed affected by elevated iron levels and a corresponding increase in diversity and abundance of benthic invertebrates. Good recovery is indicated and it is considered that further monitoring is no longer justified.

6.2 The actual mechanism(s) that caused the damage to the benthic invertebrate community remains unclear but until such times as AWS propose to dose Grafham Water again it is considered that further investigative work cannot be justified either.

7 GAYNES COVE STUDY

7.1 Introduction

The results from a special survey of Gaynes Cove in June 1993 revealed areas of very low benthic invertebrate populations. In order to (a) investigate this more fully, (b) to review the consent conditions for the discharge into the cove from Grafham Water Treatment Works, (c) to place the results from the Cove in context with the rest of the reservoir, a detailed study was initiated in August 1993.

7.2 Sampling Strategy and Methods

Gaynes Cove is situated towards the southern end of Grafham Water. Seven sites were selected within the cove with a further two sites situated towards the valve tower (Figure 22).

At each site an Ekman grab (0.0225m^2 surface area) was used to obtain a sediment sample, a sediment core taken from each grab sample was analysed for cadmium, iron, copper, chromium, zinc, lead, mercury and nickel. The grab samples were returned to the laboratory, sieved (355 μm mesh size) and sorted by eye in a white plastic tray. Sediment core samples were also taken at some sites within the main body of the reservoir at Grafham 3, 5, 6, 8, C, D and F (Figure 22).

7.3 Results

The diversity and abundance of benthic invertebrates in Gaynes Cove is summarised in Table 6.

Seventeen taxa were recorded in the survey with the communities dominated by Chironomidae and Oligochaeta. The diversity and numbers of invertebrates varied greatly between sites and ranged from 1 taxon, 1,320 individuals per square metre (site 4) to 14 taxa, 19,404 individuals per square metre (site 7).

Sediment metal samples were taken in August and October 1993 and the results are summarised in Table 7. Cadmium levels ranged from 0.859-4.15 mg/kg dry weight; iron from 28.4-218 mg/kg dry weight; copper from 10.9-57.5 mg/kg dry weight; Chromium from 25.4-79.1 mg/kg dry weight; zinc from 61-178 mg/kg dry weight; lead from $<$4.81-94.3 mg/kg dry weight; mercury from 0.123-0.241 mg/kg dry weight; and nickel from 18.4-49.1 mg/kg dry weight.

7.4 Discussion

From Table 6 it is apparent that the invertebrate communities within Gaynes Cove (sites 1-4) are subject to environmental stress. Even after considering the sorting method, which would be expected to produce lower counts, the numbers within the cove are very small. At the most affected site (site 4) only Chironomidae were present and at sites 1-3 the number of Oligochaeta recorded were much lower than might be expected compared to other sites in the reservoir. Site 7 supported the most diverse fauna while sites 8 and 9 had invertebrate communities characteristic of deeper water areas.

The interpretation of the sediment metal analyses is hampered because to date no Quality Standards have been derived in the UK for chemicals associated with sediments. The recommended values of some heavy metals derived by the National Institute of Public Health and Environmental Protection in Holland and applicable for freshwaters and dredged sediments, are detailed in Table 8. It must be stressed that due to the paucity of research data and the wealth of factors influencing sediment toxicity it is very difficult to set a Quality Standard that is applicable over a wide range of sediment types.

Using the levels recommended by the Institute of Public Health and Environmental Protection as a benchmark it is apparent that the levels of some metals, particularly cadmium, copper and nickel, in the reservoir and Gaynes Cove, may be a cause for concern.

To determine the significance of the metal levels found in Grafham it would be necessary to obtain levels of metals in the reservoir water and also in the water and sediments of the River Ouse directly upstream of the reservoir intake. This would indicate whether the sediment metal levels in Grafham are due to inputs from the river or from any discharges into the reservoir.

If the levels are due to non-river additions to the reservoir the locations of the higher levels may suggest a possible link to the water treatment works discharging into Gaynes Cove. Since ferric sulphate is used at the treatment works and has been added to the reservoir as a eutrophication control measure it is possible that the other metals are present in the ferric sulphate solution as impurities. A sample of the ferric sulphate (Grade W) being used by Anglian Water Services in Rutland Water was analysed, the results of which are detailed in Table 10. It would appear that certain trace metals, notably cadmium, are present at high levels. If the trace metals in the sediment are associated with ferric sulphate entering the reservoir (from treatment works or dosing from the aeration tower) a correlation between iron and the other metals may be discernable, despite the small amount of data available (Figures 23-29). From such a simple analysis there would appear to be a possible relationship between iron and cadmium (Figure 23) and iron and copper (Figure 24) but no apparent correlation between sediment iron and zinc, lead, nickel, chromium and mercury (Figures 25-29).

7.5 Overall Assessment

From the data currently available it appears that sites showing very poor invertebrate communities correspond to sites with high levels of metals, particularly cadmium, iron and copper.

There may be a link between some heavy metals (notably cadmium and copper) and iron with the suggestion that contaminated ferric sulphate used at the treatment works and during dosing is responsible for some of the heavy metals found in the sediments.

7.6 Recommendations

More work would be required to determine if a link exists between any of the heavy metals and low invertebrate numbers or between the heavy metals and the ferric sulphate used in the treatment processes and reservoir phosphate reduction.

It may also be useful to analyse samples for titanium since it is present in the ferric sulphate solution at a high level and could be used as a marker of contamination as a result of ferric dosing.

8 REFERENCES

Biological Monitoring of Grafham Water: Summer 1990, Central Area Biology (1991).

Grafham Water 1991, Biological Monitoring Re: Ferric Sulphate Dosing, Central Area Biology (1992).

Grafham Water 1992, Biological Monitoring Re: Ferric Sulphate Dosing, Central Area Biology (1992).

Grafham Water, Bioligical Monitoring Re: Ferric Sulphate Dosing, Supplementary Report: November 1992 - January 1993.

March 1994

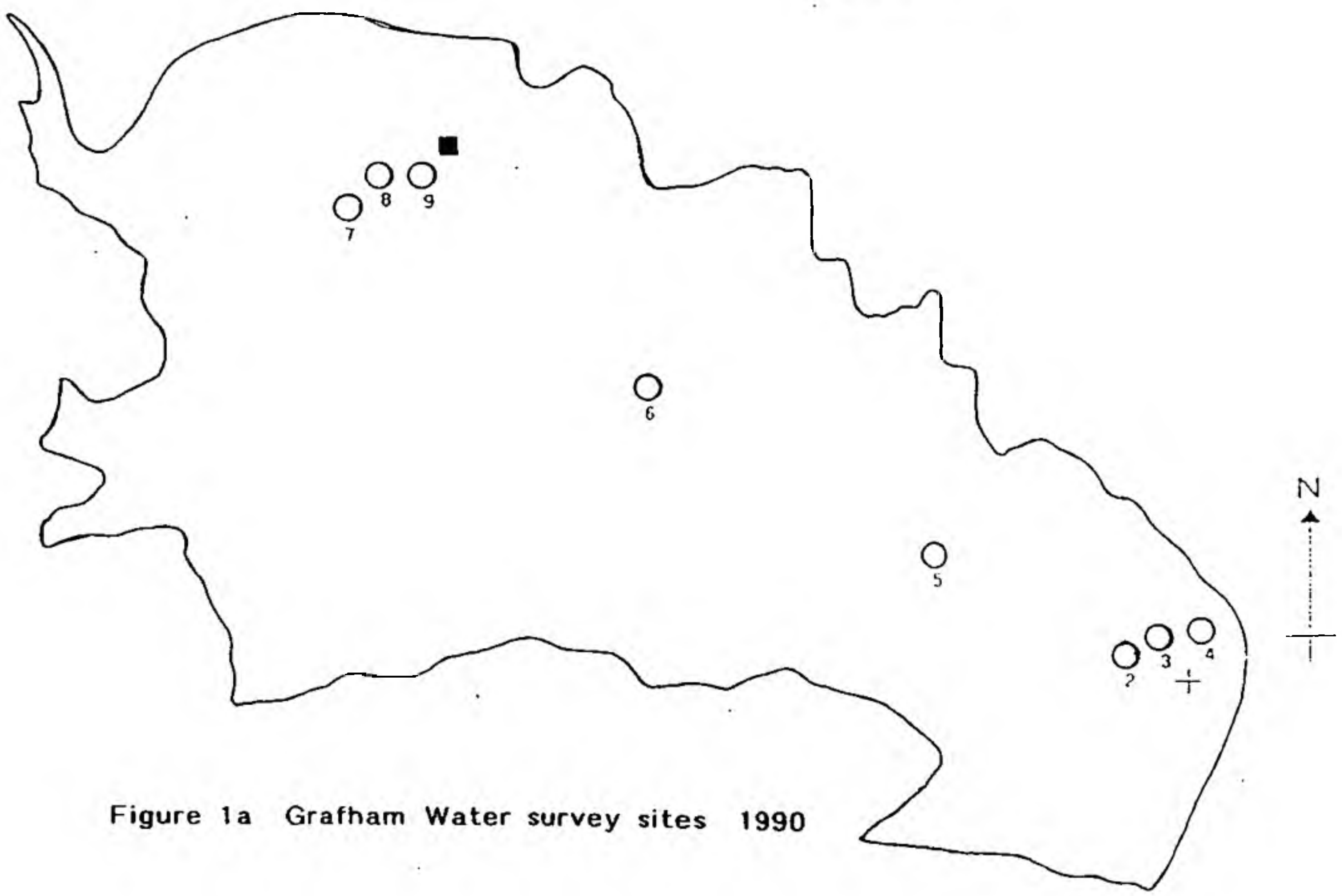


Figure 1a Grafham Water survey sites 1990

KEY

■ Aeration tower

+ Valve tower

○ Sample site

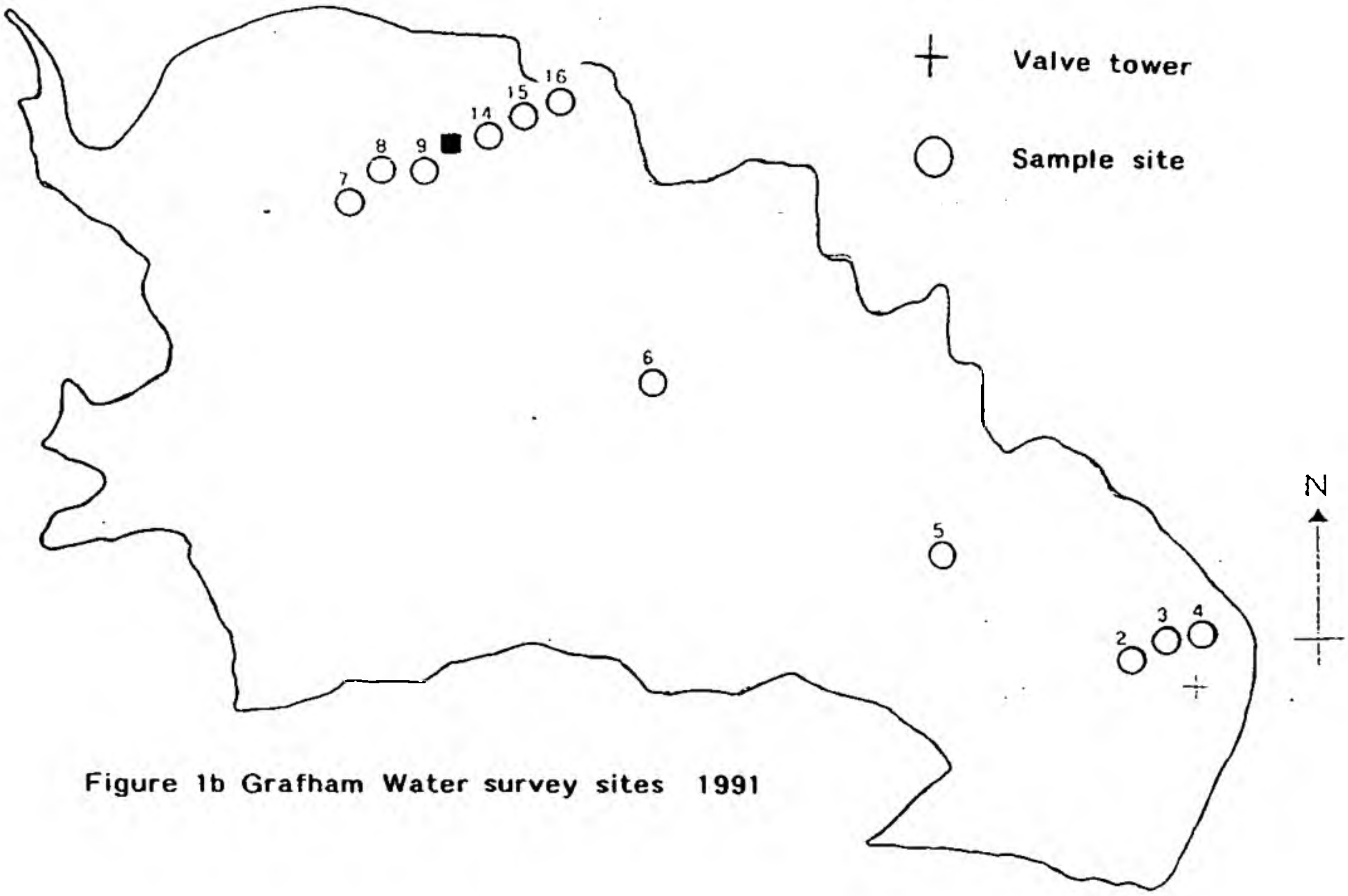


Figure 1b Grafham Water survey sites 1991

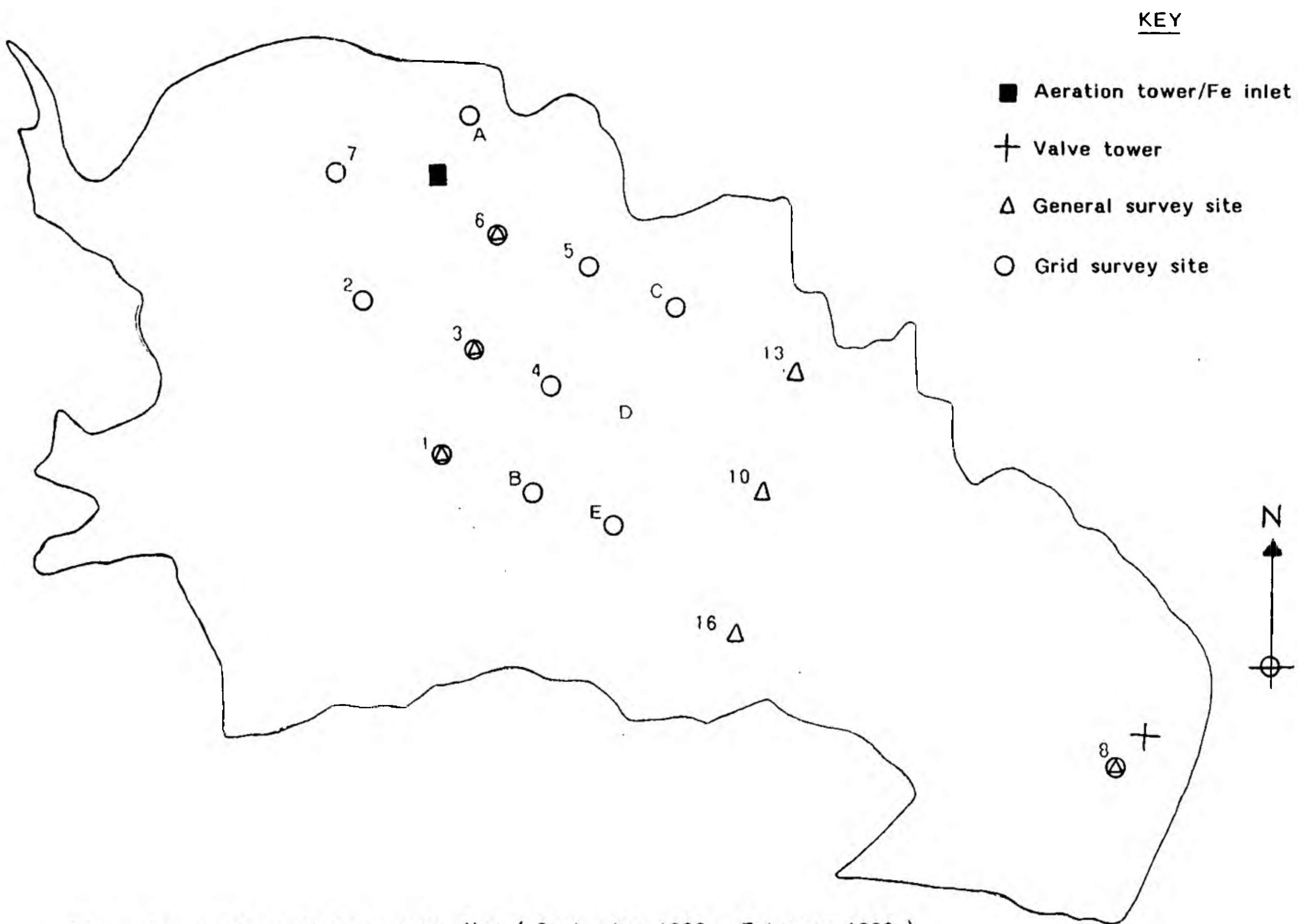


Figure 1c Grafham Water survey sites (September 1992 - February 1993)

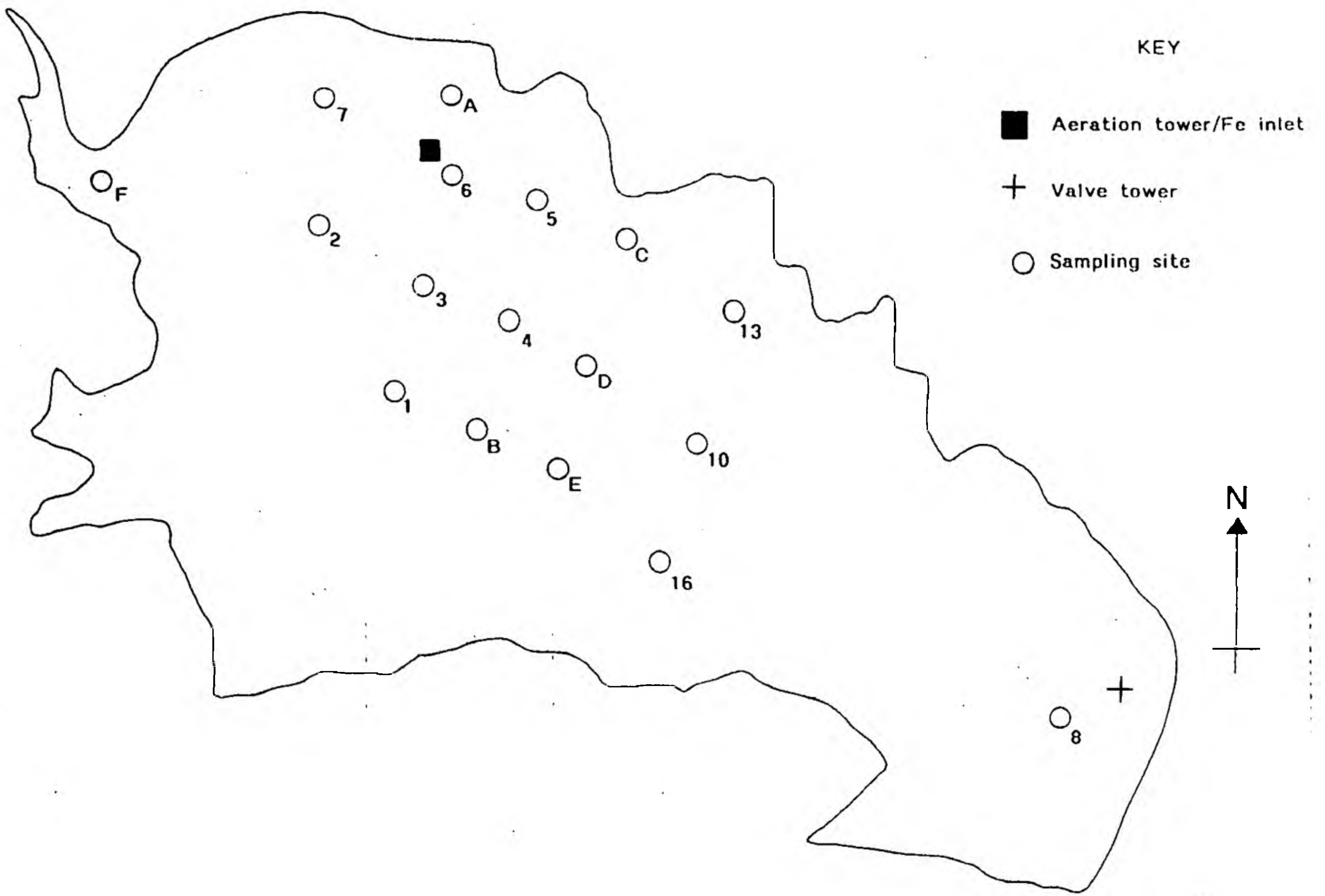


Fig. 1d GRAFHAM WATER SURVEY SITES (1993)

GRAFHAM WATER 1993

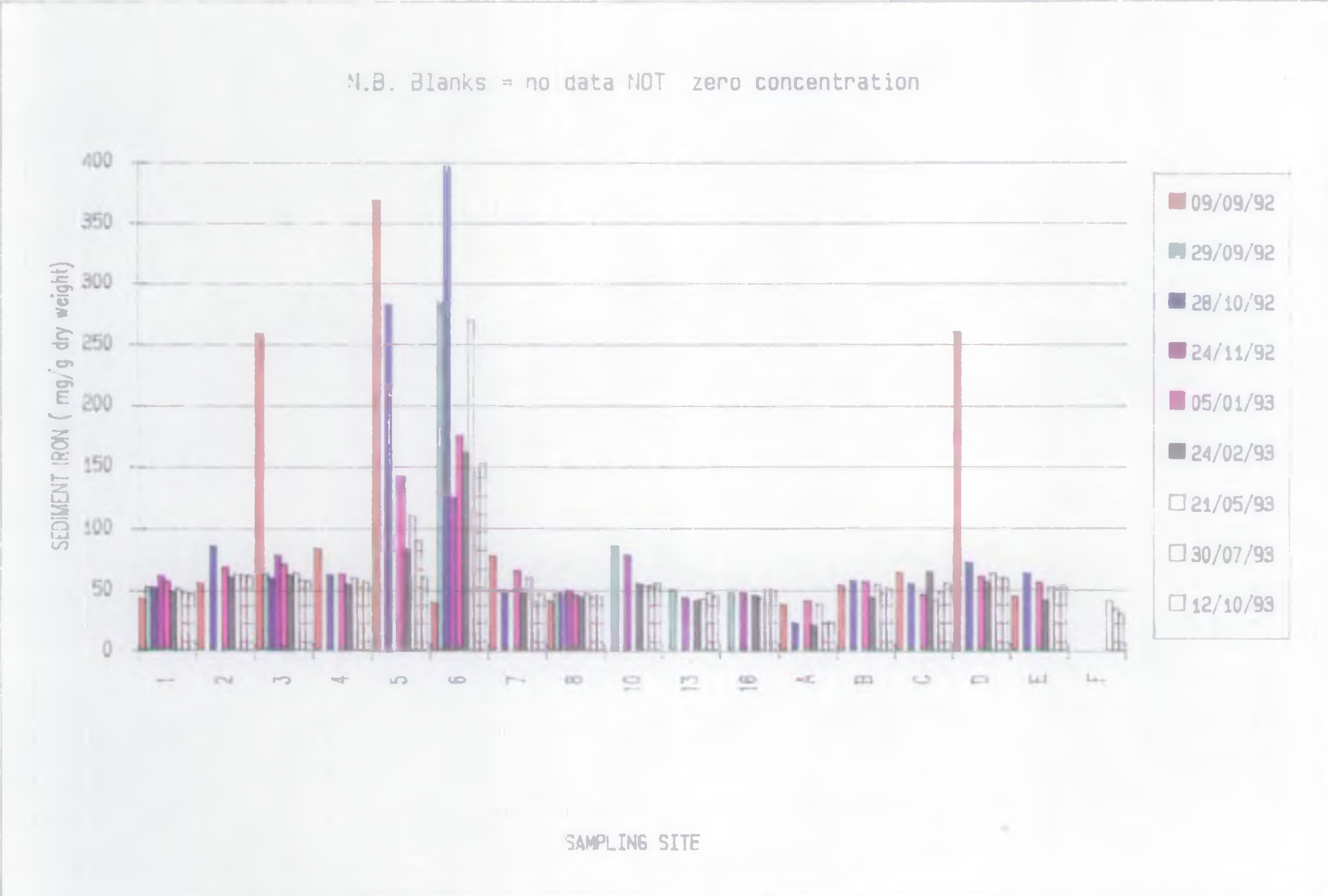


Fig. 2 MEAN SEDIMENT IRON LEVELS IN GRAFHAM WATER.

GRAFHAM WATER 1993

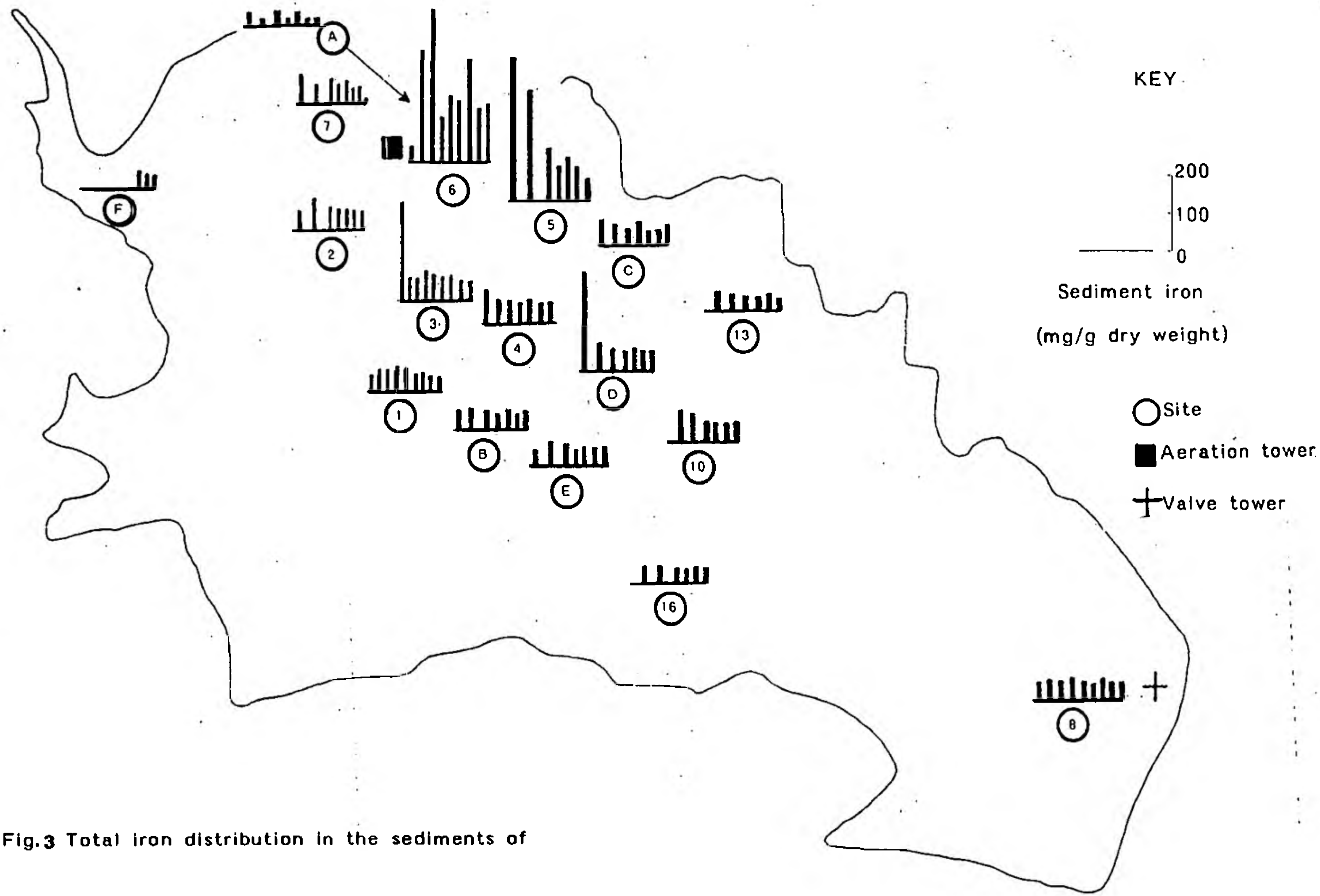


Fig. 3 Total iron distribution in the sediments of Grafham Water. September 1992 - October 1993

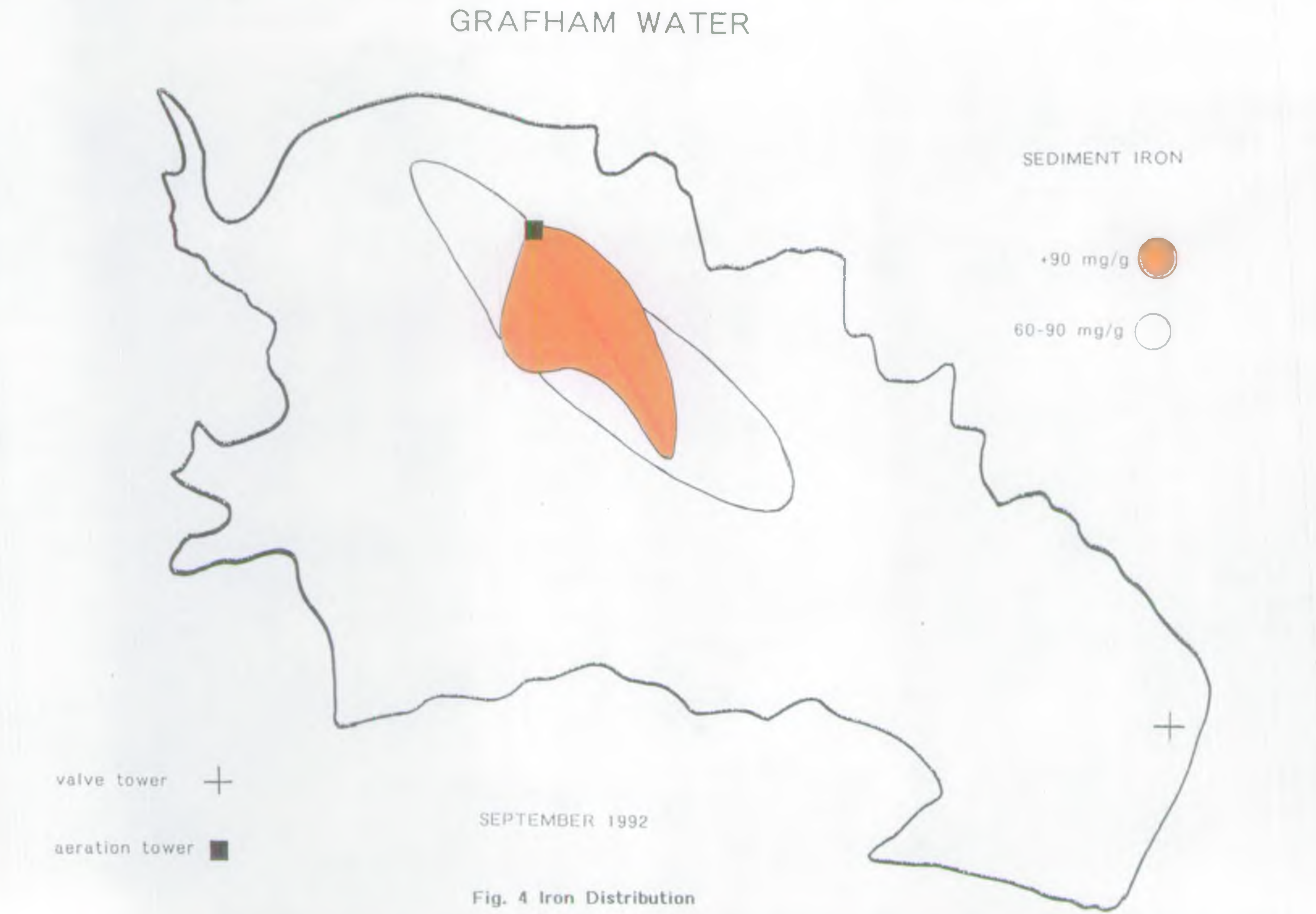


Fig. 4 Iron Distribution

GRAFHAM WATER

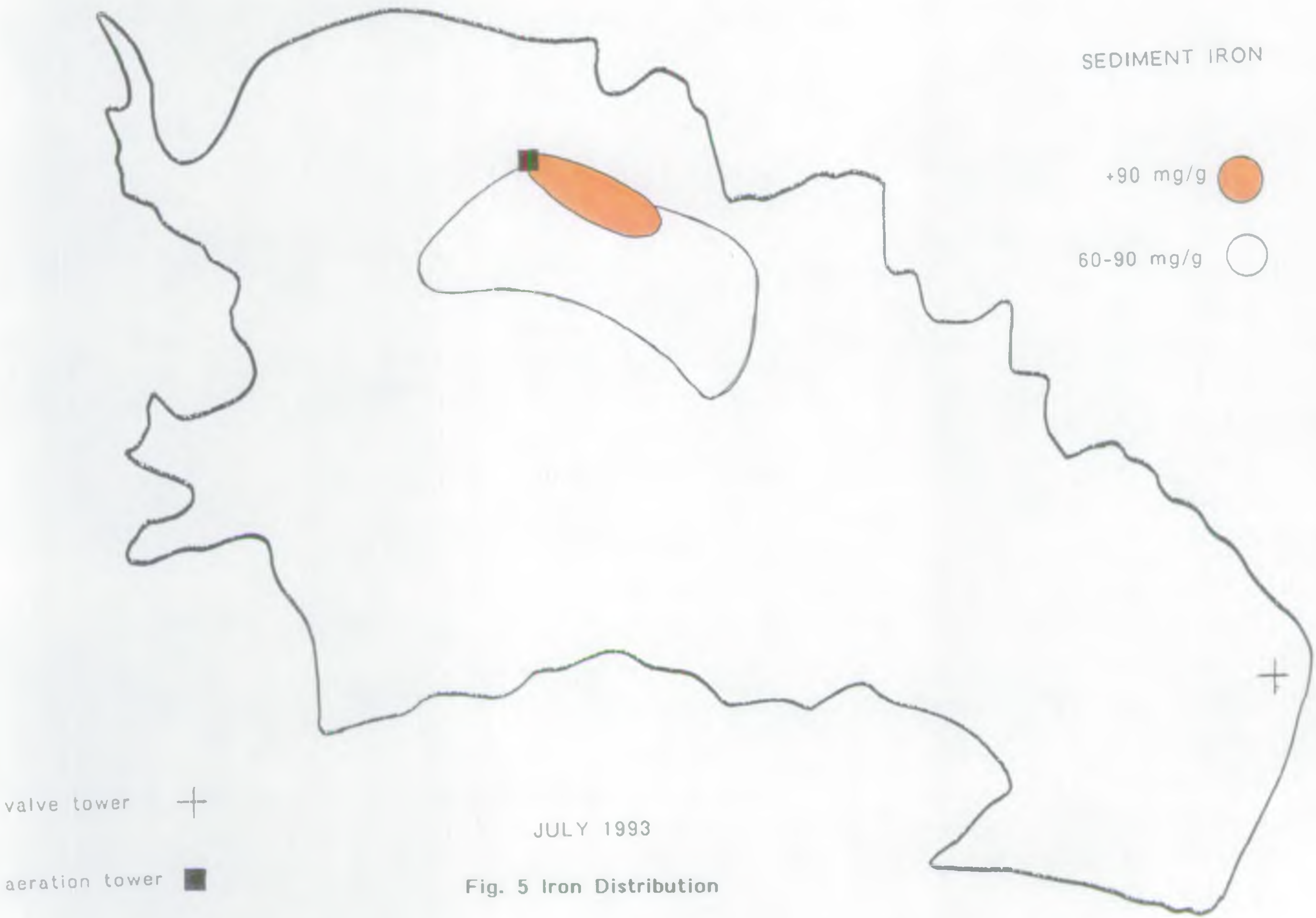


Fig. 5 Iron Distribution

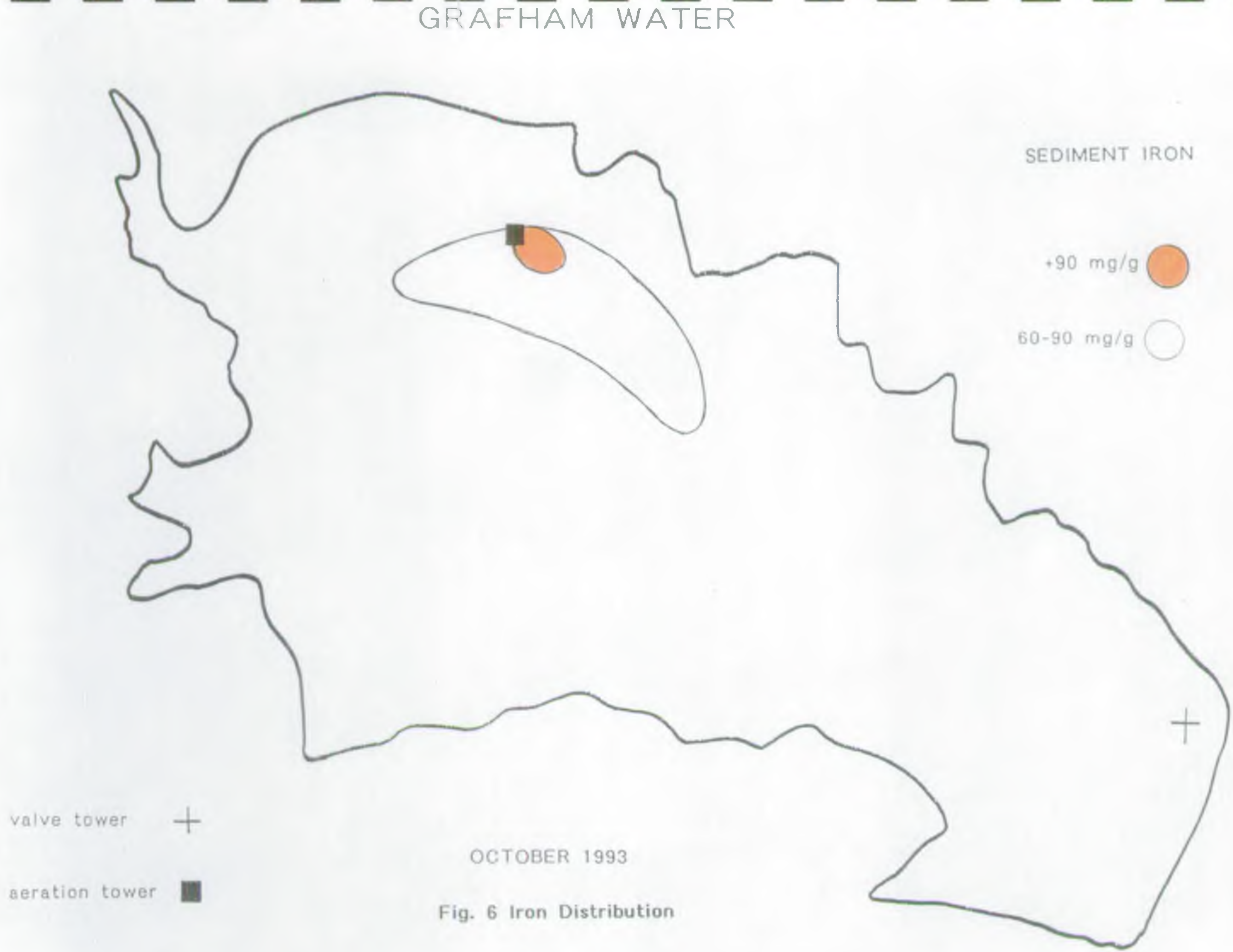


Fig. 6 Iron Distribution

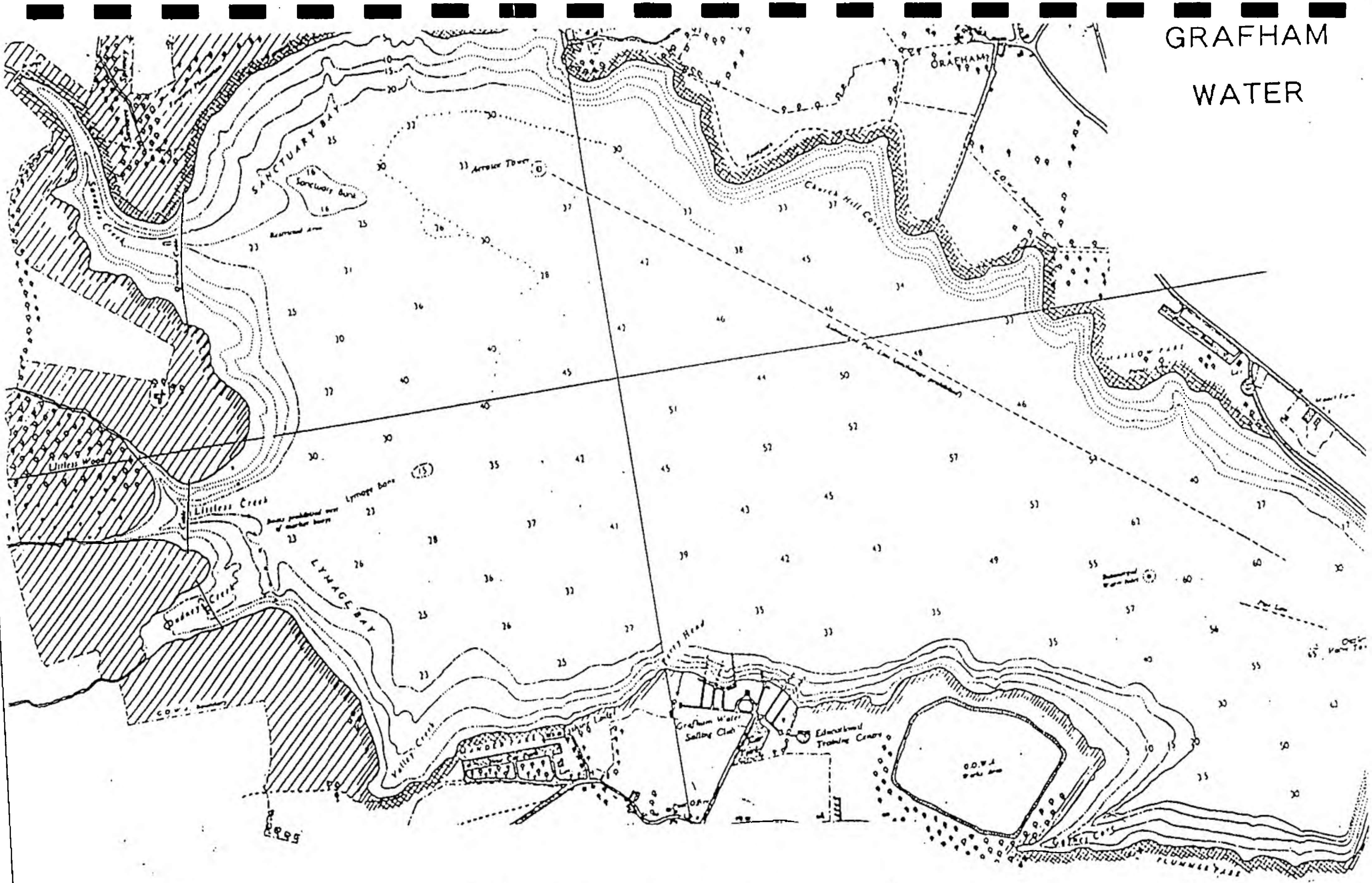


Fig. 7 Water depths at Grafham.

Soundings in feet at normal high water. (source: Grafham Water Sailing Club 1979)

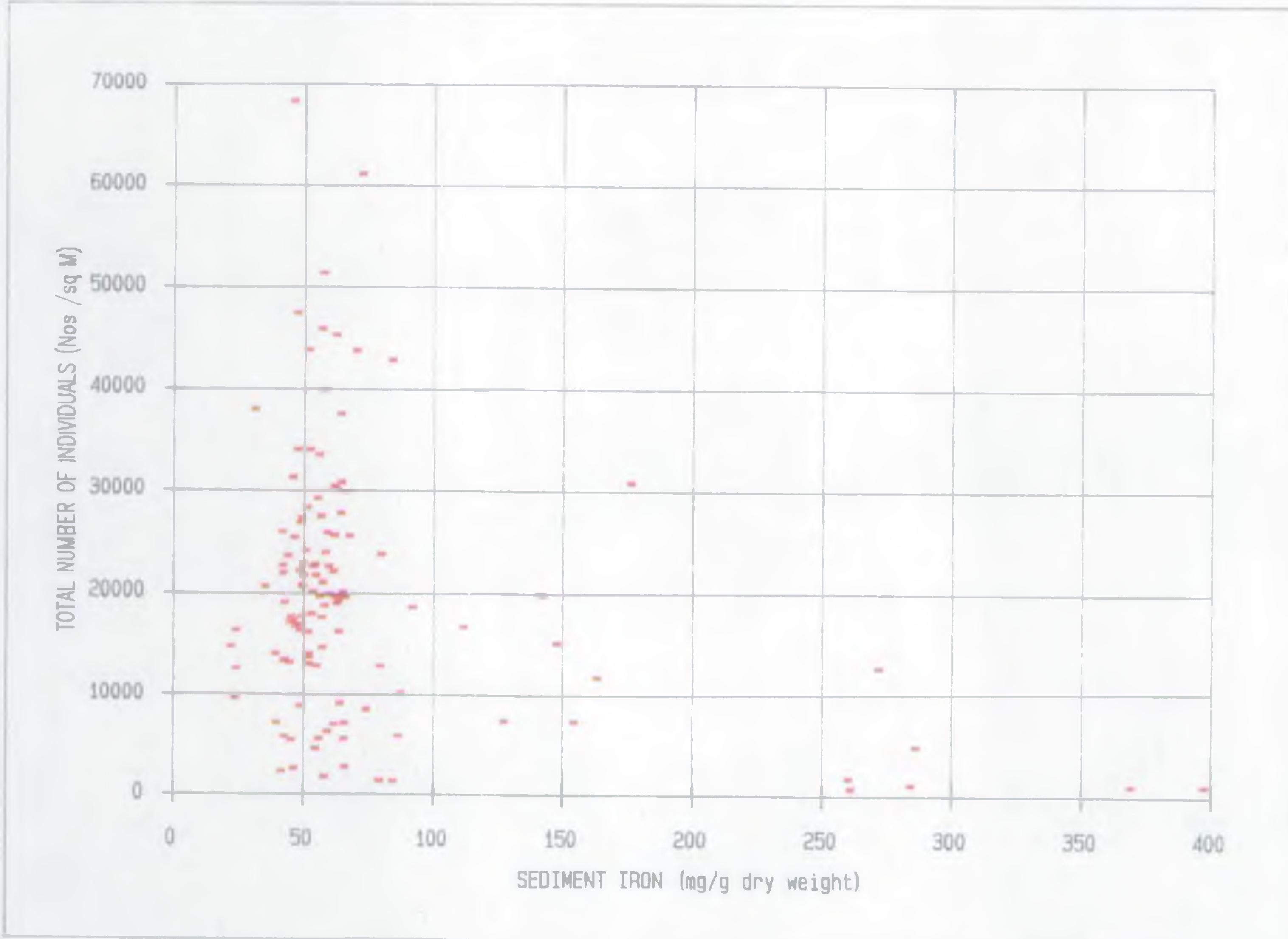


Fig. 8 NUMBER OF INDIVIDUALS PLOTTED AGAINST SEDIMENT IRON LEVELS.
(September 1992 – October 1993)

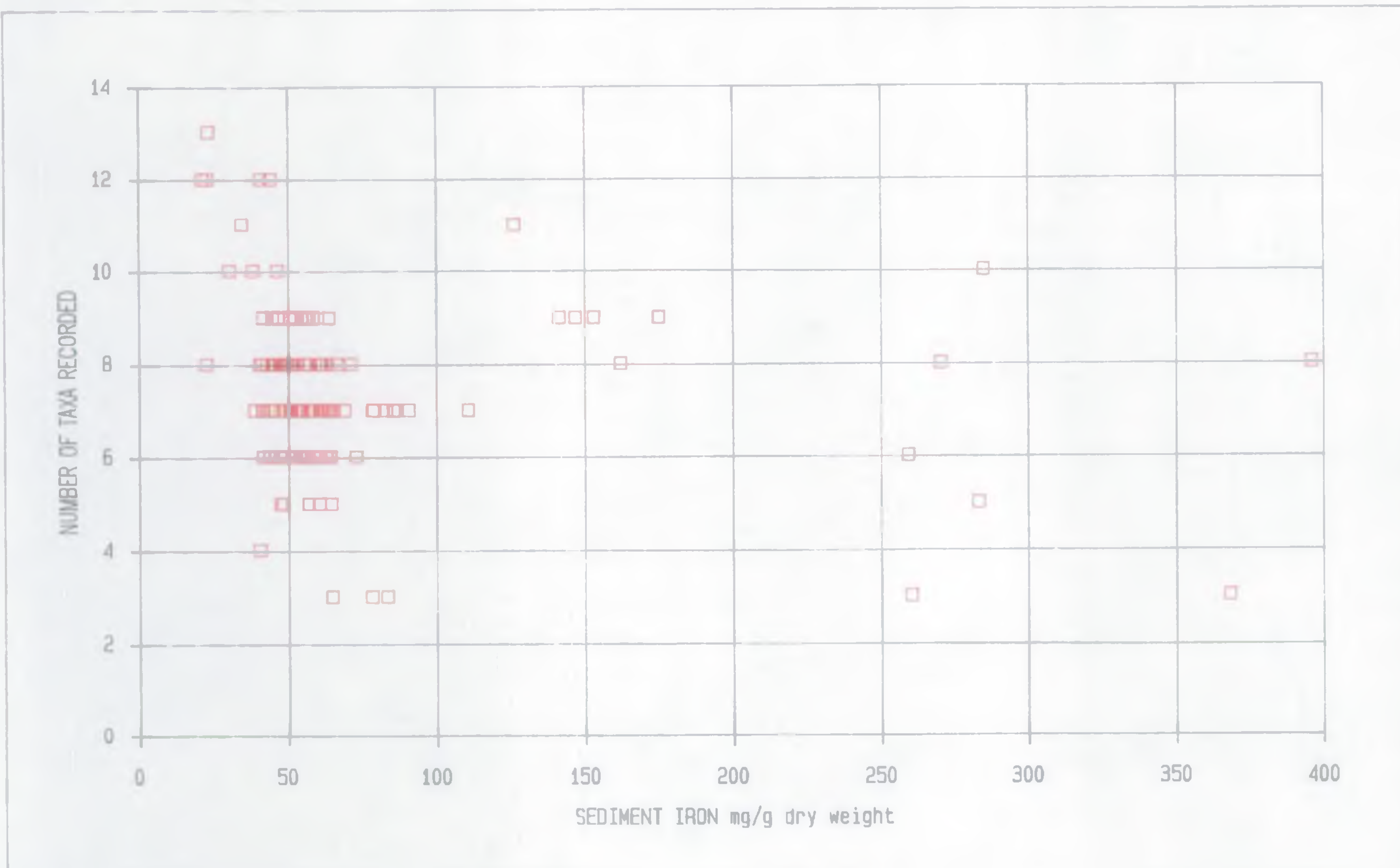


Fig. 9 NUMBER OF TAXA PLOTTED AGAINST SEDIMENT IRON LEVELS.
(SEPTEMBER 1992 - OCTOBER 1993)

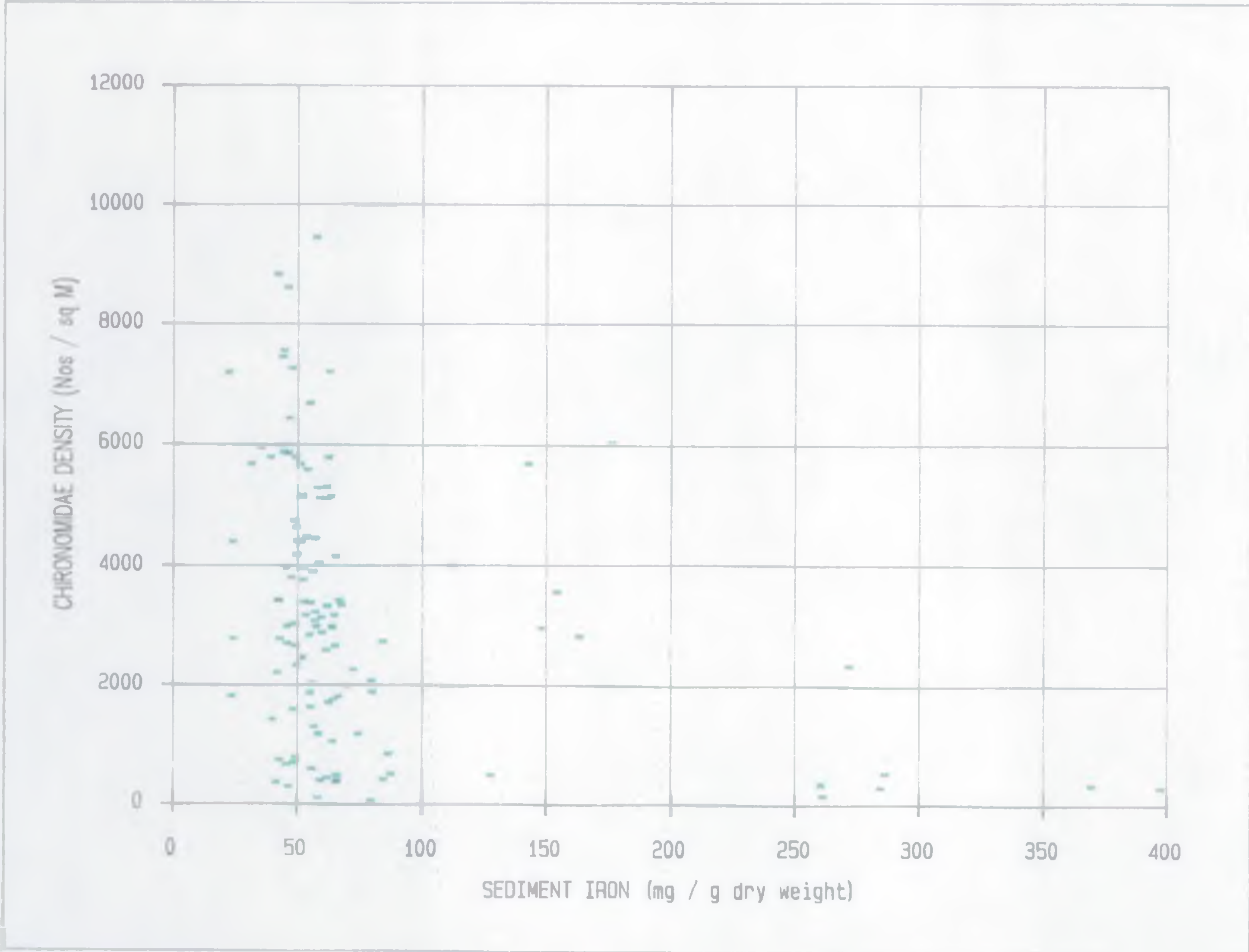


Fig. 10 NUMBER OF CHIRONOMIDS PLOTTED AGAINST SEDIMENT IRON LEVELS.
(September 1992 - October 1993)

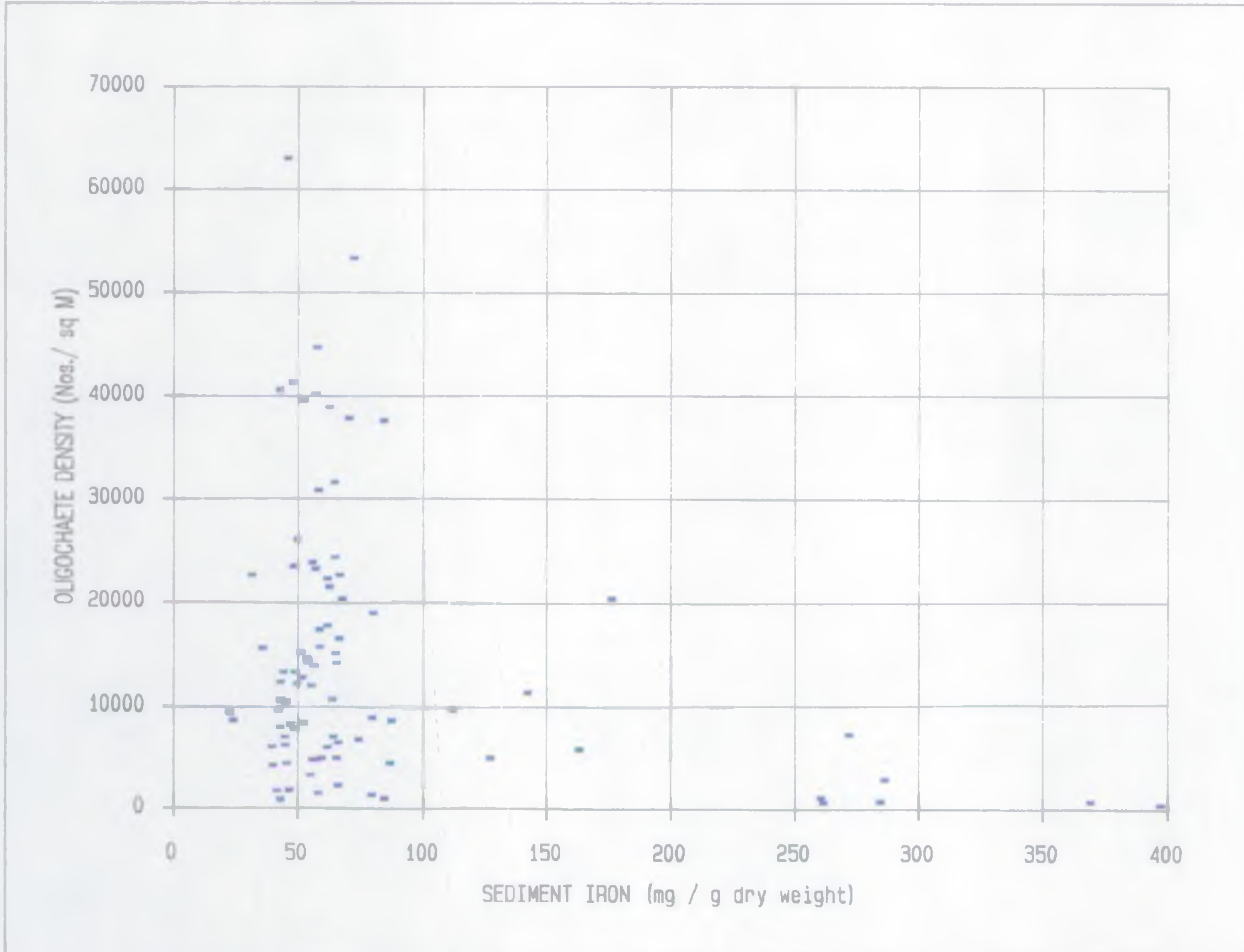


Fig. 11 NUMBER OF OLIGOCHAETES PLOTTED AGAINST SEDIMENT IRON LEVELS.
(September 1992 - October 1993)

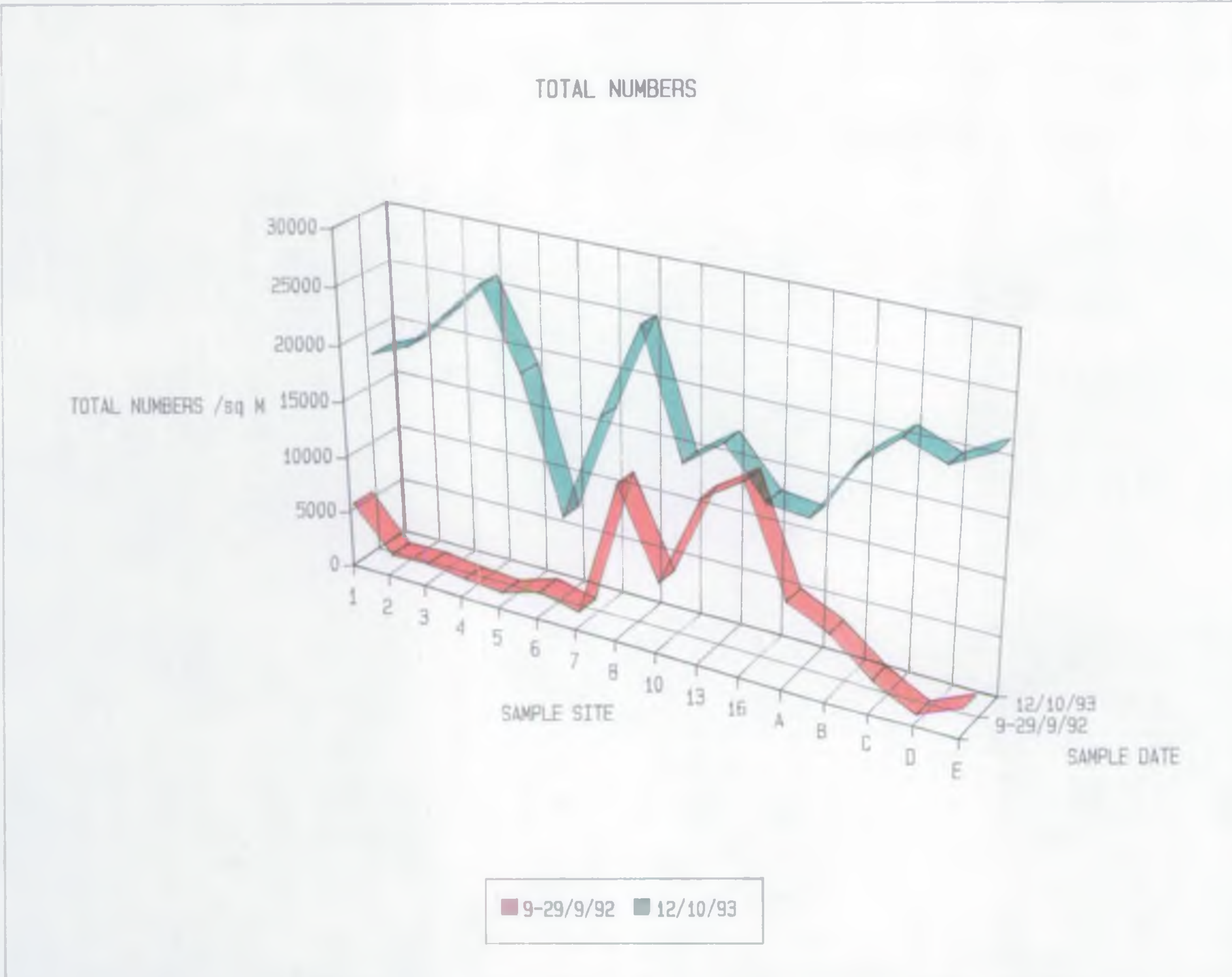


Fig. 12 COMPARISON BETWEEN THE TOTAL NUMBER OF INDIVIDUALS FOUND IN SEPTEMBER 1992 AND OCTOBER 1993.
(Figures for September are averaged if sites sampled on 9/9/92 + 29/9/92)

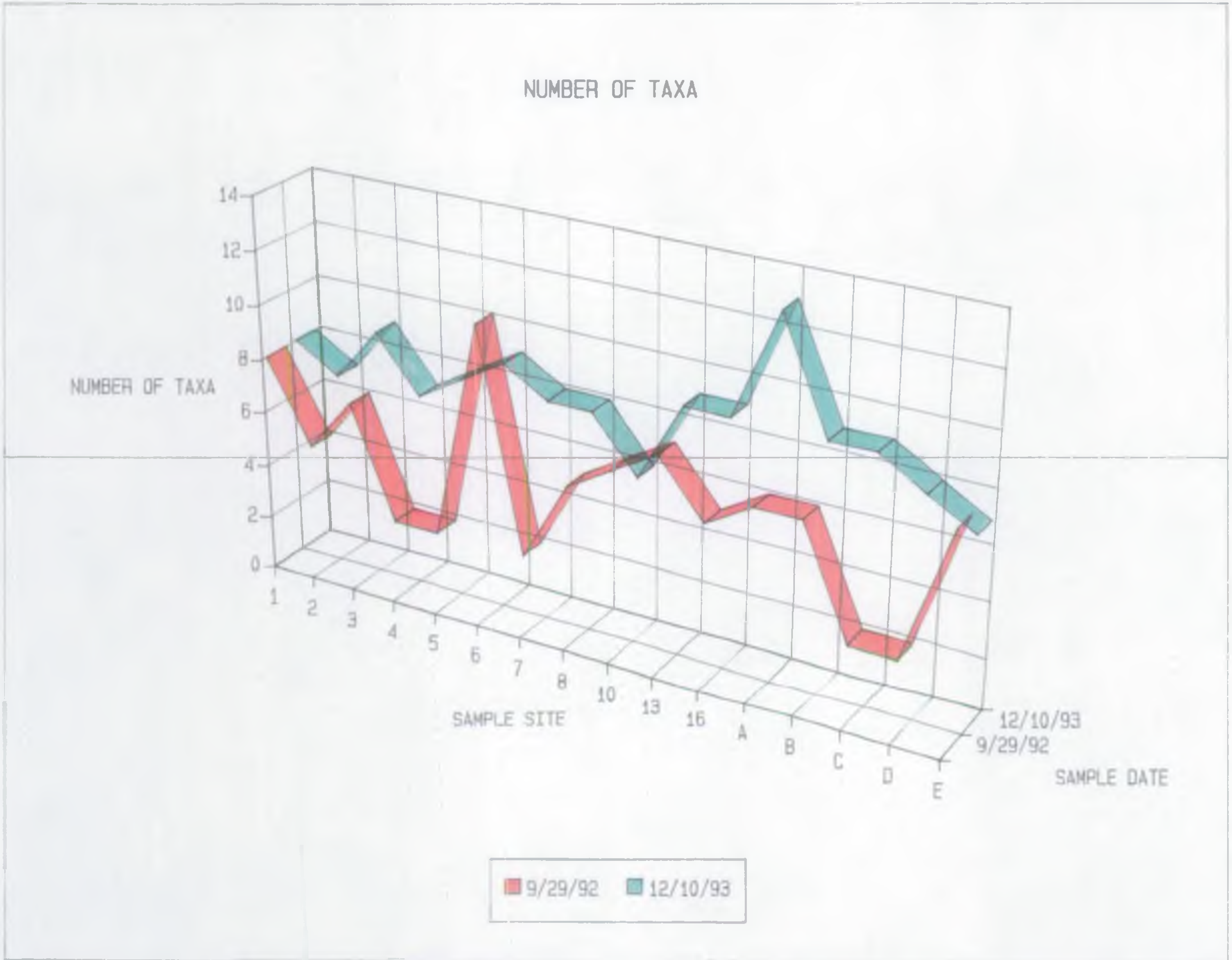


Fig. 13 COMPARISON BETWEEN THE NUMBER OF TAXA FOUND IN SEPTEMBER 1992 AND OCTOBER 1993.
(Figures for September are averaged if sampled on 9/9/92 29/9/92)

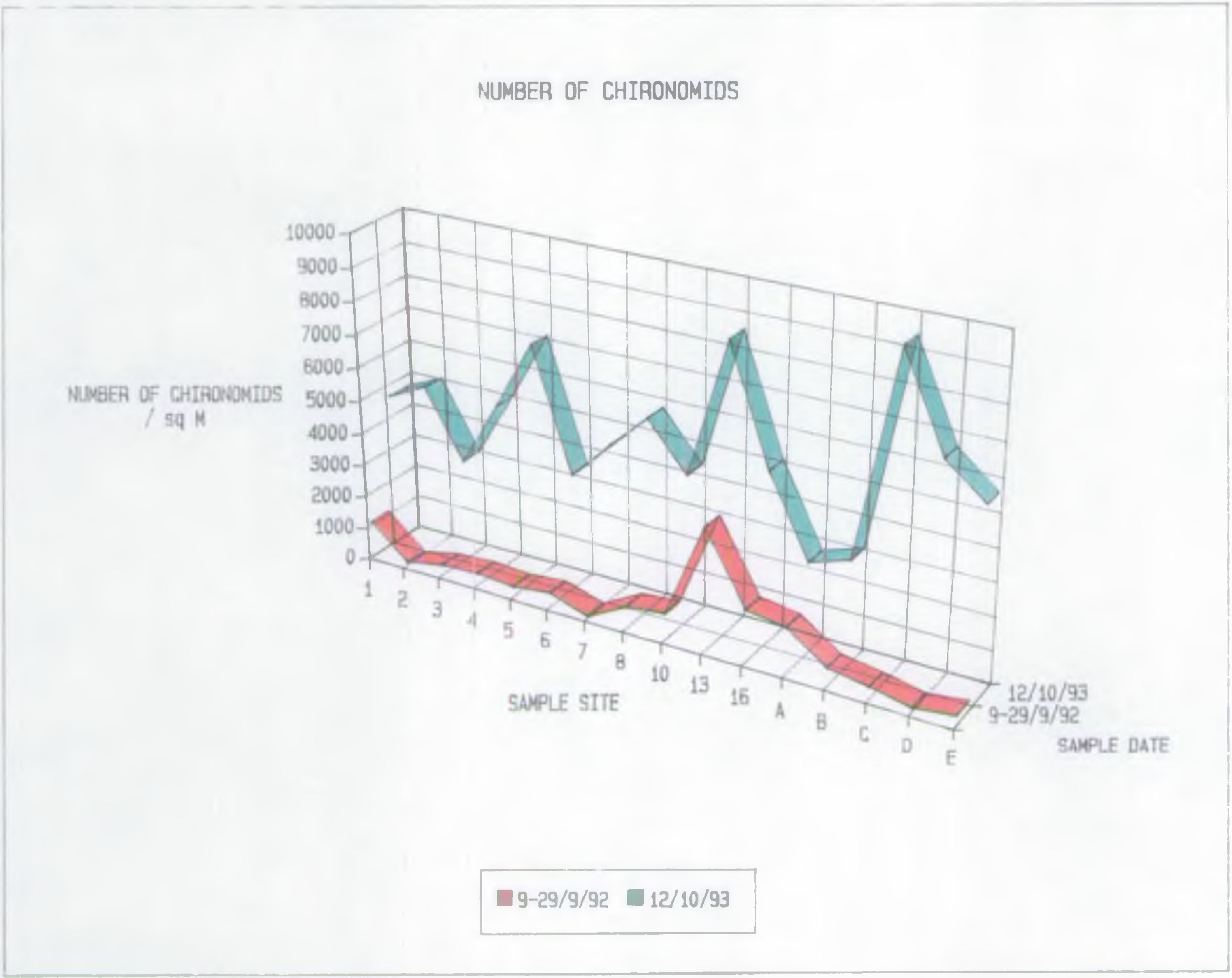


Fig. 14 COMPARISON BETWEEN THE NUMBER OF CHIRONOMIDS FOUND IN SEPTEMBER 1992 AND OCTOBER 1993.
(Figures for September are averaged if sites sampled on 9/9/92 + 29/9/92)

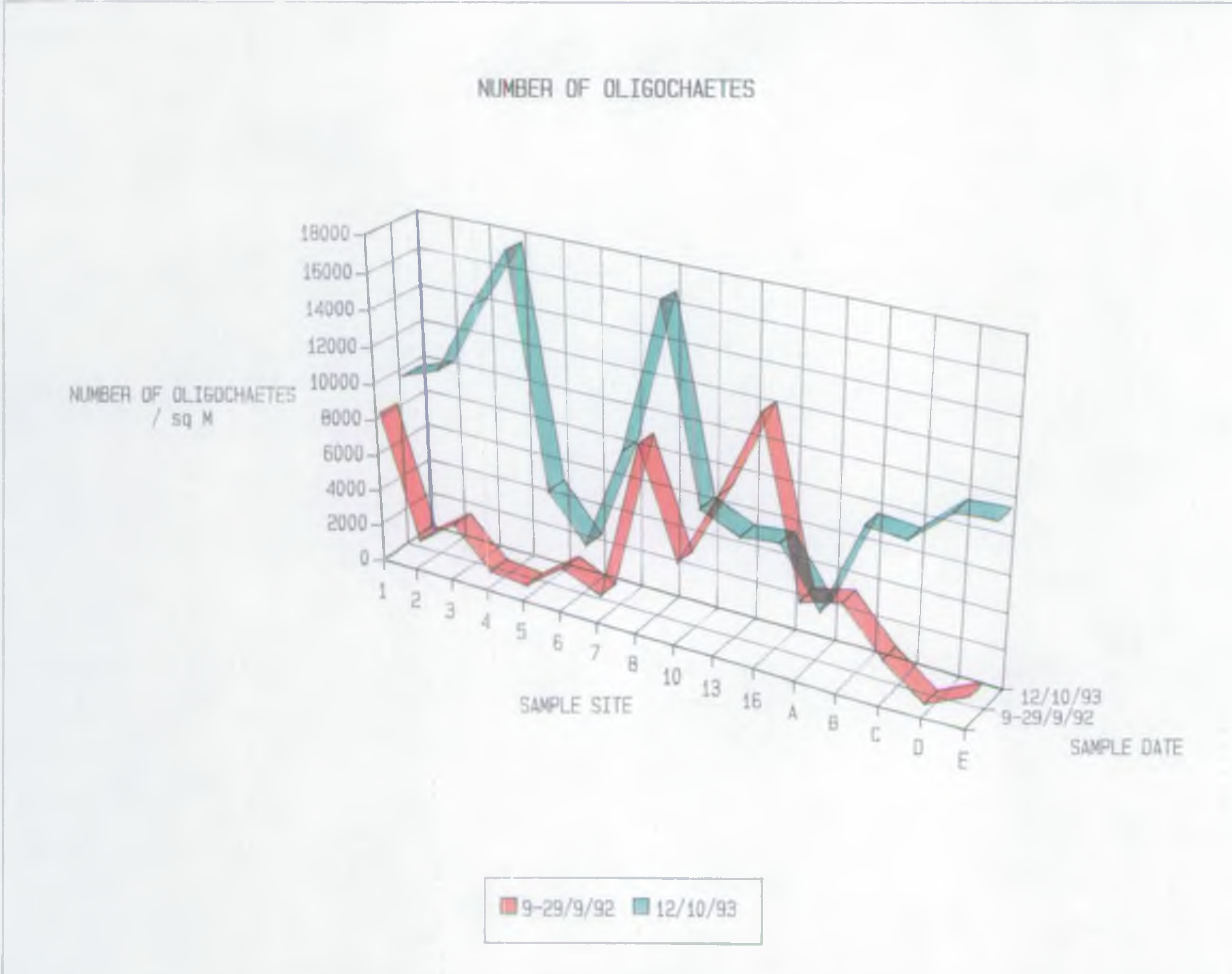


Fig. 15 COMPARISON BETWEEN THE NUMBER OF OLIGOCHAETES FOUND IN SEPTEMBER 1992 AND OCTOBER 1993.
(Figures for September are averaged if sites sampled on 9/9/92 + 29/9/92)

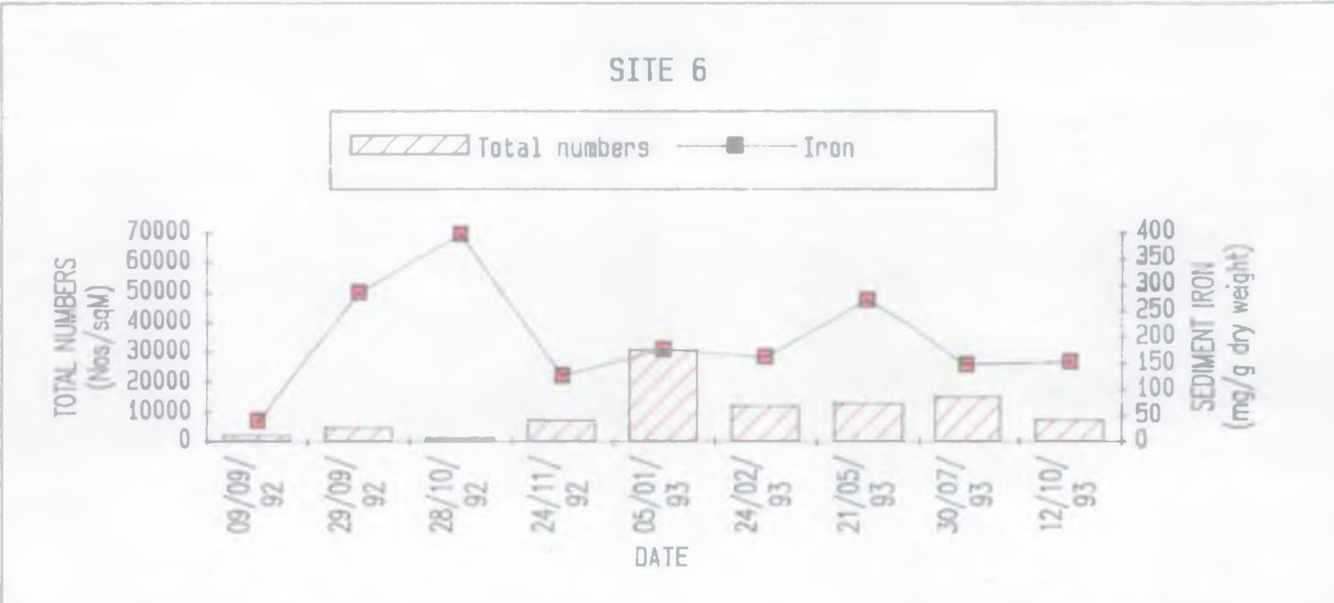
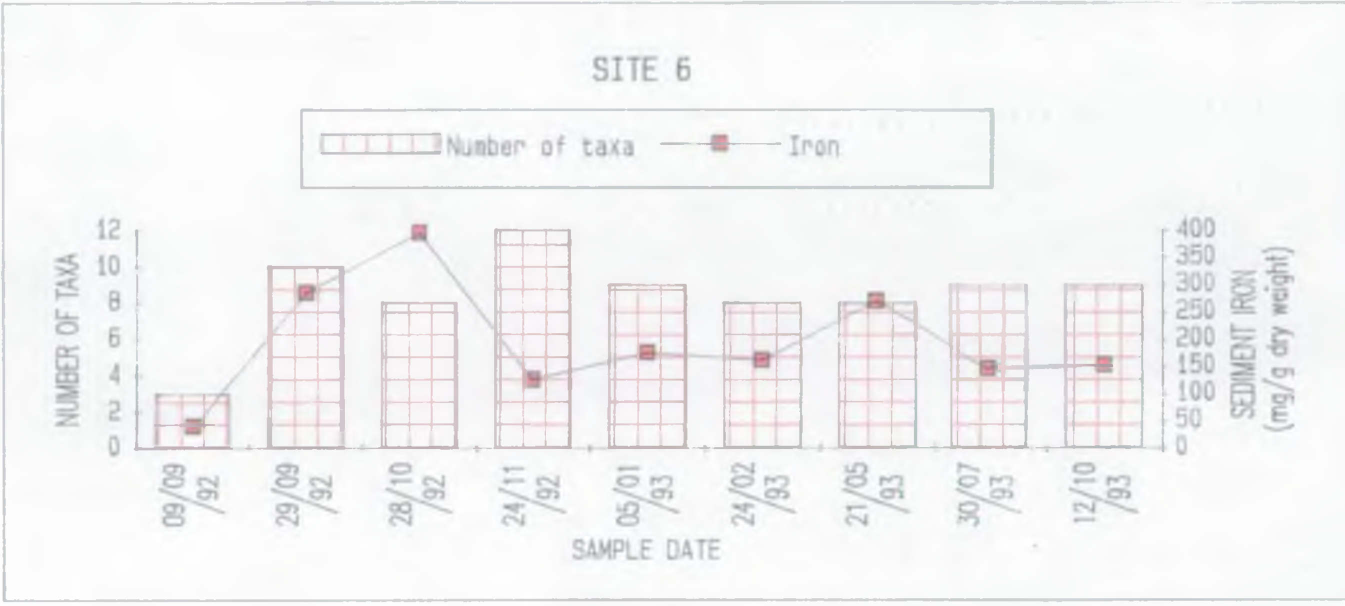


Fig. 16 TOTAL NUMBER OF INDIVIDUALS IN RELATION TO MEAN SEDIMENT IRON LEVELS.



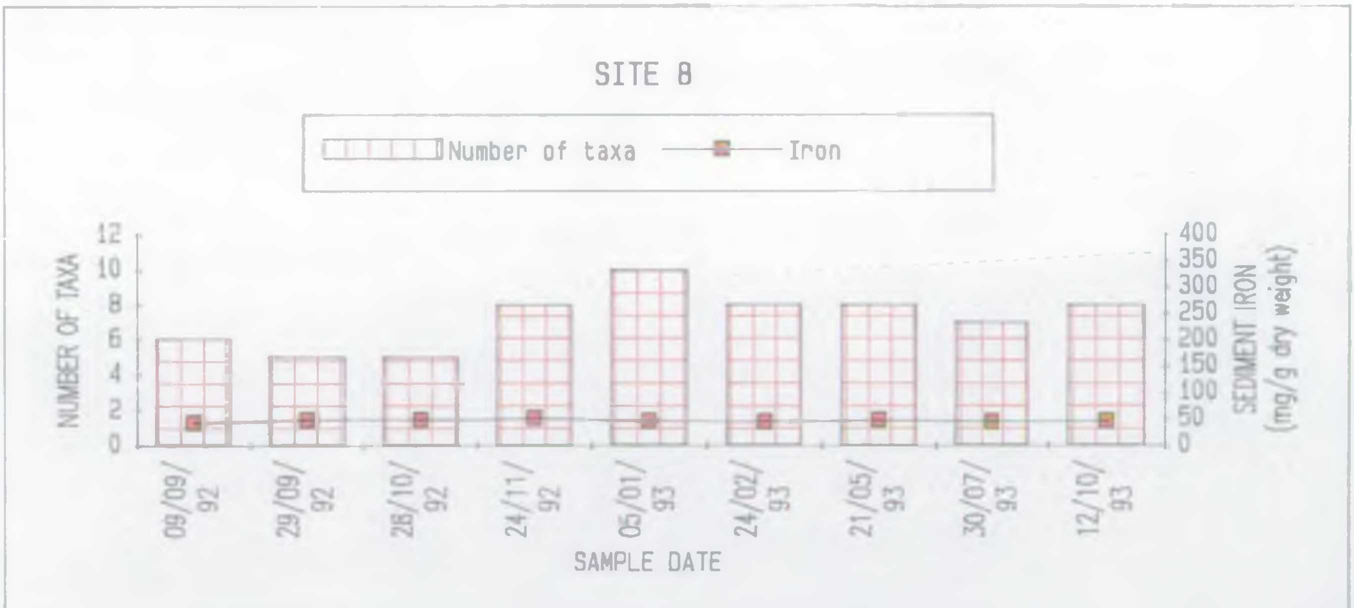


Fig. 17 NUMBER OF TAXA IN RELATION TO MEAN SEDIMENT IRON LEVELS

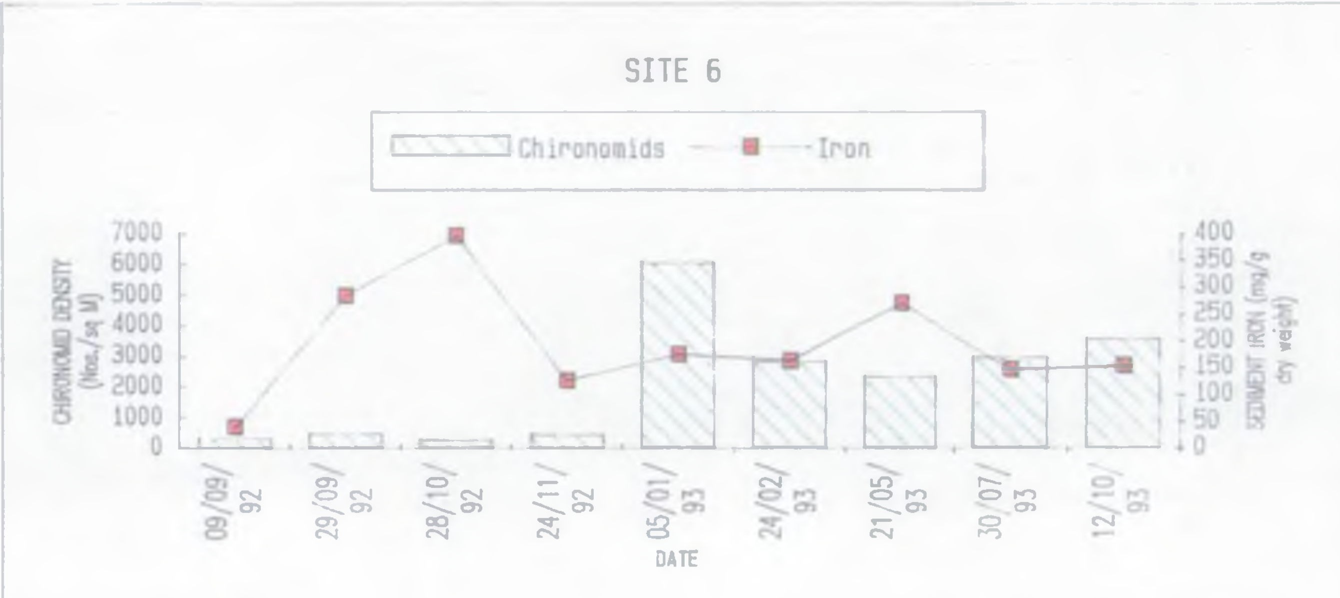


Fig.18 NUMBER OF CHIRONOMIDS IN RELATION TO SEDIMENT IRON LEVELS.

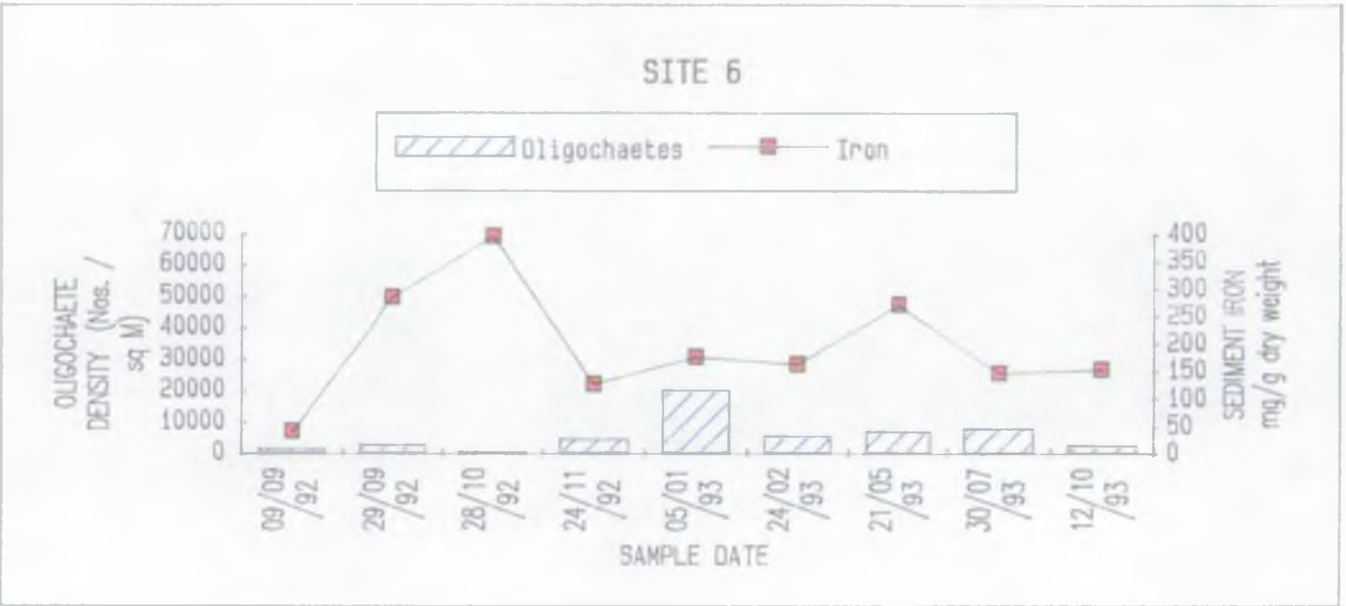
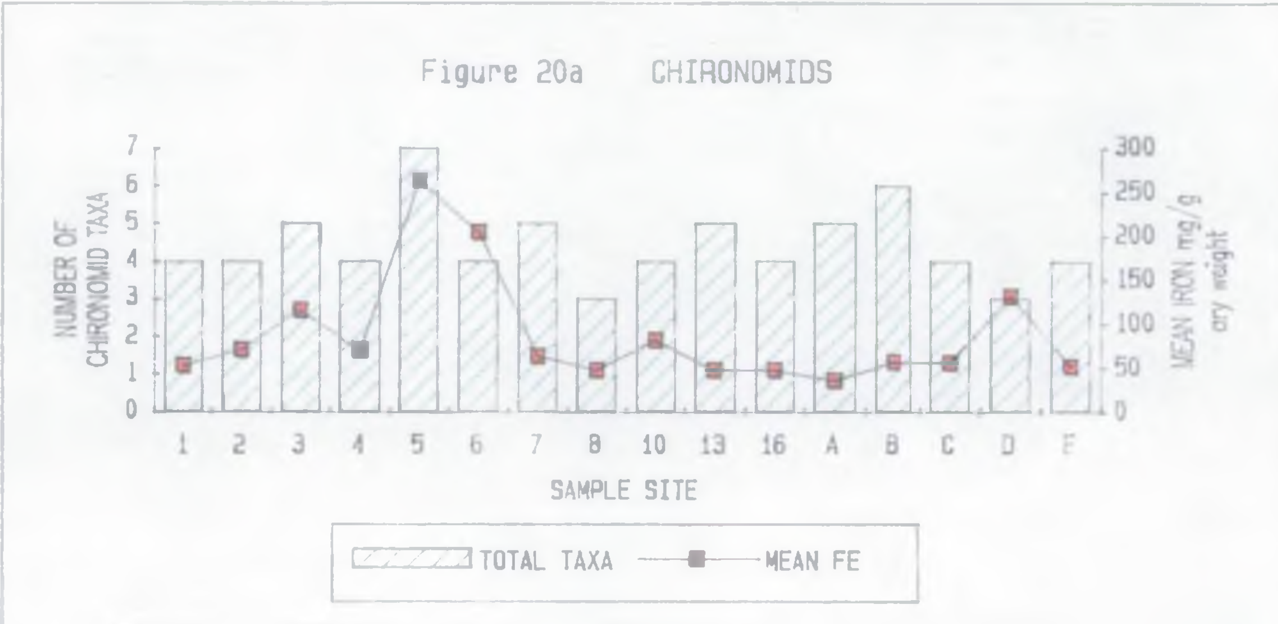


Fig. 19 NUMBER OF OLIGOCHAETES IN RELATION TO MEAN SEDIMENT IRON LEVELS.



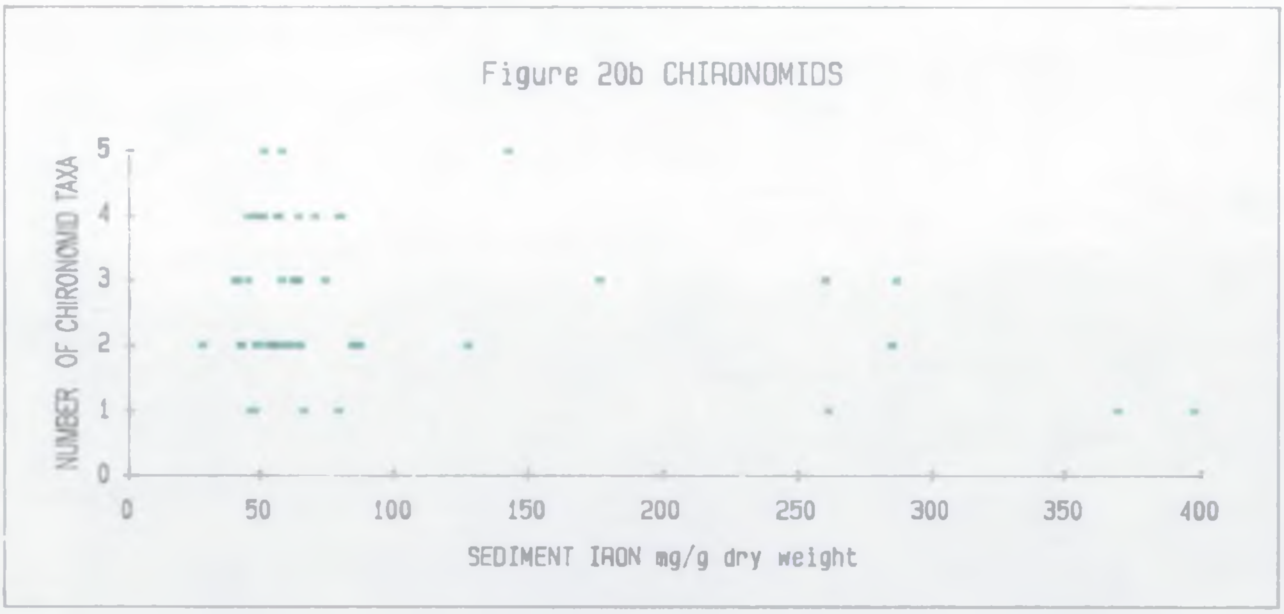
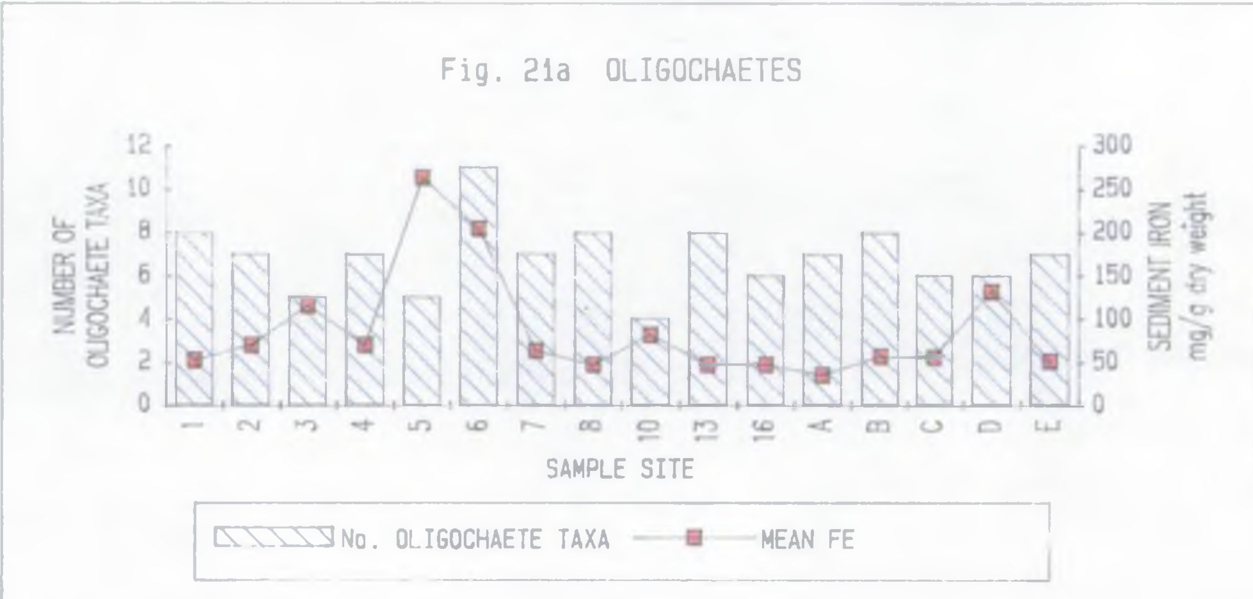


Fig. 20a,b THE RELATIONSHIP BETWEEN SEDIMENT IRON AND THE NUMBER OF CHIRONOMID TAXA. FOR PERIOD 9/9/92 - 5/1/93



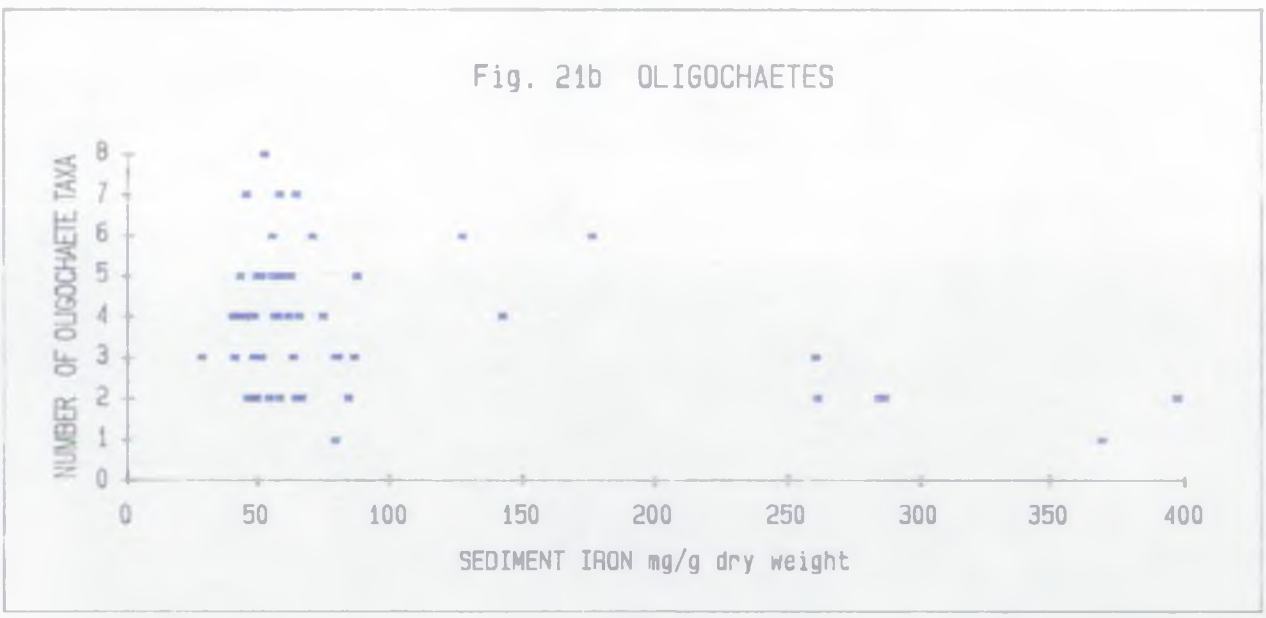
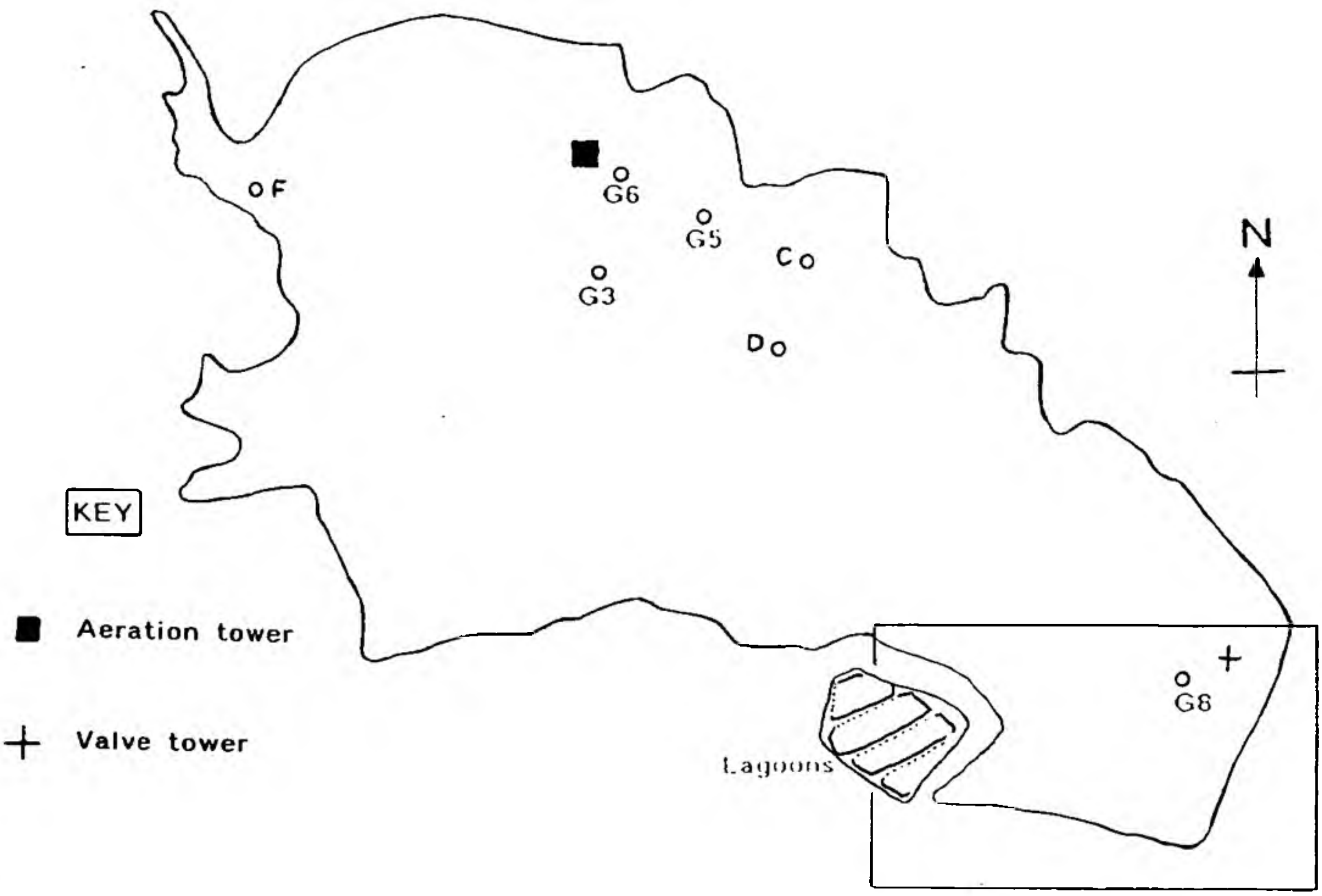


Fig. 21 a,b THE RELATIONSHIP BETWEEN SEDIMENT IRON AND THE NUMBER OF OLIGOCHAETE TAXA.
FOR PERIOD 9/9/92 - 5/1/93.

GAYNES COVE, GRAFHAM WATER



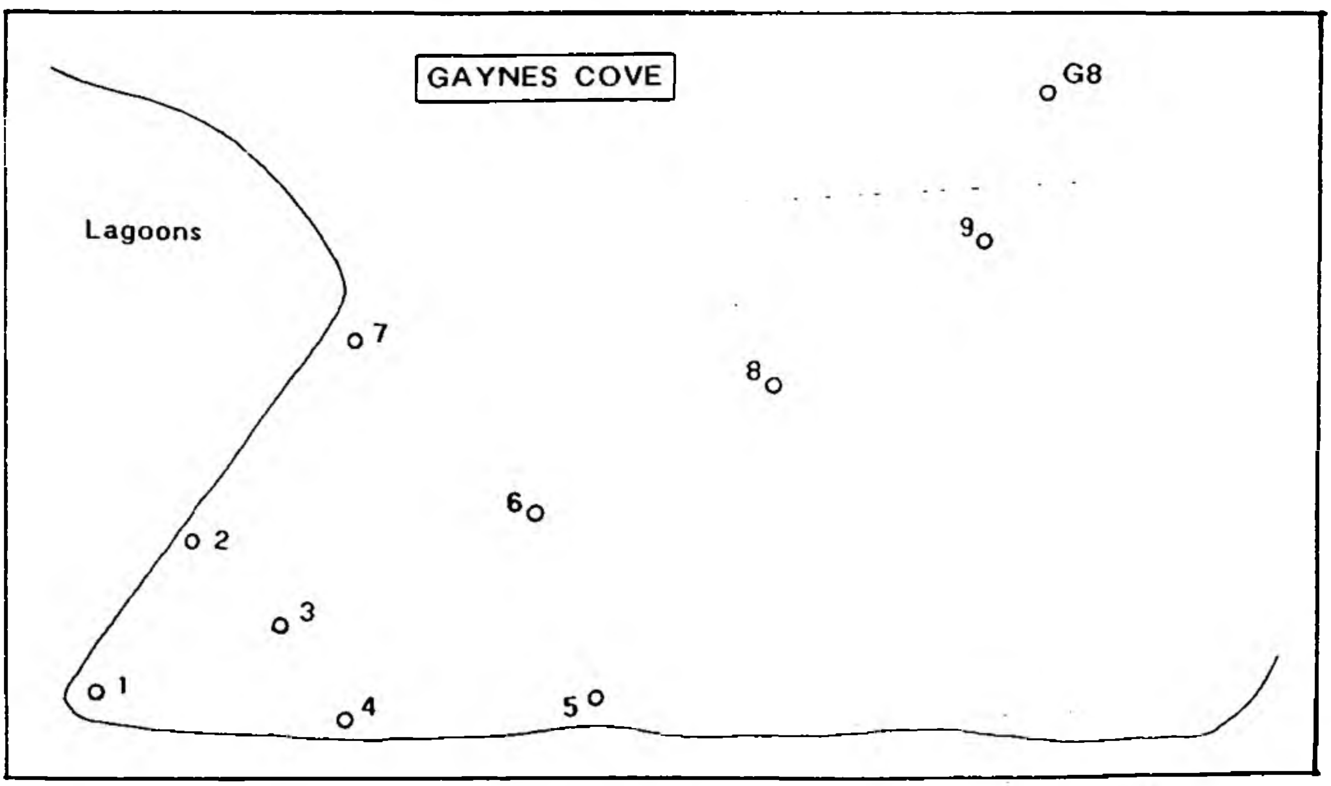


Figure 22 Gaynes Cove Site Map

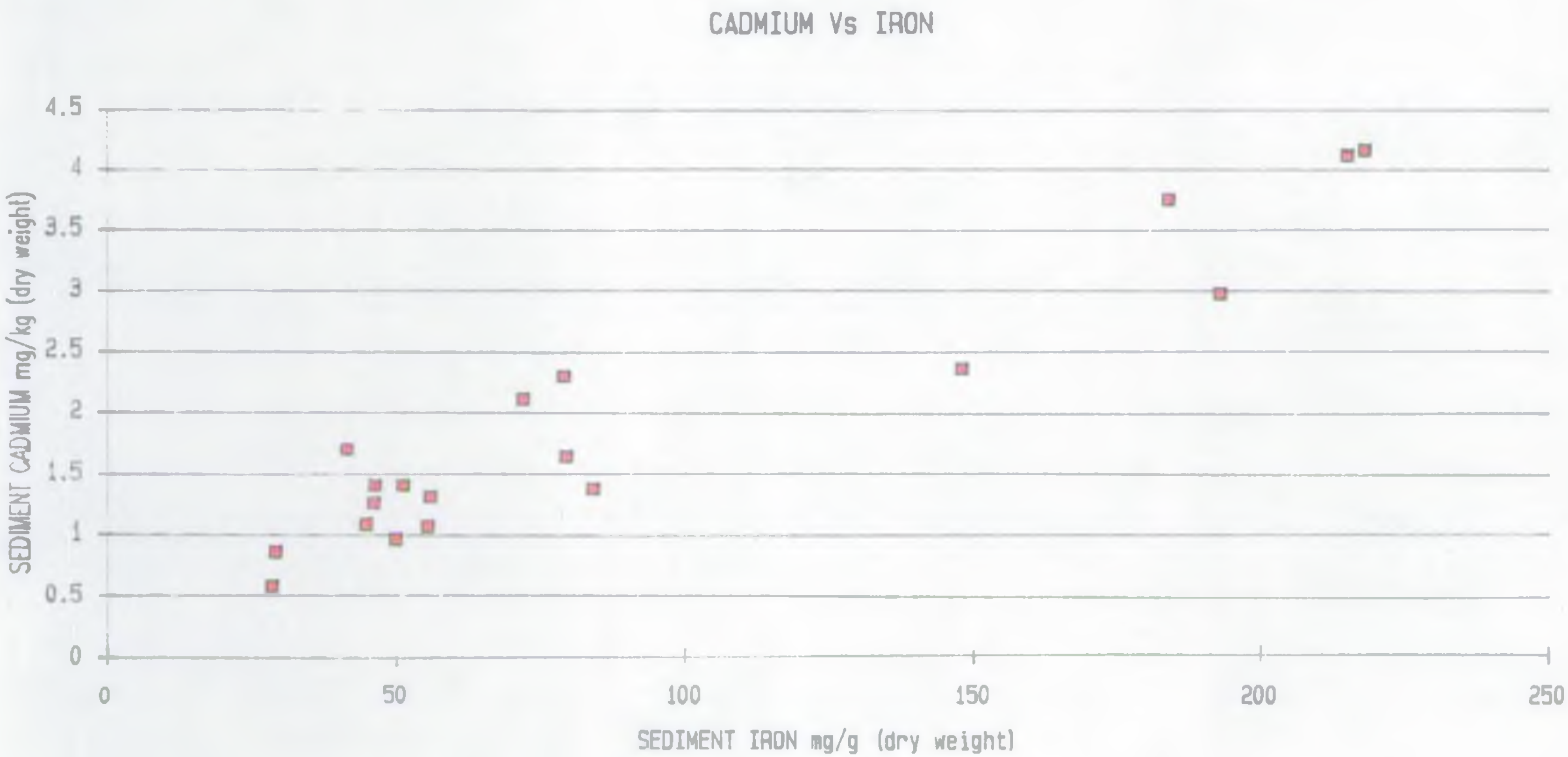


Fig. 23 GAYNES COVE AND GRAFHAM WATER SEDIMENT METALS.
COMPARISON BETWEEN IRON AND CADMIUM

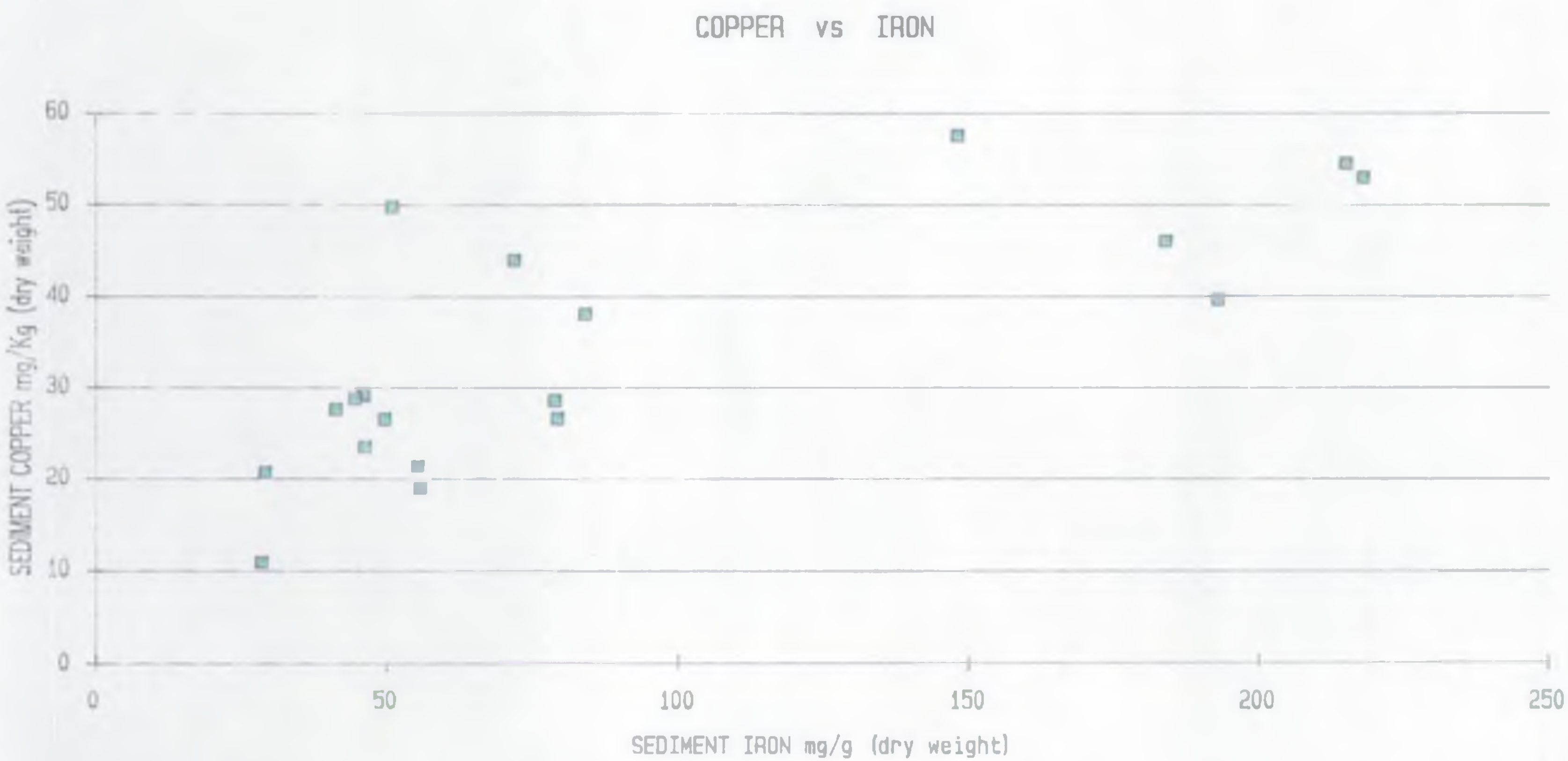


Fig. 24 GAYNES COVE AND GRAFHAM WATER SEDIMENT METALS.
COMPARISON BETWEEN IRON AND COPPER.

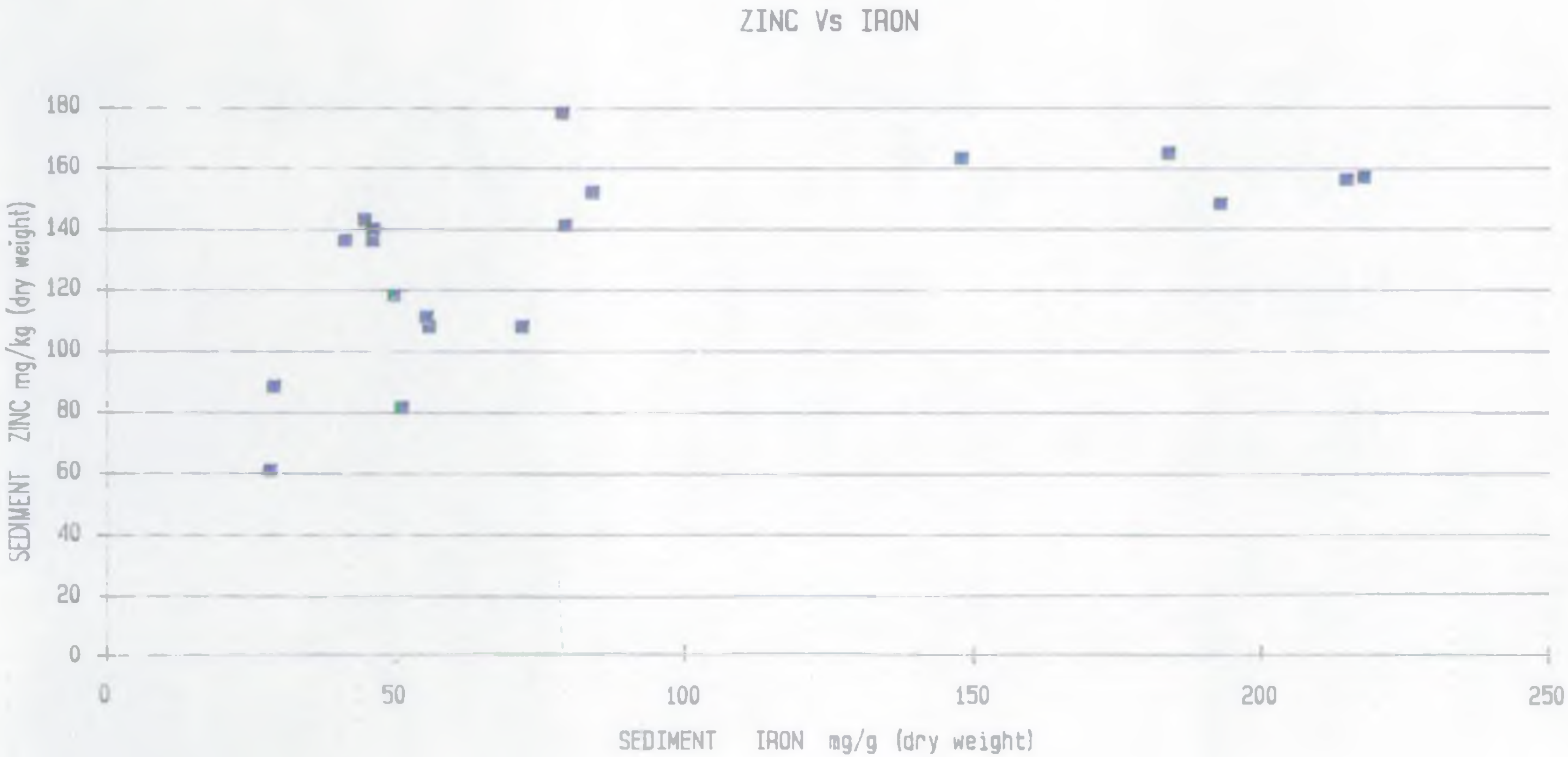


Fig.25 GAYNES COVE AND GRAFHAM WATER SEDIMENT METALS.

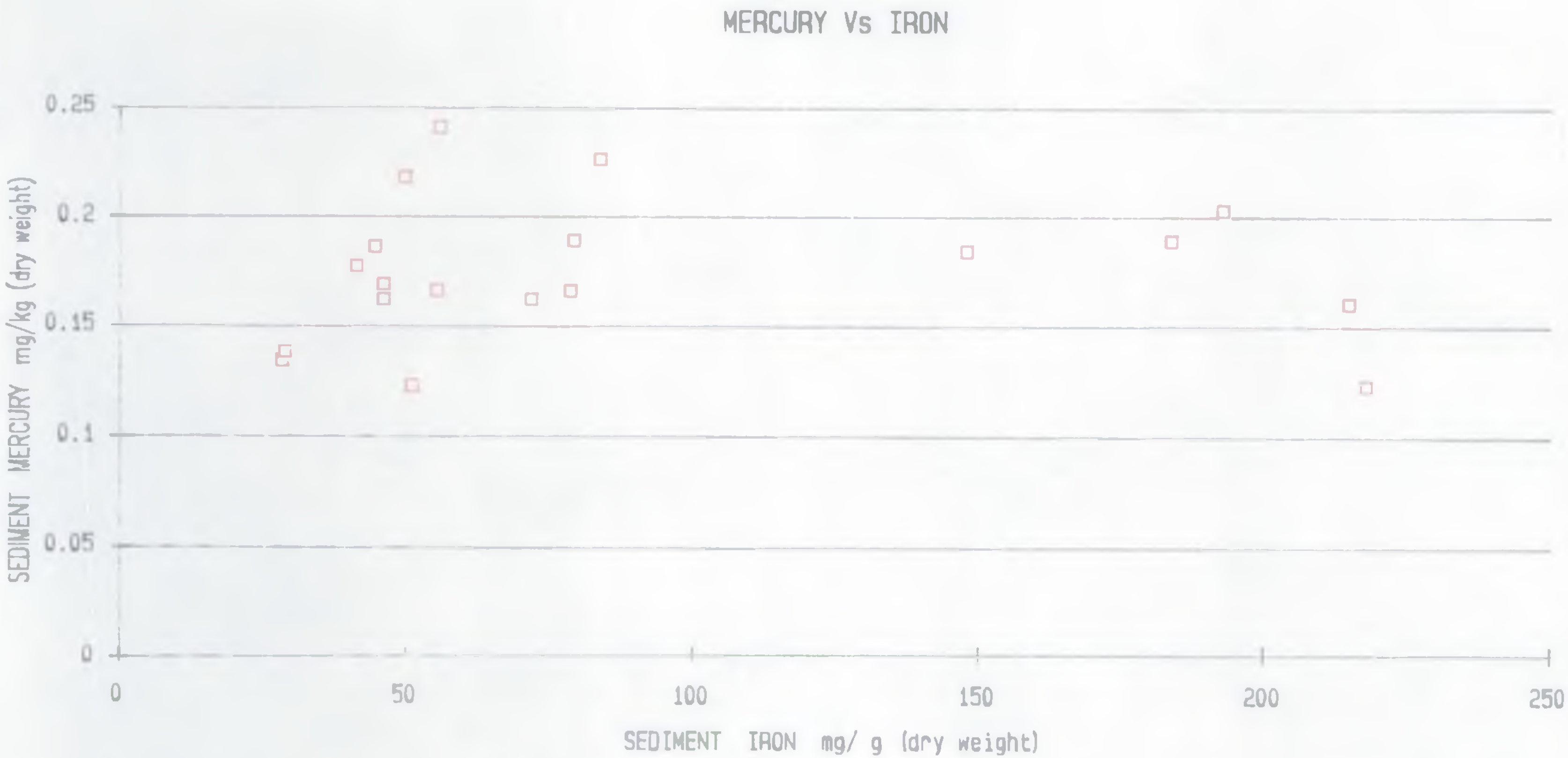


Fig. 26 GAYNES COVE AND GRAFHAM SEDIMENT METALS.

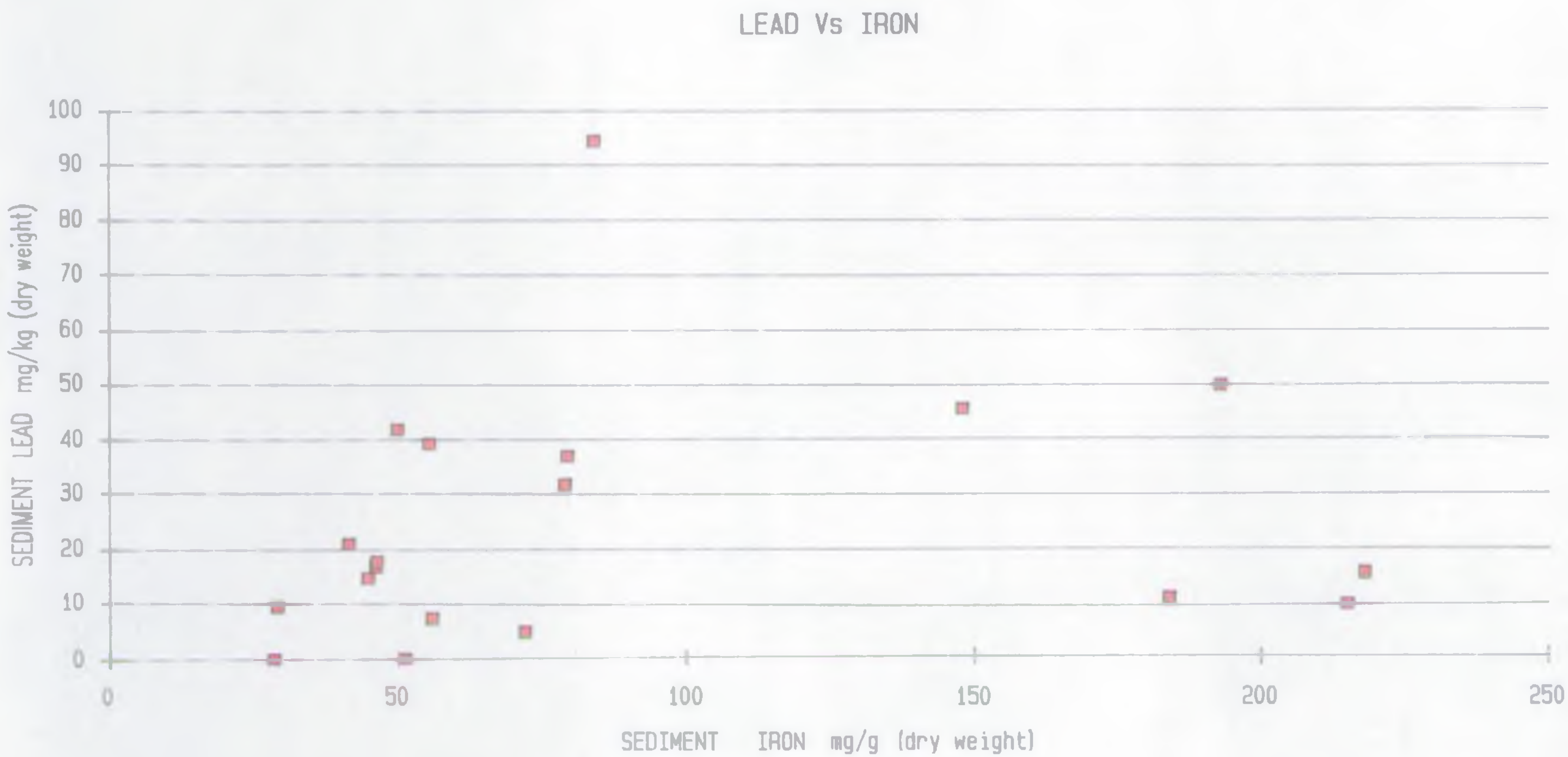


Fig. 27 GAYNES COVE AND GRAFHAM WATER SEDIMENT METALS.
COMPARISON BETWEEN IRON AND LEAD

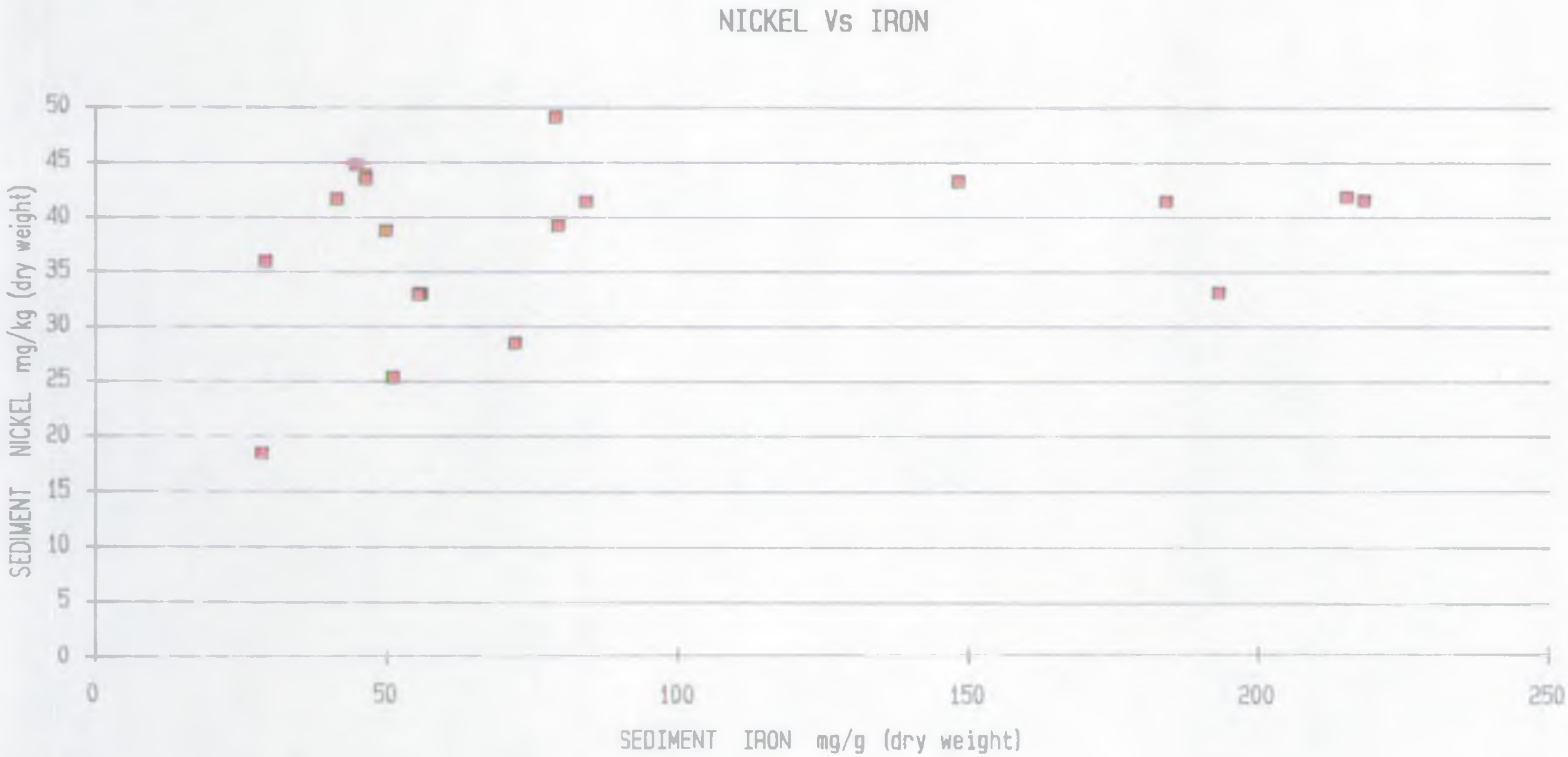


Fig. 28 GAYNES COVE AND GRAFHAM WATER SEDIMENT METALS.
COMPARISON BETWEEN IRON AND NICKEL

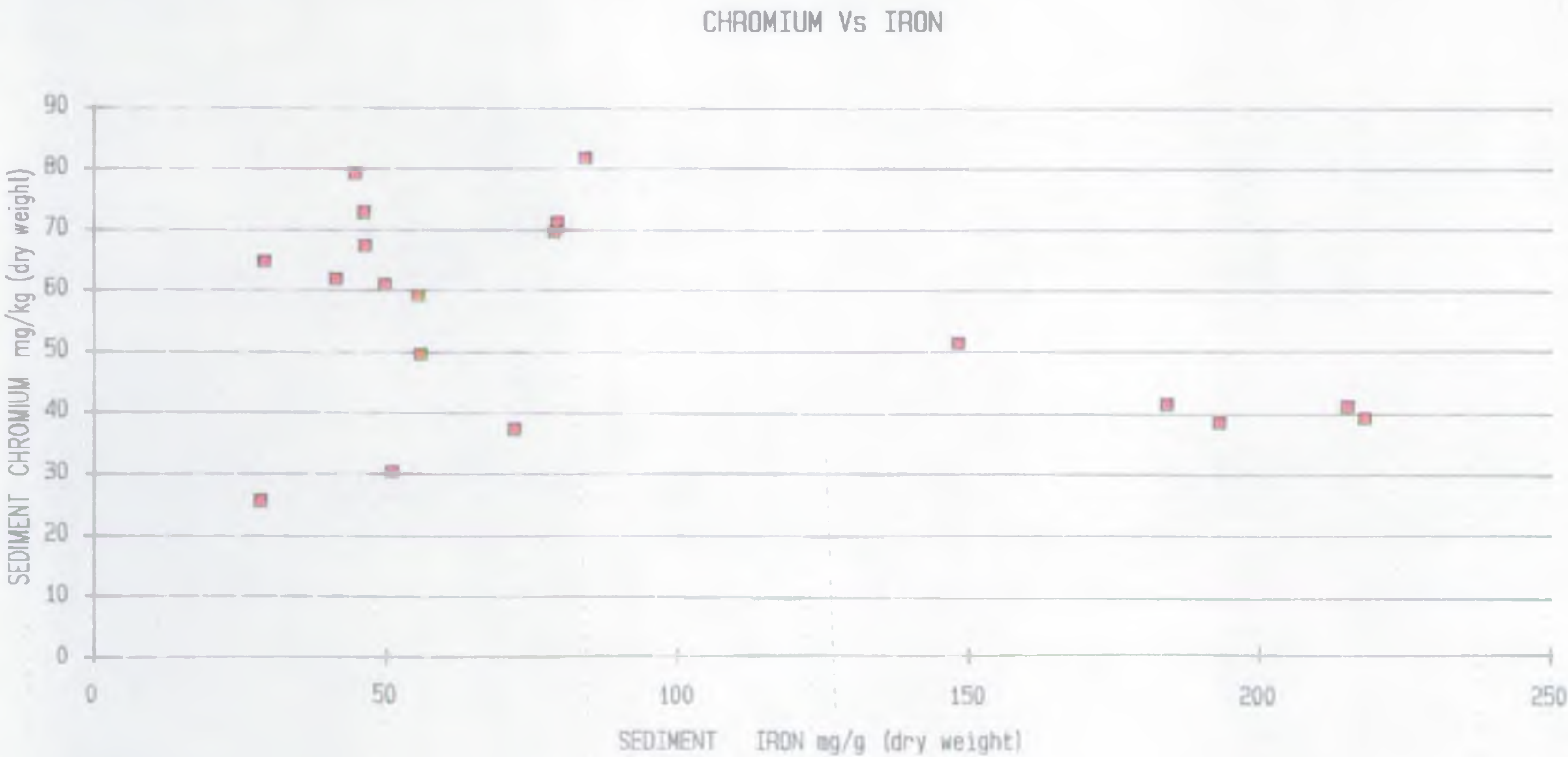


Fig. 29 GAYNES COVE AND GRAFHAM WATER SEDIMENT METALS.
COMPARISON BETWEEN IRON AND CHROMIUM

SITE	SAMPLE DATE 09/09/92	29/09/92	28/10/92	24/11/92	05/01/93	24/02/93*	21/05/93*	30/07/93*
1	44	53.8	53.4	62.2	57.1	49.5	50.8	46.2
						49.5	53.8	50.5
2	56.8		86		68.7	58.4	66.6	59.9
						63.6	60.8	65.7
3	259	64	60.3	78.7	70.8	61.9	63.8	58.4
						63.8	65.9	58.5
4	83.3		62.7		63.3	56.2	65.4	51.4
						54.7	55.3	54.7
5	368		283		141	76	72.1	76.7
						89.3	149	104
6	40.1	285	396	126	175	78.9	189	149
						245	352	144
7	78		50.3		66.3	48.9	69.2	39.6
						52.7	51.2	41.3
8	41.5	47.3	48.1	50.7	46.1	43.5	47.2	44.1
						45.2	48.2	44.8
10		85.3		78.2		53.1	53.6	54.9
						57.4	54.4	54.2
13		50.8		43.8		41.4	42.5	45.5
						41.3	42.9	51.2
16		47.2		48.2		43.9	46.8	45.9
						46.6	39.7	53.9
A	38.5		22.6		40.8	22.2	37.1	23.2
						19.8	38.9	21.5
B	54.5		57.9		56.8	43.8	54.4	48.3
						43.1	55.6	46.3
C	64.7		55.8		46.5	58	40.4	36.4
						72.3	42.1	61.1
D	260		72.7		61.1	54.8	61.7	58.6
						59	66.3	62.4
E	45		64.4		56.2	42.5	53.2	49.3
						40.3	51.8	53.2
F							42.4	34
							39.3	34.4

* Duplicates taken

TABLE 1.1 SEDIMENT IRON LEVELS (mg/g dry weight)
9 SEPTEMBER 1992 - 30 JULY 1993

SITE*	2 cm	5 cm	SAMPLE MEAN	
1A	45.6	49.9	A	47.8
1B	48.2	49.6	B	46.9
2A	56.7	56.7	A	58.7
2B	64.1	67	B	65.6
3A	59.2	58.6	A	58.9
3B	55.6	59.2	B	57.4
4A	54.2	60.3	A	57.3
4B	58.2	57.5	B	57.9
5A	71.1	58.8	A	65
5B	60.4	54.7	B	57.6
6A	199	165	A	182
6B	110	138	B	124
7A	47.3	49.1	A	48.2
7B	48.5	44.8	B	46.7
8A	44	44.7	A	44.4
8B	45.5	46.3	B	46
10A	53.1	55.1	A	54.1
10B	55.5	55.5	B	57.9
13A	45	44.7	A	44.9
13B	46.6	42.6	B	44.7
16A	51	52.5	A	51.8
16B	48	50.7	B	49.4
AA	24.9	22.7	A	23.8
AB	23.3	21.6	B	2.5
BA	50.6	53.4	A	52
BB	50.8	52.6	B	51.7
CA	54.2	56.8	A	55.5
CB	55.2	58.1	B	56.7
DA	63.8	57.6	A	60.7
DB	57.6	63.3	B	60.5
EA	50.4	57.7	A	54.1
EB	51.2	54.6	B	52.9
FA	29.1	30.3	A	29.7
FB	28.9	32	B	30.5

* Duplicates taken

TABLE 1.2 SEDIMENT IRON LEVELS (mg/g dry weight)
12 OCTOBER 1993

SITE	SAMPLE DATE 09/09/92	29/09/92	28/10/92	24/11/92	05/01/93	24/02/93	21/05/93	30/07/93	12/10/93	SITE RANGE MIN	MAX	SITE MEAN
1	44	53.8	53.4	62.2	57.1	49.5	52.3	46.6	48.3	44	62.2	52.1
2	56.8		86		68.7	61	63.7	62.8	62.1	56.7	86	65.9
3	259	64	60.3	78.7	70.8	62.9	64.9	58.5	58.2	55.6	259	86.4
4	83.3		62.7		63.3	55.5	60.4	53.1	57.6	51.4	83.3	62.3
5	368		283		141	82.7	110.6	90.4	61.3	54.7	368	162.4
6	40.1	285	396	126	175	161.9	270.5	146.5	153	40.1	396	194.9
7	78		50.3		66.3	50.8	60.2	40.5	47.4	39.6	78	56.2
8	41.5	47.3	48.1	50.7	46.1	44.4	47.7	44.5	45.1	43.5	50.7	46.2
10		85.3		78.2		55.3	54	54.6	56	53.1	85.3	63.9
13		50.8		43.8		41.2	42.7	48.4	44.7	41.3	50.8	45.3
16		47.2		48.2		45.3	43.3	49.9	50.6	39.7	53.9	47.5
A	38.5		22.6		40.8	21	38	22.4	23.1	19.8	40.8	29.5
B	54.5		57.9		56.8	43.6	55	47.3	51.9	43.1	57.9	52.4
C	64.7		55.8		46.5	65.2	41.3	48.8	56.1	36.4	72.3	54.1
D	260		72.7		61.1	56.9	64	60.5	60.6	54.8	260	90.8
E	45		64.4		56.2	41.4	52.5	51.3	53.5	40.3	64.4	52
F							40.9	34.2	30.1	28.9	42.4	35.1

TABLE 2 MEAN SEDIMENT IRON LEVELS (mg/g dry weight)
SEPTEMBER 1992 - OCTOBER 1993

SAMPLING DATE : 26/7/90

TABLE 3.1

TAXA / SITE	2	3	4	5	6	7	8	9
CHIRONOMIDAE	1474	1364	1474	1518	990	858	1100	836
OLIGOCHAETAE	770	440	1100	2200	330	968	616	660
NEMATODA	22		44		44			
SPHAERIIDAE				66				
VALVATIDAE		22						
UNIONIDAE				110				
DREISSENIDAE		22		242	22			
ERPOBDELLIDAE								
GLOSSIPHONIDAE								
GAMMARIDAE								
CULICIDAE								
TOTAL No INDIVIDUALS	2266	1848	2618	4158	1386	1826	1716	1496
NUMBER OF TAXA	3	4	3	5	4	2	2	2

SAMPLING DATE : 22/8/90

TABLE 3.2

TAXA / SITE	2	3	4	5	6	7	8	9
CHIRONOMIDAE	2024	924	1056	1430	770	704	572	726
OLIGOCHAETAE	968	1320	1166	1210	1716	2486	2068	1408
NEMATODA		22		22				
SPHAERIIDAE	22			110		22	22	
VALVATIDAE					22			
UNIONIDAE		22						
DREISSENIDAE				22				
ERPOBDELLIDAE								
GLOSSIPHONIDAE		22		44				
GAMMARIDAE								
CULICIDAE								
TOTAL No INDIVIDUALS	3014	2310	2222	2838	2506	3212	2662	2164
NUMBER OF TAXA	3	5	2	6	3	3	3	2

TABLE 3 BIOLOGICAL DATA
GRAFHAM WATER MONITORING PROGRAMME
JULY 1990 - OCTOBER 1990

Continued....

SAMPLE DATE : 20/9/90 TABLE 3.3

TAXA / SITE	2	3	4	5	6	7	8	9
CHIRONOMIDAE	594	946	616	616	616	990	1144	1958
OLIGOCHAETAE	3036	1408	902	1100	2156	1584	2024	1056
NEMATODA								
SPHAERIIDAE	396	66	110	44	66	22		
VALVATIDAE		22	22	22		22		
UNIONIDAE								
DREISSENIDAE						22		
ERPOBDELLIDAE			22		22			
GLOSSIPHONIDAE								
GAMMARIDAE	22							
CULICIDAE					22	22		
TOTAL No INDIVIDUALS	4048	2442	1672	1782	2882	2662	3168	3014
NUMBER OF TAXA	4	4	5	4	5	6	2	2

SAMPLING DATE : 23/10/90 TABLE 3.4

TAXA / SITE	2	3	4	5	6	7	8	9
CHIRONOMIDAE	1628	2024	1474	1584	1276	2288	1474	1980
OLIGOCHAETAE	4378	3608	5830	5390	2596	4378	2816	1980
NEMATODA								
SPHAERIIDAE	44	44	88	88		44		44
VALVATIDAE								
UNIONIDAE								
DREISSENIDAE								
ERPOBDELLIDAE								
GLOSSIPHONIDAE								
GAMMARIDAE								
CULICIDAE								
TOTAL No INDIVIDUALS	6050	5676	7392	7062	3872	6710	4290	4004
NUMBER OF TAXA	3	3	3	3	2	3	2	3

TABLE 3 BIOLOGICAL DATA
GRAFHAM WATER MONITORING PROGRAMME 1990
JULY 1990 - OCTOBER 1990)

Continued....

SAMPLE DATE : 23/5/91

TABLE 3.5

TAXA / SITE	2	3	4	5	6	7	8	9
CHIRONOMIDAE	1578	1267	1044	2156	1600	1311	1333	156
OLIGOCHAETAE	311	911	911	1089	2244	1511	400	1200
NEMATODA								22
SPHAERIIDAE				156				
VALVATIDAE								
HYDROBIIDAE								
LYMNAEIDAE								
DREISSENIDAE								
CULICIDAE				67	22	44	22	22
TOTAL No INDIVIDUALS sq M	1889	2178	1955	3468	3866	2866	1955	1400
NUMBER OF TAXA	2	2	2	4	3	3	3	4

SAMPLE DATE : 26/6/91

TABLE 3.6

TAXA / SITE	2	3	4	5	6	7	8	9
CHIRONOMIDAE	756	378	444	956	756	956	1356	1133
OLIGOCHAETAE	689	111	2222	667	1556	2222	2222	1556
NEMATODA	22	22						
SPHAERIIDAE								
VALVATIDAE								
HYDROBIIDAE								
LYMNAEIDAE								
DREISSENIDAE								
CULICIDAE	22							
TOTAL No INDIVIDUALS sq M	1489	511	2666	1623	2312	3178	3578	2689
NUMBER OF TAXA	4	3	2	2	2	2	2	2

Continued....

SAMPLE DATE : 22/7/91 TABLE 3.7

TAXA / SITE	2	3	4	5	6	7	8	9
CHIRONOMIDAE	867	400	600	1244	889	1289	867	1556
OLIGOCHAETAE	578	422	600	667	556	844	1778	578
NEMATODA	44		22	67	44	22	22	
SPHAERIIDAE								
VALVATIDAE								
HYDROBIIDAE								
LYMNAEIDAE								
DREISSENIDAE								44
CULICIDAE	22			89	22		22	
TOTAL No INDIVIDUALS sq M	1511	822	1222	2067	1511	2155	2689	2178
NUMBER OF TAXA	4	2	3	4	4	3	4	3

SAMPLE DATE : 30/8/91 TABLE 3.8

TAXA / SITE	2	3	4	5	6	7	8	9
CHIRONOMIDAE	400	156	111	444	156	244	556	378
OLIGOCHAETAE	89		111	1867	178	1000	1644	1178
NEMATODA					22			
SPHAERIIDAE								
VALVATIDAE								
HYDROBIIDAE								
LYMNAEIDAE								
DREISSENIDAE								
CULICIDAE	22	22		22				
TOTAL No INDIVIDUALS sq M	511	178	222	2333	356	1244	2200	1556
NUMBER OF TAXA	3	2	2	3	3	2	2	2

Continued...

SAMPLE DATE : 25/9/91

TABLE 3.9

TAXA / SITE	2	3	4	5	6	7	8	9
CHIRONOMIDAE	156			356	289	800	200	222
OLIGOCHAETAE	667	400	733	622	911	2067	2333	1756
NEMATODA								
SPHAERIIDAE								
VALVATIDAE								
HYDROBIIDAE								
LYMNAEIDAE			22					
DREISSENIDAE								
CULICIDAE								
TOTAL No INDIVIDUALS sq M	823	400	755	976	1200	2867	2533	1978
NUMBER OF TAXA	2	1	2	2	2	2	2	2

SAMPLE DATE : 23/10/91

TABLE 3.10

TAXA / SITE	2	5	6	7	8	9	14	15	16
CHIRONOMIDAE	133	326	193	326	326	178		252	30
OLIGOCHAETAE	578	1259	933	652	504	430	74	563	1081
NEMATODA									
SPHAERIIDAE									
VALVATIDAE									
HYDROBIIDAE									
LYMNAEIDAE									
DREISSENIDAE									
CULICIDAE									
TOTAL No INDIVIDUALS sq M	711	1285	1126	978	830	608	74	815	1111
NUMBER OF TAXA	2	2	2	2	2	2	1	2	2

Continued....

SAMPLE DATE : 25/11/91

TABLE 3.11

TAXA / SITE	2	5	6	7	8	9	14	15	16
CHIRONOMIDAE	1052	681	504	844	844	104		222	1126
OLIGOCHAETAE	1689	1437	1793	3170	3630	385		2030	948
NEMATODA			74	15					59
SPHAERIIDAE			15	30	15				15
VALVATIDAE									
HYDROBIIDAE				30					
LYMNAEIDAE									
DREISSENIDAE									
CULICIDAE									
TOTAL No INDIVIDUALS sq M	2741	2118	2386	4089	4489	489	0	2252	2148
NUMBER OF TAXA	2	2	4	5	3	2	0	2	4

Continued....

[redacted]

SAMPLE DATE:9/9/92

TABLE 3.12

TAXA / SITE	1	2	3	4	5	6	7	8	10	13	16	A	B	C	D	E	F
CHIRONOMIDAE	638	110	330	396	308	352	44	726				1430	572	374	132	286	
OLIGOCHAETAE	4400	1474	1122	902	682	1672	1320	12320				4114	4064	2244	594	1716	
NEMATODA	220	22	44	22				264					88	66	44	176	
HYDRACARINA	176	66	110			44	22	88				44	66			154	
SPHAERIIDAE	22	22						66				660				88	
OSTRACODA			44					44				418	66			22	
CERATOPOGONIDAE	22		66		44	88							44				
GLOSSIPHONIDAE																	
ERPOBDELLIDAE									NOT SAMPLED	NOT SAMPLED	NOT SAMPLED						NOT SAMPLED
PISCICOLIDAE																	
PLANORBIDAE																	
LYMNAEIDAE																	
VALVATIDAE																	
HYDROBIIDAE																	
ASELLIDAE																	
COROPHIIDAE																	
HYDRIDAE												594					
CULICIDAE	22												22			22	
SIALIDAE																22	
LEPTOCERIDAE												22					
CAENIDAE																	
DUGESIIDAE																	
MICROTURBELLARIA																	
UNIONIDAE																	
CORIXIDAE																	
ELMINTHIDAE																	
TOTAL No. / sq M	5500	1694	1716	1320	1034	2156	1386	13508				7292	5522	2684	770	2486	
NUMBER OF TAXA	7	5	6	3	3	4	3	6				7	7	3	3	8	

TABLE 3 BIOLOGICAL DATA
GRAFHAM WATER MONITORING PROGRAMME
SEPTEMBER 1992-OCTOBER 1993

continued...

SAMPLE DATE:29/9/92

TABLE 3.13

TAXA/SITE	1	2	3	4	5	6	7	8	10	13	16	A	B	C	D	E	F
CHIRONOMIDAE	1628		352			493		682	814	3762	1606						
OLIGOCHAETAE	12012		4940			2850		7920	4356	8470	13266						
NEMATODA	374		176			22		132	308	836	242						
HYDRACARINA	550		176			242		110	132	264	506						
SPHAERIIDAE	176		22			330		22	220	308	462						
OSTRACODA	638		66			110			22	330	352						
CERATOPOGONIDAE	22									44							
GLOSSIPHONIDAE		NOT SAMPLED		NOT SAMPLED	NOT SAMPLED		NOT SAMPLED										
ERPOBDELLIDAE																	
PISCICOLIDAE																	
PLANORBIDAE																	
LYMNAEIDAE																	
VALVATIDAE																	
HYDROBIIDAE									22					< NOT SAMPLED >			
ASELLIDAE						110											
COROPHIIDAE						132											
HYDRIDAE						484				22							
CULICIDAE						44											
SIALIDAE																	
LEPTOCERIDAE																	
CAENIDAE																	
DUGESIIDAE																	
MICROTURBELLARIA																	
UNIONIDAE																	
CORIXIDAE																	
ELMINTHIDAE																	
TOTAL No. / sq M	12782		5566			4818		9866	5874	14036	16434						
NUMBER OF TAXA	7		6			10		5	7	8	6						

TABLE 3 BIOLOGICAL DATA
GRAFHAM WATER MONITORING PROGRAMME
SEPTEMBER 1992 - OCTOBER 1993

continued...

SAMPLE DATE:28/10/92 TABLE 3.14

TAXA / SITE	1	2	3	4	5	6	7	8	10	13	16	A	B	C	D	E	F
CHIRONOMIDAE	1880	484	440	1056	286	286	2442	770	NOT SAMPLED	NOT SAMPLED	NOT SAMPLED	4400	374	3234	1188	462	NOT SAMPLED
OLIGOCHAETAE	3234	8668	5962	7062	792	484	12804	26136				8778	4840	4576	6776	6424	
NEMATODA	220	616	770	484	44		308	198				1012	902	1496	974	264	
HYDRACARINA	44	66	66	44		88	154	110				330	44	396	44	22	
SPHAERIIDAE	44	132		286			132	132				1166	88	638	462	88	
OSTRACODA	66	176	44	286	88	88	286					352	110	330	22		
CERATOPOGONIDAE	22	22			22	44	22					22		44			
GLOSSIPHONIDAE																	
ERPOBDELLIDAE																	
PISCICOLIDAE																	
PLANORBIDAE																	
LYMNAEIDAE																	
VALVATIDAE						44						44					
HYDROBIIDAE												44	22	66			
ASELLIDAE																	
COROPHIIDAE																	
HYDRIDAE						66						88					
CULICIDAE																	
SIALIDAE																	
LEPTOCERIDAE												154					
CAENIDAE												22					
DUGESIIDAE						22											
MICROTURBELLARIA																	
UNIONIDAE																	
CORIXIDAE																	
ELMINTHIDAE																	
TOTAL No. / sq M	4518	10164	7062	9218	1144	1078	16148	27346				16412	6380	17600	8646	7260	
NUMBER OF TAXA	7	7	5	6	5	8	7	5				12	7	8	6	5	

continued...

SAMPLE DATE:24/11/92

TABLE 3.15

	1	2	3	4	5	6	7	8	10	13	16	A	B	C	D	E	F
CHIRONOMIDAE	2992		1892			462		24640	2068	3982	5766						
OLIGOCHAETAE	10736		19008			4840		39644	8976	.10538	12100						
NEMATODA	748		418			110		484	572	660	440						
HYDRACARINA	330		572			198		306	176	308	462						
SPHAERIIDAE	528		308			704		959	286	966	440						
OSTRACODA	924		1474			704		88	748	990	1320						
CERATOPOGONIDAE						110				110	88						
GLOSSIPHONIDAE																	
ERPOBDELLIDAE																	
PISCICOLIDAE		N		N	N		N										
PLANORBIDAE		O		O	O		O										
LYMNAEIDAE	22	T		T	T		T										
VALVATIDAE						154			22	22							
HYDROBIIDAE		S	88	S	S	88	S	22		22	220						
ASELLIDAE		A		A	A		A							< NOT SAMPLED >			
COROPHIIDAE		M		M	M	44	M										
HYDRIDAE		P		P	P	66	P										
CULICIDAE		L		L	L		L										
SIALIDAE		E		E	E		E										
LEPTOCERIDAE		D		D	D		D			22							
CAENIDAE										22							
DUGESIIDAE																	
MICROTURBELLARIA						22		44									
UNIONIDAE										22							
CORIXIDAE																	
ELMINTHIDAE																	
TOTAL No INDIVIDUALS	16280		23760			7370		43912	12848	17666	20766						
NUMBER OF TAXA	7		7			13		8	7	12	7						

continued...

SAMPLE DATE:5/1/93 TABLE 3.16

TAXA / SITE	1	2	3	4	5	6	7	8	10	13	16	A	B	C	D	E	F
CHIRONOMIDAE	4026	1980	2266	3168	5698	6026	3344	3784				8844	5280	7260	5786	2992	
OLIGOCHAETAE	17468	37840	53460	24442	11440	20416	20372	41360				9724	30844	23518	21516	44770	
NEMATODA	484	880	462	594	264	286	484	682				506	550	484	462	660	
HYDRACARINA	418	418	792	484	550	836	330	242				990	748	440	264	946	
SPHAERIIDAE	396	880	1760	990	550	220	550	858				924	814	990	748	704	
OSTRACODA	1056	1760	2266	1254	1034	2618	462	176				770	1210	1210	1342	1320	
CERATOPOGONIDAE					154	242	22	22				154		44			
GLOSSIPHONIDAE																	
ERPOBDELLIDAE																	
PISCICOLIDAE									N	N	N						N
PLANORBIDAE									O	O	O						O
LYMNAEIDAE									T	T	T						T
VALVATIDAE												220			22		
HYDROBIIDAE		66	110	44		22	44	44	S	S	S	286	22		22		S
ASELLIDAE									A	A	A						A
COROPHIIDAE									M	M	M						M
HYDRIDAE								330	P	P	P	22	330				P
CULICIDAE									L	L	L						L
SIALIDAE									E	E	E						E
LEPTOCERIDAE	22								D	D	D			22			D
CAENIDAE					22							22					
DUGESIIDAE																	
MICROTURBELLARIA	22				154	110		22				132	22	44		22	
UNIONIDAE			22														
CORIXIDAE																	
ELMINTHIDAE																	
TOTAL No. / sq M	23892	43824	61138	30756	19866	30778	25608	47520				22616	30820	34012	30162	51414	
NUMBER OF TAXA	8	7	8	7	9	9	8	10				12	9	9	8	7	

continued...

SAMPLE DATE:24/2/93

TABLE 3.17

TAXA / SITE	1	2	3	4	5	6	7	8	10	13	16	A	B	C	D	E	F
CHIRONOMIDAE	5676	1716	1760	3080	2728	2816	3960	2992	1320	5984	6424	7194	7568	3432	1188	2772	10032
OLIGOCHAETAE	15246	38940	31548	40128	37576	5632	8580	63140	23232	10692	8404	9460	7128	22704	15840	836	40656
NEMATODA	550	2200	484	10412	616		132	748	264	836	132	2112	880	1100	132	484	76304
HYDRACARINA	814	748	880	528	132	792	308	396	600	352	616	352	440	396	352	880	968
SPHAERIIDAE	638	1056	1760	704	924	1144	308	836	1848	616	352	1892	924	1804	880	440	132
OSTRACODA	704	704	660	484	792	880	352	44	88	572	748	242	264	396	396	308	2200
CERATOPOGONIDAE		44			44	88	44		44		44	176				44	880
GLOSSIPHONIDAE								44									
ERPOBDELLIDAE																	
PISCICOLIDAE																	
PLANORBIDAE																	
LYMNAEIDAE																	
VALVATIDAE						308						176					
HYDROBIIDAE	110		396			88		132	88	44		176			44	88	
ASELLIDAE																	
COROPHIIDAE																	
HYDRIDAE	374													44			
CULICIDAE																	
SIALIDAE																	
LEPTOCERIDAE												22					
CAENIDAE												44					
DUGESIIDAE																	
MICROTURBELLARIA			44								88	88					176
UNIONIDAE																	
CORIXIDAE																	
ELMINTHIDAE																	
TOTAL No INDIVIDUALS	24112	45403	37532	45936	42812	11748	13728	68332	27544	19096	16808	14696	17204	29876	18832	5896	62348
NUMBER OF TAXA	8	7	8	6	7	8	7	8	8	7	8	11	6	7	7	8	8

continued...

SAMPLE DATE:21/5/93

TABLE 3.18

TAXA / SITE	1	2	3	4	5	6	7	8	10	13	16	A	B	C	D	E	F
CHIRONOMIDAE	4466	2662	1804	5302	4004	2332	2596	2662	3366	7458	5874	5786	3894	3432	4158	5588	3410
OLIGOCHAETAE	14608	15114	16588	22306	9724	7172	17886	23628	23870	13266	6336	6138	13860	8096	14124	14278	15620
NEMATODA	198	462	264	902	154	22	193	242	132	616	154	44	198	616	308	484	2310
HYDRACARINA	330	902	132	176	880	726	286	110	830	330	66	506	462	396	264	440	374
SPHAERIIDAE	176	638	594	902	110	242	418	286	1298	1342	484	572	528	594	506	1122	
OSTRACODA	374	176	198	814	1540	2090	594	22	176	572	220	660	550	176	198	638	572
CERATOPOGONIDAE		44	22		220	242				22				44			44
GLOSSIPHONIDAE							88										
ERPOBDELLIDAE							22										
PISCICOLIDAE																	
PLANORBIDAE												22					
LYMNAEIDAE																	
VALVATIDAE						22						88					
HYDROBIIDAE																22	
ASELLIDAE																	
COROPHIIDAE								22									
HYDRIDAE												242				22	22
CULICIDAE		44						22		22	44		66		22		
SIALIDAE																	
LEPTOCERIDAE												22					
CAENIDAE																	
DUGESIIDAE																	
MICROTURBELLARIA		44															
UNIONIDAE																	
CORIXIDAE																	
ELMINTHIDAE																	
TOTAL No INDIVIDUALS	20152	20086	19602	30404	16632	12848	22088	26944	29178	23628	13178	14080	19734	13332	19580	22594	21934
NUMBER OF TAXA	6	9	7	6	7	8	8	8	6	8	7	9	7	7	7	8	7

continued...

SAMPLE DATE:30/7/93

TABLE 3.19

TAXA / SITE	1	2	3	4	5	6	7	8	10	13	16	A	B	C	D	E	F
CHIRONOMIDAE	2332	2948	2882	2838	4004	2948	2200	2706	2024	4180	4400	1604	3036	4422	3322	3388	5940
OLIGOCHAETAE	12804	18524	13618	14454	10934	8096	20900	25212	26312	13464	17776	3564	13156	12188	16598	22308	9548
NEMATODA	352	440	66	616	22	22	528	330	220	352	220	660	396	264	506	792	1628
HYDRACARINA	132	44	264	88	308	110	88	176	176		220	616	176	154	110	220	176
SPHAERIIDAE	4708	3564	2398	2684	1782	2596	968	2486	4136	2992	1716	1716	3036	2772	3652	4356	88
OSTRACODA	2464	2068	616	1936	506	264	1188	374	660	1320	3872	1056	2376	1870	1496	2596	2816
CERATOPOGONIDAE					44	44	132										264
GLOSSIPHONIDAE	44																
ERPOBDELLIDAE																	
PISCICOLIDAE																	
PLANORBIDAE																	
LYMNAEIDAE																	
VALVATIDAE						22	44	22			88			44		220	88
HYDROBIIDAE		44	44	88		44				44	44	44				44	
ASELLIDAE																	
COROPHIIDAE																	
HYDRIDAE																	44
CULICIDAE																	
SIALIDAE																	44
LEPTOCERIDAE																	44
CAENIDAE																	
DUGESIIDAE																	
MICROTURBELLARIA					22							44					
UNIONIDAE																	
CORIXIDAE																44	
ELMINTHIDAE															22		
TOTAL No INDIVIDUALS	22836	27852	19888	22704	18678	15158	26048	31284	33528	20570	28336	9680	22176	21714	25696	33968	20614
NUMBER OF TAXA	7	7	7	7	8	9	8	6	6	6	8	8	6	7	7	9	11

continued...

SAMPLE DATE:12/10/93

TABLE 3.20

TAXA / SITE	1	2	3	4	5	6	7	8	10	13	15	A	B	C	D	E	F
CHIRONOMIDAE	4620	5148	3124	5104	7216	3564	4752	5852	4444	8624	5148	2772	3168	9460	5104	6688	5676
OLIGOCHAETAE	9504	10296	14212	17600	5060	2552	8360	16764	6292	5368	5588	2464	7700	7480	9504	9636	22704
NEMATODA	220	154	308	176	528	88	176	306	308	396	66	2068	968	484	792	572	3388
HYDRACARINA	616	220	220	176	1584	264	264	484	352	357	198	2068	176	484	352	440	748
SPHAERIIDAE	2200	1232	2244	1364	2200	264	1848	1276	2728	1320	1166	1584	2596	1980	2332	2464	1056
OSTRACODA	440	2068	2156	1452	2332	308	1276	528	484	1056	770	1320	3124	1012	968	1848	1716
CERATOPOGONIDAE	44				44	88	132			88	22	176	44	44	88		1496
GLOSSIPHONIDAE	22											44					
ERPOBDELLIDAE																	
PISCICOLIDAE						44											
PLANORBIDAE																	
LYMNAEIDAE																	
VALVATIDAE			44					22			22	308	220	88			528
HYDROBIIDAE		44	44			44		220		22	44	176	22	44	88		
ASELLIDAE																	
COROPHIIDAE																	
HYDRIDAE			176	44	44		88					88					
CULICIDAE																	
SIALIDAE																	
LEPTOCERIDAE										22		132					
CAENIDAE																	
DUGESIIDAE																	
MICROTURBELLARIA																22	22
UNIONIDAE																	
CORIXIDAE												88					660
ELMINTHIDAE																	
TOTAL No INDIVIDUALS	17666	19162	22528	25916	19008	7216	16896	25454	14608	17248	13024	12628	18018	21076	19668	21670	37994
NUMBER OF TAXA	8	7	9	7	8	9	8	8	6	9	9	13	9	9	8	7	10

TABLE 4.1

TAXA / SAMPLE DATE	26/07/90	22/08/90	20/09/90	23/10/90	23/05/91	26/06/91	22/07/91	30/08/91	25/09/91	23/10/91	25/11/91
CHIRONOMIDAE	X	X	X	X	X	X	X	X	X	X	X
OLIGOCHAETAE	X	X	X	X	X	X	X	X	X	X	X
NEMATODA	X	X			X	X	X	X			X
SPHAERIIDAE	X	X	X	X	X						X
UNIONIDAE	X	X									
DREISSENIDAE	X	X	X				X				
VALVATIDAE	X	X	X								
HYDROBIIDAE											X
LYMNAEIDAE									X		
GAMMARIDAE			X								
CULICIDAE			X		X	X	X	X			
ERPOBDELLIDAE			X								
GLOSSIPHONIDAE		X									
NUMBER OF TAXA	7	8	8	3	5	4	5	4	3	2	5

TABLE 4 TOTAL NUMBER OF TAXA RECORDED IN GRAFHAM WATER ON EACH SAMPLING OCCASION

1990 AND 1991 SURVEYS

TABLE 4.2

TAXA / SAMPLE DATE	09/09/92	29/09/92	28/10/92	24/11/92	05/01/93	24/02/93	21/05/93	30/07/93	12/10/93
CHIRONOMIDAE	X	X	X	X	X	X	X	X	X
OLIGOCHAETAE	X	X	X	X	X	X	X	X	X
NEMATODA	X	X	X	X	X	X	X	X	X
HYDRACARINA	X	X	X	X	X	X	X	X	X
SPHAERIIDAE	X	X	X	X	X	X	X	X	X
OSTRACODA	X	X	X	X	X	X	X	X	X
CERATOPOGONIDAE	X	X	X	X	X	X	X	X	X
GLOSSIPHONIDAE						X	X	X	X
ERPOBDELLIDAE							X		
PISCICOLIDAE								X	X
PLANORBIDAE							X		
LYMNAEIDAE				X					
VALVATIDAE			X	X	X	X	X	X	X
HYDROBIIDAE		X	X	X	X	X	X	X	X
ASELLIDAE		X						X	
COROPHIIDAE		X		X					
HYDRIDAE	X	X	X	X	X	X	X	X	X
CULICIDAE	X	X					X	X	
SIALIDAE	X								
LEPTOCERIDAE	X		X	X	X	X	X		X
CAENIDAE			X	X	X	X	X		
DUGESIIDAE			X						
MICROTURBELLARIA				X	X	X	X	X	X
UNIONIDAE					X				
CORIXIDAE								X	X
ELMINTHIDAE								X	
NUMBER OF TAXA	11	12	13	15	14	14	18	17	15

TABLE 4 TOTAL NUMBERS OF TAXA RECORDED IN GRAFHAM WATER ON EACH SAMPLING OCCASION

1992 - 93 SURVEY

TABLE 4.3

TAXA / SITE	2	3	4	5	6	7	8	9	14*	15*	16*
CHIRONOMIDAE	X	X	X	X	X	X	X	X		X	X
OLIGOCHAETAE	X	X	X	X	X	X	X	X	X	X	X
NEMATODA	X	X	X	X	X	X	X	X			X
SPHAERIIDAE	X		X	X	X	X	X	X			X
UNIONIDAE		X		X							
DREISSENIDAE		X		X	X	X		X			
VALVATIDAE		X	X	X	X	X					
HYDROBIIDAE						X					
LYMNAEIDAE			X								
GAMMARIDAE	X										
CULICIDAE	X	X		X	X	X	X	X			
ERPOBDELLIDAE			X		X						
GLOSSIPHONIDAE		X		X							
NUMBER OF TAXA	6	8	7	9	8	8	5	6	1	2	4

* SAMPLED ONLY ON 23/10/91 AND 25/11/91

TABLE 4 TOTAL NUMBER OF TAXA RECORDED AT EACH SITE IN GRAFHAM WATER

1990 AND 1991 SURVEYS

TABLE 4.4

TAXA / SITE	1	2	3	4	5	6	7	8	10	13	16	A	B	C	D	E	F
CHIRONOMIDAE	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
OLIGOCHAETAE	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X
NEMATODA	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
HYDRACARINA	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
SPHAERIIDAE	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
OSTRACODA	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
CERATOPOGONIDAE	X	X	X		X	X	X	X	X		X	X	X	X	X	X	X
GLOSSIPHONIDAE	X						X	X				X					
ERPOBDELLIDAE							X										
PISCICOLIDAE						X											
PLANORBIDAE												X					
LYMNAEIDAE	X																
VALVATIDAE			X			X	X	X	X	X	X	X	X	X	X	X	X
HYDROBIIDAE	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X	
ASELLIDAE						X											X
COROPHIIDAE						X		X									
HYDRIDAE	X		X	X	X	X	X			X		X	X	X		X	X
CULICIDAE	X	X				X		X		X	X		X		X	X	X
SIALIDAE																X	
LEPTOCERIDAE	X									X		X		X		X	
CAENIDAE					X					X		X					X
DUGESIIDAE						X											
MICROTURBELLARIA	X	X	X		X	X		X			X	X	X	X		X	X
UNIONIDAE			X														
CORIXIDAE												X				X	X
ELMINTHIDAE															X		
NUMBER OF TAXA	14	10	12	7	10	16	12	13	9	12	11	16	12	12	11	15	14

TABLE 4 TOTAL NUMBER OF TAXA RECORDED AT EACH SITE IN GRAFHAM WATER

1992 - 93 SURVEY

CHIRONOMIDS IDENTIFIED

SUB-FAMILY	TRIBE	GENUS/SPECIES	COMMENTS
TANYPODINAE	TANYPODINI	Procladius (choreus group)	Dominant taxa. Possibly several species
CHIRONOMINAE	CHIRONOMINI	Chironomous (plumosus group)	Dominant taxa. Possibly several species
CHIRONOMINAE	CHIRONOMINI	Polypedilum sp	Occasional taxa
CHIRONOMINAE	CHIRONOMINI	Microchironomous tener	Occasional taxa))Harnischia complex
CHIRONOMINAE	CHIRONOMINI	Cryptochironomous sp	Occasional taxa)
CHIRONOMINAE	TANYTARSINI	Tanytarsus sp	Common taxa
CHIRONOMINAE	TANYTARSINI	Cladotanytarsus sp	Common taxa

OLIGOCHAETES IDENTIFIED

TAXA	COMMENTS
Limnodrilus hoffmeisteri	Very common specimen identified in most samples over period
Limnodrilus cervix	Inreasingly common in later samples.
Limnodrilus claparedeaus	Single specimen identified.
Limnodrilus udekemianus	Very few identified in a small number of January samples.
Potamothrix hammoniensis	Commonly identified in some samples throughout period.
Potamothrix moldaviensis	Common specimen identified in most samples over period
Potamothrix bavaricus	A fairly common specimen found at most sites
Dero digitata	A fairly common specimen found at most sites
Aulodrilus pleurista	Single specimen identified in one January sample
NAIDIDAE (immature)	Very few
LUMBRICULIDAE (immature)	Single specimen
TUBIFICIDAE A	May include all Limnodrilus spp. (excluding L. helveticus) and also immature P. moldaviensis.
TUBIFICIDAE B	
TUBIFICIDAE C	May include Ryocodrilus coccineus, Tubifex tubifex. T. templetoni and P. bavaricus.

TABLE 5 CHIRONOMID AND OLIGOCHAETE TAXA IDENTIFIED IN GRAFHAM WATER.
SEPTEMBER 1992 - JANUARY 1993

TAXA / SITE	1	2	3	4	5	6	7	8	9
CHIRONOMIDAE	2068	1716	1364	1320	3344	3960	4312	4224	5324
OLIGOCHAETAE	132	264	264		4268	2992	10560	9196	7304
NEMATODA	88				44				
HYDRACARINA	1188	440	132		1760	132	1012	88	
SPHAERIIDAE	44				88	44	44	176	44
OSTRACODA	88	836	88		44		1496	176	
CERATOPOGONIDAE					88	88	44		
GLOSSIPHONIDAE	44								
PLANORBIDAE							88		
PISCICOLIDAE							44		
ASELLIDAE							44		
COROPHIDAE							44		
SIALIDAE			44						
LEPTOCERIDAE	44						44		
VALVATIDAE					44	44	308		
HYDROBIIDAE							1100		
CAENIDAE							264		
CORIXIDAE	132	132							
NUMBER OF TAXA	9	5	5	1	8	6	14	5	3
TOTAL No. / sq M	3,828	3,388	1,892	1,320	9,680	7,260	19,404	13,860	12,672

TABLE 6 GAYNES COVE SURVEY
INVERTEBRATE DATA

	1	2	3	4	5	6	7	8	9	G3	G5	G6	G8	C	D	F
CADMIUM mg/kg	2.1	1.4	4.11 2.35	4.15 2.97	1.3	3.75 1.37	0.577	0.962	1.25	1.7	1.07	1.64	1.08	1.4	2.29	0.859
IRON mg/g	72	51	215 148	218 193	55.8	184 84	28.4	49.8	46.1	41.3	55.3	79.4	44.6	46.2	78.9	29
COPPER mg/kg	43.9	49.7	54.4 57.5	52.8 39.6	18.9	46 38	10.9	26.5	29.1	27.5	21.4	26.6	28.7	23.5	28.5	20.7
CHROMIUM mg/kg	37.4	30.3	41.2 51.5	39.2 38.5	49.6	41.4 81.7	25.4	60.9	72.8	61.8	59	71.1	79.1	67.3	69.6	64.6
ZINC mg/kg	108	81.4	156 163	157 148	108	165 152	61	118	136	136	111	141	143	140	178	88.2
LEAD mg/kg	5.1	<5.0	10 45.6	15.7 49.8	7.39	11.3 94.3	<4.81	41.8	16.7	20.9	39.2	36.8	14.6	17.7	31.5	9.38
MERCURY mg/kg	0.162	0.132	0.16 0.184	0.123 0.203	0.241	0.189 0.226	0.134	0.218	0.169	0.177	0.166	0.189	0.186	0.162	0.166	0.138
NICKEL mg/kg	28.4	25.3	41.8 43.3	41.5 33.1	33	41.4 41.4	18.4	38.7	43.8	41.6	32.9	39.2	44.7	43.4	49.1	35.9

TABLE 7 GAYNES COVE GRAFHAM WATER SEDIMENT METAL ANALYSIS

METAL	TARGET	DIRECTIVE	LIMIT
CADMIUM	1.4	7.5	
MERCURY	0.5	1.6	15
COPPER	35	90	
NICKEL	40	45	100
ZINC	300	1000	2500
CHROMIUM	115	155	
LEAD	70	160	700

TABLE 8 SEDIMENT QUALITY STANDARDS (VALUES IN ug/g)

DERIVED BY THE INSTITUTE FOR PUBLIC HEALTH AND ENVIRONMENTAL PROTECTION, THE NETHERLANDS

(ANALYTICAL METHOD USED - SEDIMENT BACKGROUND APPROACH)

TRACE METALS	PPM W/W
CADMIUM	2
MERCURY	<0.05
COPPER	0.5
NICKEL	12
ZINC	80
CHROMIUM	3
LEAD	5
MANGANESE	700
COBALT	18
TITANIUM	600
ARSENIC	<1
IRON (Fe^{3+})	11.36%
IRON (Fe^{2+})	0.16%
FREE ACID AS H_2SO_4	0.37%

TABLE 9 ANALYSIS OF FERRIC SULPHATE (W GRADE) USED BY ANGLIAN WATER SERVICES AT RUTLAND WATER