Hydraulics Research
Wallingford

ESTUARINE TRANSMISSION OF HEAVY METAL POLLUTANTS

Pilot study of the River Tees

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ABSTRACT

The UK has obligations under international conventions and the directives of the EEC to control the pollution of the aquatic environment resulting from the discharge of dangerous substances. Legislative control of marine pollution from freshwater sources demands a more thorough understanding of the processes involved in the transmission of pollutants through a tidal estuary.

Hydraulics Research (HR) has been engaged in field studies of the estuarine transmission of heavy metal pollutants to determine to what extent metals entering an estuary from an outfall or freshwater source are retained within the estuarine sediments and how much (if any) passes out to sea. Previous attention has been focussed on the tidal River Parrett, an industrially polluted estuary in Somerset. The present field study was conducted to establish the feasibility of the Tees estuary as an area for further investigation in order to extend and consolidate the results of the previous studies. A field study was mounted in March 1981 and consisted of 4 main elements;

- sampling of bed sediments from Yarm Bridge downstream to the estuary mouth,
- sampling of bank deposits from Yarm Bridge upstream to Croft-on-Tees,
- sampling of the waters from the accessible outfalls and tributaries
- monitoring of water velocity, direction of flow, suspended solids concentration, salinity, temperature and dissolved oxygen content at 3 selected positions within the estuary, each one for the duration of a tidal cycle.

All sediment samples underwent particle size analysis prior to determination of the concentration of Zn, Pb, Fe, Cu, Co and Mn. Water samples of the outfalls were analysed for suspended solids concentration and metals concentrations. Water samples taken at the 3 monitoring positions were analysed for suspended solids concentration only.

This report outlines the methods of sample collection and analysis, presents and comments on the results and assesses the suitability of the Tees estuary as an area for further investigation in HR's research program into the estuarine transmission of heavy metal pollutants.

CONTENTS

TABLES

FIGURES

FIGURES (CONT'D)

1 INTRODUCTION

The Department of the Environment (DoE) has commissioned Hydraulics Research (HR) to study the estuarine transmission of heavy metal pollutants in an attempt to determine the extent to which they are accumulated within an estuary or passed out to sea and the factors affecting their transmission. This report is one of a series covering several aspects of this investigation.

Previous research by HR has been in the form of extensive field studies of the tidal River Parrett an industrially polluted tributary of the Severn Estuary. In order to establish whether the phenomena identified in the Parrett study were peculiar to that regime or occur in estuaries more generally, comparative data from another industrially polluted estuary was sought. In addition, to reduce the number of variables and thus aid the identification of measurable parameters, a hydraulically less dynamic estuarine system than that of the Parrett/Severn was of particular interest. To meet these requirements the estuary of the River Tees, N.E. England (Fig 1) was selected for appraisal.

Accordingly a pilot study was carried out by HR in March 1981 to identify the location of fine sediment and assess the suitability of the Tees estuary for further research. This report presents field data collected in the River Tees by HR during spring tides between 17-23 March 1981. Details of the survey work are presented under the categories of metal concentrations, sediment size and sediment transport, the methods of sample collection and analysis are outlined in each chapter and the results presented in tabulated and graphical form. Finally the results are commented on and the suitability of the Tees for further investigation is assessed.

2 METAL CONCENTRATIONS

The River Tees and its estuary flow through a highly industrialized area with supplies of heavy metals entering the river, its tributaries and estuary from various outfalls, Fig 2. There is also sufficient fine sediment in the estuary with the potential to scavenge these metals.

To identify the sources of heavy metals and assess their possible accumulation within the estuarine sediments, water samples from accessible outfalls and tributaries and samples of estuarine sediments were taken and subsequently analysed for Zinc (Zn), Lead (Pb), Iron (Fe), Copper (Cu), Cobalt (Co) and Manganese (Mn) concentrations. Details of the sampling exercises on outfall/tributary waters, bed sediments and bank deposits are given under their respective subtitles below. Concentrations of metals occurring in both water and sediment samples were determined by Charter Consolidated Services Ltd (CCS Ltd) using an acid-digestion/atomic absorption method of analysis (Outlined in Ref 1).

2.1 Concentrations in waters of outfalls and tributaries

To measure the concentration of metals entering the River Tees and its estuary, via tributaries and outfalls, bottle samples were taken where access could be gained. These locations are marked in Fig 3. Within the scope of this pilot study practical restrictions prevented the sampling of the outfalls discharging from the main industrial area between Billingham and Teesmouth.

On return to HR the samples were analysed for total solids content prior to determination of total metal concentrations. The results of the total solids content and total metal concentration analyses are presented in Table 1.

2.2 Concentrations on bed sediments

Samples of estuarine bed sediments were collected at approximately 1 km intervals along the tidal River Tees from Yarm road bridge to the estuary mouth. These were taken in mid channel from a survey vessel using a 2 litre Van Veen grab sampler at the positions marked in Fig 3. The samples were stored in plastic bags prior to analysis. This consisted of size analysis at HR (described in Chapter 3) and determination of heavy metal concentrations (Zn, Pb, Fe, Cu, Co and Mn) on the silt fraction by CCS Ltd. Results of the heavy metal determinations are given in Table 2. The longitudinal concentration distributions of the metals are presented in Figs 4 to 9.

2.3 Concentrations on bank deposits

Samples of the bank mud deposits were collected at accessible locations along the River Tees from Yarm road bridge to the Tees-Skerne confluence at Croft-on-Tees and also near the tidal limit of the River Leven, a tributary of the Tees. These surface smears were taken using a hand held scoop at the positions marked in Fig 3. The samples were stored in plastic bags prior to metals analysis which was identical to that for bed sediments. Results of the heavy metal determinations on these bank deposits are given in Table 3.

3 SEDIMENT SIZE ANALYSIS

It is well documented that heavy metals have an affinity for the silt fraction (ie < 0.063mm) of a given sediment (Ref 2), consequently all sediment samples were analysed for particle size distribution.

The procedure for measuring the size distribution of sand and similar materials is to sieve through a nest of standard sieves. This was carried out in the HR Sedimentology Laboratory using techniques described in Ref 3, the smallest sieve having an aperture of 0.063mm. The particle size distribution of the fraction < 0.063mm was determined in the HR Sed. Lab. using a standard settling tube technique described in Ref 3.

The results of both types of analyses are combined to give a particle size distribution curve, some examples of which are presented in Figs 10 to 12. Fig 10 is fairly typical of the curves for bed sediment samples from the lower reaches of the estuary, ie downstream (d/s) km 15 and Fig 11 is fairly typical of those from the upper reaches, ie upstream (u/s) km 15. Fig 12 is representative of the curves for the bank deposits. The particle size distribution of the fraction < 0.063mm was not determined for the bank samples. Values for percentage silt content, D_{50} and D_{80} for each of the sediment samples are given in Table 4. The longitudinal distribution of percentage silt content of bed sediments is given in Fig 13.

4 SEDIMENT TRANSPORT

In order to study the tidal sediment movement within the Tees estuary and calculate the sediment flux, suspended sediment and related flow data was collected during the hydraulic survey in March 1981.

Simultaneous observations of water depth, velocity, direction of flow, salinity and temperature were recorded on separate days but days of similar tidal range at the three boat survey positions shown in Fig 3. Current velocity and direction were recorded using a Braystoke directional current meter. Concurrent measurements of salinity and temperature were taken by an I.O.S. salinometer attached to the current meter.

Coincidental measurements of suspended solids content were taken by a Partech suspended solids monitor also attached to the current meter. Readings from all instruments were recorded on board the survey vessel and are presented in tables 5 to 7.

4.1 Sediment flux calculations

Sediment flux calculations were carried out on the data obtained from the 3 boat survey positions. Calculations of net tidal transport through the cross-section of the channel at each position are presented in the following table.

Survey position	Sediment flux calculations		
	Flood tide (tonnes)	Ebb tide (tonnes)	Difference (tonnes)
1	910	738	u/s 172
2	52	177	d/s 125
3	46	807	d/s 761

5 COMMENTS ON RESULTS

The results of analysis on the metal concentrations, sediment size and sediment transport are commented on below.

5.1 Metal concentrations

5.1.1 Concentrations in waters of outfalls and tributaries

1. Only a small proportion of the potential sources of heavy metal pollutants were sampled. The results obtained are therefore indicative rather than representative of pollutant sources in the Tees.

2. The River Skerne contains a significantly higher concentration of Zn and a slightly higher concentration of Fe than the other sampled waters.

3. Stainsby Beck has a higher concentration of Pb than the other sampled waters.

4. There is no obvious correlation between weight of dry solid matter and total metal concentration in these samples.

5.1.2 Concentrations on bed sediments

1. Metals tend to occur in similar relative proportions in each sample such that a sample containing a high concentration of any one metal generally contains a high concentration of other metals.

2. The concentration of all metals are generally lower at the estuary mouth than further upstream. However, there is no overall concentration gradient for any of the metals, instead concentration peaks occur at various positions throughout the tidal reaches of the Tees. (These peaks are common to all metals at approximately km 5-6, 14, 17-18, 22-23 and 27 and at intermediate locations for individual metals).

3. Concentration peaks between approximately km 5 and km 18 generally coincide with the location of known outfalls (which are also at their most abundant along this reach). The relationship is not as close upstream of km 18, the occurrence of outfalls is also far less frequent along this reach of the Tees.

5.1.3 Concentrations on bank deposits

1. Concentrations of Zn, Pb, Fe and Co on bank deposits were similar to those on bed sediments.

2. Cu concentrations were ~ 30% lower on bank deposits than on bed sediments

3. Mn concentrations were ~ 100% higher on bank deposits than on bed sediments.

4. These comparative values are maintained both upstream and downstream of the tidal limit of the Tees.

5.2 Sediment size

1. There is a large variation in the particle size distribution of the individual sediment samples.

2. There is no regular gradient of particle size increase or decrease, with distance upstream from the estuary mouth.

3. Sediments containing a high percentage of silt (i.e. approximately > 70%) occurred throughout the tidal reaches of the Tees but were most frequent between km 3-15. Conversely sediments containing a low percentage of silt (i.e. approximately < 30%) also occurred throughout the tidal reaches of the Tees but were most frequent from km 15 upstream.

4. The location of km 15 is of further significance as it approximately coincides with the upstream limit of dredging and the confluence of Billingham Beck with the Tees.

5. To establish any correlation between percentage silt content and metal concentration these two

factors have been plotted against each other. Fig 14 shows this relationship taking zinc as a representative example. No correlation is evident for any of the metals.

6. This apparent lack of close correlation between the two parameters is converse to the results of HR's studies in the River Parrett (Ref 4) and the findings of many other researchers (Ref 2). In the River Parrett it was found that highest metal concentrations occurred in bed sediments with the highest silt content and lowest in samples with lowest silt content. Indeed the correlation coefficient between the two parameters was calculated to be 0.97 for both Zn and Cu.

7. It may be deduced that other over-riding factors exist in the Tees preventing the expected relationship between the two parameters. At this stage only suggestions for such factors can be made; distance from source of pollutant, sediment make-up, properties of the overlying water are possibilities.

8. To establish any relationship between the distribution of silt content and metal concentration, median grain size (D_{50}) and metal concentration of the bed sediments have been plotted against each other and are presented in Figs 20 to 25. Study of the silt fraction ie > 0.063mm reveals a trend; with the exception of Pb all metal concentrations tend to increase with a decrease in $D_{50} < 0.063$mm. Therefore the size distribution of the silt fraction may be more significant than the proportion of silt within each sample.

9. It appears that metal concentrations generally reach peak values in sediments with a D_{50} of between 0.1mm and 1.0mm (ie, fine to medium sand). This does not comply with the strong affiliation

between metals and fine-grained sediments (ie, silt/clay) acknowledged by most researchers (Ref 2). Reasons for this apparent anomaly may include those outlined in 7 above, the diversity in bed sediment composition throughout the estuary and possibly the result of occasional spurious data points which cannot be identified as such in a single set of data. It is significant that metal concentrations in the lower Tees estuary (d/s km 15), where bed sediments are more uniform in composition, tend to reach peak values in sediments with a D_{50} of between 0.01 and 0.02mm, thus conforming to popular theory.

10. Percentage silt content and particle diameter may not be the most appropriate methods of defining the affinity of the Tees estuary sediments for heavy metals. The mineralogical composition and specific surface area of the sediments, for example, may be more relevant factors.

5.3 Sediment transport

1. Sediment flux figures were obtained from data collected during only one tidal cycle at each position. Accepting these limitations the calculations indicate a net flux of fine sediment passed position 1 (~ km 4) in the upriver direction, as would be expected in a stratified estuary, and a net flux of sediment downstream passed positions 2 and 3 (~ km 15 and km 21 respectively) ie, sediment transported from both upstream and downstream is deposited in the lower reaches of the estuary. Similar conclusions were arrived at in an earlier HR report on field work in the Tees estuary (Ref 5).

2. The sediment fluxes at positions 2 and 3 show differences in their magnitudes on the ebb tide with more sediment apparently passing position 3

than position 2. It follows that deposition must occur between these two positions but none of the available data provides evidence to support this possibility. However, the quantities involved are not very large compared to many estuaries (in the Parrett a sediment flux of 100 000 T per half tide is normal). The figures suggest a net accumulation of about 1000 Tonnes in the measured tide. There are 700 tides in a year giving an approximate annual rate of 700 000 Tonnes. This compares favourably with the current annual dredging rate.

6 SUITABILITY OF THE ESTUARY

The survey carried out in March 1981 and presented in this report was set up to identify the location of fine sediments and to establish the feasibility of continuing the HR study of the estuarine transmission of heavy metal pollutants in the tidal River Tees. The exercise has successfully identified the areas where fine sediments occur and has revealed both advantages and disadvantage of the Tees as an estuary for future research.

6.1 Advantages

- fine-grained bed sediments occur throughout the tidal reaches of the Tees but primarily between Billingham Beck and Teesmouth;

- potential pollutant sources are distributed throughout the tidal reaches of the Tees but are most frequent between Stockton on Tees and Teesmouth;

- detectable concentrations of metal pollutants occur on bed sediments, bank deposits and in the accessible outfall/tributary waters;

- tidal exchange and estuarine cycling of sediments (and sediment-attached metals) takes place.

6.2 Disadvantages

- The task of total or even representative monitoring of pollutant input is too vast to contemplate in the context of a small research project;

- bank deposits are available only at a few locations preventing continuity of data;

- there is no uniformity of sediment grain size along the Tees so direct comparisons between data cannot be made;

- the estuary is greatly affected by anthropogenic activities such as dredging, dumping, industrial and domestic discharges etc. and it is difficult to determine which factors affecting the transmission of heavy metal pollutants are natural and which are anthropogenic.

6.3 Effects of dredging

Dredging in the lower reaches of the Tees estuary plays a major part in the sediment cycle. The effects of dredging (and subsequent dumping) on the estuarine transmission of metals within the Tees is not fully determined but its significance is indicated in the following simplified model. On the basis of this pilot study it appears that:-

1. metals enter the estuary;

2. some metals are adsorbed onto the bed sediments; in particular the very fine silt/clay fraction is important. (On the whole metal concentrations are considerably higher than those found in other estuaries studied by HR);

3. sediment converges from both directions into the silty reaches of the lower estuary;

4. much of the sediment from the lower reaches of the estuary is removed by dredging;

5. dredging is, therefore, a very significant mechanism for removing metals from the estuary.

The extent to which dredging operations affect the estuarine transmission of heavy metal pollutants in the Tees could only be fully determined if it was studied in its own right. Such a study should take note of the effect of dredging,

- as a mechanism for removal of sediment-attached metals;
- on exposing fresh sediment surfaces for adsorption and desorption processes;
- as a cause of resuspending settled sediments;
- on dispersion of both resuspended and dumped dredged sediment.

6.4 Assessment

The results of this pilot study provide an initial appraisal of the estuarine transmission of metal pollutants within the Tees estuary and enable general comparisons to be made between the Tees and other estuaries. The restrictions outlined in 6.2 suggest that the Tees is of limited suitability as an estuary for further study in the context of formulating direct comparisons with other estuaries studied by HR. However the importance of dredging in the sediment cycle of the Tees and the high metal concentrations on bed sediments renders it a suitable estuary in which to study the consequences of dredging on the estuarine transmission of metal pollutants.

7 REFERENCES

1. HYDRAULICS RESEARCH. Estuarine transmission of heavy metal pollutants : Data collected from the River Conwy, N. Wales, HR Report No SR 15, January 1985.

2. TURNER, K A & BURT T N. Estuarine transmission of heavy metals - a literature review. HR Report No SR 35, March 1985.

3. KIFF, P R. Sedimentation methods manual, HR August 1978.

4. THORN, M F C & BURT, T N. Sediments and metal pollutants in a turbid estuary. Proceedings of the Dynamics of Turbid Coastal Environments Symposium, Bedford Institute of Oceanography, Dartmouth NS, Canada, Vol 40, Supplement No 1, 207-215, 1983.

5. HYDRAULICS RESEARCH. The Tees Estuary, HR Report No EX 336, August 1966.

TABLES

TABLE 1: **Total solids and total metal concentrations in outfall/tributary water samples**

Sample No	Sampling Position	Dry Solids (g)	Total Metal Concentration (ppm)					
			Zn	Pb	Fe	Cu	Co	Mn
1967	River Leven, small run-off d/s of Leven Bridge	0.42	36	8	460	46	6	20
1976	River Leven, at tidal limit just d/s Leven Bridge	0.35	28	6	680	32	12	26
1968	River Tees, Eaglescliffe sewage works u/s Yarm Bridge	6.06	38	20	520	14	14	72
1969	River Tees, tanning factory outfall d/s Yarm Bridge	0.54	50	16	1140	38	96	54
1996	River Tees, approx. tidal limit at Holme Farm, Low Worsall	0.21	20	8	320	12	6	14
1997	River Tees just u/s road bridge at Dinsdale Hall	0.31	52	18	560	30	8	36
1988	River Skerne, just u/s of confluence with R Tees	0.56	142	14	620	18	14	28
1987	River Tees, just u/s of confluence with R Skerne	0.50	28	8	580	36	8	28
1990	River Skerne, sewage outfall approx 100m u/s confluence	0.34	216	20	800	18	14	20
1998	River Tees, opposite Hurworth-on-Tees sewage works	0.10	20	10	620	12	4	30
1980	River Tees, just d/s of sewage outfall at Portrack	9.69	40	10	640	32	156	88
1979	Stainsby Beck, just d/s of A174 road bridge	0.54	20	28	600	12	12	38

TABLE 2: Heavy metal concentrations on bed sediments

Sample no	Chainage u/s estuary mouth (km)	Metal concentrations (ppm)					
		Zn	Pb	Fe	Cu	Co	Mn
T35	1.0	195	98	36,400	67	19	580
T34	1.8	208	113	35,000	98	21	550
T33	3.1	182	94	33,400	92	23	570
T32	4.0	440	171	38,700	148	24	740
T31	5.0	960	299	57,000	223	27	1160
T30	6.1	1490	400	62,000	355	27	1380
T29	7.2	1110	346	58,000	248	23	980
T28	8.2	990	341	60,000	242	23	1000
T27	9.3	1040	520	55,000	353	19	820
T26	10.2	990	550	41,100	289	23	620
T25	11.3	720	580	39,900	258	20	480
T24	12.5	750	590	40,100	244	15	450
T23	13.3	970	470	43,000	285	20	580
T22	14.0	1170	1170	55,000	298	26	920
T21	15.0	77	71	19,100	242	11	82
T20	15.0	1120	1340	59,000	224	25	780
T19	15.8	780	1050	39,000	194	22	690
T18	17.5	1340	2270	59,000	560	56	1490
T17	18.6	760	1370	62,000	280	73	2050
T16	19.2	730	830	56,000	131	24	630
T15*	19.8	720	810	41,100	341	34	1190
T14*	20.2	201	220	54,000	43	23	490
T13*	21.1	710	940	62,000	171	33	1290
T12*	22.3	890	910	81,000	170	100	1370
T11*	23.5	860	730	41,800	700	24	1720
T10	24.2	129	28	39,400	28	19	460
T9	25.1	216	57	40,900	47	19	1120
T8	26.1			NO ANALYSIS			
T7	27.1			NO ANALYSIS			
T6*	27.9	910	870	61,000	280	35	3190
T5	28.7			NO ANALYSIS			
T4	29.3			NO ANALYSIS			
T3	30.2	770	730	37,400	100	22	920
T2*	30.2	630	600	43,100	130	33	2100
T1	31.1	690	425	41,000	166	21	1150

* Treated with hydrogen peroxide to assist in size grading analysis.

TABLE 3: **Heavy metal concentrations on bank deposits**

Sample No	Sampling Position	Total Metal Concentration (ppm)					
		Zn	Pb	Fe	Cu	Co	Mn
L1	River Leven, just d/s tidal limit at Leven Bridge	206	50	37,200	90	25	930
L2	River Leven, just u/s tidal limit at Level Bridge	200	50	38,300	37	26	1080
Y1	River Tees, just u/s factory outfall d/s Yarm Bridge	580	1090	39,200	56	26	1770
Y2	River Tees, at Low Worsall pumping station	530	1000	35,000	46	18	1340
Y3	River Tees, approx tidal limit at Holme Farm, Low Worsall	790	2300	52,000	38	20	2110
Y4	River Tees, just u/s road bridge at Dinsdale Hall	910	1850	52,000	85	30	2490
Y5	River Tees at Neasham village	590	950	38,200	46	20	1560
Y6	River Skerne, just u/s confluence with R Tees	430	251	39,400	81	26	1240
Y7	River Tees, just u/s confluence with R Skerne	630	1440	37,500	54	20	1560

TABLE 4: Size analyses of bed sediments

Sample No	Chainage u/s Estuary Mouth (km)	% Silt (<0.063mm)	D_{50} (mm)	D_{80} (mm)
T35	1.0	10	0.14	0.21
T34	1.8	13	0.15	0.19
T33	3.1	81	0.017	0.060
T32	4.0	90	0.010	0.032
T31	5.0	32	4.0	13.5
T30	6.1	90	0.010	0.030
T29	7.2	74	0.014	0.092
T28	8.2	76	0.015	0.090
T27	9.3	93	0.008	0.024
T26	10.2	78	0.016	0.072
T25	11.3	61	0.034	0.14
T24	12.5	90	0.016	0.039
T23	13.3	86	0.018	0.042
T22	14.0	26	0.13	0.18
T21	15.0	91	0.014	0.041
T20	15.0	3	0.19	0.21
T19	15.8	11	0.23	0.29
T18	17.5	1	0.41	0.54
T17	18.6	1	1.6	3.7
T16	19.2	9	0.16	0.20
T15	19.8	20	-	-
T14	20.2	4	0.35	0.54
T13	21.1	2	0.54	0.90
T12	22.3	9	0.18	0.24
T11	23.5	0	13.5	23.0
T10	24.2	91	0.011	0.025
T9	25.1	93	0.015	0.032
T8	26.1	0	12.0	17.5
T7	27.1	0	7.4	11.3
T6	27.9	0	1.0	5.5
T5	28.7	0	8.5	19.0
T4	29.3	0	26.0	29.0
T3	30.2	72	0.029	0.083
T2	30.2	6	25.0	36.0
T1	31.1	84	0.016	0.051

TABLE 5: **Hydraulic observations at Position 1 on 20.3.81**

Time	Water depth (m)	Ht instrument above bed (m)	Velocity (m/s)	Direction (°True)	Bottle no	Solids conc (ppm)	Temp (°C)	Salinity (ppt)	D.O. (% sat)
0750		0.5	0.10	010	932	8	5.3	32.7	94
55		1.0	0.10	050			5.3	32.65	94
0800		2.0	0.11	000			5.3	32.65	93
02		4.0	0.11	070			5.4	32.65	93.5
08		8.0	0.14	020	933	18	5.4	32.3	88
11	13.7	12.0	0.46	350			6.0	29.4	69
16		13.2	0.55	010	934	13	6.0	28.9	67
0830		0.5	0.10	300	935	13	5.4	32.65	92
34		1.0	0.11	350			5.4	32.65	90
37		2.0	0.05	010			5.4	32.65	90
40		4.0	0.12	060			5.5	32.35	89
45		8.0	0.14	070	936	10	5.6	32.6	83
49	13.5	12.0	0.50	000			6.1	29.1	66
51		13.0	0.52	000	937	30	6.2	29.0	65
0902		0.5	0.04	070	938	15	5.4	32.65	91
05		1.0	0.03	060			5.4	32.65	90
07		2.0	0.06	050			5.4	32.55	90
09		4.0	0.08	050			5.5	32.45	89
12		8.0	0.18	050			5.6	32.40	83
15		10.0	0.29	340	939	8	6.0	30.50	71
18	13.3	12.0	0.44	000			6.2	29.0	64
20		12.8	0.48	000	940	13	6.3	28.7	63
0931		0.5	-	-	941	8	5.5	32.55	91
33		1.0	0.08	140			5.4	32.65	93
36		2.0	0.11	140			5.4	32.65	91
38		4.0	-	-			5.4	32.6	89
40		6.0	0.04	080			5.4	32.4	86
43		10.0	0.15	010	942	10	5.9	31.4	74
46	13.5	12.0	0.42	010			6.4	28.6	61
48		13.0	0.49	010	943	10	6.5	28.4	60
1001		0.5	0.19	140	944	25	5.4	32.75	94
03		1.0	0.18	190			5.4	32.7	92
06		2.0	0.22	170			5.4	32.7	94
08		4.0	0.20	190			5.4	32.6	92
11		8.0	0.03	250			5.6	32.05	-
14		10.0	0.13	310	945	10	6.0	30.9	70
17	13.3	12.0	0.39	000			6.4	28.4	60
19		12.8	0.42	010	946	5	6.4	28.3	59

Time	Water depth (m)	Ht instrument above bed (m)	Velocity (m/s)	Direction (°True)	Bottle no	Solids conc (ppm)	Temp (°C)	Salinity (ppt)	D.O. (% sat)
1032		0.5	0.21	160	947	8	5.4	32.9	99
34		1.0	0.22	180			5.4	32.9	98
37		2.0	0.29	170			5.4	32.9	98
39		4.0	0.27	160			5.4	32.65	93
42		8.0	0.18	190			5.6	32.2	83
45		10.0	-	-	948	10	6.0	30.5	67
46	13.4	12.0	0.24	000			6.4	29.0	60
48		12.9	0.28	000	949	13	6.4	28.8	60
1100		0.5	0.25	190	950	15	5.4	32.9	98
02		1.0	0.28	160			5.4	32.9	97
05		2.0	0.30	160			5.4	32.9	98
08		4.0	0.32	170			5.5	32.7	94
10		8.0	0.27	170			5.6	32.5	82
12		10.0	0.03	130	951	25	6.0	30.7	69
15	13.4	12.0	0.18	070			6.3	28.9	59
17		12.9	0.17	000	952	13	6.3	28.9	60
1138		0.5	0.26	180	953	10	5.4	32.9	96
41		1.0	0.24	180			5.4	32.9	96
44		2.0	0.31	180			5.4	32.9	96
46		4.0	0.39	180			5.4	32.8	93
49		8.0	0.40	180			5.6	32.1	84
51		10.0	0.38	180	954	10	5.8	32.1	78
53	14.6	12.0	0.24	220			6.0	30.9	67
56		14.1	0.02	-	955	10	8.4	26.7	58
1203		0.5	0.22	180	956	8	5.4	32.85	95
06		1.0	0.28	190			5.4	32.85	94
08		2.0	0.30	190			5.4	32.85	94
10		4.0	0.36	180			5.4	32.8	94
13		8.0	0.38	180			5.4	32.55	84
15		10.0	0.38	180	957	25	5.6	32.4	77
17	15.0	12.0	0.39	180			6.0	31.4	71
19		14.5	0.08	060	958	30	7.5	26.9	56
1235		0.5	0.27	180	959	15	5.4	32.9	97
38		1.0	0.31	180			5.4	32.9	96
39		2.0	0.32	170			5.4	32.9	96
41		4.0	0.34	170			5.4	32.7	92
44		8.0	0.49	170			5.4	32.6	90
46		10.0	0.39	180	960	53	5.6	32.15	84
49	15.7	12.0	0.36	180			6.0	31.1	70
51		15.2	0.08	140	961	20	6.8	28.8	63

Time	Water depth (m)	Ht instrument above bed (m)	Velocity (m/s)	Direction (°True)	Bottle no	Solids conc (ppm)	Temp (°C)	Salinity (ppt)	D.O. (% sat)
1303		0.5	0.28	170	962	23	5.4	32.9	96
04		1.0	0.25	170			5.4	32.9	96
07		2.0	0.33	170			5.4	32.9	95
10		4.0	0.37	170			5.4	32.85	93
13		8.0	0.40	180			5.4	32.55	88
16		10.0	0.43	180	963	20	5.5	32.25	83
18	16.2	12.0	0.34	180			5.9	31.5	71
20		15.7	0.08	110	-	-	6.3	30.3	67
1334		0.5	0.22	170	964	18	5.4	32.9	97
38		1.0	0.26	170			5.4	32.9	96
40		2.0	0.24	170			5.4	32.9	95
42		4.0	0.31	170			5.4	32.9	95
45		8.0	0.26	180			5.5	32.55	88
47		10.0	0.34	180	965	23	5.5	32.45	86
50	17.1	12.0	0.28	200			5.6	32.10	71
52		16.6	0.07	130	966	15	6.2	30.8	69
1400		0.5	0.23	200	967	20	5.4	32.9	93
02		1.0	0.23	180			5.4	32.9	92
04		2.0	0.30	180			5.4	32.9	93
06		4.0	0.36	170			5.4	32.85	93
10		8.0	0.24	180			5.5	32.70	90
12		10.0	0.24	190	968	30	5.5	32.35	85
16	17.2	14.0	0.13	130			6.4	30.7	66
19		16.7	0.14	050	969	25	6.5	29.7	65
1431		0.5	0.20	180	970	33	5.4	32.9	93
34		1.0	0.20	170			5.4	32.9	94
36		2.0	0.20	200			5.4	32.9	93
38		4.0	0.23	180			5.4	32.9	93
41		8.0	0.27	170			5.6	32.5	88
43		10.0	0.30	190	971	25	5.6	32.15	85
48	17.0	14.0	0.11	090			6.4	30.3	66
49		16.5	0.15	000	972	30	6.4	30.3	68
1500		0.5	0.22	170	973	35	5.4	32.95	95
03		1.0	0.13	200			5.4	32.95	94
06		2.0	0.30	200			5.4	32.95	94
08		4.0	0.18	200			5.4	32.9	93
12		8.0	0.23	190			5.5	32.5	88
13		10.0	0.24	190	974	30	5.6	32.3	86
17	17.2	14.0	0.23	020			6.2	30.6	67
20		16.7	0.19	070	975	25	6.2	30.6	67

Time	Water depth (m)	Ht instrument above bed (m)	Velocity (m/s)	Direction (°True)	Bottle no	Solids conc (ppm)	Temp (°C)	Salinity (ppt)	D.O. (% sat)
1532		0.5	0.12	150	976	38	5.4	33.0	94
34		1.0	0.04	140			5.4	33.0	94
36		2.0	0.08	140			5.4	33.0	94
39		4.0	0.10	160			5.4	32.9	92
41		8.0	0.13	170			5.5	32.7	90
44		10.0	0.14	160	977	23	5.5	32.45	88
47	17.4	14.0	0.20	350			6.2	30.5	66
51		16.9	0.22	010	978	15	6.3	30.5	66
1601		0.5	0.04	100	979	40	5.5	32.95	92
04		1.0	0.07	190			5.4	32.95	91
06		2.0	0.03	140			5.4	32.95	91
08		4.0	0.04	170			5.4	32.95	92
11		8.0	0.07	180			5.4	32.8	89
14		10.0	0.07	180	980	28	5.5	32.7	88
17	17.3	14.0	0.24	030			6.1	30.9	68
20		16.8	0.32	020	533	18	6.4	30.8	66
1630		0.5	0.02	090	534	18	5.4	32.95	92
31		2.0	0.03	060			5.4	32.9	92
34		8.0	0.07	010			5.4	32.75	88
36		10.0	0.07	040	535	10	5.5	32.6	87
39	17.2	14.0	0.28	000			6.1	30.8	68
41		16.7	0.29	010	536	20	6.2	30.7	66
1703		0.5	0.09	060	537	23	5.4	32.95	93
05		1.0	0.10	070			5.4	32.9	92
07		2.0	0.11	050			5.4	32.95	92
10		4.0	0.16	010			5.4	32.9	92
12		8.0	0.22	350			5.4	32.8	89
16		10.0	0.20	010	538	20	5.6	32.4	85
19	17.0	14.0	0.30	000			6.0	31.5	71
21		16.5	0.34	040	539	13	6.0	31.4	68
1731		0.5	0.22	330	521	18	5.4	32.95	93
34		1.0	0.19	330			5.4	32.95	92
35		2.0	0.16	320			5.4	32.95	91
37		4.0	0.20	340			5.4	32.85	90
40		8.0	0.31	340			5.4	32.65	87
42		10.0	0.19	340	522	13	5.6	32.4	84
46	16.5	14.0	0.26	020			5.8	31.7	73
49		16.0	0.32	030	523	25	6.1	30.7	68
1800		0.5	0.22	330	524	20	5.4	32.85	90
03		1.0	0.22	000			5.4	32.85	89
06		2.0	0.25	350			5.4	32.8	89
09		4.0	0.31	010			5.4	32.75	88
12		8.0	0.32	350			5.5	32.5	87
14		10.0	0.32	000	525	25	5.5	32.45	84
17	16.0	14.0	0.42	020			5.8	32.0	76
20		15.5	0.48	010	526	5	6.0	31.2	71

Time	Water depth (m)	Ht instrument above bed (m)	Velocity (m/s)	Direction (°True)	Bottle no	Solids conc (ppm)	Temp (°C)	Salinity (ppt)	D.O. (% sat)
1830		0.5	0.18	320	527	18	5.4	32.8	88
33		1.0	0.26	350			5.4	32.75	87
35		2.0	0.25	350			5.4	32.7	87
38		4.0	0.30	350			5.6	32.0	78
41		8.0	0.32	000			5.8	32.3	78
43		10.0	0.34	000	528	23	5.8	32.4	77
48	15.5	14.5	0.61	020	520	18	5.8	31.2	72
1900		0.5	0.18	000	512	10	5.5	32.8	88
03		1.0	0.26	010			5.5	32.75	87
06		2.0	0.28	000			5.5	32.75	88
09		4.0	0.31	030			5.6	32.55	87
12		8.0	0.31	010			5.6	32.3	84
14		10.0	0.38	000	502	20	5.8	32.5	78
16		12.0	0.53	010			6.0	31.1	71
19	14.8	14.3	0.58	010	513	15	6.0	30.1	68
1931		0.5	0.18	030	514	13	5.4	32.75	87
33		1.0	0.20	020			5.4	32.75	87
35		2.0	0.21	020			5.4	32.75	87
37		4.0	0.23	010			5.4	32.6	85
40		8.0	0.35	350			5.7	32.4	74
42	14.5	10.0	0.38	330	515	25	6.0	31.3	70
46		14.0	0.57	010	516	18	6.0	29.6	65
2000		0.5	0.14	050	517	25	5.4	32.8	85
02		1.0	0.16	340			5.4	32.8	85
04		2.0	0.19	350			5.4	32.75	86
06		4.0	0.19	030			5.5	32.75	87
08		8.0	0.35	340			5.8	31.8	74
11		10.0	0.42	350	518	18	5.9	30.8	72
13	14.2	12.0	0.59	000			6.1	29.6	63
15		13.7	0.55	000	519	28	6.2	29.6	62

TABLE 6: Hydraulic observations at Position 2 on 21.3.81

Time	Water depth (m)	Ht instrument above bed (m)	Velocity (m/s)	Direction (°True)	Bottle no	Solids conc (ppm)	Temp (°C)	Salinity (ppt)	D.O. (% sat)
0749	5.1	0.5	0.36	020	511	8	6.4	23.9	48
51		1.0	0.55	–			6.4	17.1	56
55		2.0	0.90	310	510	15	6.4	14.1	62
0800		3.0	1.06	320			6.3	11.2	68
03		4.0	1.13	320			6.3	10.7	68
06	4.7	4.2	1.14	000	509	13	6.3	10.6	69
0818	4.6	0.5	0.36	320	508	10	6.3	16.9	62
22		1.0	0.51	320			6.3	12.6	68
23		2.0	0.83	320	507	15	6.3	12.9	70
25		3.0	0.94	320			6.3	9.3	74
27	4.5	4.0	1.02	320	506	13	6.3	8.8	75
0848	4.2	0.5	0.38	300	505	30	6.3	10.9	68
50		1.0	0.61	020			6.3	9.0	72
52		2.0	0.78	010	504	20	6.2	7.5	74
54		3.0	0.88	010			6.2	6.2	77
56		3.7	0.93	010	503	23	6.2	5.9	79
0917		0.5	0.19	330	501	25	6.2	7.4	80
19		1.0	0.44	310			6.3	5.8	91
22		2.0	0.69	350	500	20	6.2	4.0	96
24		3.0	0.84	350			6.2	2.9	88
26	3.8	3.3	0.89	350	499	18	6.1	2.7	98
0947		0.5	0.18	–	498	25	6.4	3.8	91
49		1.0	0.21	–			6.3	3.0	90
50		2.0	0.61	–	497	25	6.2	1.4	92
53	3.6	3.0	0.76	–	496	83	6.1	1.1	92
1016		0.5	0.11	010	495	75	6.4	2.4	93
19		1.0	0.23	–			6.4	1.7	90
21		3.0	0.40	000	494	23	6.2	1.0	90
23	3.6	3.0	0.47	000	493	25	6.1	0.8	91
1048		0.5	0.13	000	492	45	6.4	2.6	89
50		1.0	0.26	010			6.3	1.0	91
54		2.0	0.27	010	1127	73	6.2	0.8	91
56	3.7	3.0	0.29	010			6.2	0.7	90
58		3.2	0.30	020	1128	43	6.2	0.7	90
1123		0.5	0.32	200	1129	73	6.3	15.1	66
27		1.0	0.41	170			6.3	5.3	80
28		2.0	0.10	120	1130	53	6.3	1.0	88
30	3.9	3.0	0.18	350			6.4	0.9	89
31		3.4	0.24	350	1131	15	6.5	0.9	90

Time	Water depth (m)	Ht instrument above bed (m)	Velocity (m/s)	Direction (°True)	Bottle no	Solids conc (ppm)	Temp (°C)	Salinity (ppt)	D.O. (% sat)
1147		0.5	0.20	200	1132	60	6.3	19.8	58
48		1.0	0.49	160			6.3	10.9	72
50		2.0	0.22	200	1133	23	6.4	1.3	90
52		3.0	0.10	060			6.6	1.0	87
54	4.2	3.7	0.10	010	1134	28	6.6	1.0	87
1217		0.5	0.60	190	1135	30	6.3	27.6	50
20		1.0	0.60	200			6.3	27.1	48
21		2.0	0.60	180	1136	15	6.6	8.0	76
23		3.0	0.43	180			6.6	2.5	88
25	4.7	4.0	0.10	270	1137	18	6.7	1.5	90
1241		0.5	0.34	190	1138	15	6.2	29.4	53
43		1.0	0.38	190			6.2	29.4	47
45		2.0	0.47	190	1139	20	6.2	29.1	46
47		3.0	0.67	190			7.1	8.7	76
48		4.0	0.28	210			6.8	4.5	83
50	5.2	4.7	0.18	200	1140	30	6.8	3.8	84
1320		0.5	0.45	170	1141	42	6.0	30.6	59
23		1.0	0.48	180			6.0	30.8	57
25		2.0	0.63	180	1142	28	6.0	30.7	55
26		3.0	0.76	180			6.0	29.4	53
28	6.0	4.0	0.95	190			7.8	16.8	59
31		5.0	0.88	190	1143	20	7.5	7.7	78
1346		0.5	0.40	180	1144	18	5.9	31.1	50
48		1.0	0.49	–			5.9	31.1	61
50		2.0	0.51	170			5.9	31.0	60
52		3.0	0.66	170	1145	13	5.9	30.7	60
54		4.0	0.72	180			6.0	30.3	57
56	6.5	5.0	0.90	180			6.7	20.7	62
58		6.0	0.71	190	1146	13	7.6	8.6	83
1416		0.5	0.38	190	1147	15	5.9	31.4	58
19		1.0	0.45	190			5.9	31.3	57
22		2.0	0.49	180			5.9	31.2	57
23		3.0	0.56	180	1149	15	5.9	31.1	56
25	7.3	4.0	0.61	180			5.9	30.8	56
28		5.0	0.74	180			6.1	30.0	54
29		6.0	0.74	180			6.7	21.4	59
32		6.8	0.59	170	1150	18	7.4	11.5	73
1446		0.5	0.31	180	1151	25	5.9	31.5	64
48		1.0	0.33	190			5.9	31.5	61
50		2.0	0.34	190			5.9	31.5	60
52		4.0	0.57	180	1152	13	6.0	30.7	60
55	7.6	6.0	0.62	170			6.6	23.7	58
57		7.1	0.25	150	1153	13	7.6	12.0	71

Time	Water depth (m)	Ht instrument above bed (m)	Velocity (m/s)	Direction (°True)	Bottle no	Solids conc (ppm)	Temp (°C)	Salinity (ppt)	D.O. (% sat)
1517		0.5	0.26	190	1154	13	5.9	31.6	68
19		1.0	0.26	190			5.8	31.6	65
20		2.0	0.27	190			5.9	31.6	64
23		4.0	0.38	190	1155	30	5.9	31.3	61
25	7.8	6.0	0.47	180			6.0	30.0	60
27		7.3	0.08	200	1156	20	7.4	12.3	72
1546		0.5	0.21	180	1157	5	5.8	31.8	62
48		1.0	0.22	180			5.8	31.9	62
50		2.0	0.23	190			5.8	31.9	61
52		4.0	0.35	180	1158	8	5.9	31.5	60
55	8.1	6.0	0.49	190			6.4	29.0	59
57		7.6	0.30	210	1159	8	7.2	13.6	63
1619		0.5	0.05	350	1160	18	5.8	32.1	68
21		1.0	0.08	100			5.8	31.5	61
23		2.0	0.04	140			5.8	31.5	60
25		4.0	0.05	170	1161	8	5.8	31.5	59
27	8.0	6.0	0.14	170			5.9	31.2	60
30		7.5	0.07	040	1162	13	7.6	12.6	68
1648		0.5	0.02	050	1163	10	5.8	32.1	60
51		1.0	0.06	130			5.9	32.0	62
53		2.0	0.03	130			5.8	32.0	60
55		4.0	0.04	070	1164	8	6.0	31.8	59
57		6.0	-	-			6.0	30.2	56
59	8.0	7.5	0.33	000	1165	20	7.4	13.1	71
1715		0.5	0.20	020	1166	5	5.8	32.0	60
18		1.0	0.22	010			5.8	32.0	60
21		2.0	0.32	010			5.8	31.9	59
22		4.0	0.34	000	1167	10	5.9	31.1	56
24		6.0	0.34	350			6.4	28.5	55
26	7.7	7.2	0.57	000	1168	10	7.5	14.6	65
1757		0.5	0.27	000	1169	13	5.9	31.5	62
1800		1.0	0.35	000			5.9	31.4	59
01		2.0	0.46	000			5.9	31.3	58
03		4.0	0.61	350	1170	5	6.0	30.5	56
05	7.3	6.0	0.66	350			7.2	18.9	60
07		6.8	0.82	350	1171	10	7.2	18.1	62
1817		0.5	0.36	000	1172	13	5.9	31.0	58
19		1.0	0.40	000			5.9	31.0	59
22		2.0	0.51	000			6.0	30.9	56
24		4.0	0.71	000	1173	15	6.0	30.1	54
26	6.8	6.0	0.93	000			6.7	23.6	57
29		6.3	1.02	350	1174	8	7.1	18.5	61

Time	Water depth (m)	Ht instrument above bed (m)	Velocity (m/s)	Direction (°True)	Bottle no	Solids conc (ppm)	Temp (°C)	Salinity (ppt)	D.O. (% sat)
1846		0.5	0.31	350	1175	-	6.0	30.1	53
48		1.0	0.39	340			6.0	30.1	52
51		2.0	0.47	000			6.0	30.0	52
53		4.0	0.86	000	745	25	6.6	24.0	54
55	6.5	6.0	1.05	000	744	10	6.9	19.0	59
1917		0.5	0.47	000	743	13	6.2	28.7	53
20		1.0	0.57	350			6.2	28.6	51
22		2.0	0.63	350			6.2	27.1	51
24		3.0	0.86	000	742	25	6.5	23.5	54
28		4.0	0.98	000			6.7	19.6	57
29	5.8	5.0	1.11	000			6.6	18.9	57
31		5.3	1.24	000	741	15	7.0	15.5	59
1947		0.5	0.35	000	740	50	6.3	26.3	52
49		1.0	0.44	000			6.3	24.0	53
51		2.0	0.76	000			6.5	19.2	58
53		3.0	0.83	000	739	23	6.5	16.4	61
55		4.0	1.00	350			6.5	15.2	63
57	5.4	4.9	1.09	350	738	23	6.6	14.4	64
2015		0.5	0.36	000	737	33	6.4	22.2	53
17		1.0	0.63	000			6.4	19.3	57
19		2.0	0.81	000			6.4	15.8	61
22		3.0	0.94	000	736	43	6.4	13.2	64
24	5.0	4.0	1.06	350			6.4	12.5	65
26		4.5	1.12	000	746	10	6.4	12.1	65

TABLE 7: Hydraulic observations at Position 3 on 23.3.81

Time	Water depth (m)	Ht instrument above bed (m)	Velocity (m/s)	Direction (°True)	Bottle no	Solids conc (ppm)	Temp (°C)	Salinity (ppt)	D.O. (% sat)
0747	5.5	5.0	1.24	110	747	174	3.8	0.5	98
51		0.5	0.87	110	748	174	3.8	0.5	98
53		1.0	0.83	110			3.8	0.5	94
55		2.0	1.03	120	749	199	3.8	0.5	98
57		3.0	1.08	120			3.8	0.5	99
59		4.0	1.21	120			3.8	0.5	99
0817		0.5	0.86	130	750	174	3.8	0.5	98
19		1.0	0.90	120			3.8	0.5	96
21		2.0	1.17	140	751	161	3.8	0.5	96
23		3.0	1.23	130			3.8	0.5	96
25	5.0	4.0	1.39	110			3.8	0.5	96
26		4.5	1.39	110	752	182	3.8	0.5	97
0847		0.5	1.04	120	754	166	3.8	0.5	107
49		1.0	1.05	130			3.8	0.5	99
51		2.0	1.20	120	755	166	3.8	0.5	99
54		3.0	1.18	120			3.8	0.5	99
56	4.5	4.0	1.32	120	756	183	3.8	0.5	99
0918		0.5	0.93	130	757	166	3.8	0.5	107
20		1.0	1.09	150			3.8	0.5	105
22		2.0	1.08	150	758	174	3.8	0.5	103
25		3.0	1.24	120			3.8	0.5	101
27	4.4	3.9	1.33	130	759	191	3.8	0.5	99
0948		0.5	1.01	150	760	191	3.8	0.5	103
50		1.0	1.06	150			3.8	0.5	95
53		2.0	1.26	140	761	183	3.8	0.5	99
55	4.1	3.0	1.32	130			3.8	0.5	101
57		3.6	1.33	130	762	183	3.8	0.5	95
1017		0.5	1.03	150	763	183	3.8	0.5	98
20		1.0	1.05	130			3.8	0.5	94
22		2.0	1.22	110	764	166	3.8	0.5	94
24	3.8	3.0	1.28	110			3.8	0.5	94
26		3.3	1.29	120	765	149	3.8	0.5	94
1047		0.5	0.89	160	766	157	3.8	0.5	98
50		1.0	1.01	140			3.8	0.5	96
52		2.0	1.19	140			3.8	0.5	94
54	3.7	3.2	1.24	120	767	166	3.8	0.5	98
1116		0.5	0.91	140	768	141	3.8	0.5	101
18		1.0	1.12	160			3.8	0.5	97
20		2.0	1.18	140	769	166	3.8	0.5	97
22	3.5	3.0	1.22	100	770	166	3.8	0.5	97

Time	Water depth (m)	Ht instrument above bed (m)	Velocity (m/s)	Direction (°True)	Bottle no	Solids conc (ppm)	Temp (°C)	Salinity (ppt)	D.O. (% sat)
1147		0.5	0.95	120	772	157	3.8	0.5	105
51		1.0	1.14	120			3.8	0.5	97
53		2.0	1.22	120			3.8	0.5	97
55	3.3	2.8	1.32	120	774	-	3.8	0.5	97
1218		0.5	1.09	130	775	149	3.8	0.5	96
20		1.0	1.18	110			3.8	0.5	96
22		2.0	1.19	120			3.8	0.5	92
24	3.2	2.7	1.18	120	776	132	3.8	0.5	92
1245		0.5	0.96	110	777	108	3.8	0.5	96
47		1.0	0.81	110			3.8	0.5	96
49		2.0	0.99	110			3.8	0.5	96
52	3.3	2.8	1.00	130	778	125	3.8	0.5	98
1316		0.5	0.76	110	779	141	3.8	0.5	95
18		1.0	0.89	110			3.8	0.5	87
22		2.0	0.94	120			3.8	0.5	87
23	3.4	2.9	1.08	110	780	116	3.8	0.5	86
1347		0.5	0.56	110	781	116	3.8	0.5	99
50		1.0	0.62	120			3.8	0.5	99
51		2.0	0.67	120			3.8	0.5	97
53	3.8	3.3	0.72	120	782	133	3.8	0.5	95
1415		0.5	0.23	110	783	141	3.8	0.5	97
17		1.0	0.28	120			3.8	0.5	95
19		2.0	0.24	100			3.8	0.5	95
20	4.0	3.5	0.20	110	784	158	3.8	0.5	91
1445		0.5	0.04	320	402	141	3.8	0.5	94
49		1.0	0.06	290			3.8	0.5	92
51		2.0	0.07	330	401	133	3.8	0.5	90
55	4.8	4.3	0.09	320	399	166	3.8	0.5	90
1519		0.5	0.19	300	400	158	3.8	0.5	90
22		1.0	0.15	300			3.8	0.5	88
25		2.0	0.16	310	398	141	3.8	0.5	88
27		3.0	0.12	270			3.8	0.5	90
30	5.5	5.0	0.16	320	397	108	3.8	0.5	90
1547		0.5	0.13	300	396	141	3.8	0.5	91
50		1.0	0.13	290			3.8	0.5	91
52		2.0	0.12	260	395	141	3.8	0.5	89
54		3.0	0.20	240			3.8	0.5	89
56		4.0	0.19	290			3.8	0.5	89
58	6.0	5.0	0.12	260			3.8	0.5	89
1600		5.5	0.19	330	394	141	3.8	0.5	89

Time	Water depth (m)	Ht instrument above bed (m)	Velocity (m/s)	Direction (°True)	Bottle no	Solids conc (ppm)	Temp (°C)	Salinity (ppt)	D.O. (% sat)
1617		0.5	-	-	403	149	3.8	0.5	91
20		1.0	0.03	340			3.8	0.5	89
21		2.0	0.03	-	404	116	3.8	0.5	89
23		3.0	-	-			3.8	0.5	89
25	6.0	5.5	-	-	405	125	3.8	0.5	89
1645		0.5	0.03	-	406	133	3.8	0.5	88
49		1.0	0.08	090			3.8	0.5	86
51		2.0	0.06	090	407	141	3.8	0.5	86
54		3.0	0.04	-			3.8	0.5	85
57		4.0	0.03	-			3.8	0.5	85
59	5.5	5.0	0.02	-	408	133	3.8	0.5	86
1715		0.5	0.05	060	410	133	3.8	0.5	86
19		1.0	0.08	070			3.8	0.5	84
20		2.0	0.10	090	411	133	3.8	0.5	84
23		3.0	0.12	090			3.8	0.5	84
26		4.0	0.16	110	412	141	3.8	0.5	84
28	6.5	6.0	0.14	100	413	131	3.8	0.5	84
1745		0.5	0.16	110	414	141	3.8	0.5	91
48		1.0	0.23	110			3.8	0.5	87
51		2.0	0.26	110	415	116	3.8	0.5	86
53		3.0	0.30	100			3.8	0.5	87
56		4.0	0.30	100	416	125	3.8	0.5	87
58		5.0	0.36	100			3.8	0.5	86
1800	6.5	6.0	0.40	110	417	133	3.8	0.5	86
1821		0.5	0.31	130	418	158	3.8	0.5	89
24		1.0	0.38	140			3.8	0.5	86
26		2.0	0.45	140	419	133	3.8	0.5	86
27		3.0	0.50	150			3.8	0.5	84
31		4.0	0.54	140	420	149	3.8	0.5	87
32		5.0	0.59	140			3.8	0.5	87
34	6.3	5.8	0.58	140	421	141	3.8	0.5	87
1847		0.5	0.40	140	422	141	3.8	0.5	91
49		1.0	0.50	140			3.8	0.5	88
51		2.0	0.59	140	423	125	3.8	0.5	87
53		3.0	0.57	140			3.8	0.5	87
55		4.0	0.60	140	424	125	3.8	0.5	87
57		5.0	0.59	140			3.8	0.5	87
59	6.4	5.9	0.63	140	425	125	3.8	0.5	87
1917		0.5	0.48	-	426	141	3.8	0.5	90
20		1.0	0.51	-			3.8	0.5	88
22		2.0	0.67	-	427	149	3.8	0.5	86
24		3.0	0.78	-			3.8	0.5	86
25		4.0	0.81	-	428	116	3.8	0.5	86
27		5.0	0.90	-			3.8	0.5	86
29	5.9	5.4	0.84	-	429	141	3.8	0.5	90

Time	Water depth (m)	Ht instrument above bed (m)	Velocity (m/s)	Direction (°True)	Bottle no	Solids conc (ppm)	Temp (°C)	Salinity (ppt)	D.O. (% sat)
1947		0.5	0.60	130	430	141	3.8	0.5	94
50		1.0	0.75	120			3.8	0.5	88
52		2.0	0.90	110	431	133	3.8	0.5	90
53		3.0	0.99	110			3.8	0.5	94
56	5.6	4.0	0.99	120	432	108	3.8	0.5	88
58		5.1	1.02	110	433	125	3.8	0.5	88
2016		0.5	0.77	110	434	149	3.8	0.5	91
18		1.0	0.75	120			3.8	0.5	91
20		2.0	0.94	110	435	133	3.8	0.5	93
21		3.0	1.06	120			3.8	0.5	89
23	5.2	4.0	1.06	120	436	133	3.8	0.5	87
25		4.7	1.01	120	437	116	3.8	0.5	84

FIGURES

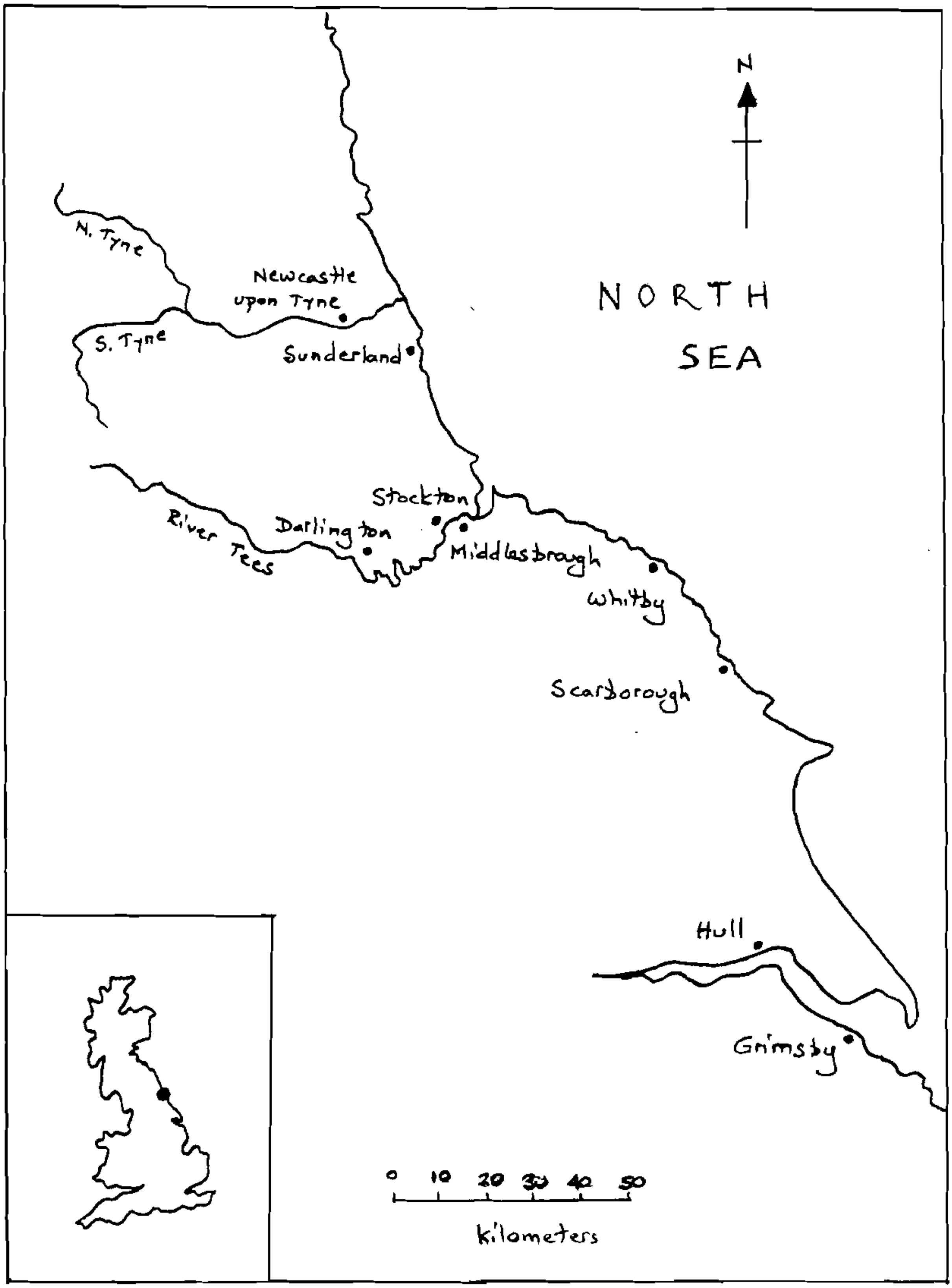

Fig 1 General location map

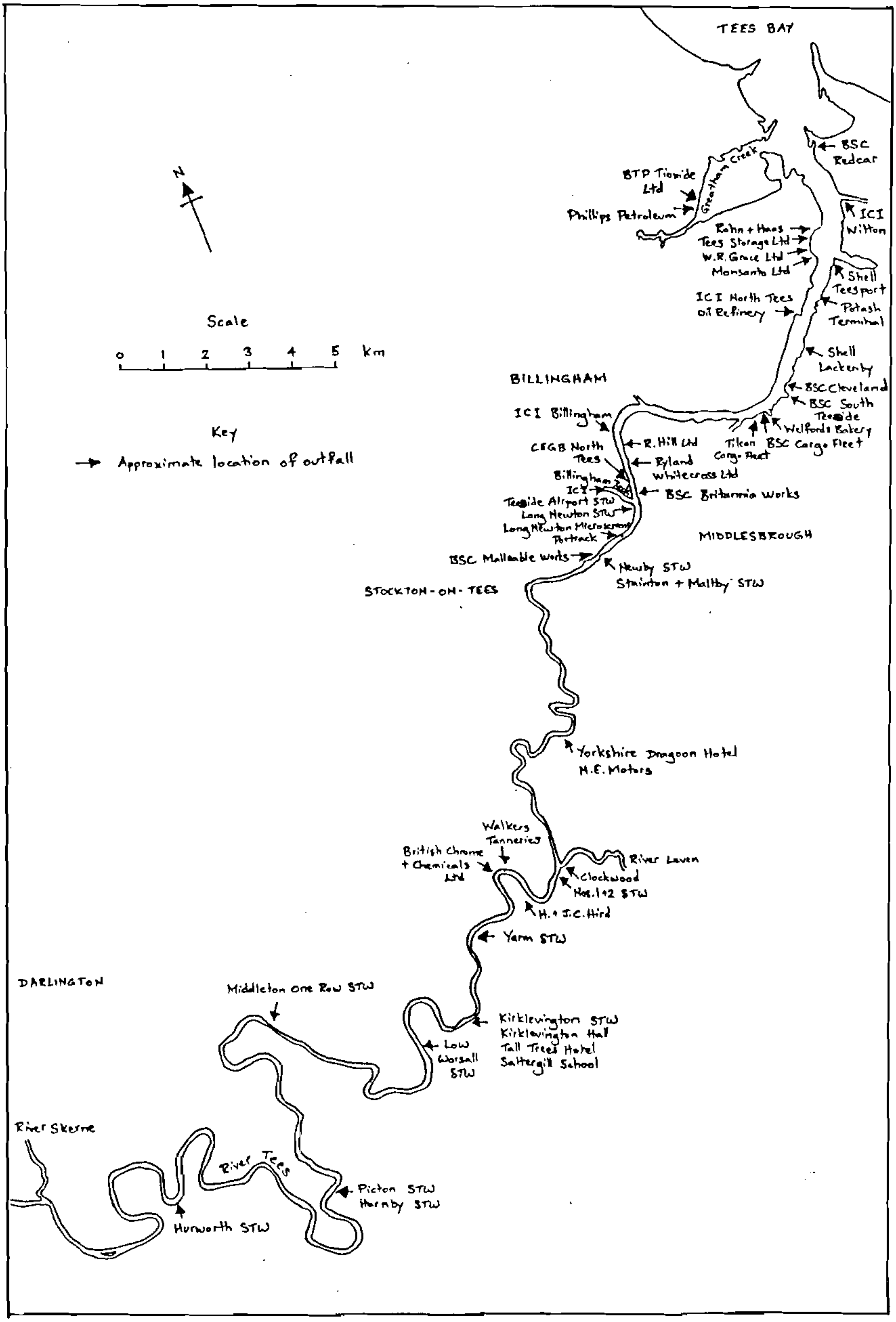

Fig 2 Location of potential sources of heavy metal pollutants

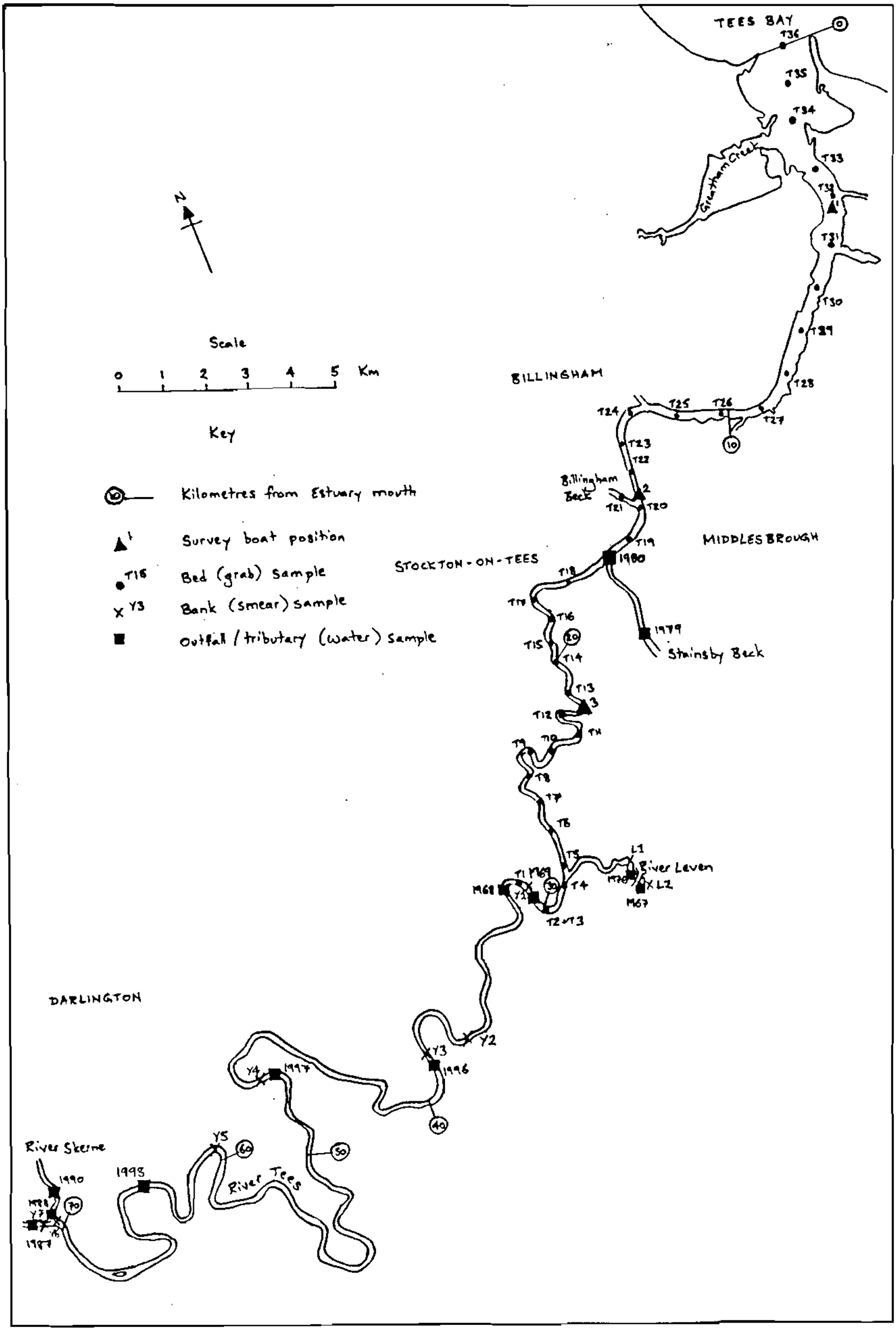

Fig 5 Survey and sampling positions, March 1[illegible]

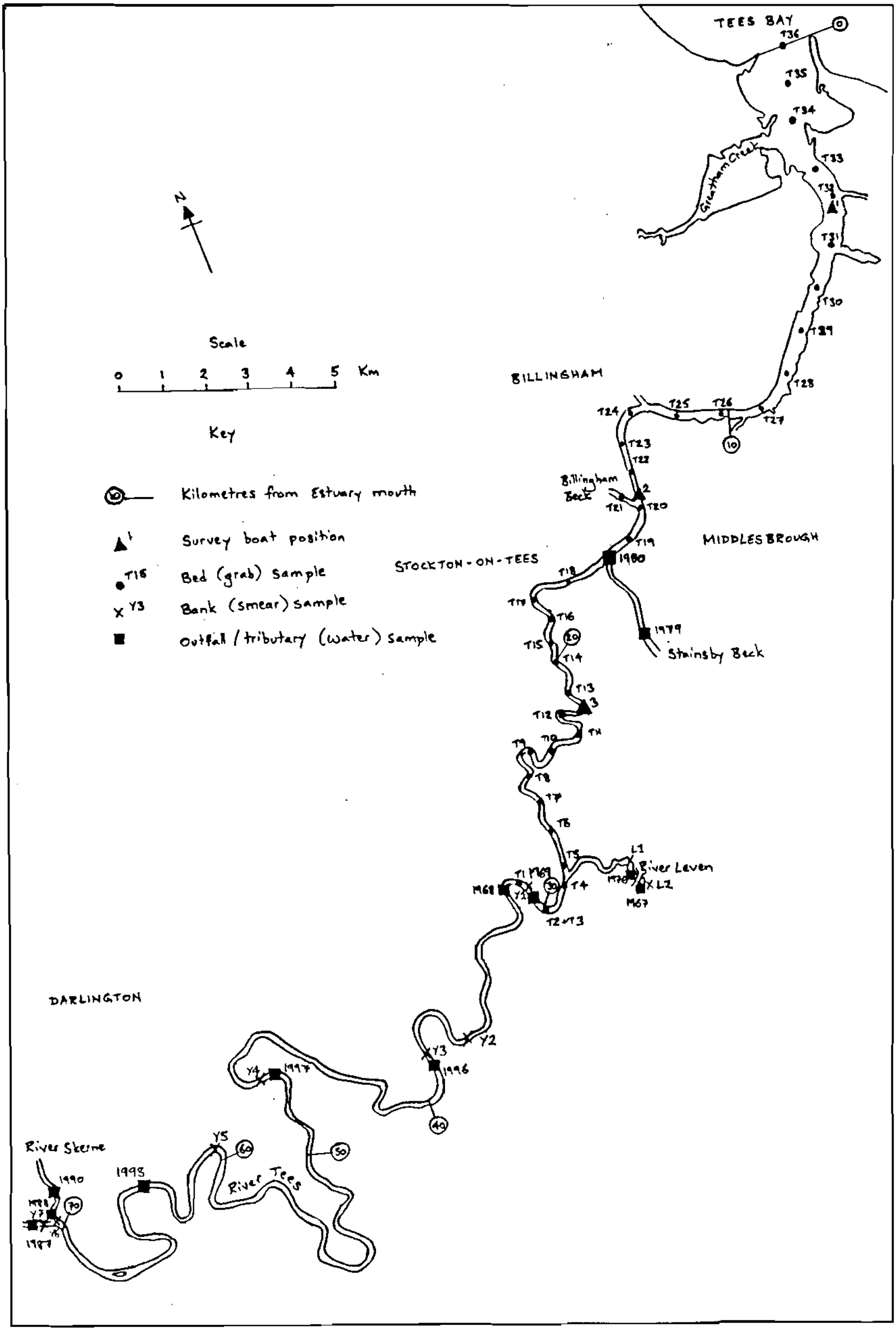

Fig 5 Survey and sampling positions, March [illegible]

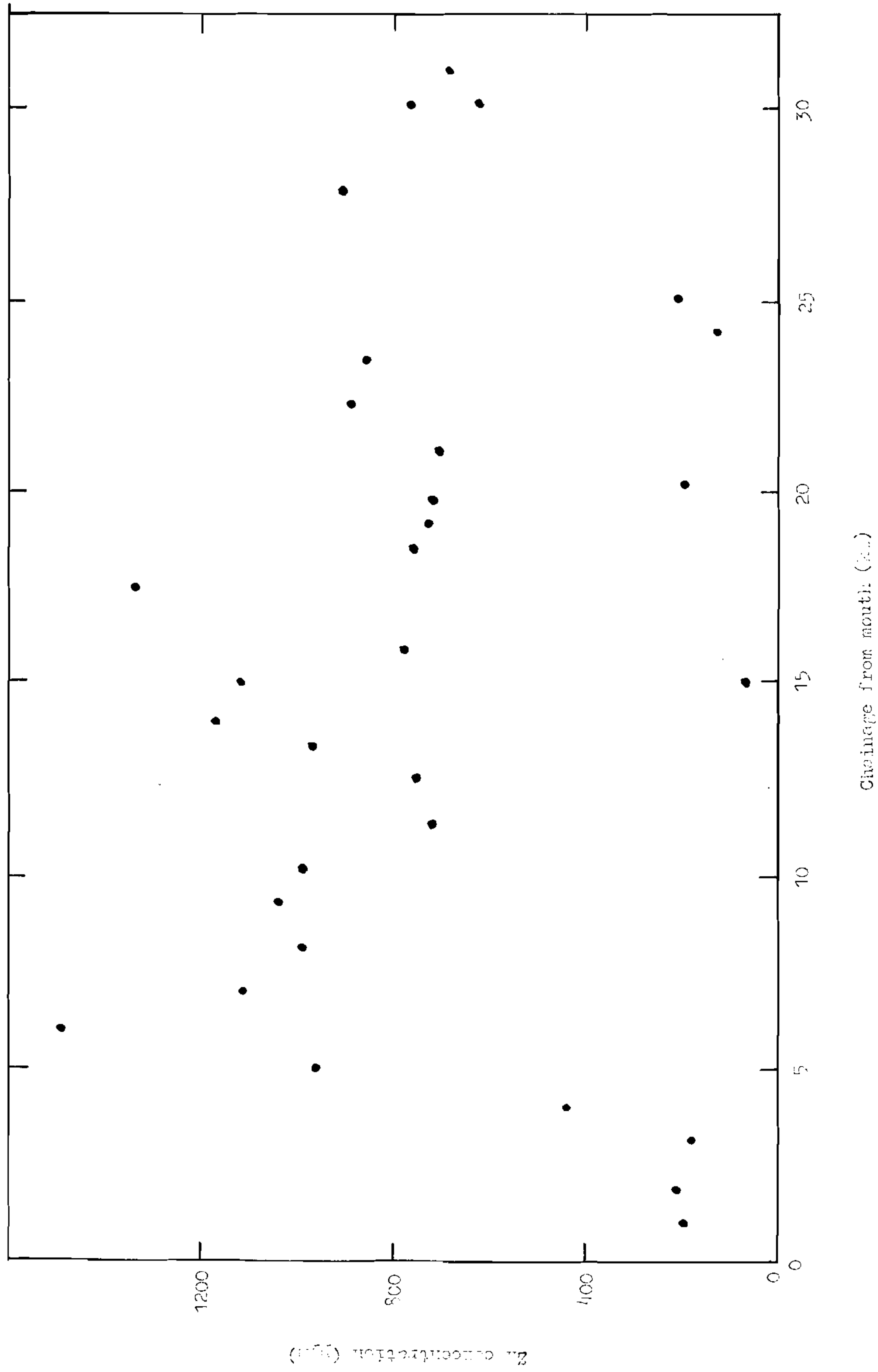

Fig 4 Longitudinal distribution of zinc on bed sediments

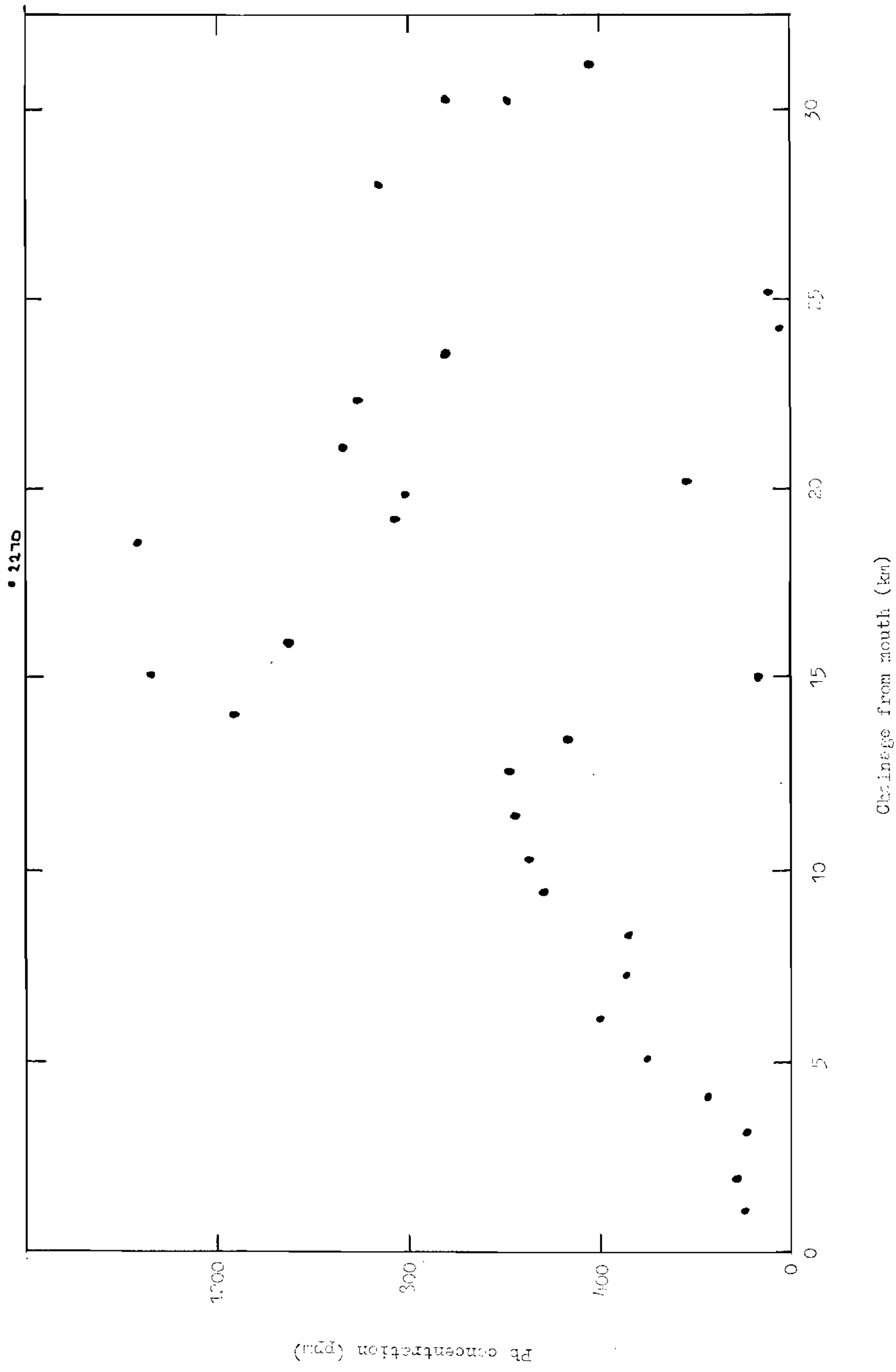

Fig 5 Longitudinal distribution of lead on bed sediments

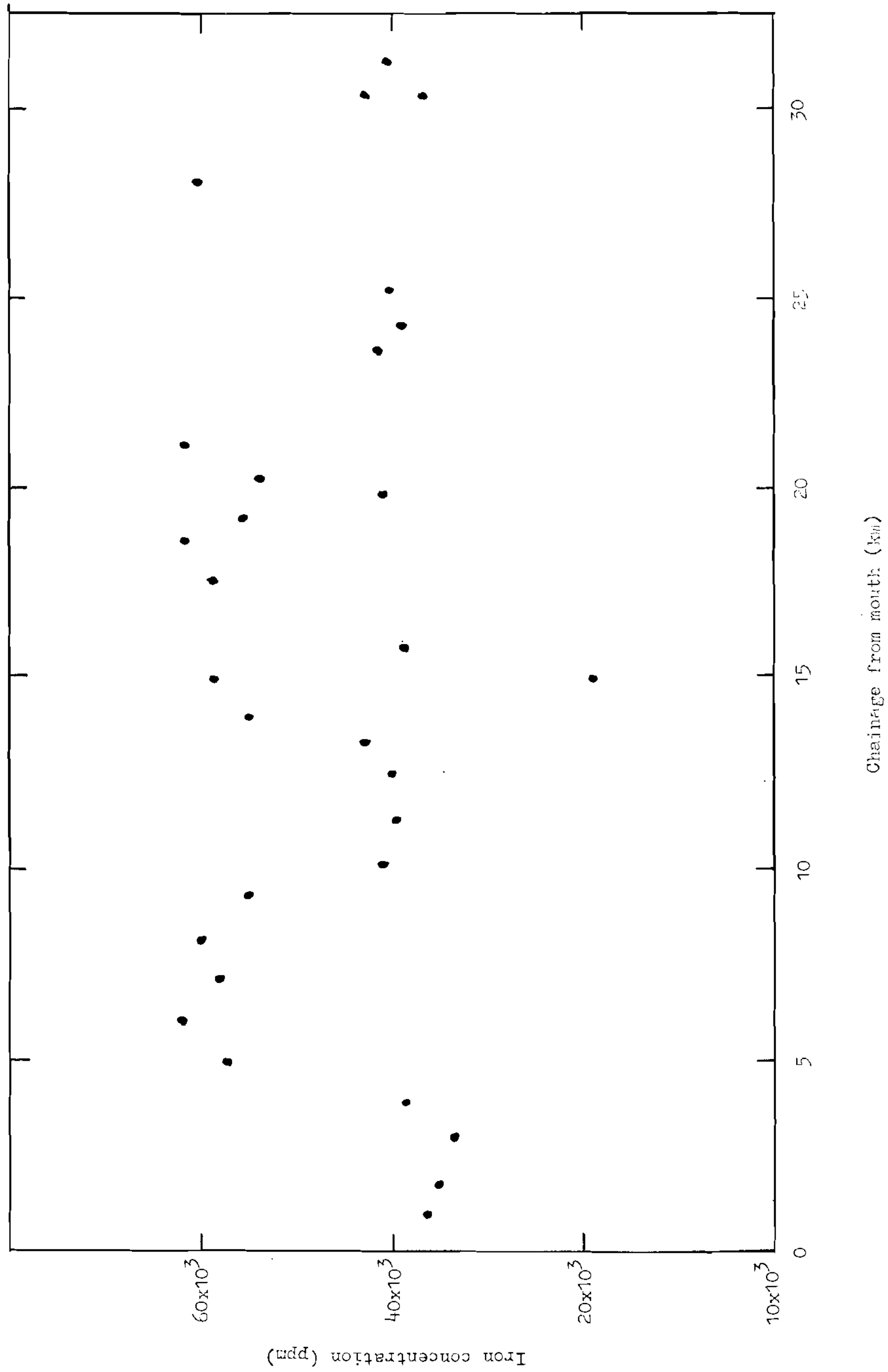

Fig 6 Longitudinal distribution of iron on bed sediments

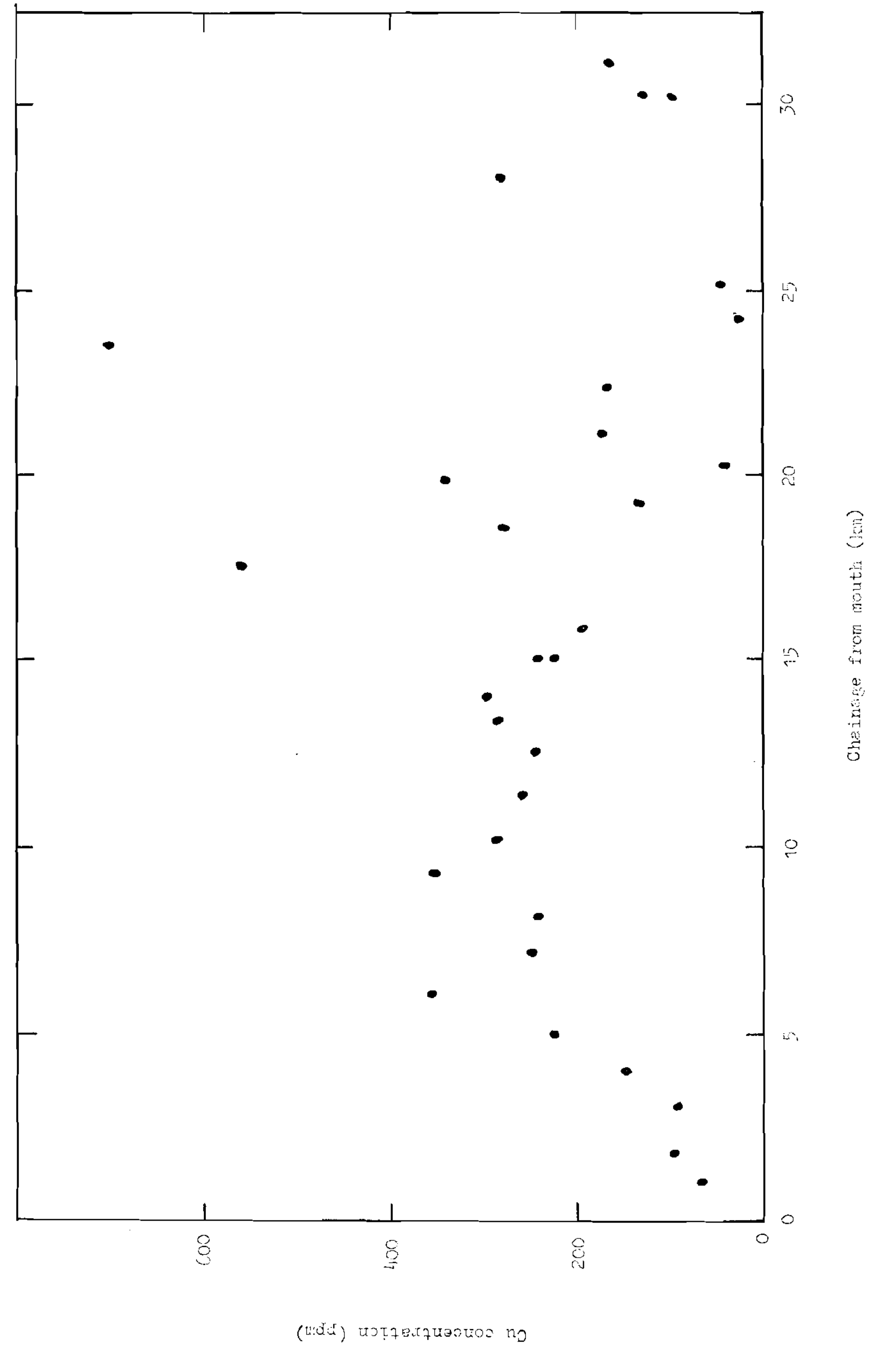

Fig 7 Longitudinal distribution of copper concentration on bed sediments

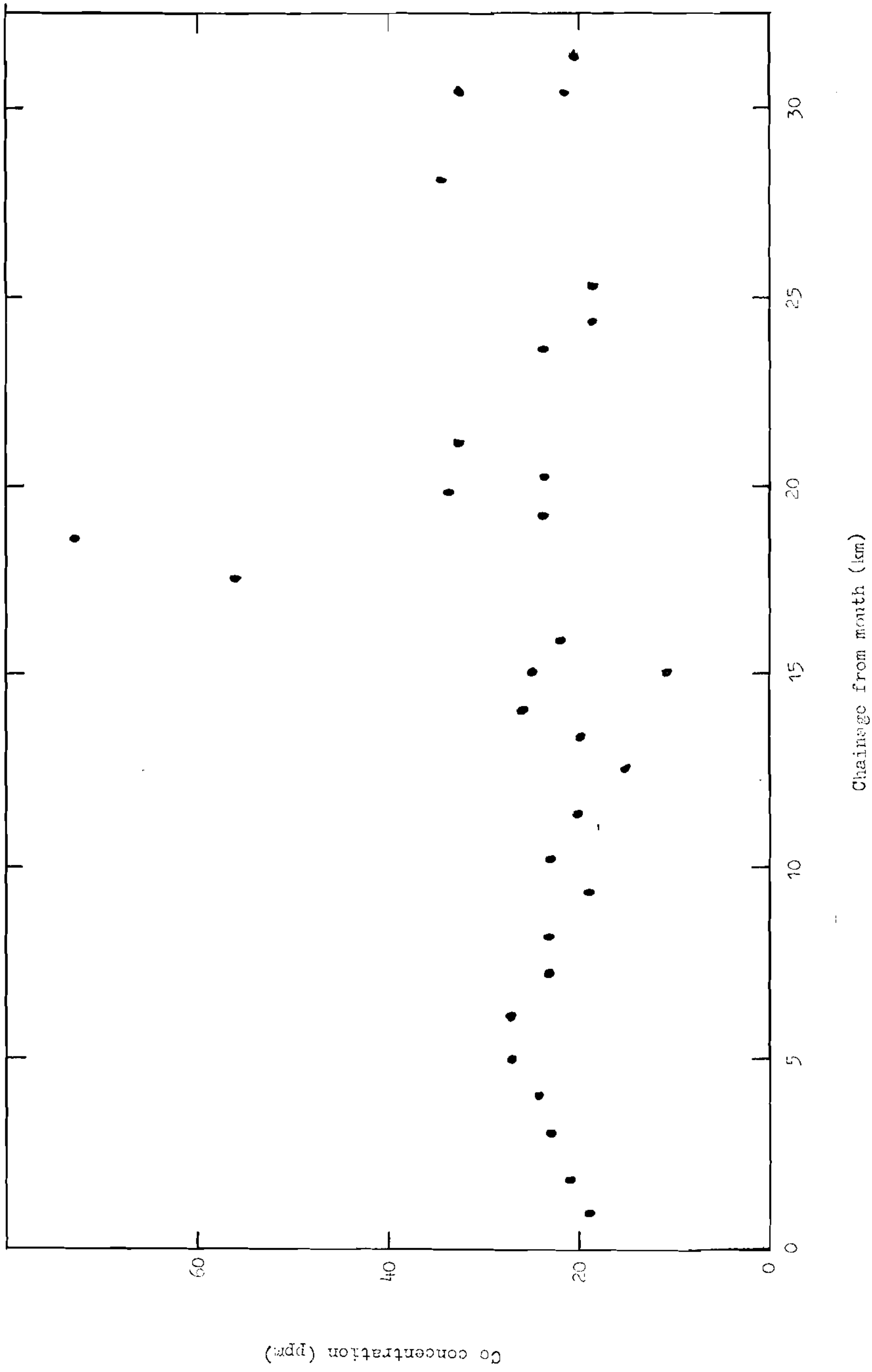

Fig 8 Longitudinal distribution of cobalt on bed sediments

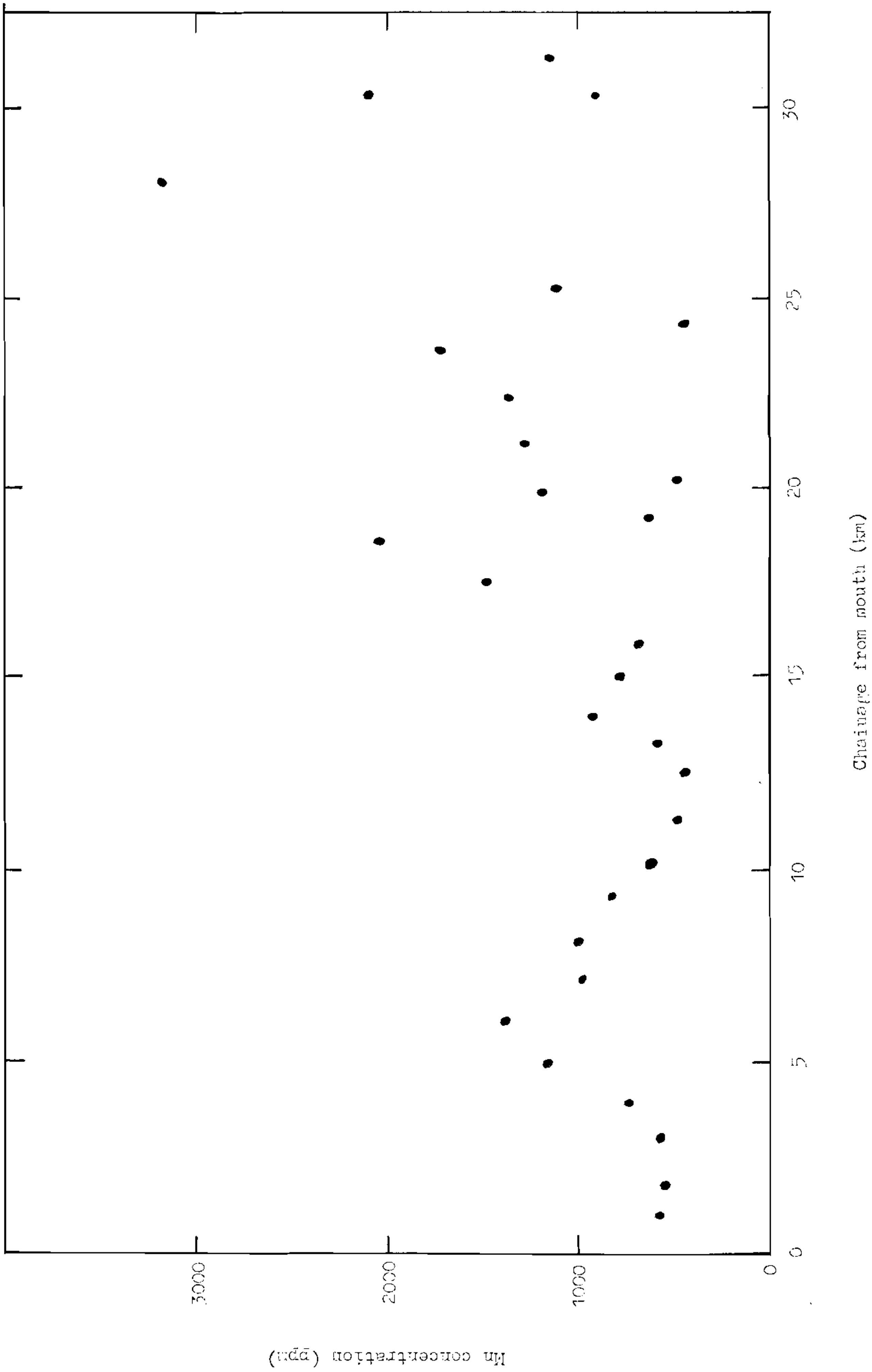

Fig 9 Longitudinal distribution of manganese on bed sediments

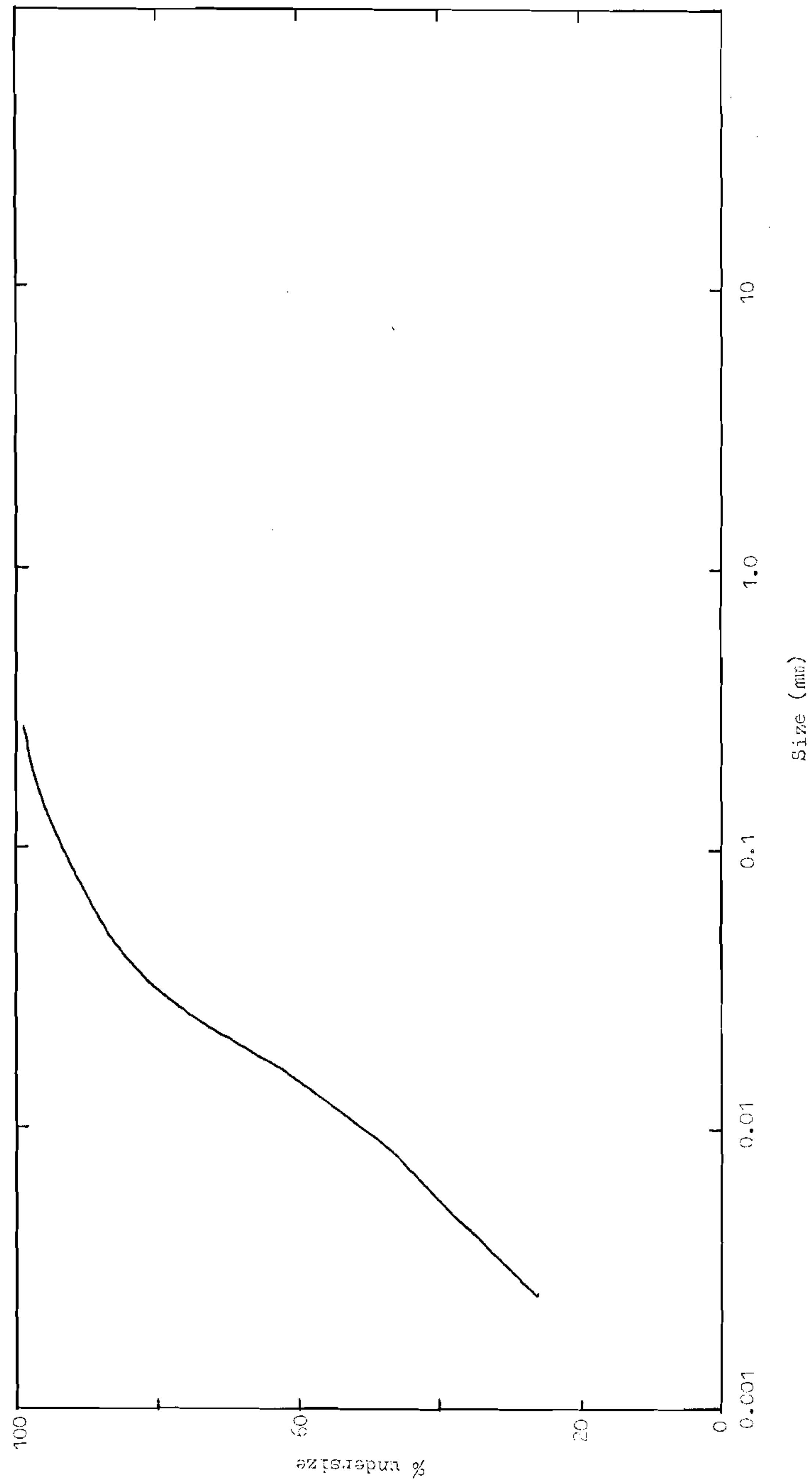

Fig 10 Size grading of sample no T32

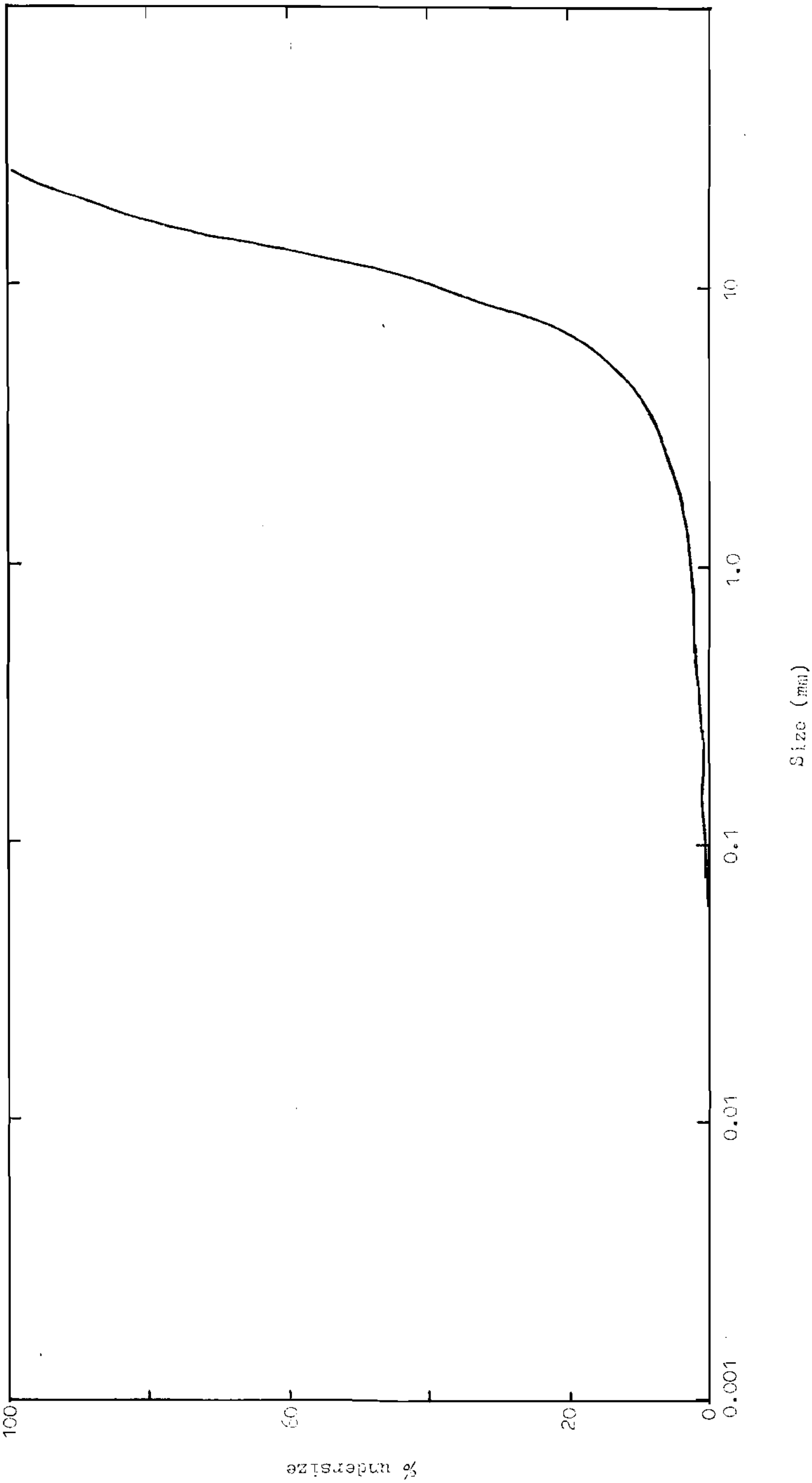

Fig 11 Size grading of sample no T8

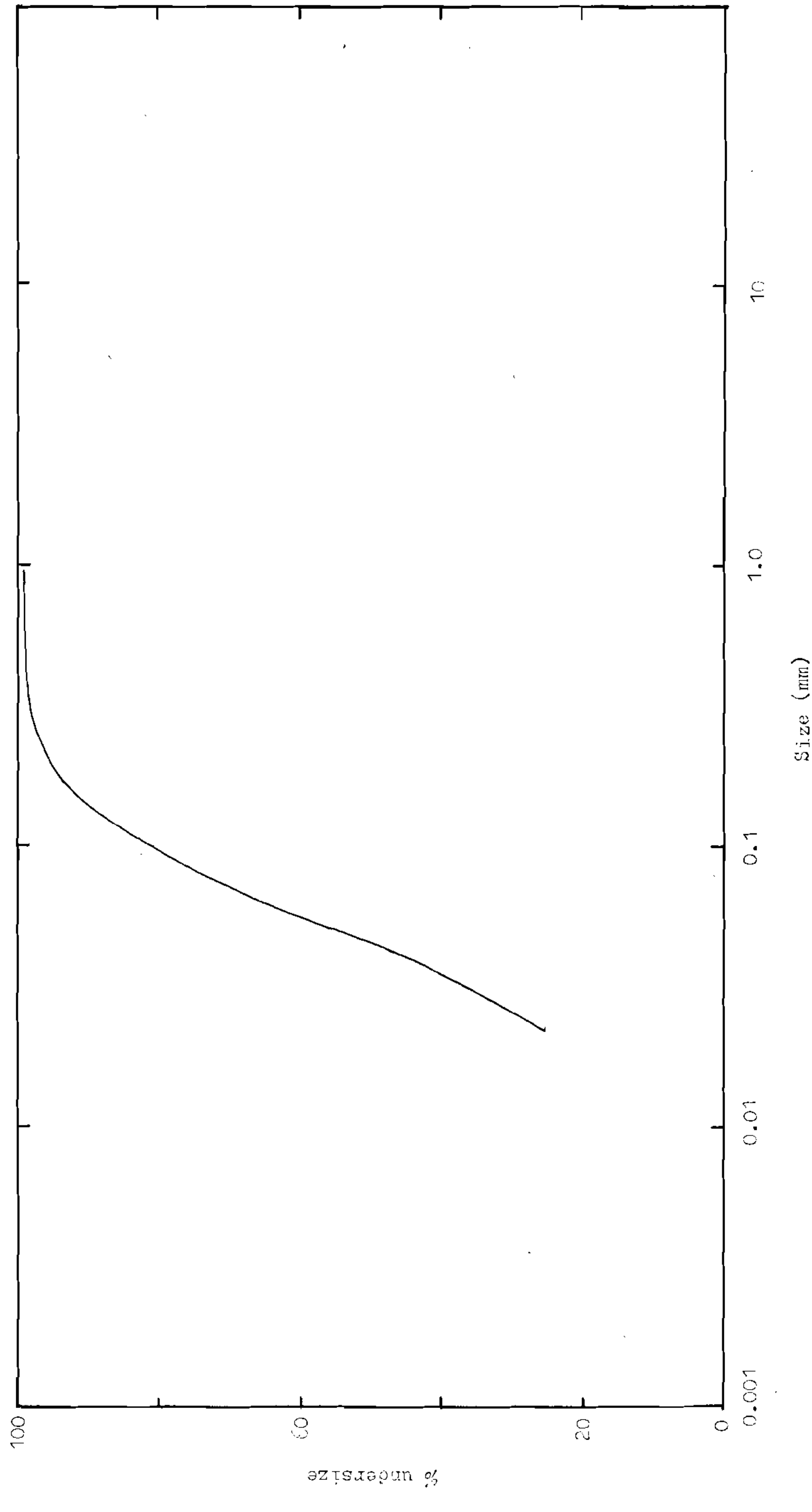

Fig 12 Size grading of sample no Y2

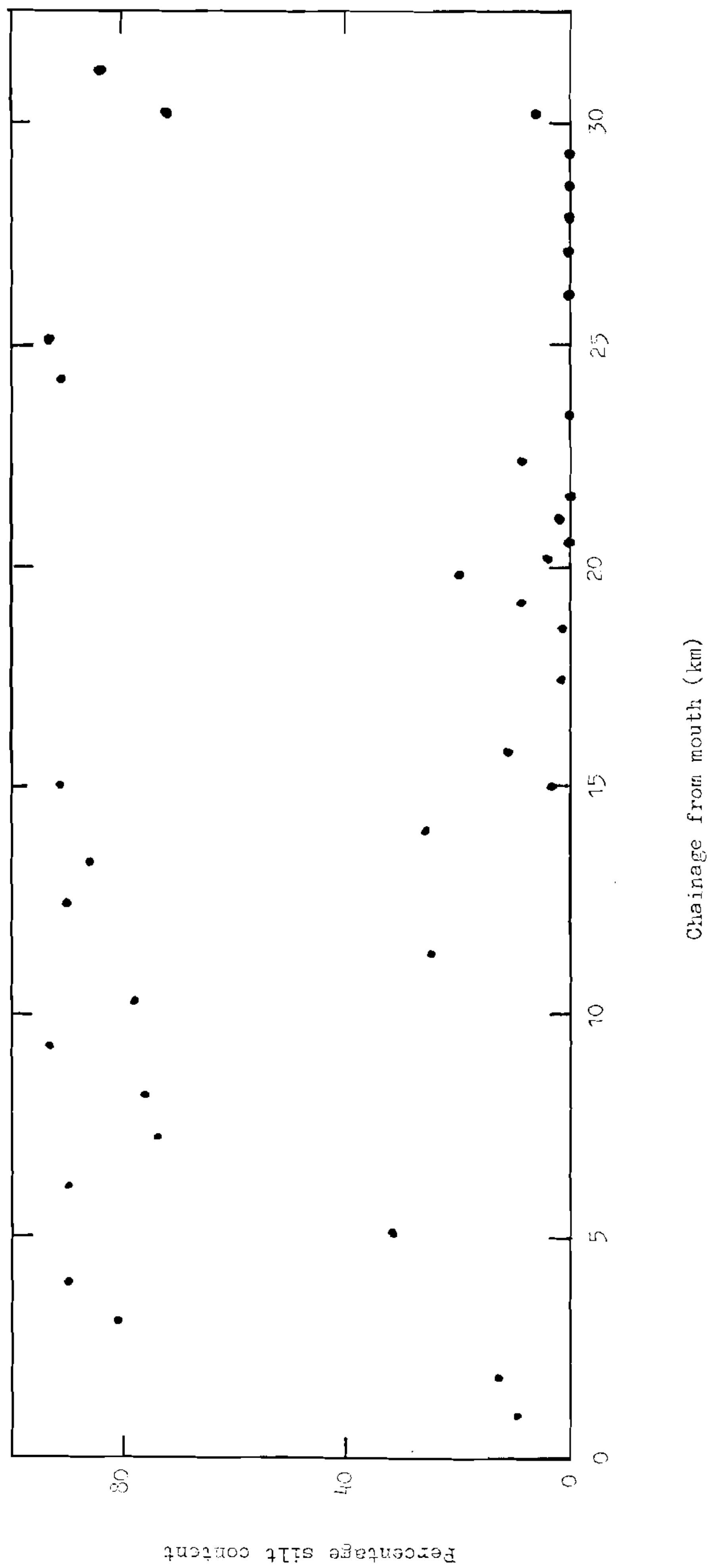

Fig 13 Longitudinal distribution of silt content in bed sediments

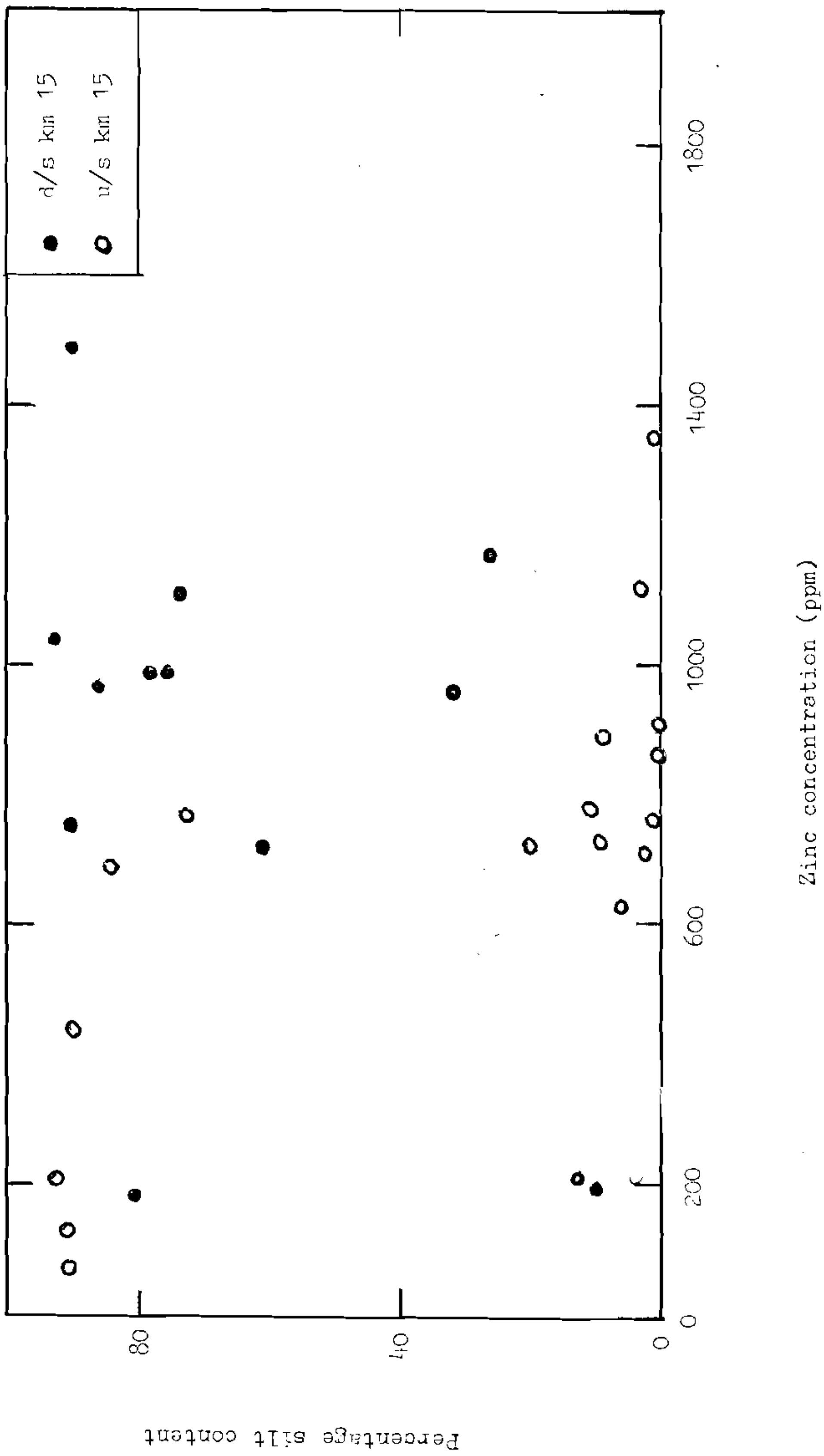

Fig 14 Relationship between zinc concentration and percentage silt content of bed sediments

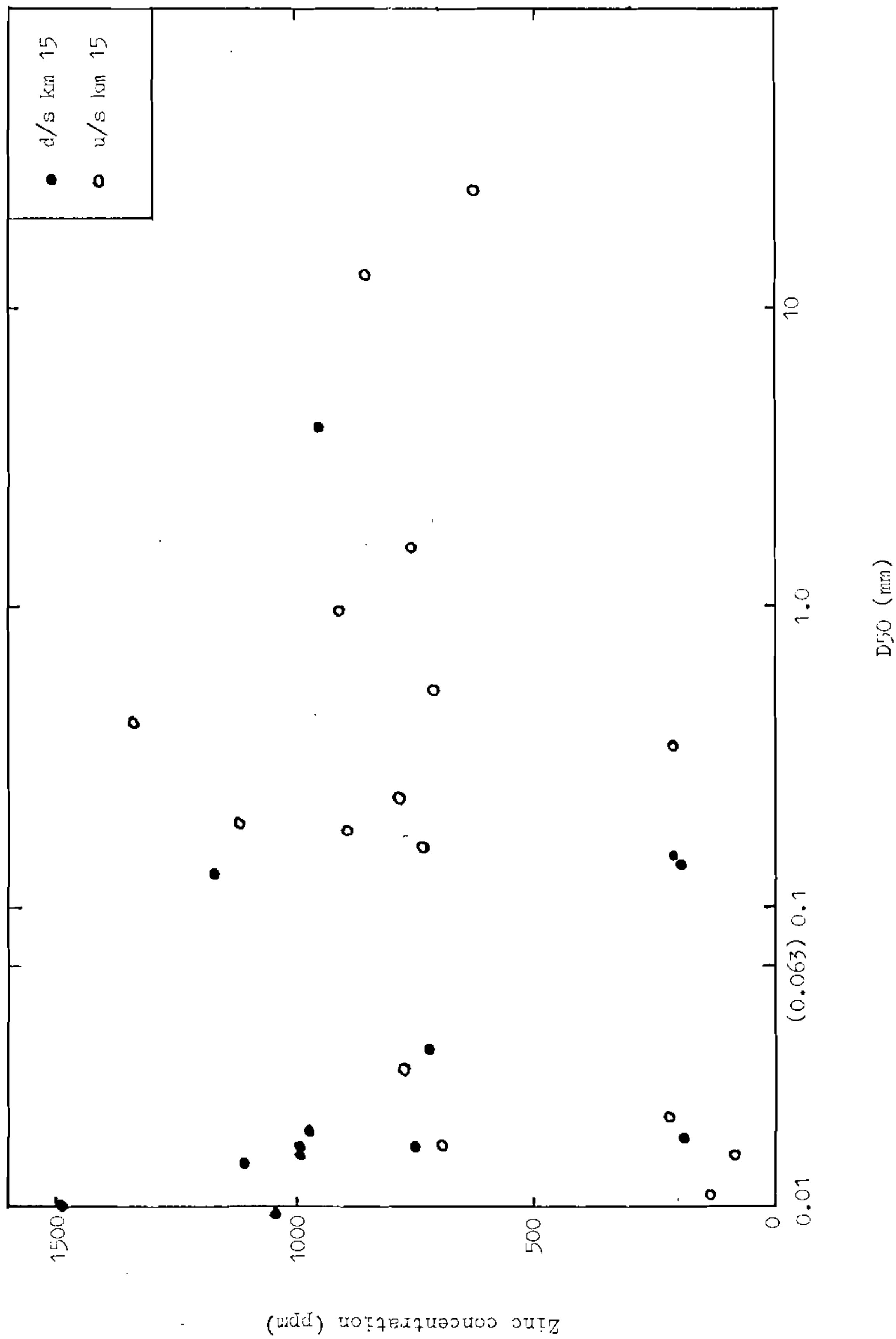

Fig 15 Relationship between D50 and zinc concentration of bed sediments

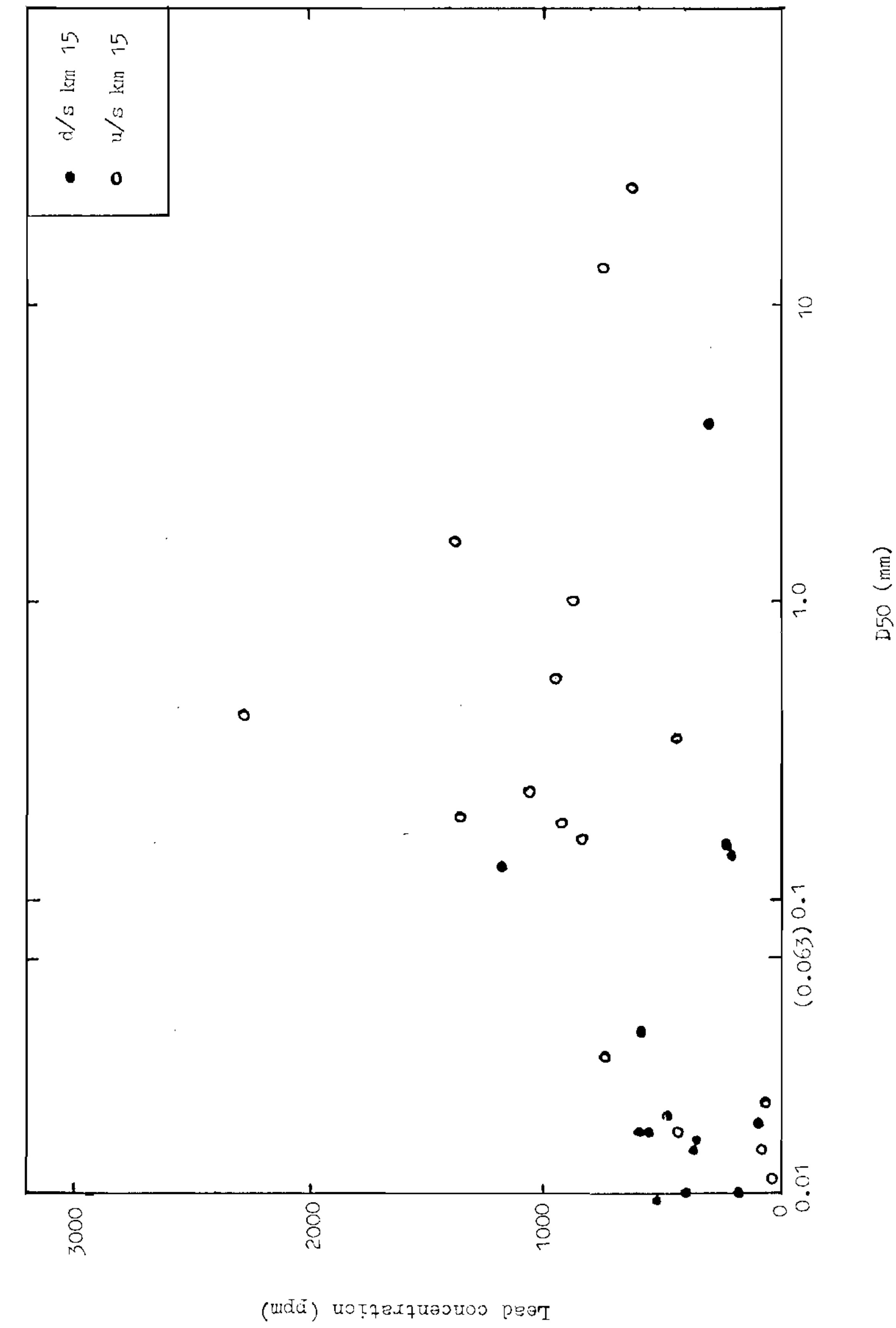

Fig 16 Relationship between D50 and lead concentration of bed sediments

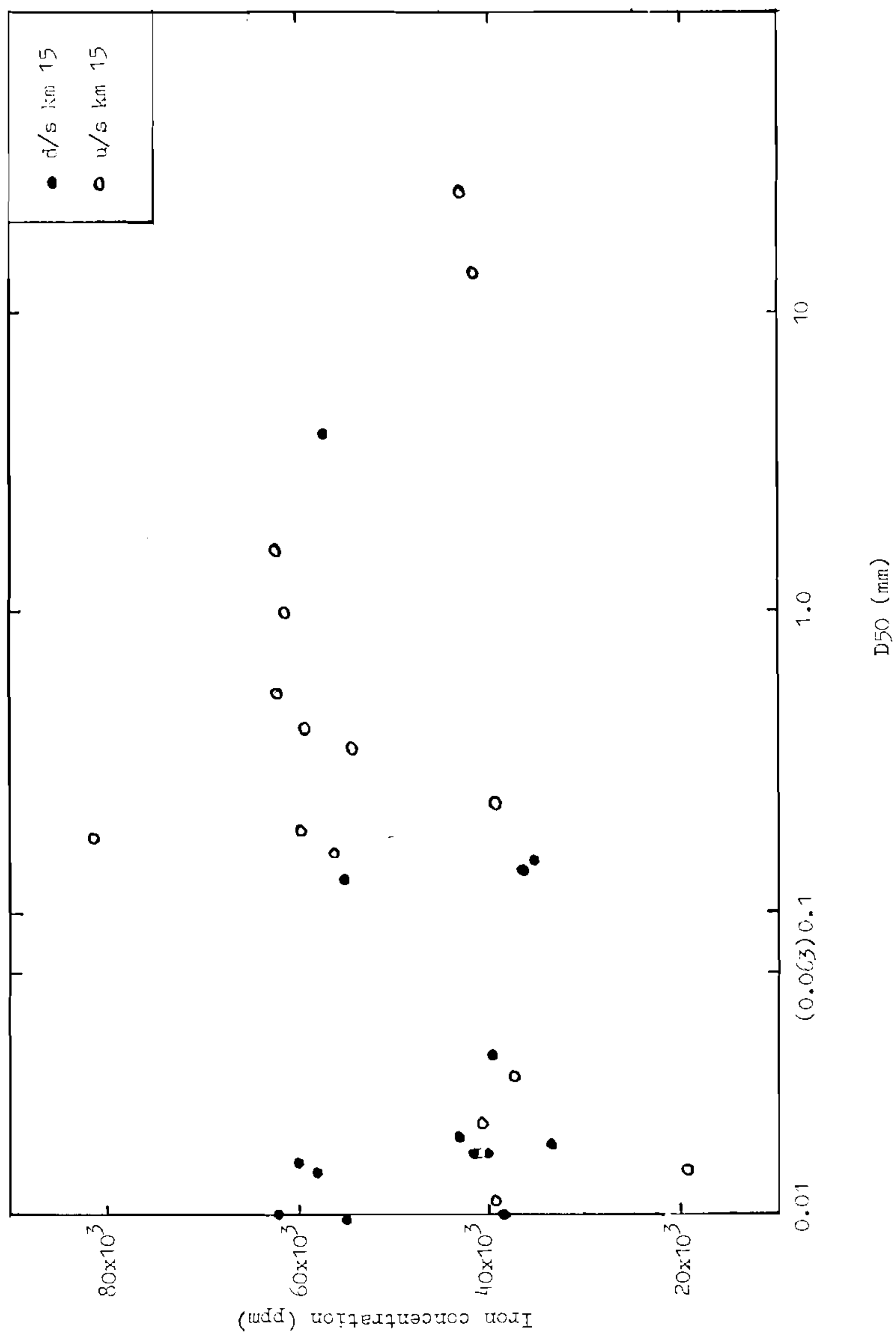

Fig 17 Relationship between D50 and iron concentration of bed sediments

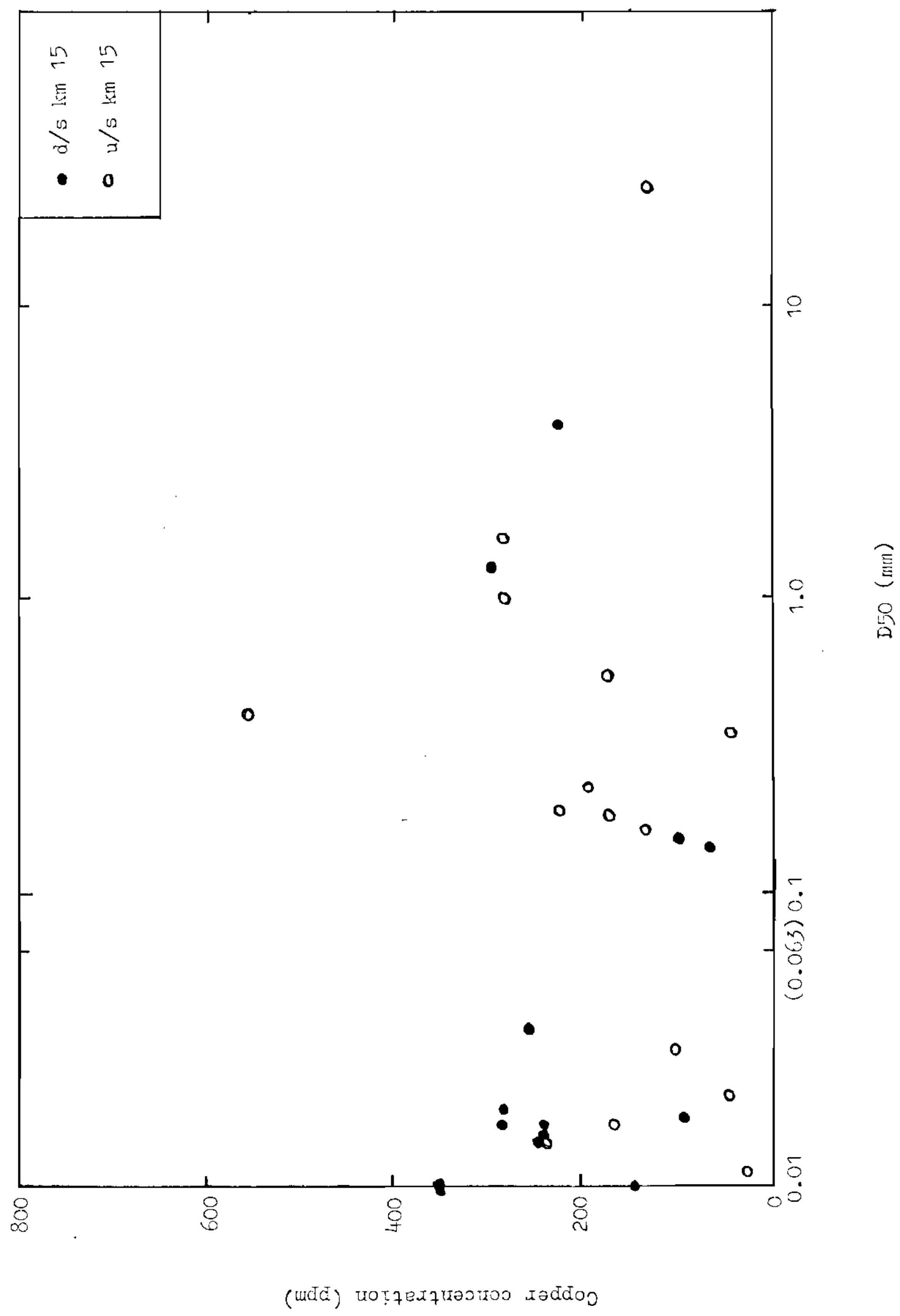

Fig 18 Relationship between D50 and copper concentration of bed sediments

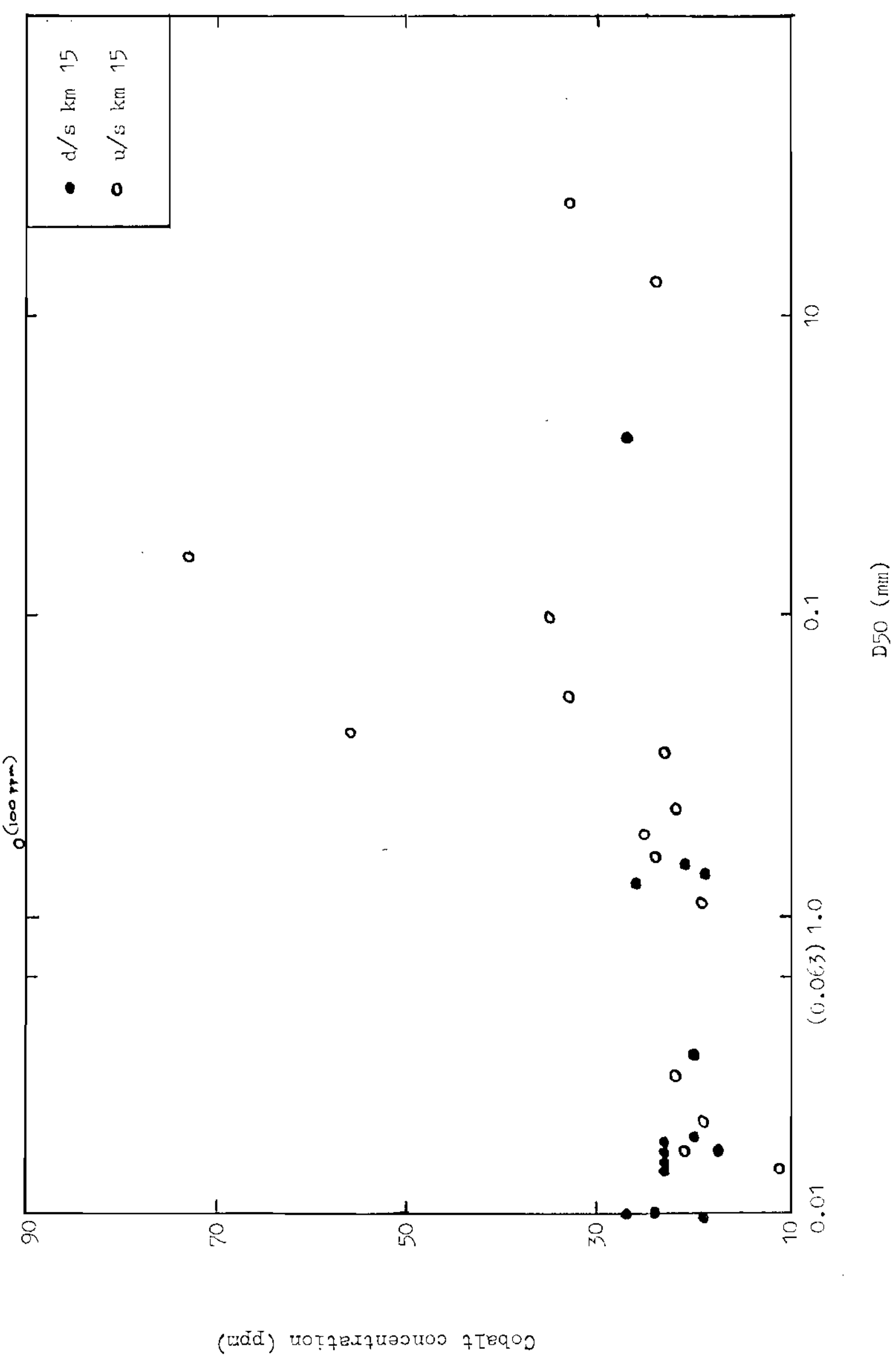

Fig 19 Relationship between D50 and cobalt concentration of bed sediments

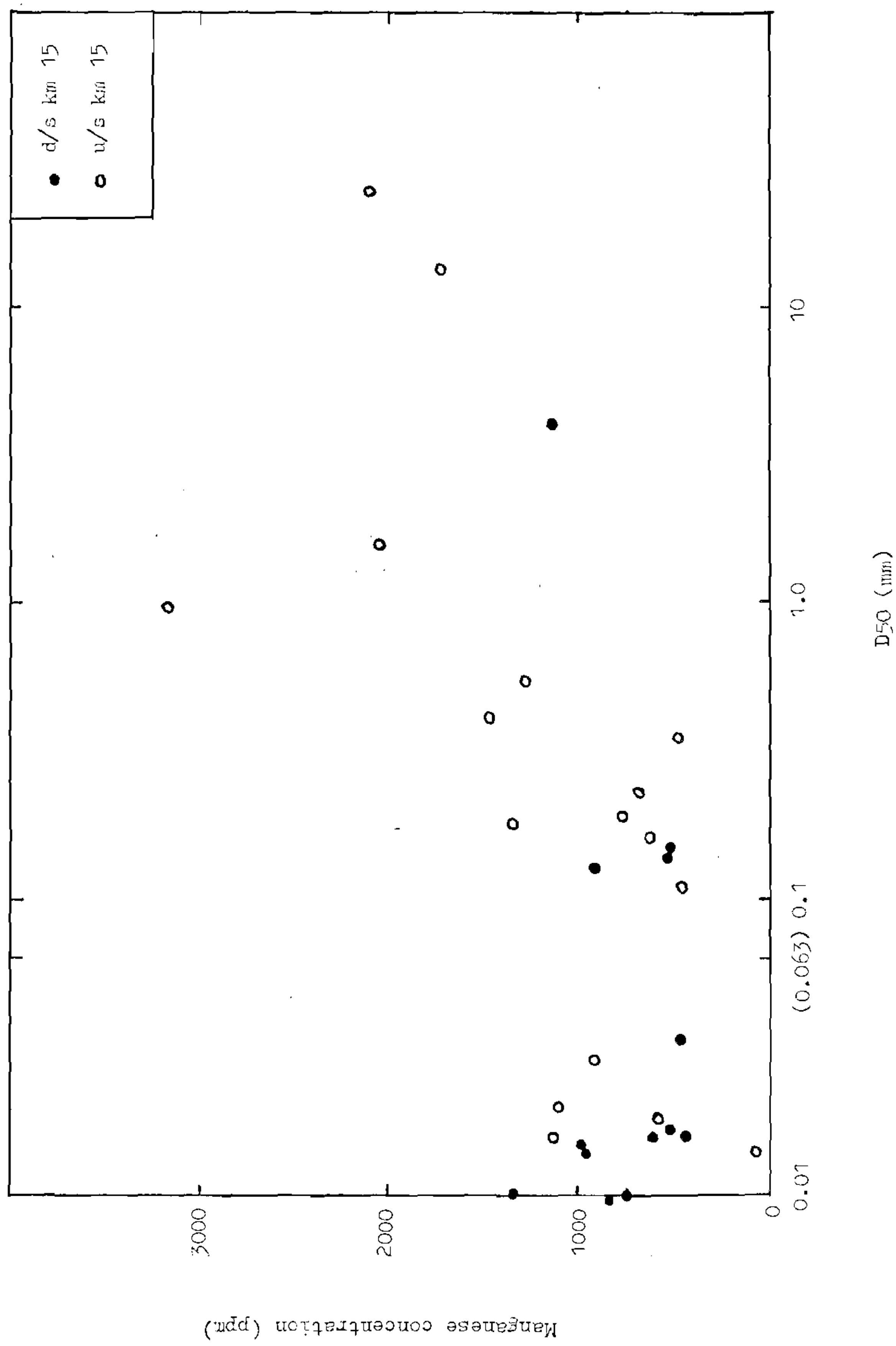

Fig 20 Relationship between D50 and manganese concentration of bed sediments