HR Wallingford

FLOOD DISCHARGE ASSESSMENT

Peak Velocity Meter - evaluation of a device for measuring flood plain flow velocity

Progress to March 1991

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At the time of reporting this project, Hydraulics Research's nominated project officer was Dr W R White.

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SUMMARY

Hydraulics Research Ltd are studying methods of improving the assessment of flood discharge on behalf of the Ministry of Agriculture, Fisheries and Food. The research is being carried out with the co-operation of the National Rivers Authorities in England and Wales, and includes the analysis of existing flood flow data, and the development of new methods for assessing flood discharge.

This report describes modifications to and check calibrations of a peak velocity meter designed to measure flow velocities on flood plains and which can be interrogated after the passage of a flood.

The report also describes the site installation of the meter.

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CONTENTS (Cont'd)

1 INTRODUCTION

1.1 Background

The Water Resources Act 1963 placed on the Water Resources Board the duty of collecting data relating to the demand for water and the actual and prospective water resources for England and Wales. Consequently, many gauging stations were primarily designed to establish the quantity of water available for the community. The provision of flood data was originally considered to be of secondary importance.

When a flow measurement structure or rated channel section is out flanked by a flood flow the uncertainties associated with flow measurement rise from 3-10% for in-bank flow conditions to 30% or more for out of bank flood conditions. Uncertainties of this magnitude can have a profound impact on the return period associated through standard statistical techniques with a particular discharge. They may also lead to the design of a flood protection scheme being too conservative with associated economic losses, or alternatively inadequate with the benefits of the proposed scheme not being achieved. Reporting upon the errors in flood discharge measurement the Wolf Report (1985) stated :

" A research programme should be set up to develop new methods for measuring or estimating flow particularly over a flood plain. The objective of the project should be to produce a method which is inexpensive and effective and can possibly be applied after the event."

These recommendations formed the basis for the present research, which is being carried out by Hydraulics

Research Limited (HRL) for the Ministry of Agriculture, Fisheries and Food (MAFF). The development and testing of an inexpensive, effective instrument capable of measuring flow velocity to an accuracy of +/- 10%, which can be read after the passage of a flood was reported by Hollinrake (1990).

This report describes further laboratory experiments of the peak velocity meter and the field installation of the instrument undertaken up to March 1991.

1.2 Objectives

The objectives for any new method of estimating or assessing the discharge, particularly peak discharge, of a flood that can be used at typical lowland gauging sites in the UK were that :

(a) the method can be applied after the event.

(b) the error in discharge measurement is not greater than +/- 10%.

(c) no appreciable afflux is caused by the method.

(d) the method is inexpensive.

1.3 The proposed solution

The solution was provided by developing a very simple mechanical system, see Hollinrake (1990). The instrument operates on the principle of a deflecting vane and comprises a vane suspended centrally from a horizontal shaft, one end of which is located in a needle roller bearing, the other in a roller clutch bearing. The clutch bearing will only allow rotation in the direction of flow, consequently after the passage of a flood the vane will retain the deflection due to the peak velocity.

Flood plain flows would be assessed based upon the velocity-area principle. A schematic representation of a flow measurement site is shown in Figure 1.

2 PEAK VELOCITY METER - DESIGN 1

During the development stage the instrument was tested with vane lengths of 135mm with the shaft axis 150mm above the channel bed, see Fig 2. Dural and Stainless Steel plate, 6mm thick were used to make two sets of vanes in order to assess the influence of different density materials upon the calibration of the vane. Five vane shapes were tested, see Fig 3, consisting of three rectangular elements 12.5, 25 and 50mm wide and two trapezoidal elements. The first trapezoidal element had a top width of 10mm with a base width of 60mm, the second being the invert of the first. The data from the tests were fitted by third order polynomials. The trapezoidal element made from dural plate and with a top width of 10mm and a base width of 60mm, Type 4, provided the most sensitive calibration and all further testing was undertaken with this design.

3 DESIGN MODIFICATIONS

Three minor modifications were made to the initial design of peak velocity meter shown in Figure 2.

These consisted of:

sleeving the needle and clutch bearings in order to prevent sediment and other materials entering the bearing race.

positioning the deflection scale on the body of the meter, instead of above, so as to reduce the chance of trash snagging on the meter, see Plate 1.

providing a recess in the base plate of the meter to allow the insertion of a small wooden block. This block prevents deflection of the vane by wind prior to a flood event but floats out with increasing flood level so allowing the vane to deflect as floodplain velocities increase, see Plate 1.

4 TEST RESULTS - DESIGN 3

4.1 General

Due to the modifications made to the meter, in particular the possible increase in friction caused by sleeving the bearings, a check calibration of the meter was undertaken. The experimental facility used is described in Hollinrake (1990).

4.2 Flow alignment

In positioning the meter along a floodplain transect the intention would be to align the vane normal to the flow line. The direction of flow may not be readily known and indeed may vary with depth. Consequently in calibrating the meter the response of the vane to normal flow and flow approaching at 10 degrees and 20 degrees to the centreline was investigated. Tests on the effect of meter alignment were undertaken by gradually increasing the flow in the flume, with no tailwater control, in order to simulate the build up and passage of a flood.

The alignment tests with the type 4 vane are shown in Figure 4 with the data from the flume tests for the Design 3 meter compared with the best fit line calibration and +/-10% envelope for Design 1.

The threshold velocity of the Design 3 meter remains the same as for Design 1 with a threshold velocity of 0.05 m/s with an angular deflection of 0 to 80 degrees covering a velocity range of 0.05 m/s to 0.75 m/s. However, the increased friction caused by sleeving the bearings has reduced the sensitivity of the vane for flow velocities between 0.05 m/s and 0.20 m/s causing the data to lie outside the 10% calibration envelope for the Design 1 meter.

4.3 Effect of flow depth

Besides giving consideration to flow alignment thought needs to be given to the effect of varying depth upon the calibration of the meter. This could be caused by flood plain storage prior to the onset of flow, backwater influences due to structures or flood plain features such as hedges or fences. These effects were simulated by raising the tailgate so increasing the depth at which flow impacted the vane. Two levels of tailgate, 50mm and 100mm were tested.

The increased friction due to the sleeved bearings has reduced the sensitivity of the vane for flow velocities between 0.05 m/s and 0.22 m/s causing the data to lie outside the 10% calibration envelope for the Design 1 meter, see Figure 5.

4.4 Meter calibration

Data from both the alignment and backwater tests for the Design 3 meter with the type 4 vane were fitted with a best fit line represented by the fourth order polynomial

$$v = 0.07 + 0.01145y - 1.141E{-}4y^2 + 1.907E{-}7y^3 + 9.387E{-}9y^4$$

where v is the mean flow velocity in metres per second and y is the angular deflection of the vane in degrees. The vane provides a good calibration with a majority of the data points contained within the +/-10% envelope, see Figure 6.

4.5 Effect of silt

It was noted in the initial report that the influence of sediment on the bearings of the meter and the effect of trash on the vane calibration would need to be further investigated. The degree to which the instrument attracts trash will be determined from the site study.

In order to investigate the influence of suspended solids on the bearings a meter was immersed in the River Thames at Wallingford for a period of two months during the winter of 1990/1991. On retrieval of the meter a check calibration was undertaken with the meter aligned to the flow, with and without the influence of backwater. Figure 7 shows the results from these tests compared with the initial calibration of the instrument.

Protracted immersion has influenced the meter calibration causing a reduction in sensitivity of the vane for flow velocities between 0.05 m/s and 0.20 m/s. However, it is considered that with maintenance of the meter after a flood event and the fact that most out of bank flood events are of short duration, that the calibration as described in paragraph 4.4 will produce satisfactory results.

5 SITE INSTALLATION

5.1 General

In choosing an experimental site for installation of the meter three main points were considered:

- the site should be rated for out of bank flows.

- out of bank flows should occur relatively frequently.

- the site should be close to Hydraulics Research Limited.

Based upon data provided by the NRA units and sites visited during 1987, Tagg et al, 1987 and Ramsbottom, 1989 the River Blackwater at Ower in Hampshire was chosen as the experimental site, see Figure 8.

5.2 Background

The River Blackwater at Ower drains an area of 104.7 sq.km. in the county of Hampshire. This is a region of low rainfall, the average annual total being 800mm, and low relief, with a mainstream slope of 1.52m/km, see Appendix. The underlying geology is predominantly London Clay overlain by Bagshot Sands. There are also areas of valley gravels and alluvium along the length of the river valley. The catchment has a predominantly agricultural land use.

The flow in the River Blackwater is gauged at Ower by a Crump weir sited approximately 100m upstream of Blackwater bridge, see Plate 2. The weir drowns at a head of 0.365m and the higher flow ratings on the stage-discharge relationship have been measured by current metering both in-bank and out of bank flows, see Figure 9 and Table 1. The weir has been in operation since 1976. Out of bank events occur relatively frequently, the impervious underlying geology causing rapid runoff, with flood hydrographs generally having a duration of the order of 12 hours.

5.3 Site details

The river channel at the weir site is 6m wide with a left flood plain 14m wide and a right flood plain 40m wide. The left flood plain, covered by coarse vegetation, is bounded at its limit by the A31, the pasture of the right flood plain by a fence and hedgerow surrounding a nursery, see Figure 10.
The metering transect was established 2m upstream of the weir crest, excepting the left bank between the weir wall and gauging hut, along the line used by the National Rivers Authority - Southern Region (NRA- SR) for their current metering exercises, see Figure 11. Between the left flank wall of the weir and the gauging hut the transect was in line with the weir crest.

Eight meters were located along the line of the transect with an increased density adjacent to the river channel on the right flood plain, see Plates 3 to 5.

5.4 Comments

Since the installation of the meters there have been no out of bank flows. The meters have also been subject to vandalism. The meters have subsequently been repaired. It is now proposed that in the event of a possible flood event arising the NRA-SR will notify HRL such that the meters can be taken to site for installation. In this manner it is hoped to reduce the possibity of further damage occurring.

6 CONCLUSIONS

Minor modifications were made to the initial design prior to installing the instrument in the field; primarily sleeving of the bearings to ensure sediment did not enter the bearing race and the provision of a wind block to prevent vane deflection due to wind velocity.

The modified design of peak velocity meter was calibrated.

The peak velocity meter has been immersed in the River Thames for a period of two months during the winter of 1990/91 to establish whether fines within the river flow would influence the meter bearings.

Check calibrations of the meter showed that the protracted immersion influenced the meter vane deflection at low flow velocities.

Eight peak velocity meters were installed on the River Blackwater at Ower in Hampshire.

7 ACKNOWLEDGEMENTS

The co-operation of Peter Midgley and Garth Syms, Resources, National Rivers Authority - Southern Region (Winchester) is gratefully acknowledged.

8 REFERENCES

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Progress to March 1990. Hydraulics Research Limited, Report SR 244, March, 1990.

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RAMSBOTTOM D M. Flood Discharge Assessment - Interim Report. Hydraulics Research Limited, Report SR 195, March, 1989.

TABLE.

TABLE 1 Current metering data - River Blackwater at Ower, Hampshire

Date	Stage (m) before gauging	Stage (m)	Stage (m) after gauging	Flow (cumecs)
21.03.78		0.260		1.524
2.05.78		1.774		11.120
3.05.78		0.420		2.837
31.07.78		0.990		4.429
31.07.78		1.050		4.902
1.08.78	0.365		0.345	1.723
2.08.78	1.000		1.020	4.877
2.08.78	1.060		1.090	5.093
2.08.78	1.155		1.165	5.900
2.08.78		1.165		5.883
11.12.78	1.900		1.870	10.997
11.12.78	1.860		1.835	10.193
11.12.78	1.830		1.795	9.816
11.12.78	1.783		1.740	9.241
31.10.79		0.095		0.372
6.11.79		0.100		0.371
12.11.79	0.163		0.159	0.772
15.12.79	1.600		1.480	7.956
1.04.80	0.560		0.530	3.434
8.01.86	1.795		1.777	9.476
1.02.88	1.970		2.005	12.008

FIGURES.

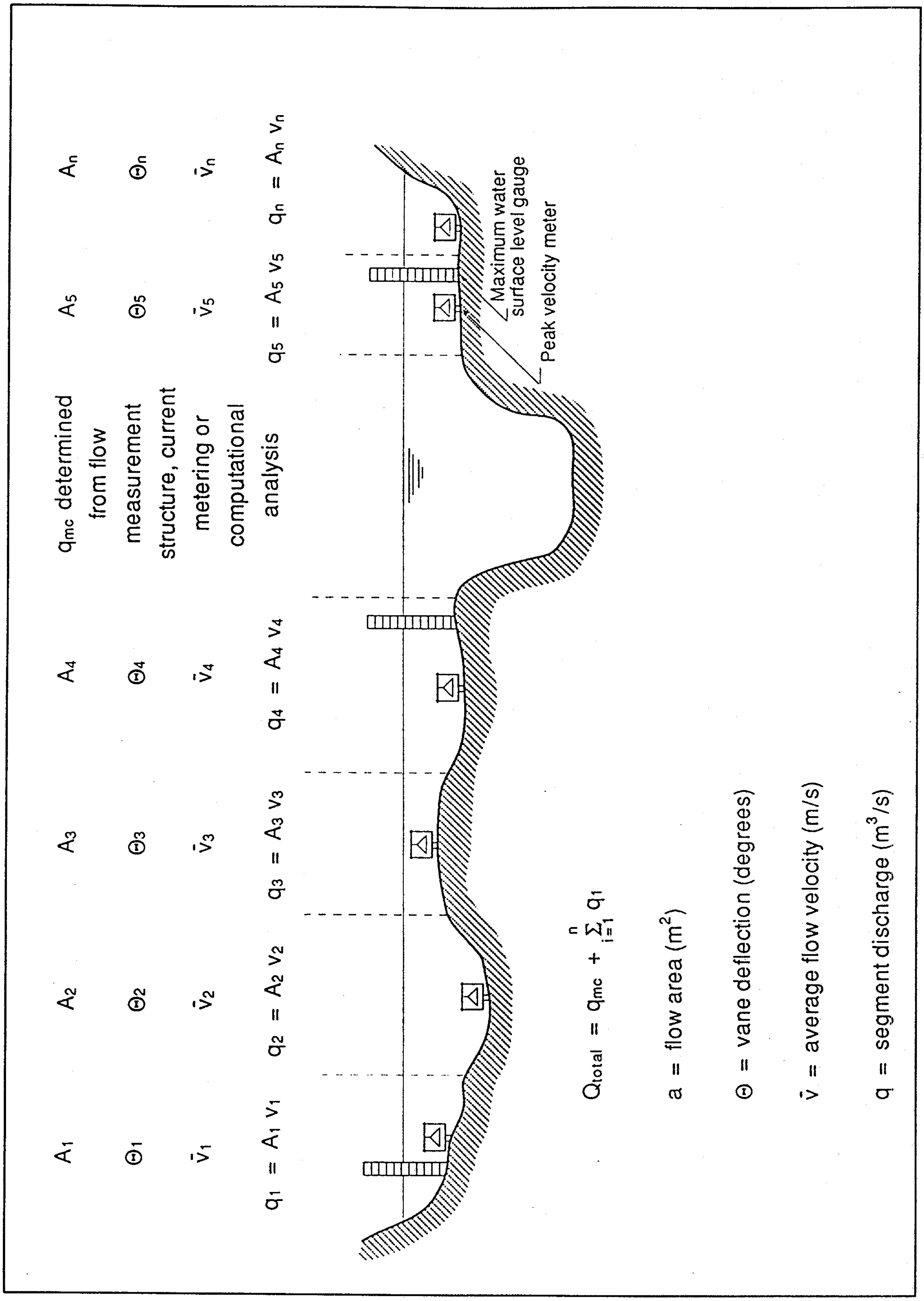

Fig 1 Flow measurement site

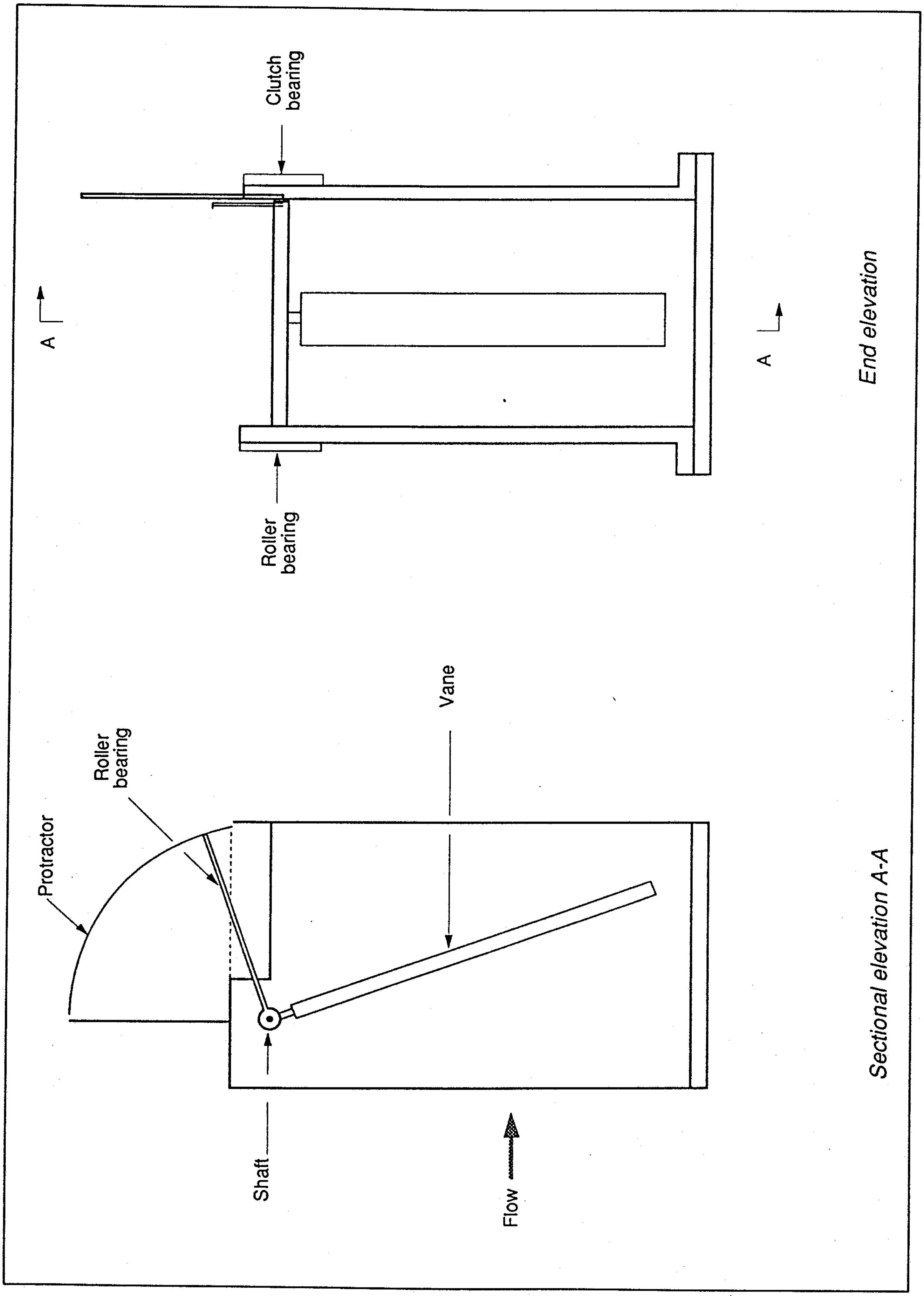

Fig 2 Peak velocity meter - Design 1

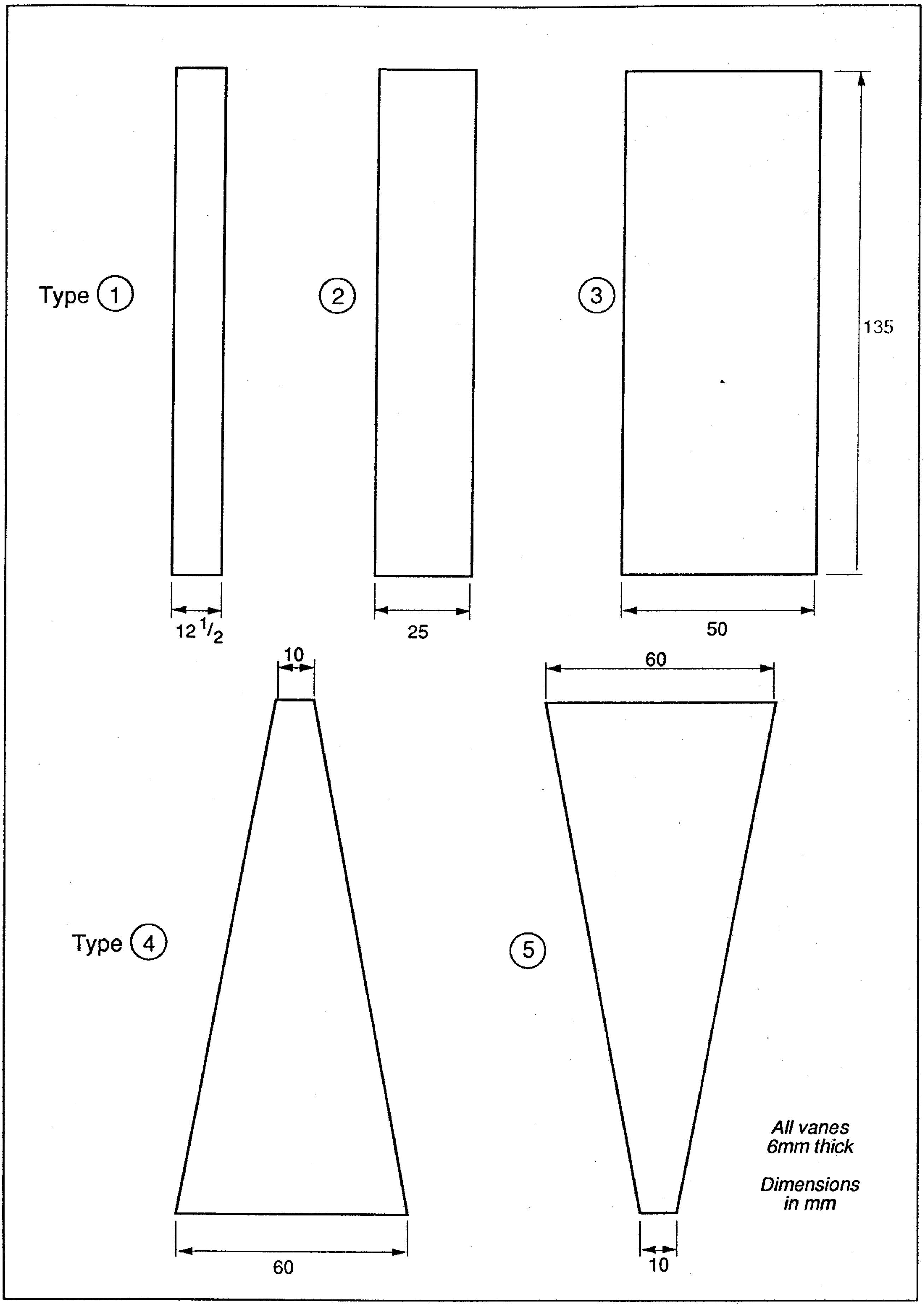

Fig 3 Vane shapes - Design 1

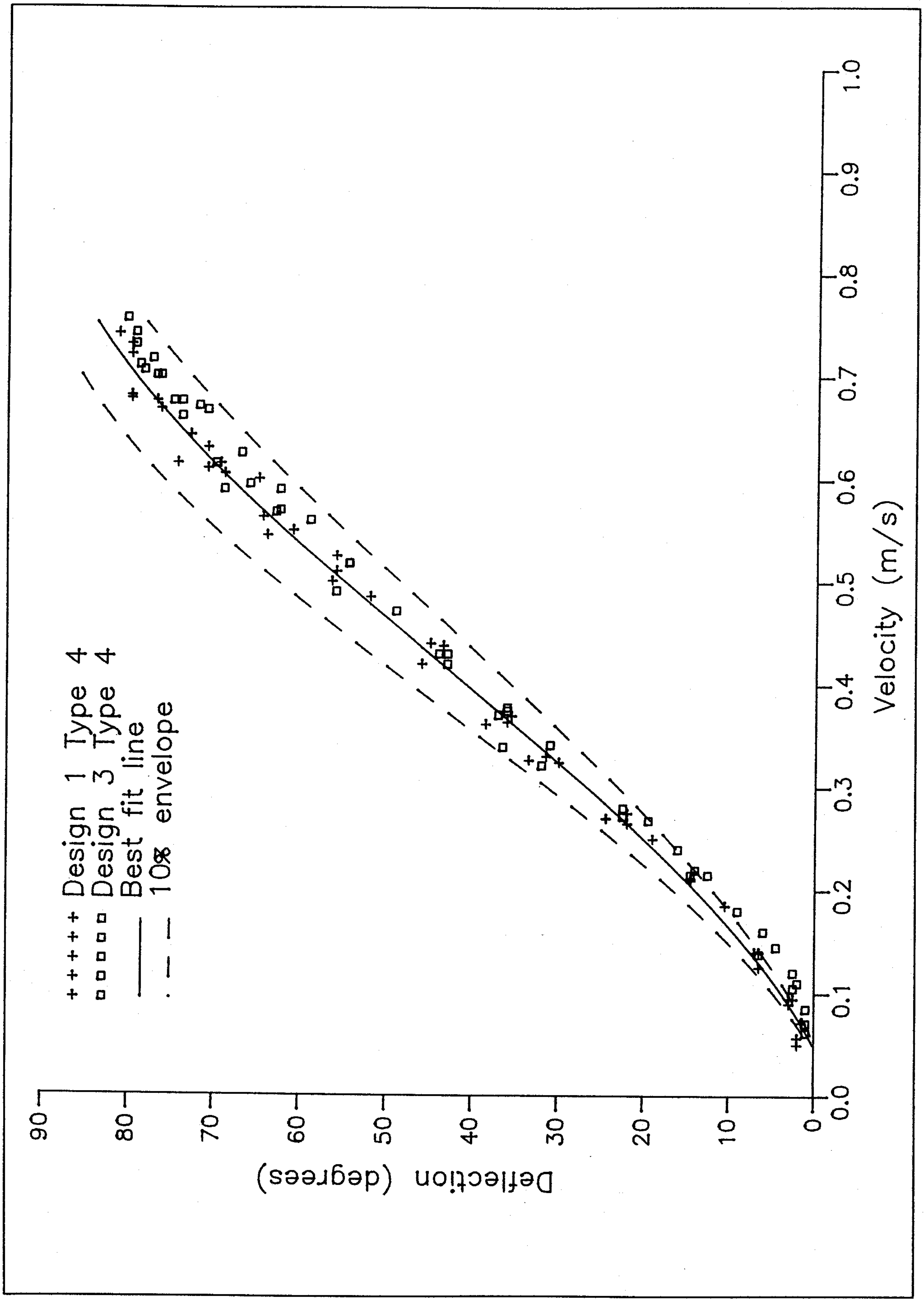

Fig 4 Design 1/Design 3 - Type 4, effect of sleeved bearing on flow alignment calibration

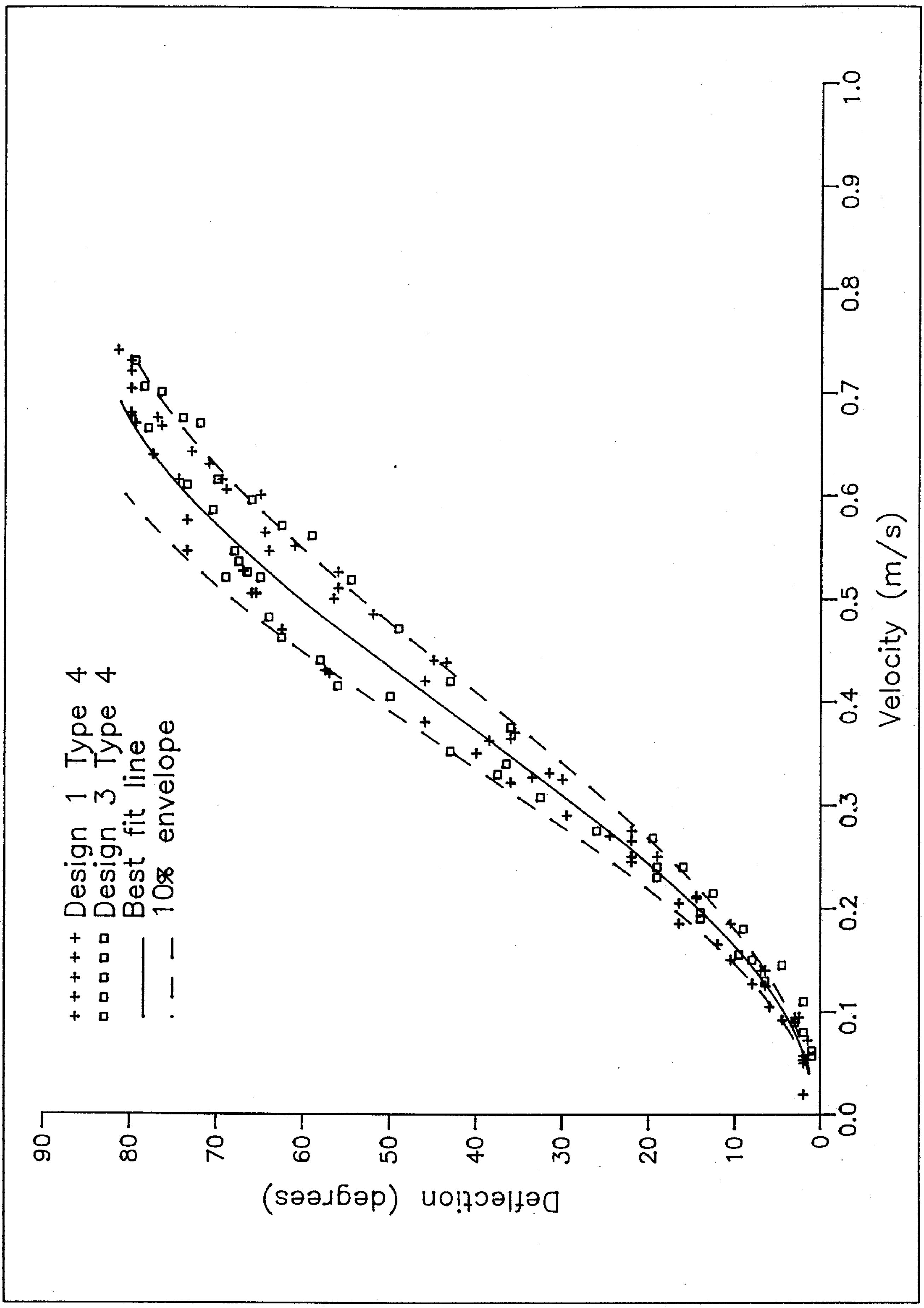

Fig 5 Design 1/Design 3 - Type 4, effect of sleeved bearing on flow depth calibration

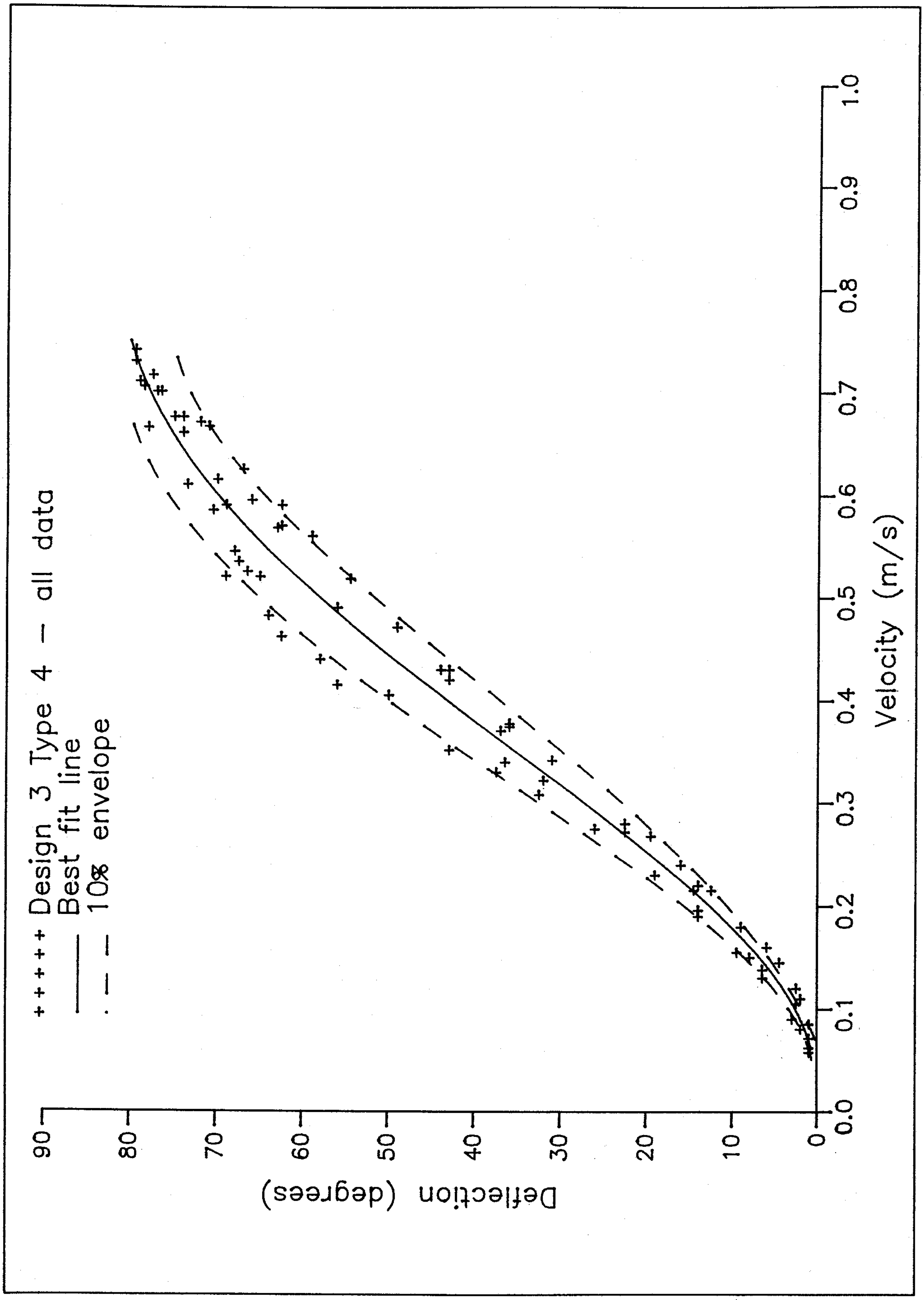

Fig 6 Design 3 - Type 4, meter calibration

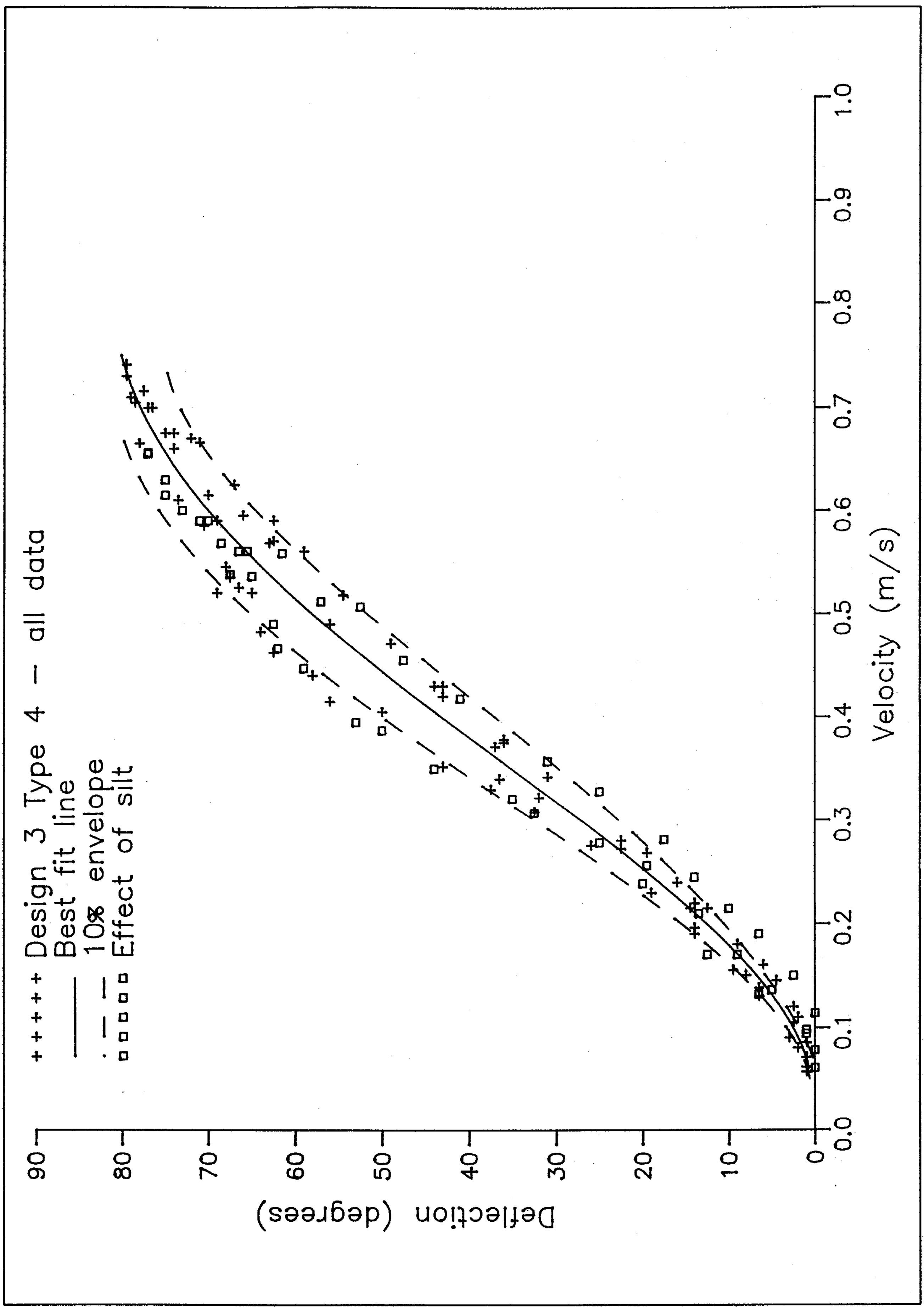

Fig 7 Design 3 - Type 4, effect of silt on meter calibration

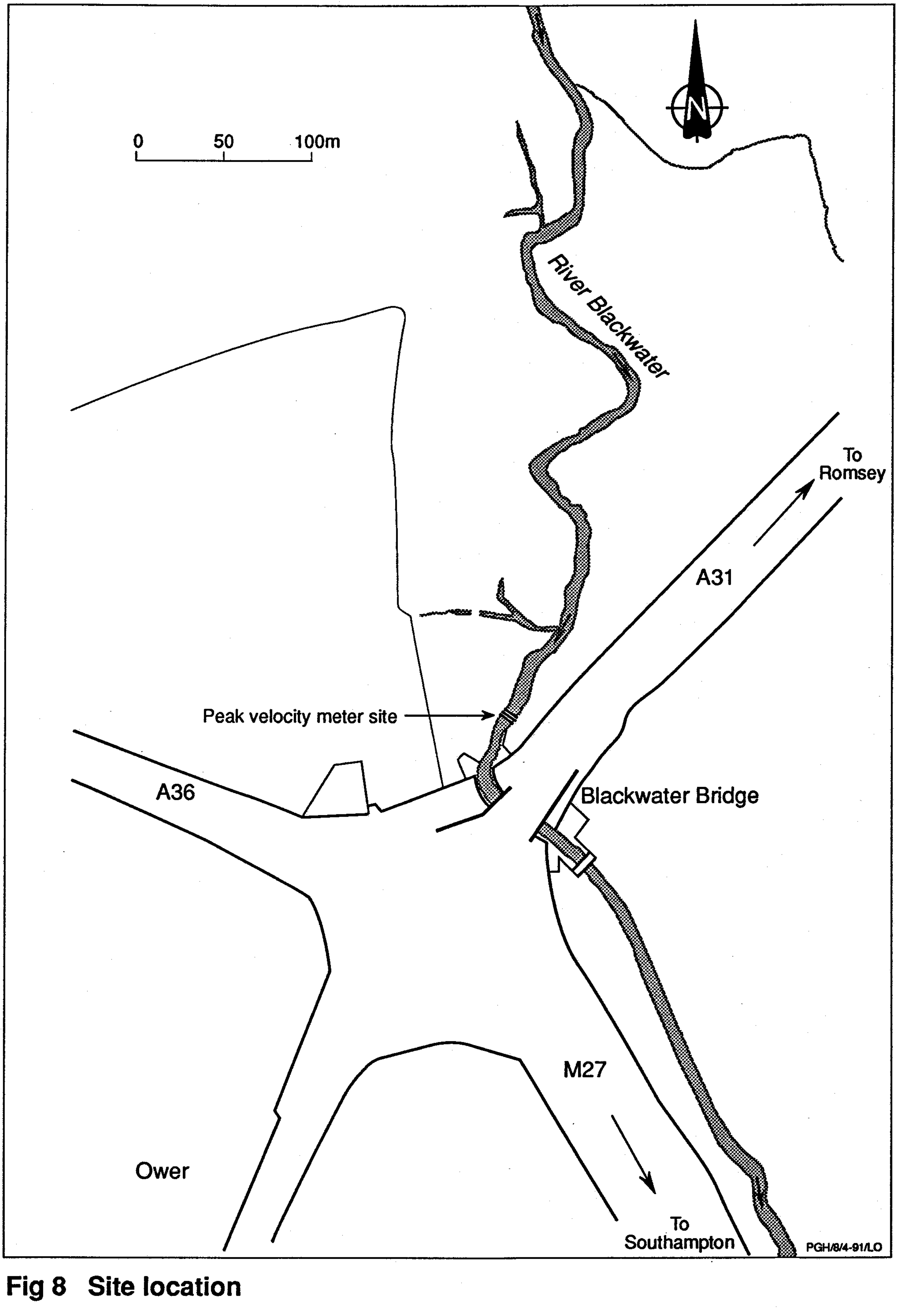

Fig 8 Site location

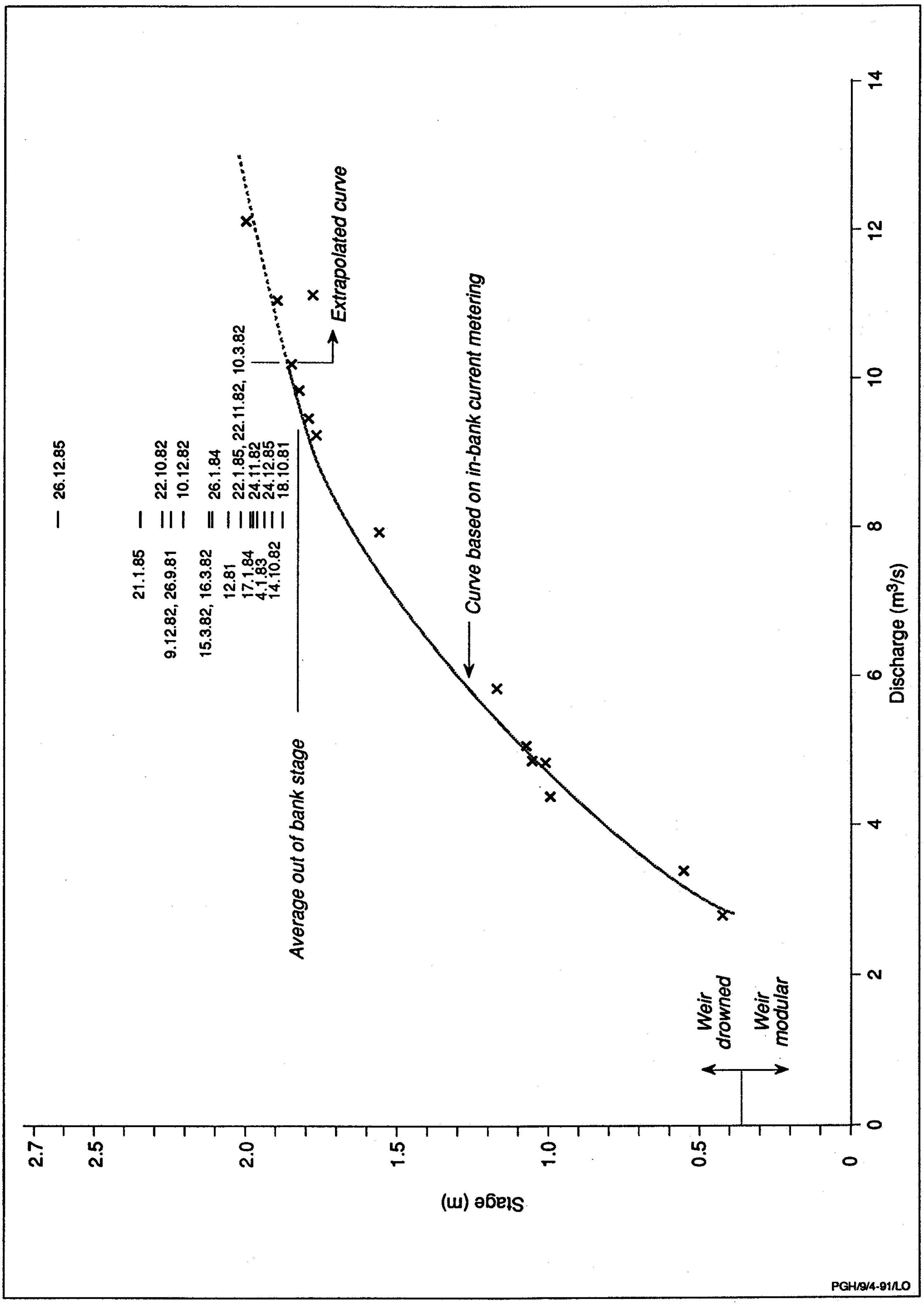

Fig 9 Stage discharge curve for the River Blackwater at Ower

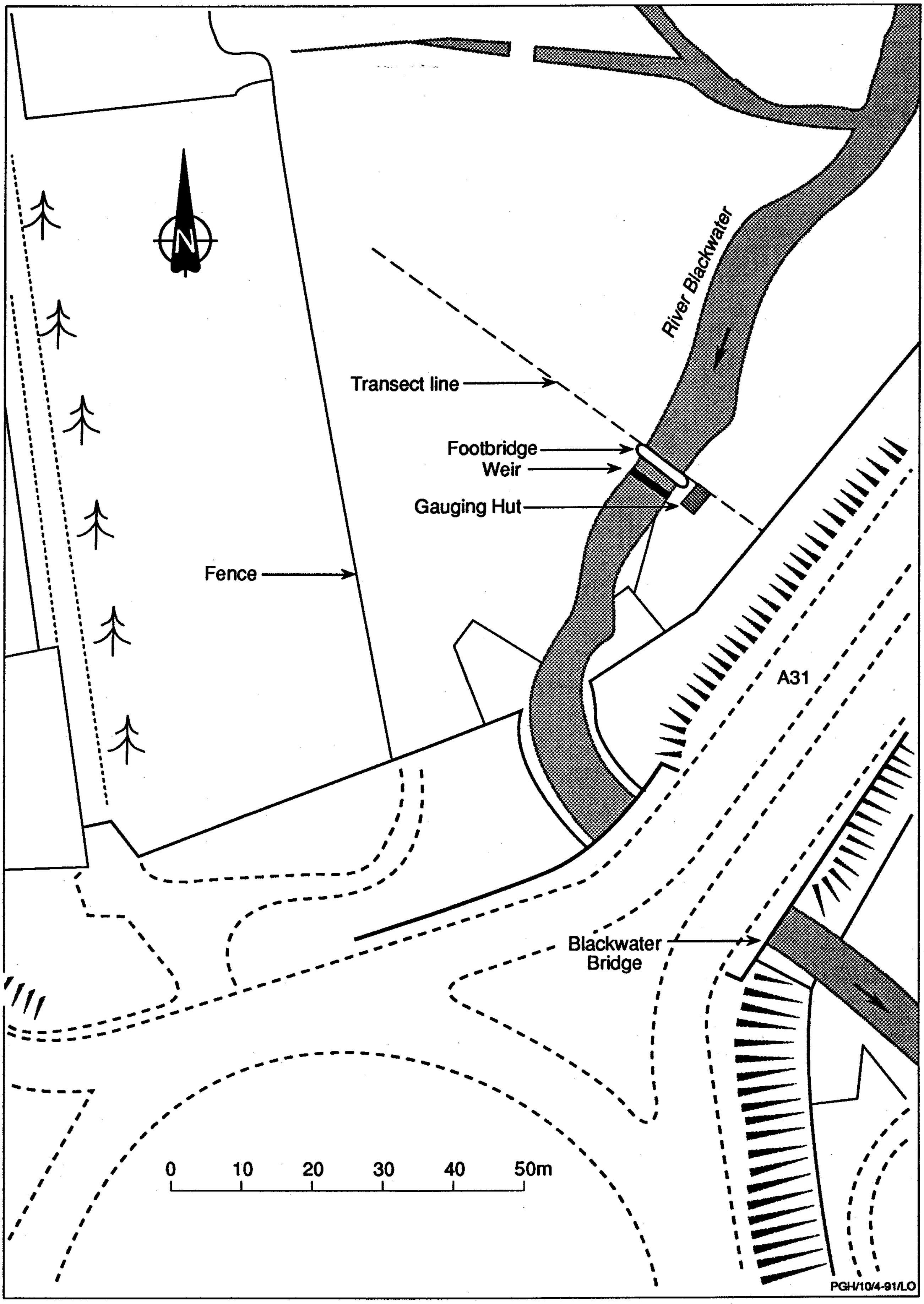

Fig 10 Peak velocity meter site

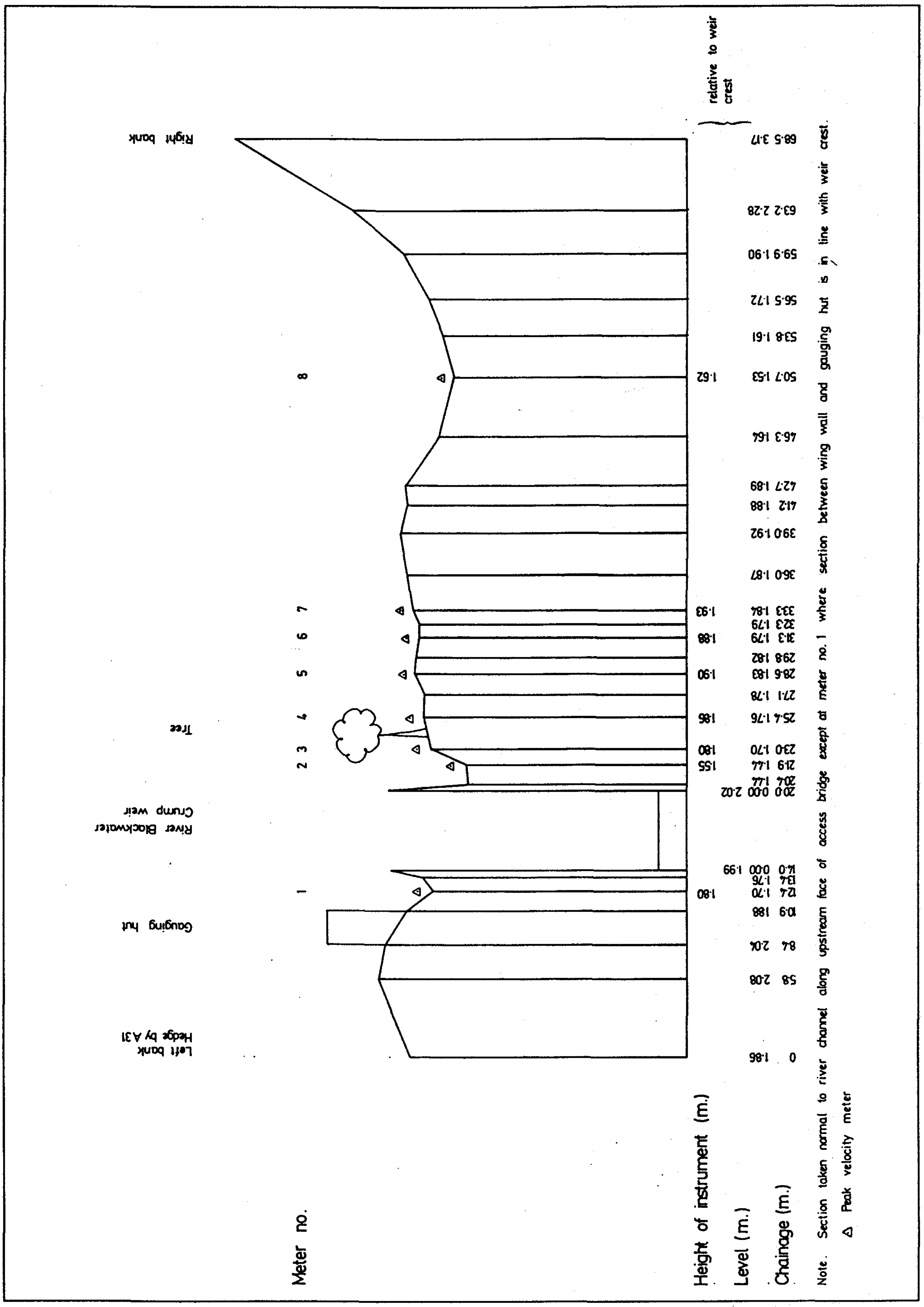

Fig 11 Cross section of metering transect

PLATES.

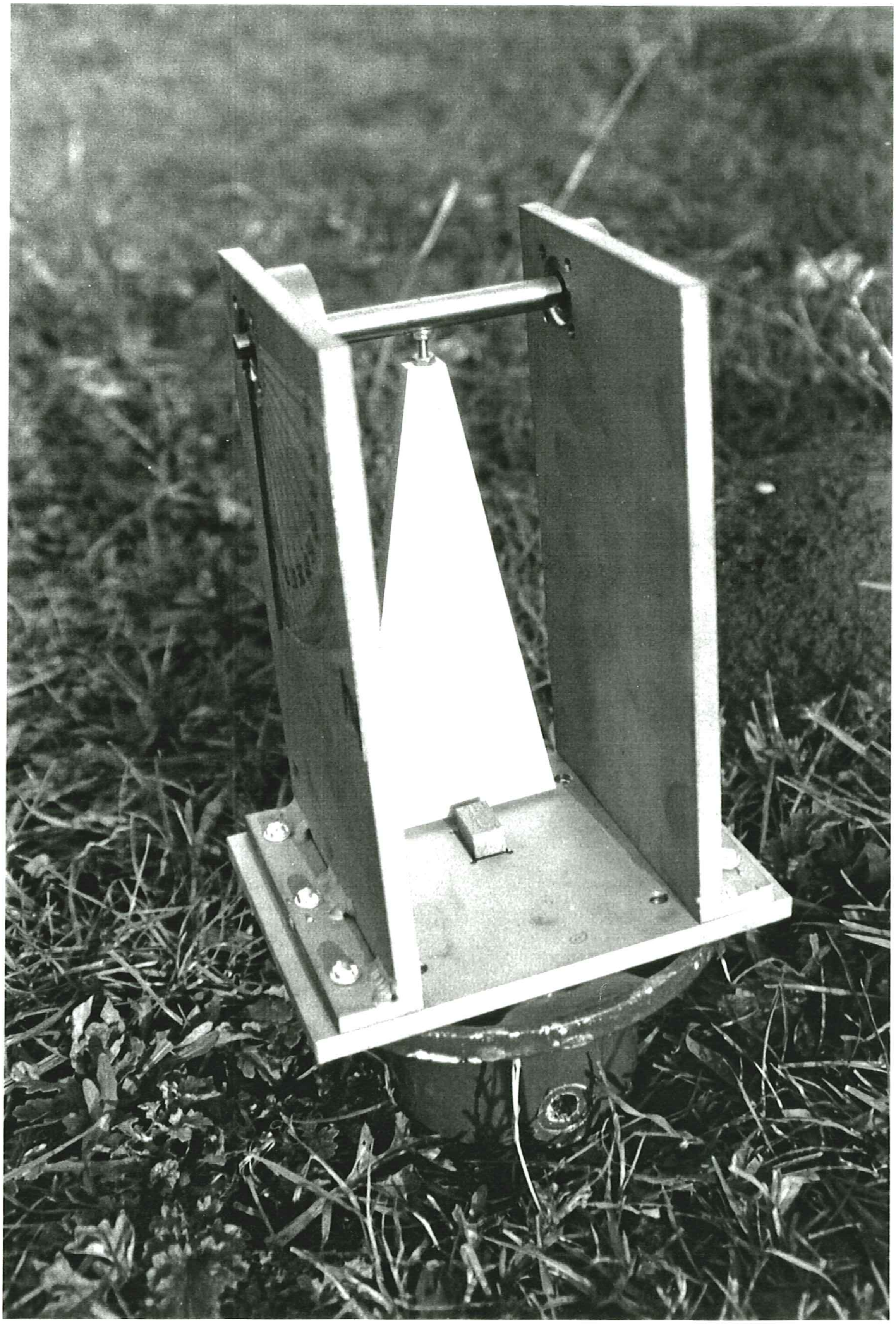

Plate 1 Peak velocity meter — Design 3

Plate 2 River Blackwater at Ower, general view of site looking upstream

Plate 3 Peak velocity meter No 1 — left bank floodplain

Plate 4 Peak velocity meters Nos 2 to 4 — right bank floodplain

Plate 5 Peak velocity meters Nos 3 to 7 — right bank floodplain

APPENDIX

SITE DATA

SITE : OWER
RIVER : BLACKWATER
GAUGING STATION NUMBER : 42014

WATER AUTHORITY : SOUTHERN (HAMPSHIRE)

BRIEF DESCRIPTION Crump weir, drowned at high flow. Rating extended using current metering.

Channel bed material : Silty and muddy. Copious weed growth
Floodplain vegetation/topography : Pasture; some trees; bushes on river bank

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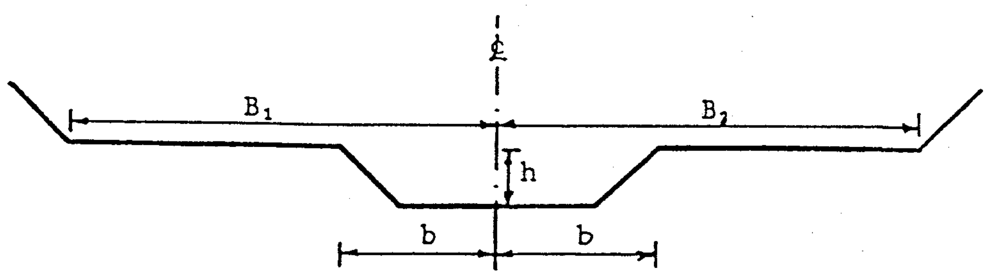
SITE CATEGORY	YES	NO	Nr overbank points
Overbank flow rating	√		4
Structure rating with nearby floodplain	√		
Flood routing reach		√	

REMARKS

Floodplain narrows towards road bridge (c 100m downstream)
Current metering data available
Photographs

DATA FOR OVERBANK FLOW CALCULATION



SECTION
(looking downstream)

Half width of main channel (b)	6	m	B_1	14	m
Bankfull depth of main channel (h)	1.8	m	B_2	40	m
Area of main channel at bankfull stage	11.7	m^2			
Hydraulic radius of main channel at bankfull stage	0.79	m			
Bankfull discharge (stage 1.8m)	9.9	m^3/s			
Maximum recorded discharge (stage 1.99m)	12.0	m^3/s			
Channel slope	1.52	m/km			
Valley slope	1.69	m/km			
Sinuosity (length of channel/length of valley)	1.11				