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Hydraulics Research
Wallingford

DREDGED SPOIL AND HEAVY METALS IN TIDAL WATERS

Research Summary

Report SR 199

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CONTRACT

This report describes work funded by the Department of the Environment under Research Contract PECD 7/7/164, for which the DoE nominated officer was Mr C E Wright, and by the British Ports Federation. It is published on behalf of the Department of the Environment and the British Ports Federation, but any opinions expressed in this report are not necessarily those of the funding organisations. The work was carried out in Dr E A Delo's and Mr T N Burt's sections in the Tidal Engineering Department of Hydraulics Research, Wallingford, under the management of Mr M F C Thorn.

ABSTRACT

This is a summary report of the work conducted by Hydraulics Research between April 1985 and March 1987 on a contract funded by the Department of the Environment. This work was also partly funded by the British Ports Federation (BPF). The work described in this report comprises those aspects of the main contract which are relevant to BPF, namely, the dispersal of dredged material disposed of at open-water sites. The results of the work are presented as far as possible in engineering terms and practical applications of the work are highlighted.

The objectives of the work of interest to BPF were to develop an economic computational model to predict the dispersion of dredged material, and to monitor a dredged river and related disposal site to determine the concentrations of heavy metals on the sediments.

Four strategic research reports were produced in relation to the above objectives. The review of the literature and the field work conducted have enabled the dispersal process of bottom disposal at open-water sites to be qualitatively and quantitatively described. The amount of fine suspended material put into suspension during bottom disposal was measured to be between 0.5% and 2% of the total mass of dredged material. A mathematical model was developed to predict the fate of material put into suspension during disposal at open-water sites.

The sediment transport paths around the Tees Inner Disposal Site were determined by analysis of sediment grain size distributions and were found to agree with the residual current direction. The concentrations of six heavy metals were measured on bed sediments in the River Tees and within and around the Inner Disposal Site. The metal concentrations within the disposal site were found to be much lower than those in river.

The report was compiled by Dr E A Delo in the Tidal Engineering Department, headed by Mr M F C Thorn.

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1 INTRODUCTION

This is a summary report of the work conducted by Hydraulics Research between April 1985 and March 1987 on a contract funded by the Department of the Environment. This work was also partly funded by the British Ports Federation (BPF). The work described in this report comprises those aspects of the main contract which are relevant to BPF, namely, the dispersal of dredged material disposed of at open-water sites.

The results of the work are presented as far as possible in engineering terms and practical applications of the work are highlighted. This report also describes the objectives of a three year extension contract on heavy metals, dredging and spoil disposal in tidal waters which is also funded by the Department of the Environment.

2 OBJECTIVES

The relevant objectives of the contract to BPF were:

1. To develop an economic computational model to predict the dispersion of dredged material

2. To monitor a dredged river and related disposal site to determine the concentrations of heavy metals on the sediments

The field work associated with the second objective was carried out in co-operation with the Tees and Hartlepool Port Authority (Fig 1) on the River Tees and the Inner Disposal Site in Tees Bay (Fig 2). The dredging at the Tees is carried out by two trailing suction hopper dredgers which dispose of the material by bottom dumping. The field work was carried out on very silty material dredged from the upper reaches of the river.

3 REPORTS

Four strategic research reports were produced in relation to the above objectives. These are detailed in the references section. The important aspects of the work detailed in these reports is discussed in the following sections.

4 DESCRIPTION OF DISPERSAL PROCESS

The field work carried out and the review of the literature has enabled the disposal process by bottom disposal at open-water sites to be qualitatively, and in some aspects, quantitatively described.

The disposal process may be divided into three distinct transport phases according to the physical forces or processes that dominate during each period (Fig 3). These stages have been described by a number of investigators and the most common terminology for these stages is convective descent, dynamic collapse and passive diffusion.

Following release from the hopper, the dredged material descends through the water column as a well defined jet. During the descent large volumes of water are entrained in the jet and some of the material becomes separated from the jet and remains in the upper portion of the water column. This material may be described as a near surface plume and would be advected by the current away from the disposal point.

The descending jet collapses as a result of impact on the bed and material which is not deposited on impact will move out radially under its own momentum. When sufficient energy has been dissipated, the material will begin to settle rapidly to the bed.

The material on the bed will then be transported under the influence of the tidal currents and waves.

A quantitative estimate of the amount of material which became separated from the jet during the descent stage was made from the field work conducted at the Tees in September 1986 (Ref 2). This was found to be in the region of 0.5% to 2% of the total mass of material disposed of. Other researchers have found that between 1% and 5% of the disposed material is entrained into the upper part of the water column during disposal operations.

The extent of the initial spread of the material on the bed was found to be affected by both the bed slope and the direction of the tidal current. It appeared that material from the disposal of a single 1500m^3 hopper load spread as a bed wave a distance of 150m-300m from the disposal point.

A total of 25000m^3 of material with an average density of 1.15tm^{-3} was disposed of within a 50m by 50m area during the field experiment. However, no significant change in the elevation of the bed within this area could be detected after the disposal operations (Fig 4).

There was an appreciable increase in the percentage of silt in the bed sediment within the area as a result of the disposals (Fig 5). This was, however, limited to the area within 250m of the centre of the disposal region.

5 MODELLING THE DISPERSAL OF ENTRAINED MATERIAL

A computational model was developed to predict the movement of the plume of material put into suspension during the disposal process and its settling to the bed (Ref 3). The objective of the work was to create an economic means of predicting the dispersal of dredged materials in tidal waters. The model was based on an analytical solution of a simplified differential equation which described the spread of material from a source. A technique of convoluting solutions was implemented to enable the model to represent changes in the direction of the current and the depth of the water.

Two practical applications of this model have been made. The first was for the Tees Bay Inner Disposal Site in which material in suspension is the result of entrainment from the descending plume (Figs 6 and 7). This type of model is however well suited to predicting the fate of material put in suspension from side-cast dredging operations. The model has been applied to such a situation of side-cast dredging as part of the extension contract.

6 LONG TERM TRANSPORT OF DREDGED MATERIAL

A novel technique for predicting transport paths within an area, based on the size grading of the bed material, was employed to derive the predominant transport direction in the Inner Disposal Site (Ref 4). Although the technique was applied only to the sand fraction of the bed samples the resulting prediction of the transport direction corresponded to that determined by current-metering at the site.

7 HEAVY METAL CONCENTRATIONS

The concentrations of six heavy metals - copper, zinc, lead, iron, manganese and cobalt - were determined on bed sediments in the River Tees and in and around the disposal site (Ref 4). An estimation of the average concentration of these heavy metals within the annual quantity of dredged material was made and compared to the concentrations found on sediment within the disposal site and surrounding it.

Metal concentrations were considerably lower within and around the disposal site compared to those estimated for the dredged material. Within the 2km by 2.5km disposal site copper had a concentration of only 20% of that of the dredged river material (Fig 8). The values for the other metals were zinc 55%, lead 33%, iron 44%, manganese 55% and cobalt 33%. The concentrations of these metals in the area surrounding the disposal site (approximately 2km radius) were similar to those within the site.

More extensive surveys of the disposal site and the surrounding area (10km by 10km) have been conducted as part of the extension contract.

8 SUMMARY OF FINDINGS

1. The review of the literature and the field work conducted have enabled the dispersal process of bottom disposal at open-water sites to be qualitatively and quantitatively described.

2. The amount of fine suspended material put into suspension during bottom disposal was measured to be between 0.5% and 2% of the total mass of dredged material.

3. A mathematical model was developed to predict the fate of material put into suspension during disposal at open-water sites.

4. The sediment transport paths around the Tees Inner Disposal Site were determined by analysis of sediment grain size distributions and were found to agree with the residual current direction.

5. The concentrations of six heavy metals were measured on bed sediments in the River Tees and within and around the Inner Disposal Site. The metal concentrations within the disposal site were found to be much lower than those in the river.

9 OBJECTIVES OF CONTRACT EXTENSION

The objectives of the current contract funded by the Department of the Environment and which formed an extension to the one described above are:

1. Investigate by field and laboratory studies the processes of long term dispersion of disposed dredged material.

2. Develop computational techniques to create an economic means of predicting long term dispersion of dredged material on the sea bed.

3. Test the short term dispersion predictive model developed under the first contract in a different field situation with different hydraulic and sediment characteristics.

4. Disseminate knowledge gained by participating in the London Dumping Convention.

10 REFERENCES

1. Dispersal of dredged material: Tees field survey June 1985. Hydraulics Research Report SR 110 June 1987

2. Dispersal of dredged material: Tees field survey September 1986. Hydraulics Research Report SR 112 June 1987

3. Dispersal of dredged material: Mathematical model of plume. Hydraulics Research Report SR 133 June 1987

4. Heavy metal transport and dispersal by maintenance dredging: A study of the Tees. Hydraulics Research Report SR 142 May 1988

FIGURES

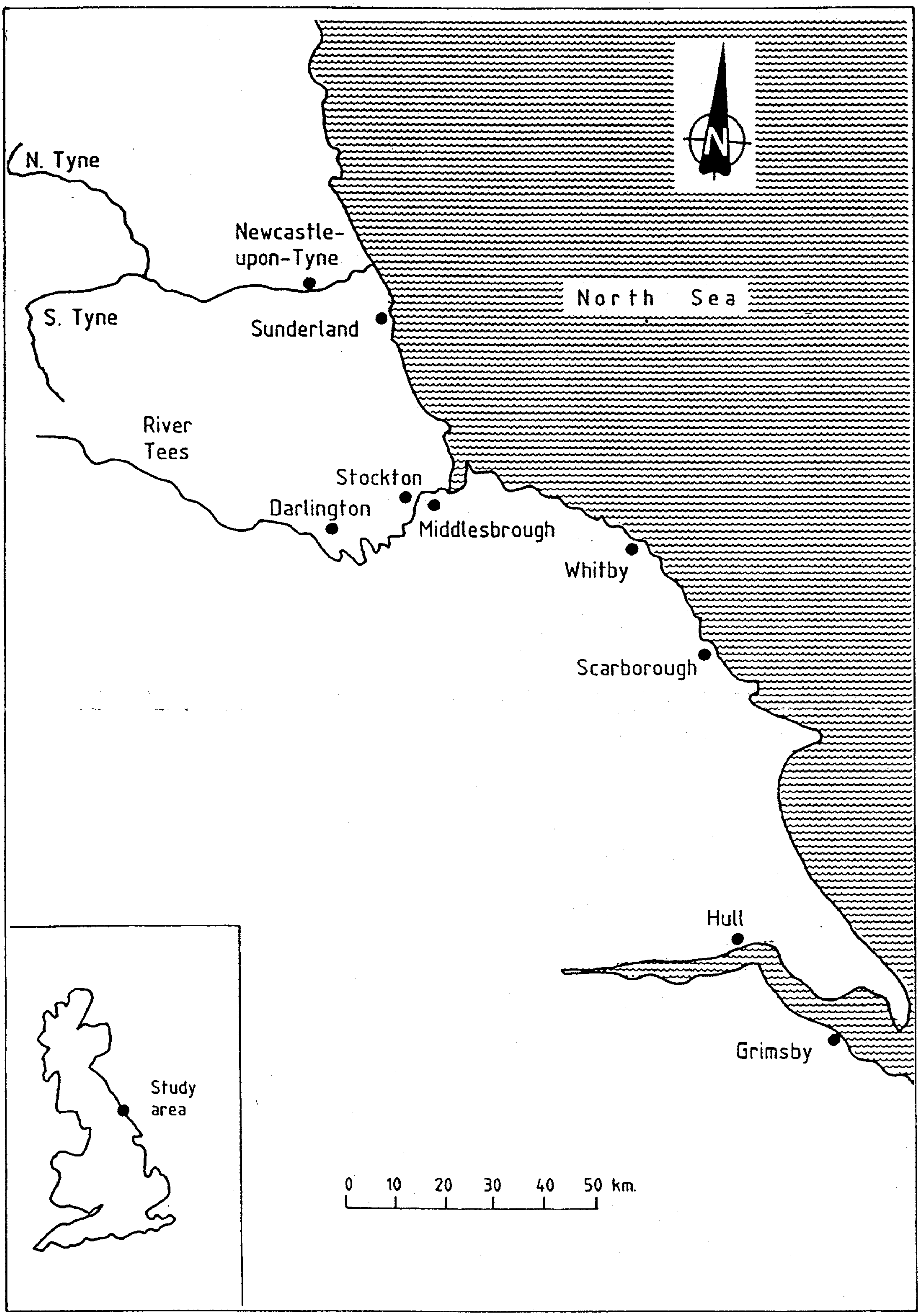


Fig 1 Location map of River Tees

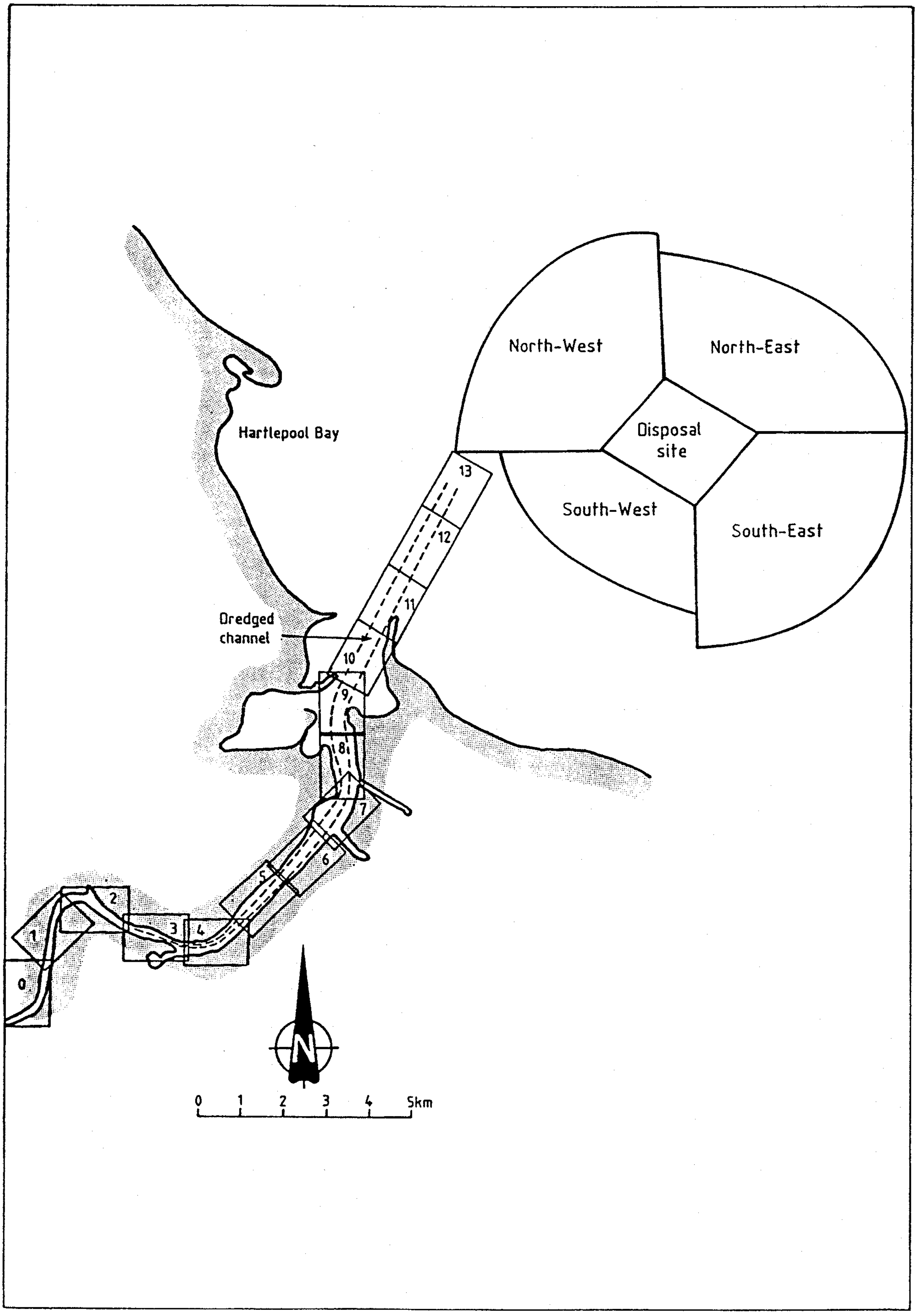


Fig 2   Location map of Inner Disposal Site

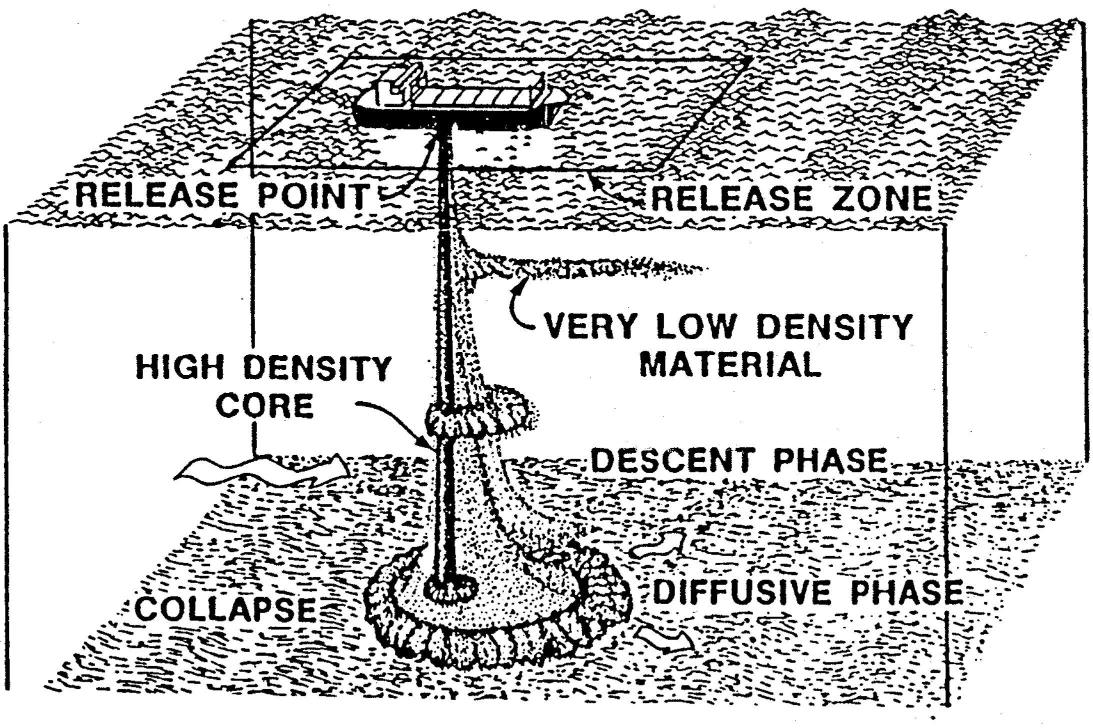


Fig 3 Transport phases during bottom disposal

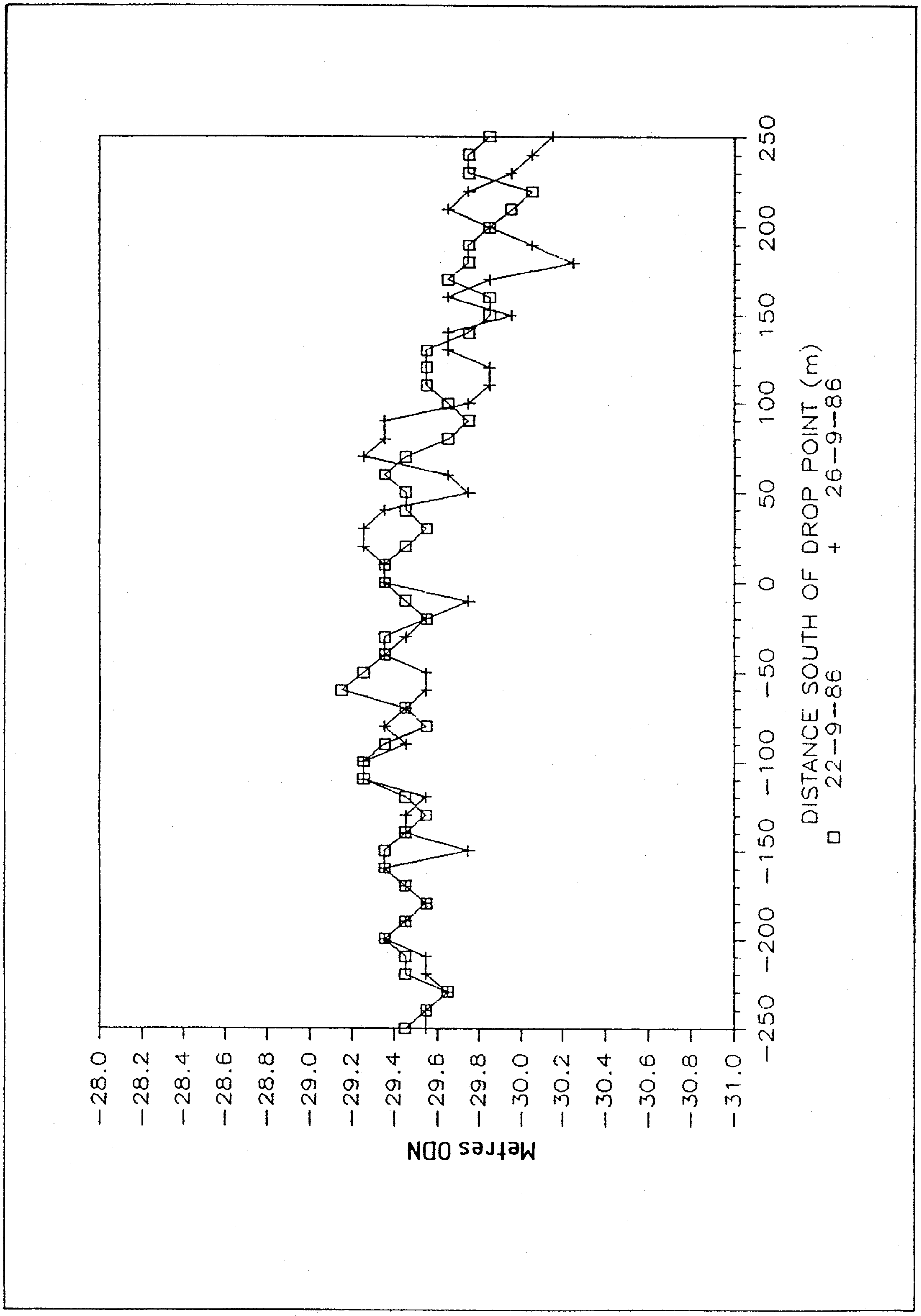


Fig 4 Pre and post disposal hydrographic survey on Line 4

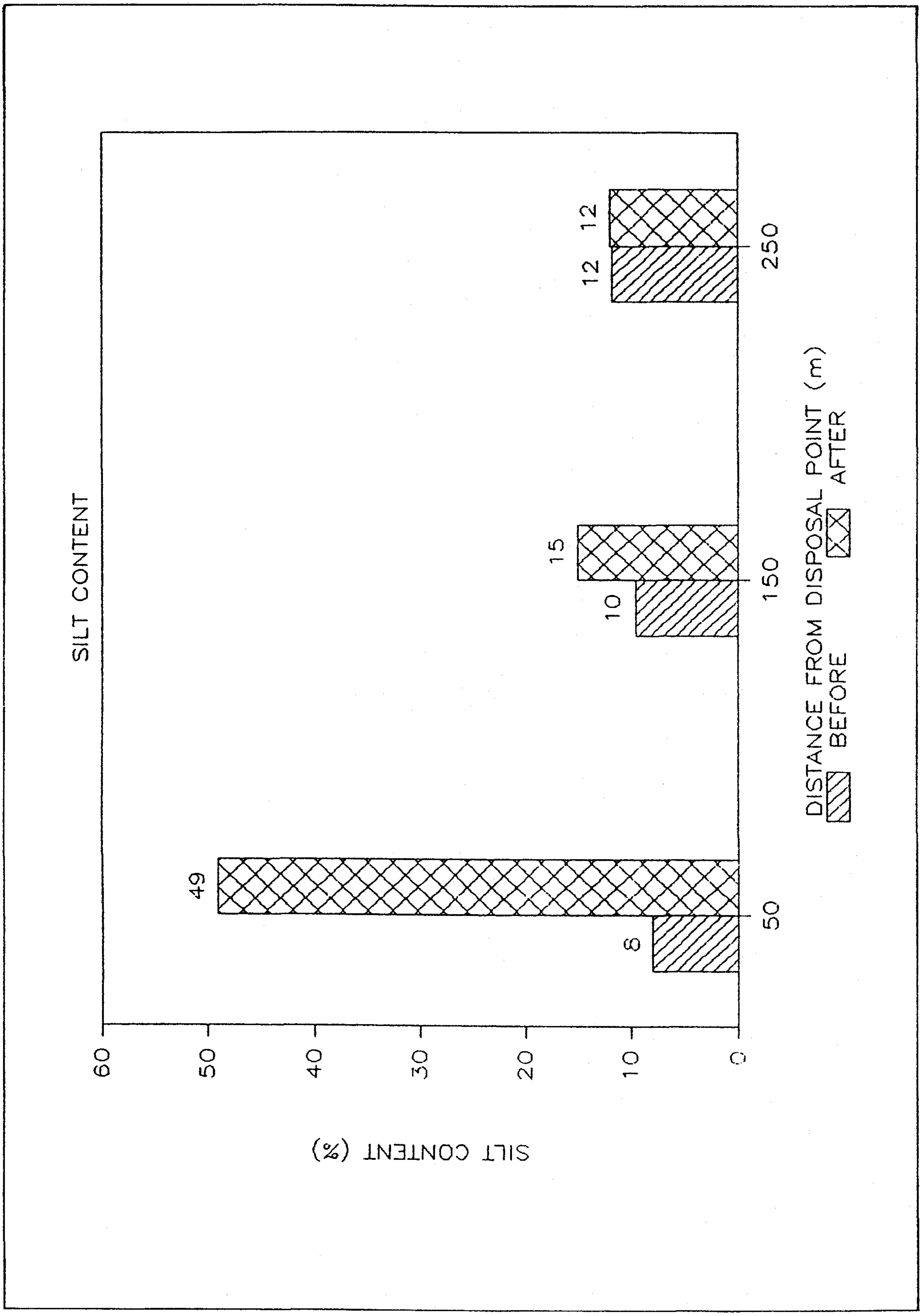


Fig 5 Silt content of bed samples taken in test area before and after disposal

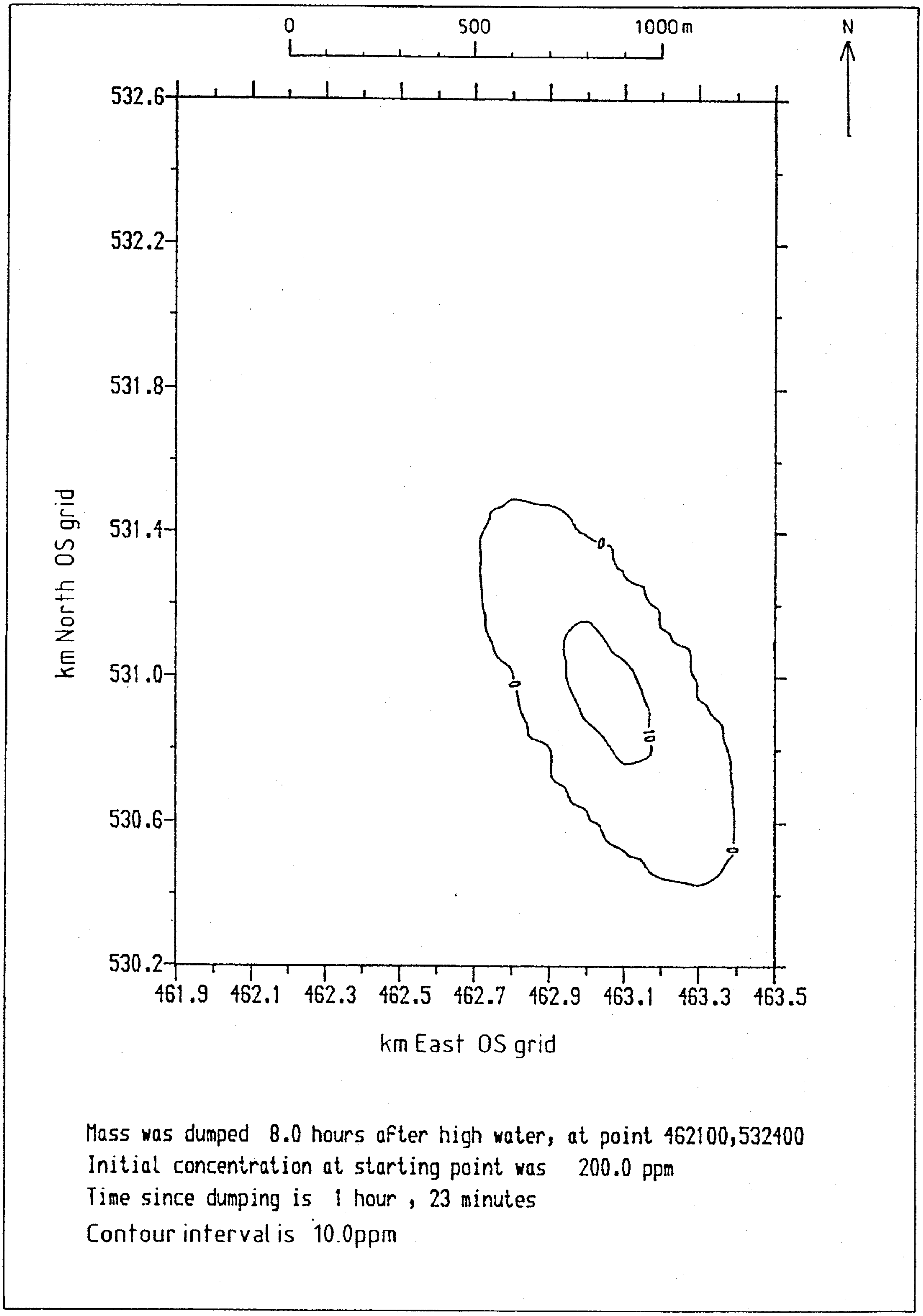
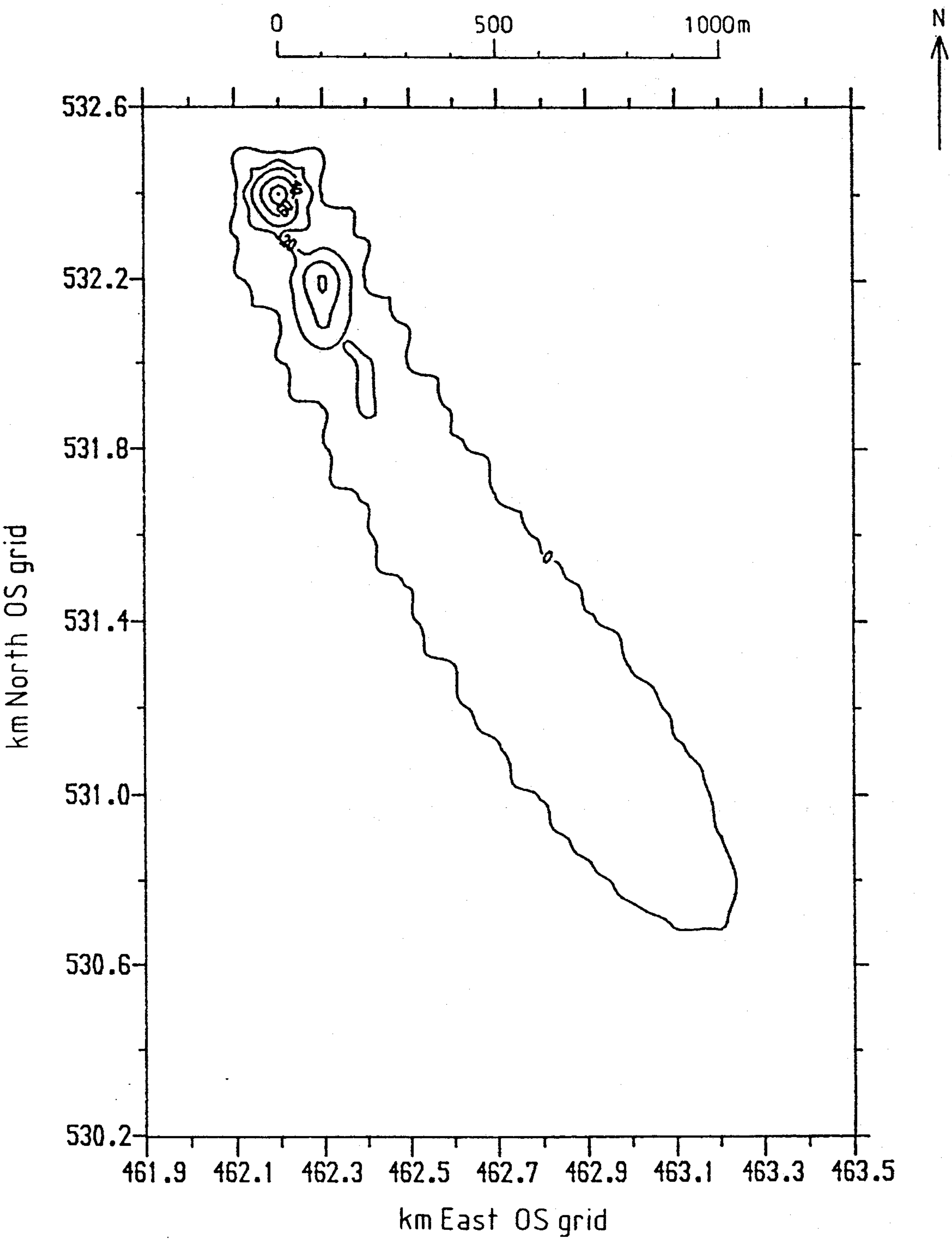


Fig 6 Plume model with input data from the Tees estuary. Concentrations in suspension (ppm) 1 hour 23 minutes after disposal



Mass was dumped 8.0 hours after high water, at point 462100,532400
Initial concentration at starting point was 200.0 ppm
Time since dumping is 1 hour , 23 minutes
Contour interval is 20.10^{-5}
Initial mass dumped 1.0

Fig 7 Plume model with input data from the Tees estuary. Distribution of mass on bed after 1 hour 23 minutes as proportion of dumped mass

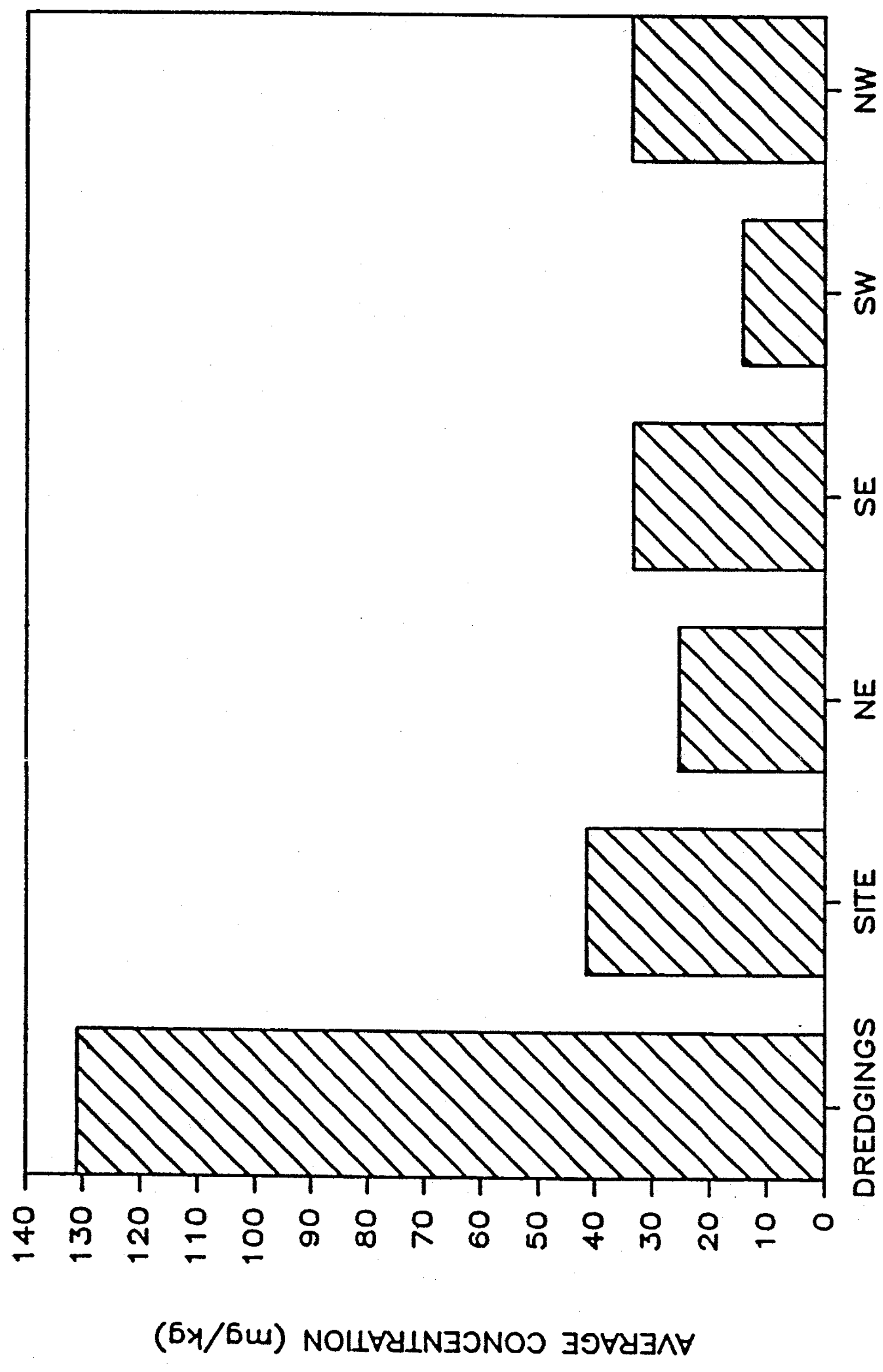


Fig 8 Distribution by region of copper on bed sediments at the Tees Inner Disposal Site