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Current Meter Gauging Methods

Small Streams and Rapidly Changing Stage

HR Wallingford Limited

R&D Project Record W6/i/529/1

Current Meter Gauging Methods

Small Streams and Rapidly Changing Stage

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Statement of Use
This report summarises the findings of research carried out into Current Meter Gauging Methods. The information within this document is intended for use by hydrometric officers in current meter practice.

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EXECUTIVE SUMMARY

Current meter stream flow gauging is a technique of primary importance in hydrometry. Methods for stream flow gauging are generally specified in detail in British Standards, but there are some situations where flow measurement is required which are not covered by existing Standards. These include measurement of flow where the stage is changing rapidly, and flow measurement in small streams.

The objective of the project was to develop flow gauging procedures for use where the stage is changing rapidly, and for small streams. Visits were made to all Environment Agency Regions and the Clyde RPB to find out what techniques are used at present, and to collect data on flow gauging for use in the project.

Rapidly varying stage

The approach adopted for measuring flow where the stage is changing rapidly was to reduce the gauging time as much as possible in order to minimise the errors associated with changing stage, but to avoid gross errors resulting from the use of a simplified procedure. The effects of reducing the number of verticals and current meter exposure time were investigated, together with the effect of using different measurement points in each vertical. The errors associated with different combinations of these three variables were estimated together with the corresponding gauging times.

A procedure was developed for measuring flow where the stage is changing rapidly which involves a single measurement point in each vertical, a 30 second current meter exposure time, and different numbers of verticals depending on the time available for the gauging. Guidelines are given on how to estimate the time available for the gauging. The recommended minimum number of verticals is five under any circumstances.

Small streams

A gauging procedure for small streams was developed using a laboratory flume, with both rectangular and trapezoidal channels. The procedure was tested in the field adjacent to existing gauging stations, and some modifications were made. The procedure includes recommendations for the number of verticals to use, the minimum depth of flow, methods for measuring the cross section, choice of site, and flow conditions.

The suitability of different types of current meters for flow measurement in small streams was investigated and recommendations are given. In order to achieve an adequate measurement section, modifications to the channel section will be required in some cases. If possible, flow gauging should be carried out without wading. Where wading is the only viable option, guidance is given on the wading procedure which should be adopted.

1. INTRODUCTION

1.1 Background

Current meter stream flow gauging is a technique of primary importance to hydrometry. It is used to provide data to calibrate river gauging stations and to make spot measurements for abstraction license and discharge consent determination and compliance. Its importance can be judged by the fact that the instrumentation, calibration, gauging practices, flow calculation, etc. are covered by BS 3680 Parts 3A to R. The application of the full technique, giving the highest degree of accuracy, is limited to larger streams and rivers and situations where the change in stage is relatively slow.

The overall aim of this project is to determine standard techniques and best practices for non-standard situations not adequately covered by BS 3680 Part 3. This will give increased confidence to both the users and indirect recipients of information from the current meter gaugings. The particular non-standard situations covered by the project are the following:

- Flow measurement where the stage is changing rapidly, for example during floods
- Flow measurement in small streams which are smaller than those covered by existing British Standards

The project has been carried out by HR Wallingford on behalf of the Environment Agency (formerly the National Rivers Authority).

1.2 Terms of Reference

The terms of reference are contained in the memorandum of Agreement between the Environment Agency and HR, and a copy is contained in Appendix A. The specific objectives of the study may be summarised as follows:

1. To examine the effect of a reduction of the number of verticals on the accuracy of a gauging under the rapidly changing stage of a flood event.
2. To examine the effect of a reduction of the current meter exposure time on the accuracy of a gauging under rapidly changing stage.
3. To examine the optimum depth, and/or depths, of the current meter on the accuracy of a gauging under rapidly changing stage.
4. To examine the balance to be achieved between accuracy of individual gaugings (fewer verticals, short exposure time, single point versus many verticals, longer exposure time, multi point) against gauging time.
5. To define a standard practice(s) for current meter gaugings on shallow (<0.1 m deep) and/or narrow (<2.0 m wide) streams where BS 3680 Part 3A cannot be applied.
6. To produce a final Project Record, R&D Note and Digest.
7. To produce a synopsis for field use. (R&D Note B).

It was subsequently agreed that the R&D Digest would be produced by the Environment Agency.

The scope of the work includes the following items.

a) Collection of existing data from the eight Environment Agency Regions and Scottish River Purification Boards (RPB), from HR archives and from European literature.
b) Analysis of relevant data and the development of optimum procedures for the measurement of flood flows where stage varies rapidly using velocity area techniques.
c) Analysis of relevant data and the development of procedures for the measurement of flows in small, shallow channels using velocity area techniques. Testing of these procedures in a small channel either in the laboratory or in the field.
d) Liaison, reporting and dissemination within the Environment Agency.

1.3 Methodology

The general methodology used for the study was as follows:

1. Contact key Environment Agency and RPB staff to identify what techniques are currently used under rapidly changing stage conditions and shallow/narrow streams. Visit Environment Agency Regional offices and RPB offices to discuss techniques and collect information.
2. Obtain information regarding techniques applied in other countries.
3. Critically review these methods.
4. Undertake laboratory and field tests as required to supplement available information.
5. Analyse available data and develop recommended methods.
6. Undertake field trials using recommended techniques for small stream flow measurement, and amend recommendations if necessary. It was not practicable to undertake field trials of measurement of rapidly varying flow within the scope of the project, and it is anticipated that this will be carried out by the Environment Agency.
7. Define accuracy of techniques.
8. Prepare a Project Record.
9. Prepare an R&D Note A.
10. Prepare an R&D Note B (User Guide).

1.4 Data Collection

In order to obtain information from Environment Agency Regional Offices, a list of data required was prepared and agreed with the Project Manager and sent to Environment Agency Regional Offices in November 1994. A copy of the list is contained in Appendix B, letters 1 and 2. All Environment Agency Regional Offices were visited between October 1994 and February 1995 and a visit was also made to the Clyde River Purification Board. A schedule of visits is given in Appendix C, including a list of the Environment Agency and RPB staff members met by the Consultants. A summary of information obtained from the Environment Agency Regions and

Clyde RPB is contained in Appendix D, in which over 900 individual flow gaugings are listed. The Environment Agency Regions and Clyde RPB have shown considerable interest in the project and their assistance and co-operation is gratefully acknowledged.

Data for use in the project was also collected from archives at HR Wallingford, including detailed current meter gaugings undertaken in connection with the verification of other flow measurement methods.

It can be seen that a large amount of data were collected and it was necessary to select data for analysis. The selection criteria and the data used for each part of the study are discussed in more detail in the relevant sections of the report.

Information on methods of flow gauging for rapidly varying flows and small streams was also requested from relevant organisations in European countries, and the response received is summarised in Appendix E.

1.5 Framework of the report

The research carried out into the measurement of rapidly varying flow is described in Chapter 2, including the development of the recommended method. Detailed results of the analyses are contained in Appendices F, G H, I, and J.

The research carried out into the measurement of flow in small streams is described in Chapter 3, including the development of the recommended method. Detailed results of laboratory and field tests and subsequent analysis are contained in Appendices L and M.

Chapter 4 contains conclusions and recommendations, and Chapter 5 summarises the recommended methods in a form suitable for field use. This will also be presented separately in the form of an Environment Agency R&D Note B (User Guide).

2 MEASUREMENT OF FLOW WHERE THE STAGE IS VARYING RAPIDLY

2.1 Background

Section 9.4 of BS3680: Part 3A: 1980 deals with situations where the water level varies during the period of the velocity area measurement. An International Standard, ISO748 (1979), will be revised shortly. It has similar wording to this Section but there are subtle changes.

ISO748 identifies two cases:-

a) where the water level changes occurring during the velocity area measurement correspond to less than five percent of the mean depth. In this case the mean water level shall be adopted for the computation of discharge.
b) where the water level changes occurring during the velocity area measurement correspond to more than five percent of the mean depth. In this case the potential non-linearity of the situation has to be taken into account, and a method is given in ISO748.

In both cases the minimum number of verticals is 20 and the minimum exposure time for the current meter is 30 seconds. Alternatives are permitted for the number of measurements in each vertical including single point, two points, three points, five points, six points and integration methods.

The difficulty of adopting the recommended method is that the flow rate could vary considerably during the gauging period, and this will be particularly significant near the peak of the flood wave where the shortest possible gauging period may be required in order to gauge the flood peak.

The objective of the research is to determine a method for gauging rapidly varying flows which can be carried out quickly enough to avoid gross errors due to changing flow rate during the gauging and yet provides gaugings of reasonable accuracy which avoid gross errors caused by the use of a simplified method. The research also identified the approximate measurement accuracy of the proposed alternative method.

The three main variables that can be altered in the gauging procedure are:

- Number of verticals
- Current meter exposure time
- Number of measurement points in each vertical

The approach adopted has been to investigate the errors associated with each variable independently, and then combine the errors from each source. Existing flow gauging data has been used for the analysis, although in some cases this has been supplemented with results from additional fieldwork.

The analysis for the three variables is described in Sections 2.3, 2.4 and 2.5 respectively, and the combination of errors is described in Section 2.6. The development of the method is covered in Sections 2.7 and 2.8, and issues arising from the research are discussed in Section 2.9.

During the meetings with Environment Agency and RPB hydrometric staff, a number of difficulties associated with gauging flood flows were discussed, including the following.

- Trash affecting the current meter
- Difficulty of detecting the bed
- Difficulty getting the current meter either into the water or to a reasonable depth for sampling velocity.

Ideally the new method should include recommendations for flow gauging under these circumstances.

2.2 Definition of rapidly varying stage

A definition of rapidly varying stage is required in order to enable gauging staff to decide whether to use the new procedure or the existing Standard procedure.

When a standard gauging is made during a period of rapidly changing stage the flow measured will be approximately the average flow during the gauging period assuming that the rate of rise is steady. Whilst this will provide a point on the stage discharge curve for the site the following problems arise:

- The rate of rise is not always steady and changes in the rate of rise are difficult to predict
- The flow of greatest interest in flood defence design is the peak flow, and a larger number of quick gaugings are preferable to a small number of standard gaugings in order to measure the peak when it occurs
- Significant bed movement can occur during the course of a flood gauging.

Variation in the rate of rise is illustrated in the following data from the River Falloch in Scotland

Table 2.1 Variation in the rate of rise in the River Falloch in Scotland

Time (hrs)	Stage (mAD)	Flow (m^3/s)	Change in Stage (m)	Change in flow (m^3/s)
04.45	1.783	74.72		
			0.111	11.36
05.00	1.894	86.08		
			0.177	19.04
05.15	2.071	105.12		
			0.235	26.88
05.30	2.306	132.00		
			0.247	30.04
05.45	2.553	162.04		
			0.129	16.37
06.00	2.682	178.41		
			0.100	13.00
06.15	2.782	191.41		
			0.040	5.27
06.30	2.822	196.68		

From inspection of these data it is clear that any full current metering (which may take perhaps 45 minutes) during this period will be subject to significant error caused by the variation in rate of change.

It is proposed that the objective of the method should be to measure the flow during a period in which the total flow does not change by more than 10%. A typical full flow gauging (20 verticals, 100 second exposure time, single point) takes about one hour, and it therefore follows that the new method should be applied where the total flow changes by more than 10% during one hour. The corresponding change in depth is of the order of 5%, but this will vary from river to river.

This criterion can be translated into a rate of change of stage. For practical purposes the type of guideline required by flow gauging staff is change of stage during perhaps ten minutes, as this can be measured as soon as they arrive on site.

Where the stage is changing very rapidly the above criterion may lead to very short gauging times and correspondingly large errors. In these cases a longer gauging time is required in order to keep the errors within acceptable limits.

The procedure recommended for deciding whether to use the new method and how to apply it is given in Section 2.8.

2.3 Reduction of number of verticals

The aim of this work is to find the errors associated with reducing the number of verticals used in a flow gauging. The data used were existing current meter gaugings provided by the Environment Agency and Clyde RPB, who had been asked during the data collection exercise to provide flow gaugings for high river flows.

A large number of flow gaugings were provided, and selection of data for analysis was based on the following criteria:

- Representative range of river sizes. Total flow against river width was plotted for all gaugings. The plot was divided into river width bands (0 - 10m, 10 - 20m, etc) and flow bands (0 - 50 cumecs, 50 - 100 cumecs, etc) and at least one gauging was selected from each block (eg 10 - 20m wide, 50 - 100 cumecs).
- More than fifteen verticals (except for small rivers where gaugings with more than fifteen verticals were not available)
- Discharges greater than $10m^3/s$

Forty four separate gaugings were used from forty two different gauging sites. A summary of this data is shown in Table F1. The number of gauging stations in each river width band are shown below:

Table 2.2 The number of gauging stations in each river width band

River width band (m)	Number of gauging stations
<10	7
10 - 20	9
20 - 30	12
30 - 50	10
50 +	4

A computer program in BASIC was set up to calculate the discharges from each gauging using the mean section method outlined in Section 9.2.2.1 of ISO748. The program calculated the discharge from ASCII input data files created for each gauging. The program was run for each gauging to calculate the discharge using the full data set. This is the value of discharge against which all errors are calculated. The program was verified by checking the calculated total flows with those calculated by the Environment Agency and Clyde RPB.

The number of verticals was reduced for each gauging by selecting verticals in the data set and removing them from the ASCII file. The verticals to be removed were selected such that the remaining verticals were as evenly spaced as possible. The discharges for each gauging using one, two, three, four, five, seven, ten, fifteen and twenty verticals were calculated and the error in discharge determined. The discharges and errors produced for each gauging are shown in Tables F2 and F3 respectively. The 95 and 67%ile error exceedence limits were calculated from these errors to give the results shown in Figure 2.1, which is plotted from the data presented in Table F4.

From the results it was apparent that errors exceeded 10% where less than five verticals were used. One important variable is river width, and it might reasonably be expected that the larger the panel width the larger the error. In order to investigate the effects of river width on error the results were separated into river width bands of 0 to 10 metres, 10 to 20 metres, 20 to 30 metres, 30 to 50 metres and greater than 50 metres. The 95%ile and 67%ile error exceedance limits were calculated for each band for the same number of verticals as before, and the results are shown in Table F5. The results for the 95%ile error exceedance limit are shown in Figure 2.2. It was shown that the errors were independent of panel width for five or more verticals.

It was concluded that errors increase rapidly where the number of verticals is less than five and therefore the minimum number of verticals that should be used under any circumstances is five.

2.4 Current Meter Exposure Time

The aim of this work is to find the error associated with reducing the exposure time used in a gauging. The data used in this work was obtained from measurements made in a flume at HR Wallingford and also in the field by HR at Shipston-on-Stour. The flume data includes 32 measurements and the field data contains 15 measurements. Some data were also provided by the Environment Agency but these were not used either because there were insufficient data for rigorous analysis or because the basis of the actual flow measurement used to calculate the error was not known.

The flume data was obtained in a general purpose flume at HR Wallingford using exposure times of 200, 100, 50, 10 and five seconds, and the results are summarised in Table G1. The 200 second exposure time readings were used as the base from which all the percentage errors are calculated. The errors in each reading were calculated and are shown in Table G4, and the 95%ile and 67%ile error exceedance limits were calculated as shown in Table G7. The results are plotted in Figure 2.3.

The effects of exposure time on accuracy will be affected by stream velocity, turbulence and the results for the flume data were then analysed by velocity band. The results were divided into two velocity bands, of between 0.1 to 1.0 m/s and 1.0 to 1.8 m/s. The 95%ile and 67%ile error exceedance limits were calculated for each group and the results are shown in Figure 2.5. The results show that exposure time errors reduce with increased velocity.

The field data were obtained at a site at Shipston-on-Stour. Exposure times of 200, 100, 50, 10 and five seconds were used, and the results are summarised in Table G2. The 200 second exposure time readings are used as the base from which all the percentage errors are calculated. The errors in each reading were calculated and are shown in Table G5, and the 95%ile and 67%ile error exceedance limits were calculated as shown in Table G8. The results are plotted on Figure 2.4. The velocity range during the measurements is of the order of 0.2 to 0.6m/s, and it would be expected that the errors would reduce with the higher velocities which would occur under flood conditions.

The field data provided by the Environment Agency is summarised in Table G3, and the errors associated with reduced exposure times are shown in Table G6. One general problem in the analysis is the lack of data for high flow velocities, which may reach 3 - 4 m/s during a flood.

Some data were provided in June 1995 from the Irish Bridge site in Environment Agency Welsh Region where the velocities were in the range 1.9 - 2.3 m/s. Some difficulties were encountered holding rods at these velocities, but it was found that fluctuations were relatively small and the error for 5 second exposure times compared with 100 seconds did not exceed 5%. It was also noted that the current meter took between 5 and 15 seconds to reach stream velocity, and this must be allowed for in the recommended procedure.

It was generally concluded that errors increase significantly for exposure times of less than 20 seconds. The overall results were however rather inconclusive because of the lack of field data at high flow velocities. It is recommended that further field data is collected to improve the estimates of errors associated with reduced exposure time. The small amount of field data obtained for velocities of about 2m/s indicate that errors will be small with short exposure times, but time should be allowed for the current meter to settle before taking readings.

2.5 Current meter location(s) in the vertical

The aim of this work is to find the error associated with reducing the number of points in a vertical used in a gauging. The data used was taken from current meter gaugings provided by the Environment Agency in which several measurement points in the vertical had been used. Twenty three separate gaugings were used including fourteen different gauging sites and 356 separate verticals as shown in Table H.1. Gaugings with at least five points in the vertical and with discharges greater than $10m^3/s$ were selected for analysis.

ISO Technical Report number 7178 contains ten methods for calculating the mean velocity in a vertical, with between one and six measurement points in the vertical. The methods are listed in Table 2.3, and six of these methods are contained in ISO748. The mean velocity was calculated using all the methods listed in Table 2.3 except method seven, which is one of those not covered by ISO748.

Table 2.3 Mean velocity equations recommended in ISO report number 7178

Method Number	Mean Velocity Equation
1*	$v_{0.6}$
2*	$0.96v_{0.5}$
3*	$0.5(v_{0.2} + v_{0.8})$
4*	$0.25v_{0.2} + 0.5v_{0.6} + 0.25v_{0.8}$
5	$0.4v_{0.2} + 0.3v_{0.6} + 0.25v_{0.8}$
6	$1/3(v_{0.2} + v_{0.6} + v_{0.8})$
7	$1/4(v_{0.2} + v_{0.4} + v_{0.7} + v_{0.9})$
8*	$0.1v_{SURF} + 0.3v_{0.2} + 0.3v_{0.6} + 0.2v_{0.8} + 0.1_{vBED}$
9	$1/6(v_{SURF} + v_{0.2} + v_{0.4} + v_{0.6} + v_{0.8} + v_{BED})$
10*	$0.1v_{SURF} + 0.2v_{0.2} + 0.2_{v0.4} + 0.2v_{0.6} + 0.2\ v_{0.8} + 0.1v_{BED}$

* Included in ISO 748 (Draft)

The analysis requires velocity readings at the surface, 0.2, 0.4, 0.6, and 0.8 of the depth, and the bed. In addition, method 2 requires the velocity at 0.5 depth. The surface and bed velocities were not provided in every case and where there was no measurement at these points the values were interpolated. This interpolation was based on the assumption that the velocity near the bed and surface of the channel is proportional to the logarithm of the distance x from the boundary and therefore the velocity at the bed and surface can be approximated. In some cases it was also necessary to interpolate between measurement points in the vertical.

Method 10 is recommended for use as the six point method in Section 8.1.4.4 of ISO748 and it is the mean velocity calculated using this method against which all the percentage errors are calculated.

The results of the mean velocity calculations for each vertical are shown in Table H2 and the corresponding errors compared with method 10 are shown in Table H3. The 95 and 67%ile error exceedence limits were calculated from these errors and are listed in Table H4. The results in Figure 2.6 show errors well in excess of 10% for the commonly used gauging methods (methods 1, 2, and 3).

The data was then analysed in terms of error in velocity over a complete river. The mean velocity was calculated using each of the methods for every individual vertical in a gauging, and the total flow was then calculated. The error in the total flow was calculated for each method by comparison with the total flow calculated for method 10 for each of the 23 full river gaugings. The 95 and 67%ile error exceedence limits were calculated from these errors to give the results shown in Table H5. The results plotted in Figure 2.7 show that the errors for whole rivers are much smaller than for individual verticals, and were less than 10% in every case.

The reason that the errors for complete rivers is less than for individual verticals may be identified from inspection of the results in Table H3. Both positive and negative errors occur at different verticals in the same river gauging, and the effect of combining these errors is to reduce the overall error. A gauging method is being developed in which the number of verticals is to be reduced, and the above results indicate a dependence between the number of verticals and the errors associated with number of measurement points in the vertical.

The data was therefore analysed in terms of error in velocity over a complete river with reduced numbers of verticals. The mean velocity was calculated using each of the methods for every individual vertical in a gauging, and the total flow was then calculated. The number of verticals was reduced in the same way as described in Section 2.3. The error in the total flow was calculated by applying each method for 10, 7 and 5 verticals, and comparing the total flow with that calculated using method 10 for each of the full river gaugings. The 95 and 67%ile error exceedence limits were calculated from these errors to give the results shown in Table H6, and the results are plotted in Figure 2.8. The results show that there was no significant change in errors compared with the full number of verticals, other than the base error which has already been quantified in Section 2.3.

Typical velocity depth profiles are shown in Figures 2.9 and 2.10, which show the type of variation observed across a river. The profiles were taken at Longbridge gauging site on the River Test where several current meters were attached to a rod at fixed distances apart. Measurements were therefore not taken at the standard positions (0.5d, 0.6d, etc). The profiles also show mean velocity and the velocities calculated by standard methods 1 and 2 (single point measurements). The standard methods overpredict velocity at some verticals and underpredict at others, explaining why the errors associated with whole river gauging are smaller than those for individual verticals.

Discharge measurement using surface velocities only

One problem identified during the consultations was the difficulty of getting the current meter to enter the water during high flows. Analysis of the error in velocity using a single surface velocity measurement multiplied by a constant was therefore carried out. The data used in this analysis were obtained from the Environment Agency and earlier work undertaken by HR Wallingford referred to in Section 1.4.

The flow was calculated using surface velocities and multiplied by factors ranging from 0.5 to 1.0. The errors in the calculated discharges were compared with the total flows for the full gaugings. The results for the 95 and 67%ile error exceedance limits were calculated from these data and are shown in Table H7 and plotted in Figure 2.11. The results show that the minimum 67%ile error of about 10% occurs when a constant of 0.8 is used, and the minimum 95%ile error of about 24% occurs when a constant of 0.78 is used.

It was concluded that for flow measurements using surface velocities, the surface velocity should be multiplied by 0.8 to obtain the mean velocity. The 95%ile error associated with this procedure is of the order of 24%.

2.6 Error Analysis

The overall uncertainty in the gauging of discharge depends upon both random and systematic uncertainties. Random uncertainties include measurement of width and depth, and uncertainties in the process of measuring mean velocity (number of verticals, exposure time, number of points in the vertical, and current meter rating). Systematic uncertainties which occur in the measurement of width and depth, and the rating of current meters are generally small and have not been included in the analysis.

The random uncertainty in discharge measurements by means of current meters (X_Q) is calculated using the equation below

$$X_Q = \sqrt{X_m^2 + \frac{1}{m}[X_b^2 + X_d^2 + X_p^2 + \frac{1}{p}(X_e^2 + X_c^2)]}$$

Where

X_m = Uncertainty due to reducing the number of verticals, m, obtained from Table F4
X_b = Uncertainty in width measurement
X_d = Uncertainty in depth
X_p = Uncertainty due to reduced number of points in vertical, p, obtained from Table H5
X_e = Uncertainty due to reduced exposure time obtained from Table G7
X_c = Uncertainty due to the current meter rating

The errors used to produce the values of combined error were obtained using the results obtained in the data analysis described in Sections 2.3, 2.4, and 2.5 above. The values of the uncertainties in depth, width measurement and current meter rating were taken as zero.

The results have been calculated for reduced numbers of verticals and reduced points in the vertical under the following conditions. The results are presented in tables in Appendix I:

Table 2.4 Results presented in tables in Appendix I

Table number	Individual verticals / whole river analysis	Source of exposure time data
I1 - I7	Individual verticals	Flume data
I8 - I14	Whole river	Flume data
I15 - I19	Individual verticals	Field data
I20 - I24	Whole river	Field data

The whole river analysis is more appropriate for practical purposes, and the flume data on exposure time is the best currently available data set. The results from Tables I8 to I14 have therefore been used in the development of the recommended procedure.

The above results are based on the assumption that the error for the following case is zero.

- Number of verticals: 25
- Six measurement points in vertical Method 10
- Current meter exposure time: 200 seconds.

There is uncertainty in the accuracy of this base condition, and ISO748 Annex E contains estimates of these uncertainties from various sources. These "base errors" are given in Table 2.5 below.

Table 2.5 Base errors used in analysis as derived from BS 3680, Part A

Uncertainties in determination of the mean velocity	Uncertainty % (95% confidence level)
Two hundred second exposure period (X_e)	4
Six point method (X_p)	4
Current meter rating (X_c)	0
Twenty five verticals (X_m)	4

The effects of these errors is to increase the errors given in Appendix I by about 4 to 5%. The base errors have not been included in the analysis.

2.7 Time taken to complete a gauging

The recommended current metering procedures will reduce the gauging time but will increase the random errors associated with the gauging. They will consist of a range of options which will allow gauging staff to choose the method they wish to use depending on the time available. It is therefore necessary to estimate the gauging times associated with the new procedures in order to allow gauging staff to select the option to use

The time taken to complete a gauging depends on the exposure time, the number of measurement points in the vertical, and the time taken to move between measurement positions. Existing gauging times were used to calculate the time taken to move the current meter per vertical. Seventy six gaugings were used in the analysis, and the results are summarised in table J1. The moving time was calculated using the following equation.:

$$t_m = \frac{t_t - (p.t_e.n)}{n}$$

Where

t_m = Time taken to move between verticals in seconds
t_t = Time recorded in seconds by the Environment Agency for completing the gauging
p = Number of points in the vertical
t_e = Exposure time in seconds
n = Number of verticals completed in the gauging

From inspection of the data, moving times per vertical were estimated for use in the calculation of total gauging times. These were 90 seconds for single point measurements and 160 seconds for two point measurements. The total gauging time was calculated for a range of single and two point measurements, and the results are shown in Table J2 together with the random error for the method, calculated as described in Section 2.6 above. The following equation was used to calculate the total gauging time.

$$t_t = p.n.t_e + n.t_m$$

The results from Table J2 are plotted in Figure 2.12, which shows random error against time of gauging. The following conclusions can be drawn from the results:

- The largest single influence on accuracy is the number of verticals
- Exposure time has little effect on accuracy
- The best compromise between speed of gauging and accuracy is to take a single point velocity measurement at a depth of 0.5d.

The recommended procedure is based on the following, and is discussed in further detail in Section 2.8 below.

- 40 second exposure time in which the meter is allowed to settle in the first ten seconds and the measurement takes place in the remaining 30 seconds
- one velocity measurement per vertical, at 0.5d
- a minimum of five verticals, but more if time permits

2.8 Recommended procedure for current meter gauging

The recommended procedure for current meter gauging of rapidly varying flow is as follows

1. Several methods are recommended depending on the available time for gauging, which is calculated in steps 3 and 5 below. All methods have the same exposure time and number of measurements in the vertical, but different numbers of verticals. The methods are as follows:

Exposure time 40 seconds including 30 second measurement period

One measurement in vertical, at 0.5d. $v_m = 0.96v_{0.5}$

Time for gauging (mins)	No. of verticals	Uncertainty (%)
10 - 15	5	12.6
15 - 20	7	9.9
20 - 30	10	6.6
30 - 40	15	4.5
>40	20	2.3

These times are given for guidance purposes, and may vary from site to site.

The uncertainties do not include the systematic and base random errors, which are discussed in Section 2.6 above. The effect of these errors will be to increase the overall uncertainties by about 4-5%.

It would be possible to reduce gauging times further by reducing the exposure time to 10 seconds and further reducing the number of verticals. The error associated with reducing the number of verticals could be calculated from the information provided in the research, but reducing the number of verticals below five is generally not recommended.

Reduction of the exposure time is generally not recommended except where trash is a problem, and a very short exposure time is necessary to avoid the meter being affected by the accumulation of trash.

2. Calculate the rate of change of stage which corresponds to a change in flow of 10% in one hour for the relevant ranges of water levels. This can be done in advance in the office using the existing stage discharge curve for the site.

   If the rate of rise exceeds this amount the new procedure should be used.

3. For cases where the discharge changes by more than 10% in one hour, a table should be produced of the rates of rise which would occur if the flow changed by 10% in different time periods. For example,

Time for discharge to change by 10% (mins)	Rate of rise mm/hr	Rate of rise mm/10 mins
EXAMPLE		
25	600	100

The table should be prepared in advance in the office. It may be necessary to produce more than one table to cover different water level ranges, as the relationship between change of flow and change of water level will vary with stage.

4. The rate of rise should be measured over a ten minute period as soon as the gauging staff reach the site. If the rate of rise corresponds to a change of flow of more than 10% in one hour the new procedure must be adopted.

5. The look-up table produced in 3 above should be used to decide how long the gauging should take. In the example given, if a rate of rise of 100mm is recorded in 10 minutes, the gauging should be completed in 25 minutes or less.

6. The table given in 1 above should be used to decide the number of verticals to use. For the example given, in which the discharge varies by 10% in 25 minutes, the following method should be used.

   - Exposure time 30 seconds including 20 second measurement period
   - One measurement in vertical, at 0.5d. $v_m = 0.96v_{0.5}$
   - 10 verticals

7. The tables referred to in 1 and 3 above could be combined into a single table of rate of rise against current metering procedure for each site. These tables would be unique for each site, as the relationship between rate of rise and rate of change of discharge will vary from site to site. This will enable gauging staff to decide immediately which method to use by reference to one table.

8. In cases where trash accumulates rapidly on current meters a shorter exposure time may be used. Present information indicates that this should not be less than 10 seconds, although there is insufficient information currently available to estimate errors for very short exposure times at high velocities.

9. In cases where it is not possible to get the current meter into the water a surface velocity measurement should be taken. The mean velocity for the vertical should be calculated using the formula:

$$v_m = 0.80v_{SURF}$$

   The cross section of the river channel at the site should be based on measurements taken either before or after the event. In this case the errors will be of the order of 24% excluding systematic and base random errors.

10. The water level should be monitored when each measurement is taken, to identify significant variations in rate of change of water level and discharge. If it is found that the water depth variation exceeds 5% during the gauging, account should be taken of the potential non-linearity of the situation when calculating flow, as discussed in 11 below.

11. The flow should be calculated using the standard mean or mid-section methods given in current British Standards and ISO748, although this may be subject to review as discussed in the paragraph on edge effects in Section 2.9 below.

Where the depth variation exceeds 5% during the gauging, the flow should be calculated using the measured depth at each vertical, and not the mean water level. The procedure is this case is that given in Section 9.4 of ISO748, which is reproduced in Appendix K.

It is recommended that the method is applied in the field and modified if necessary based on the experience obtained.

The final recommended procedure given in Section 5.1 includes additional practical considerations. An analysis was carried out of flood hydrographs at a range of sites in order to determine the percentage change in shape which corresponds to either 10% change in discharge or the minimum gauging time of 10 minutes in cases where the discharge changes very rapidly. It was found that the stage changed by 5% or more, and it was therefore decided to adopt the flow calculation procedure outlined in Appendix K.

2.9 Discussion

There are a number of factors arising from the research which require further consideration, and these are discussed below.

Position of verticals

Verticals are normally spaced equally across the section. However, when small numbers of verticals are used large errors might occur if the verticals are not located at the optimum positions.

It is recommended that the position of verticals is predetermined from inspection of cross section profiles obtained from recent full gaugings at the site. The objective will be to identify locations which permit the best coverage using a small number of verticals, and may include the following:

- Lowest point in channel
- Points where there is a change in the lateral slope across the bed

The bed profile may change during a flood event and it is therefore still necessary to measure the depth at each vertical during the gauging. This procedure will however minimise errors caused by the selection of vertical locations.

This is included in the final recommended procedure given in Section 5.1.

Edge effects

The width used to calculate the flow for each vertical in the mid-section method is the sum of half the panel widths on either side of the vertical. For this reason it is normally necessary to take the first and last measurements as close to the banks as possible.

When the number of verticals is reduced, the error associated with flow near the banks increases. The effects of reducing the number of verticals on cross sectional area and velocity are shown in an example in Figures 2.13 and 2.14 respectively.

All the errors in this report have been calculated based on the standard application of British Standard procedures. In this case however it may be possible to modify the standard procedure to take account of edge effects with small numbers of verticals.

Stable channel sections

Most river channels are liable to change in shape during a flood as a result of erosion and bed movement, and therefore it is normally necessary to measure the bed during the gauging. However, where stable channels exist it would be possible to prepare in advance a schedule of vertical locations and corresponding bed levels. The measurement depth would then be calculated from the water level, and there would be no need to measure the depth during the gauging. This would result in a reduction of overall gauging time.

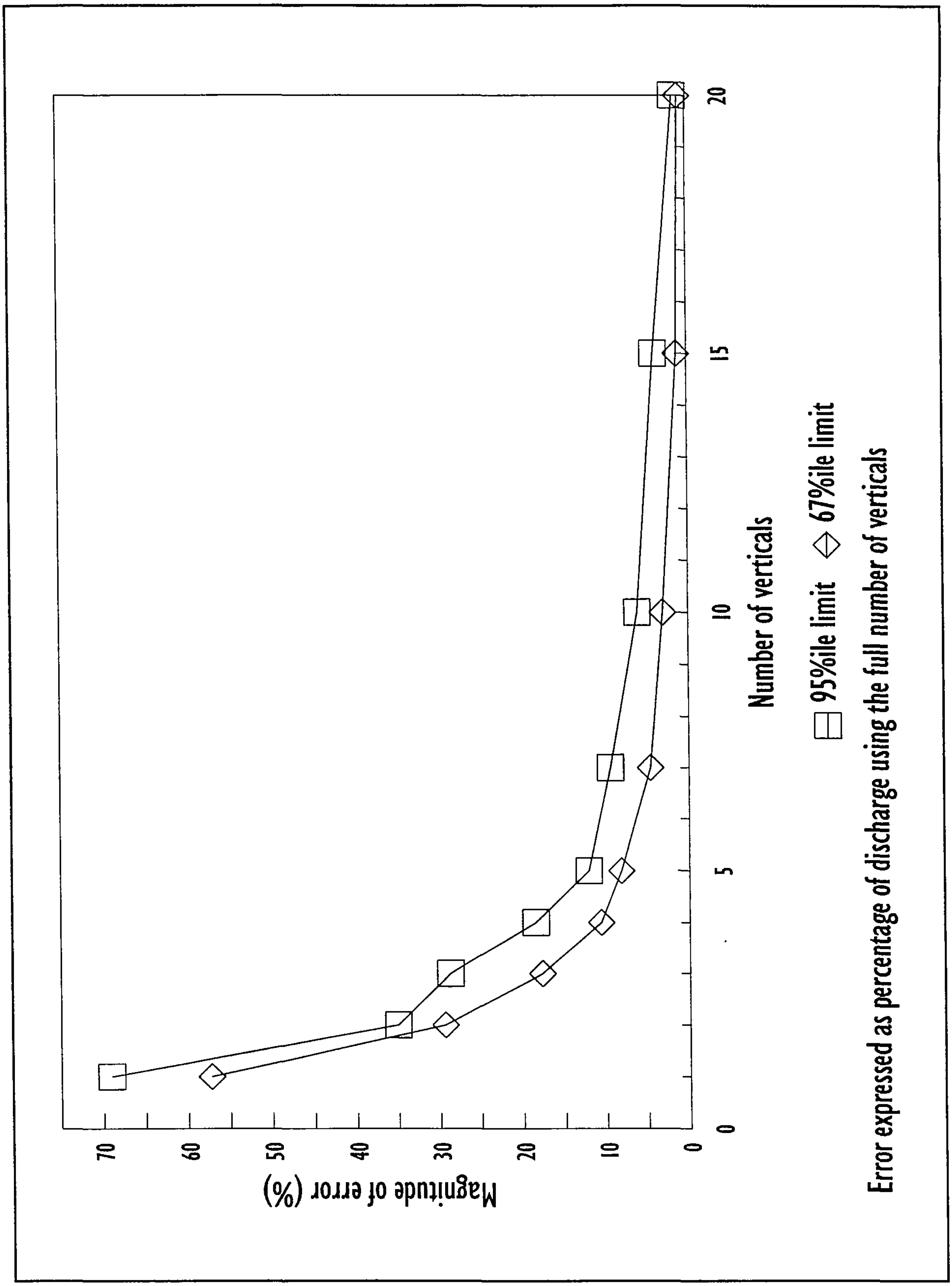

Figure 2.1 Error in discharge with reduced number of verticals

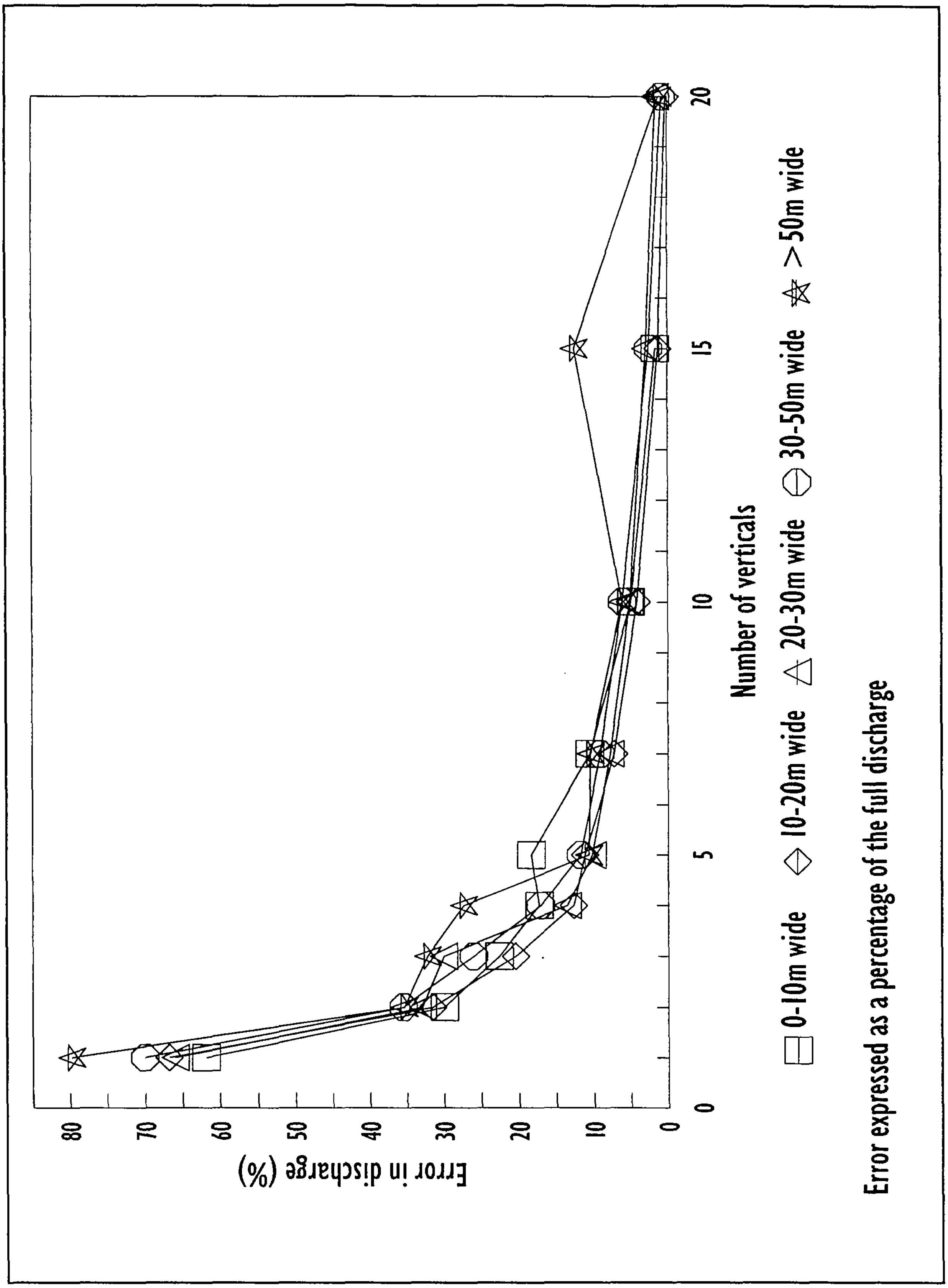

Figure 2.2 Error in discharge with reduced number of verticals by river width band

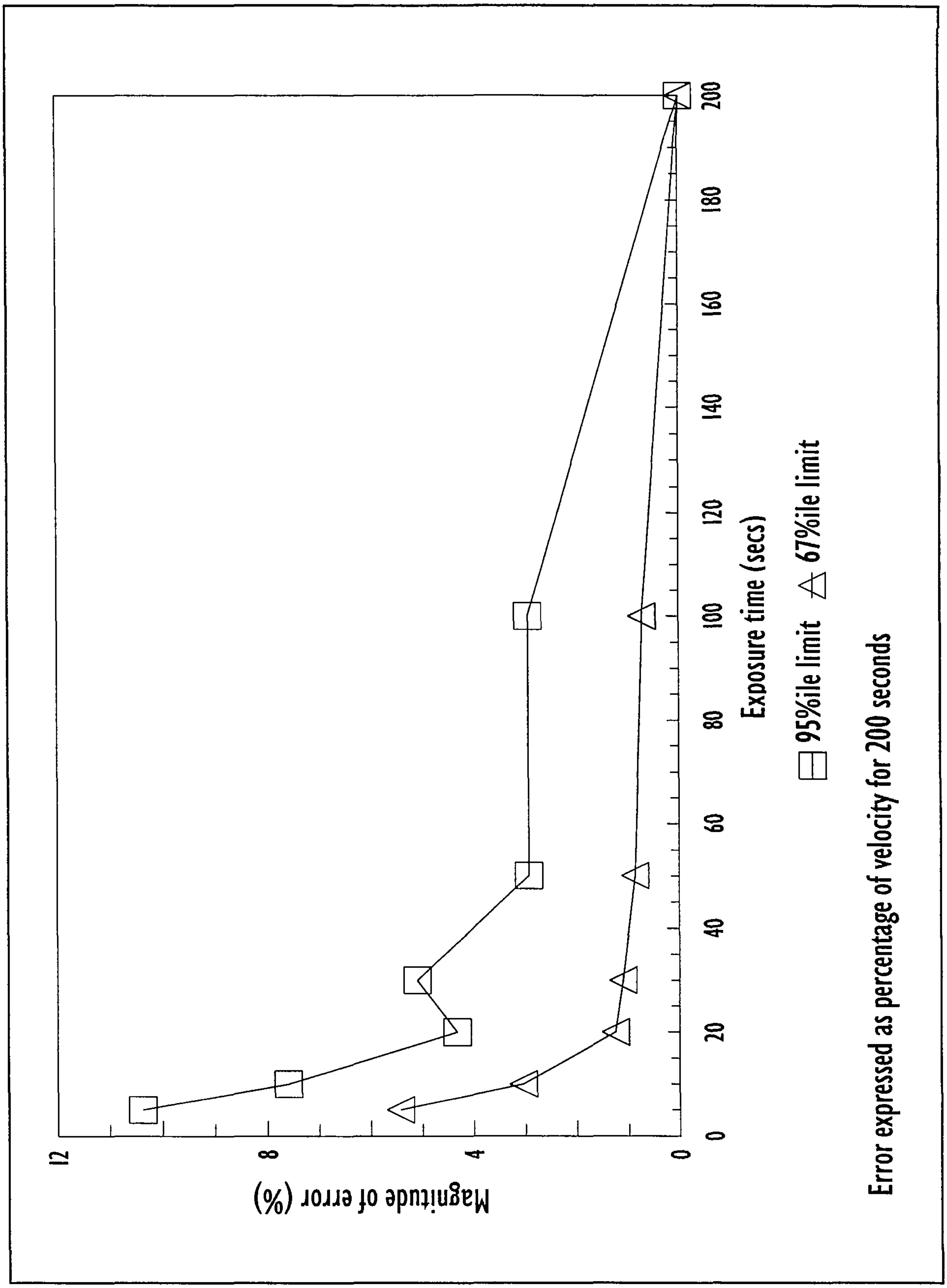

Figure 2. 3 Error in velocity with reduced exposure time - flume data

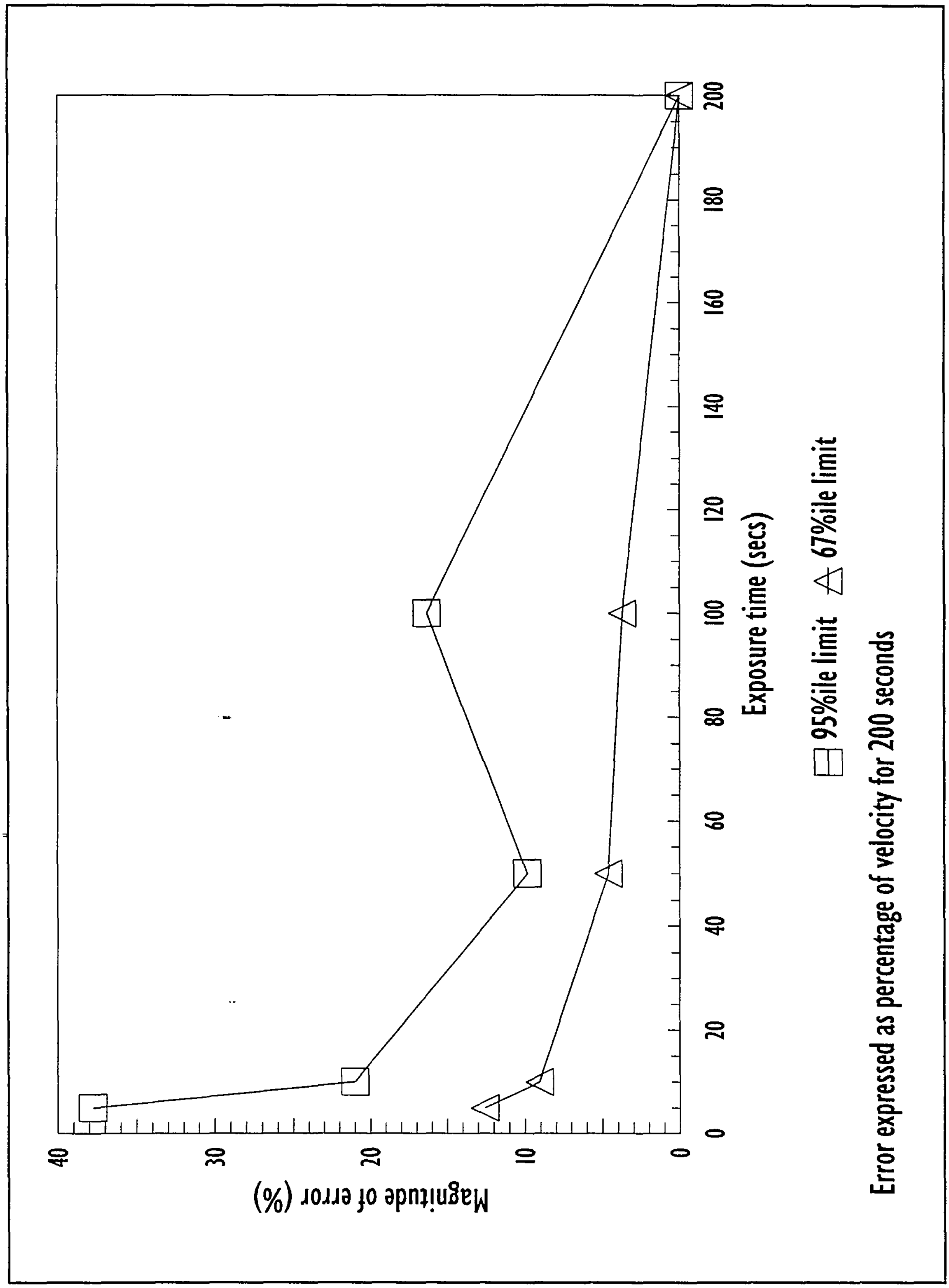

Figure 2.4 Error in velocity with reduced exposure time - field data

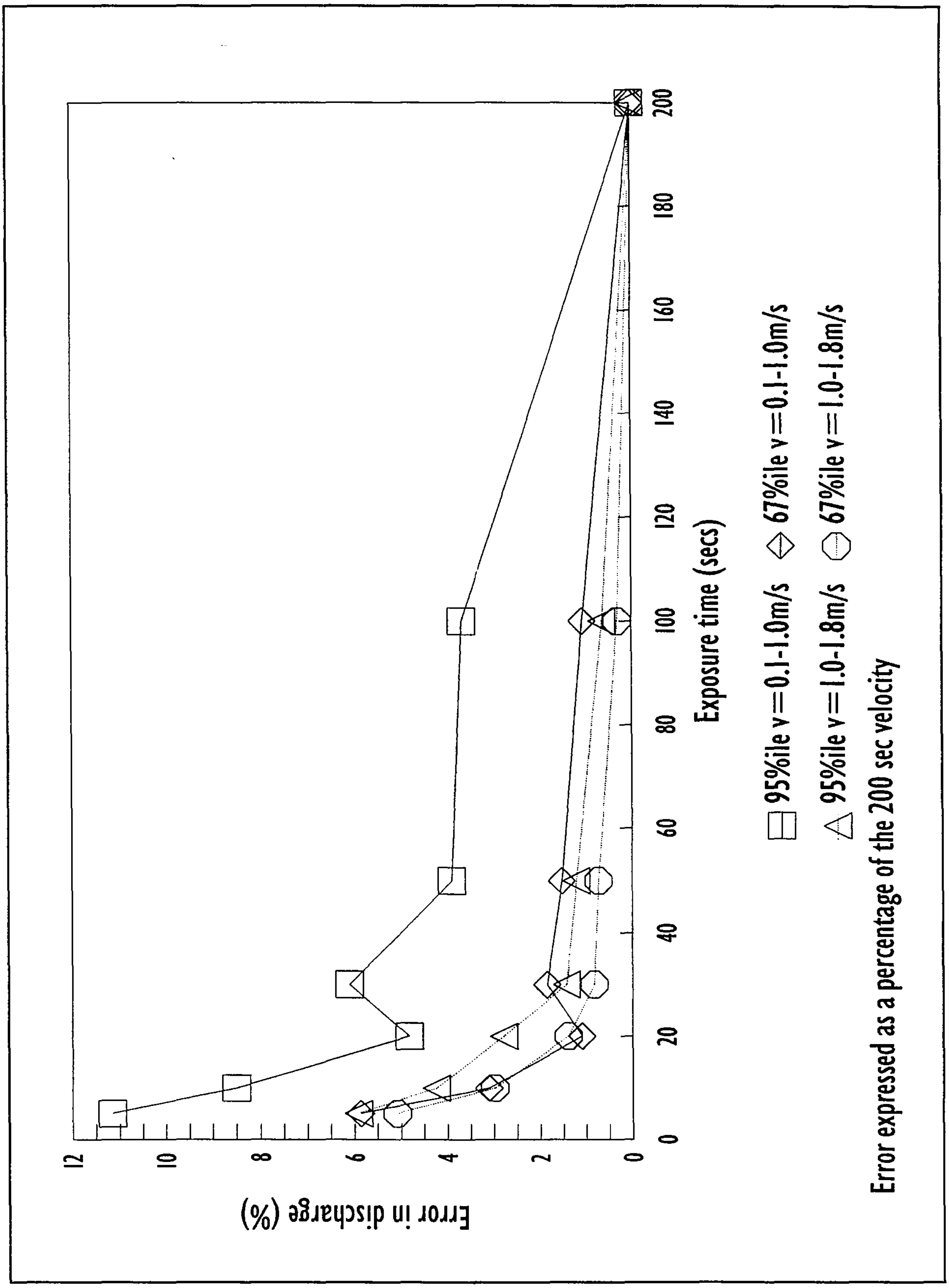

Figure 2.5 Error in velocity with reduced exposure time - flume data

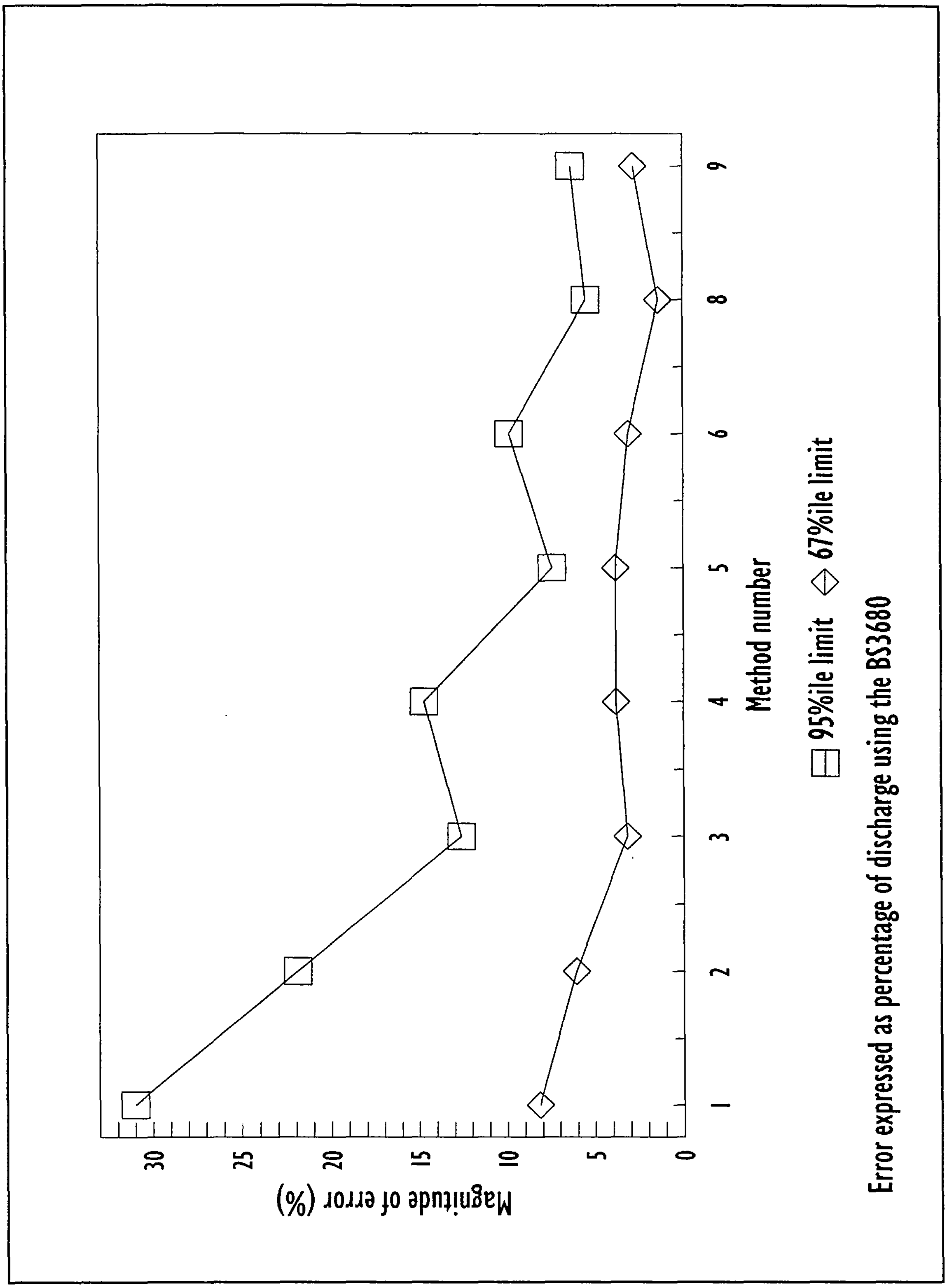

Figure 2.6 Error in discharge with reduced points in vertical - individual verticals

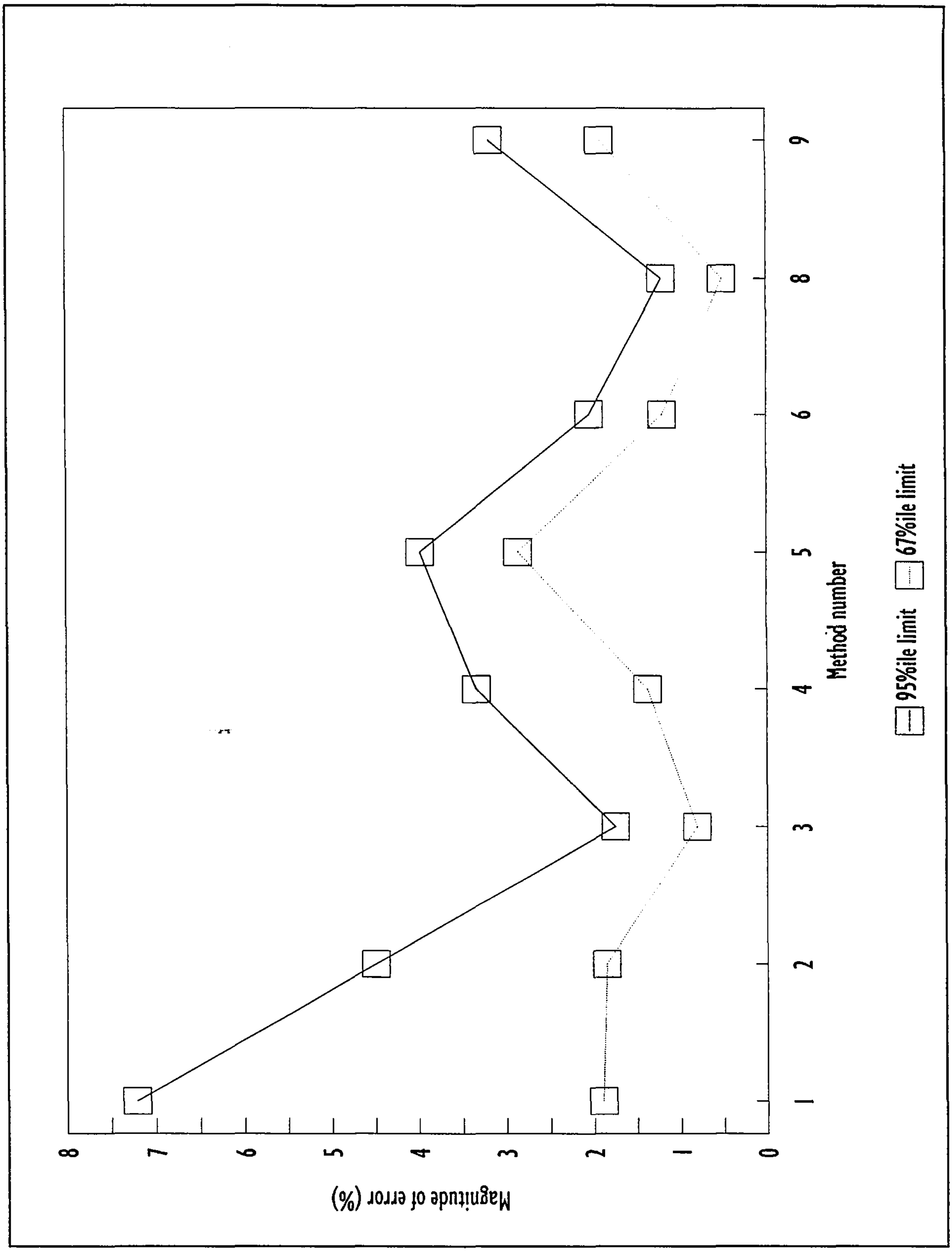

Figure 2.7 Error in discharge with reduced points in vertical - whole rivers

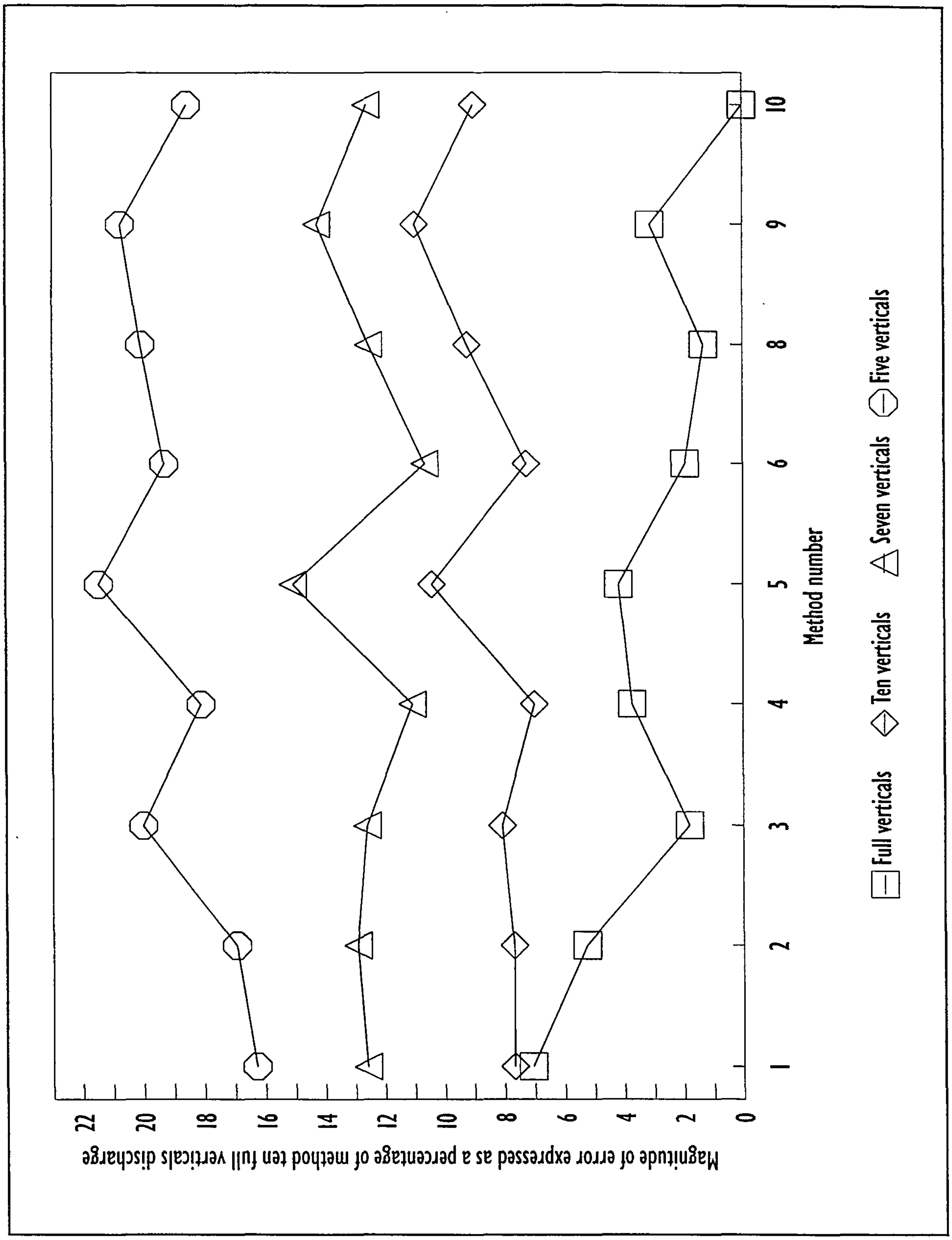

Figure 2.8 Error in discharge with reduced points in vertical - whole rivers

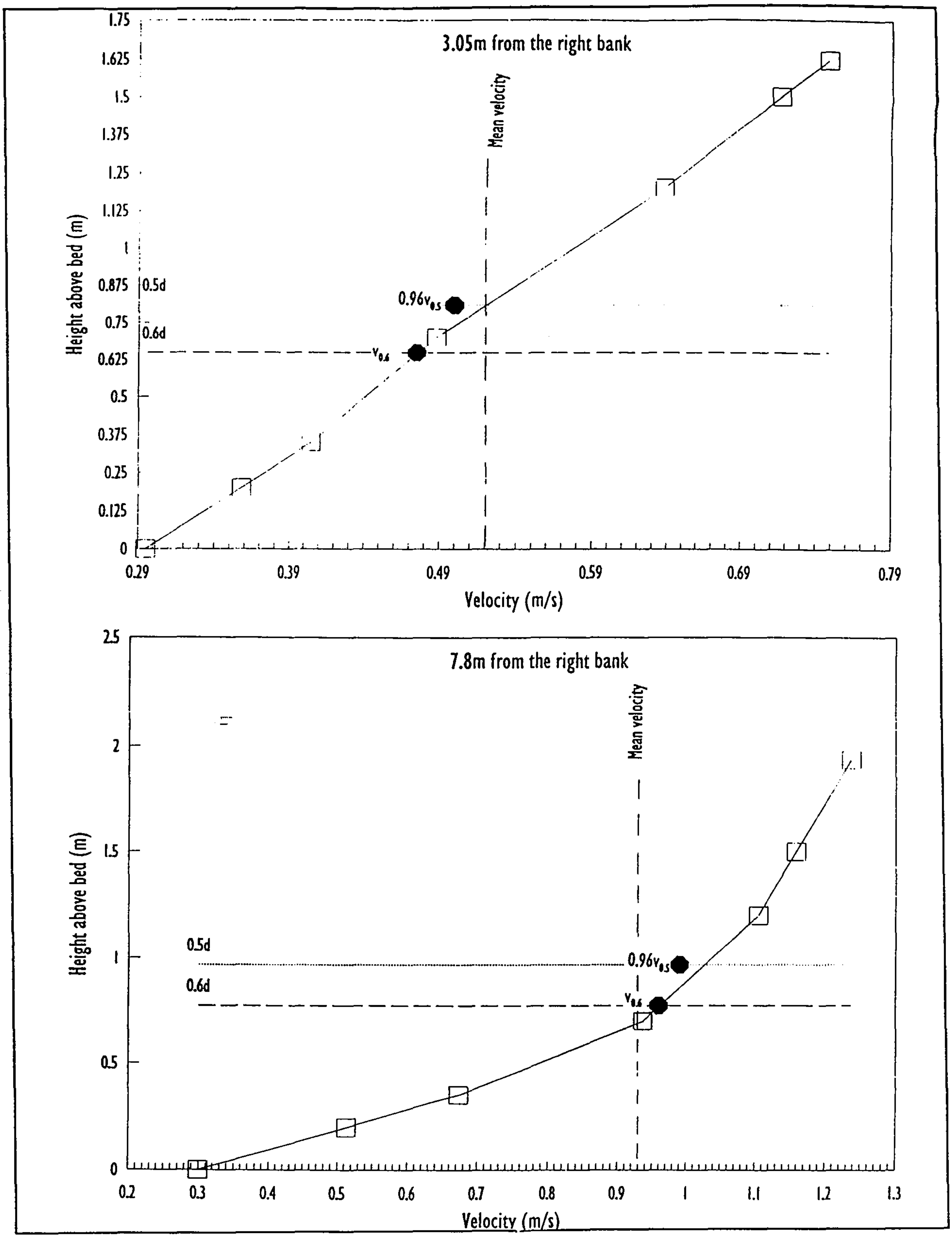

Figure 2.9 **Velocity depth profiles at Longbridge gauging station (Discharge = $15.0m^3s^{-1}$)**

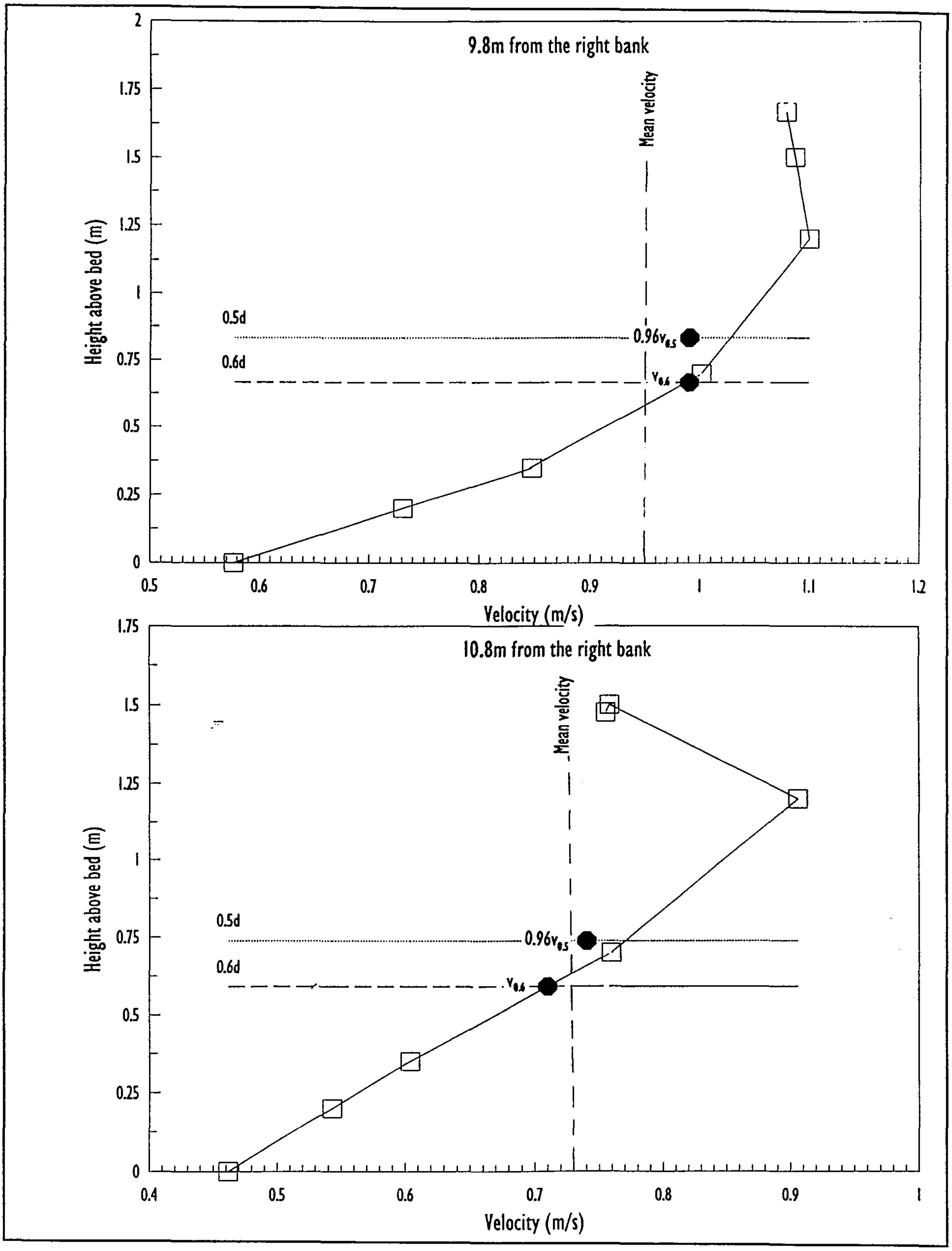

Figure 2.10 Velocity depth profiles at Longbridge gauging station (Discharge = $15.0 m^3 s^{-1}$)

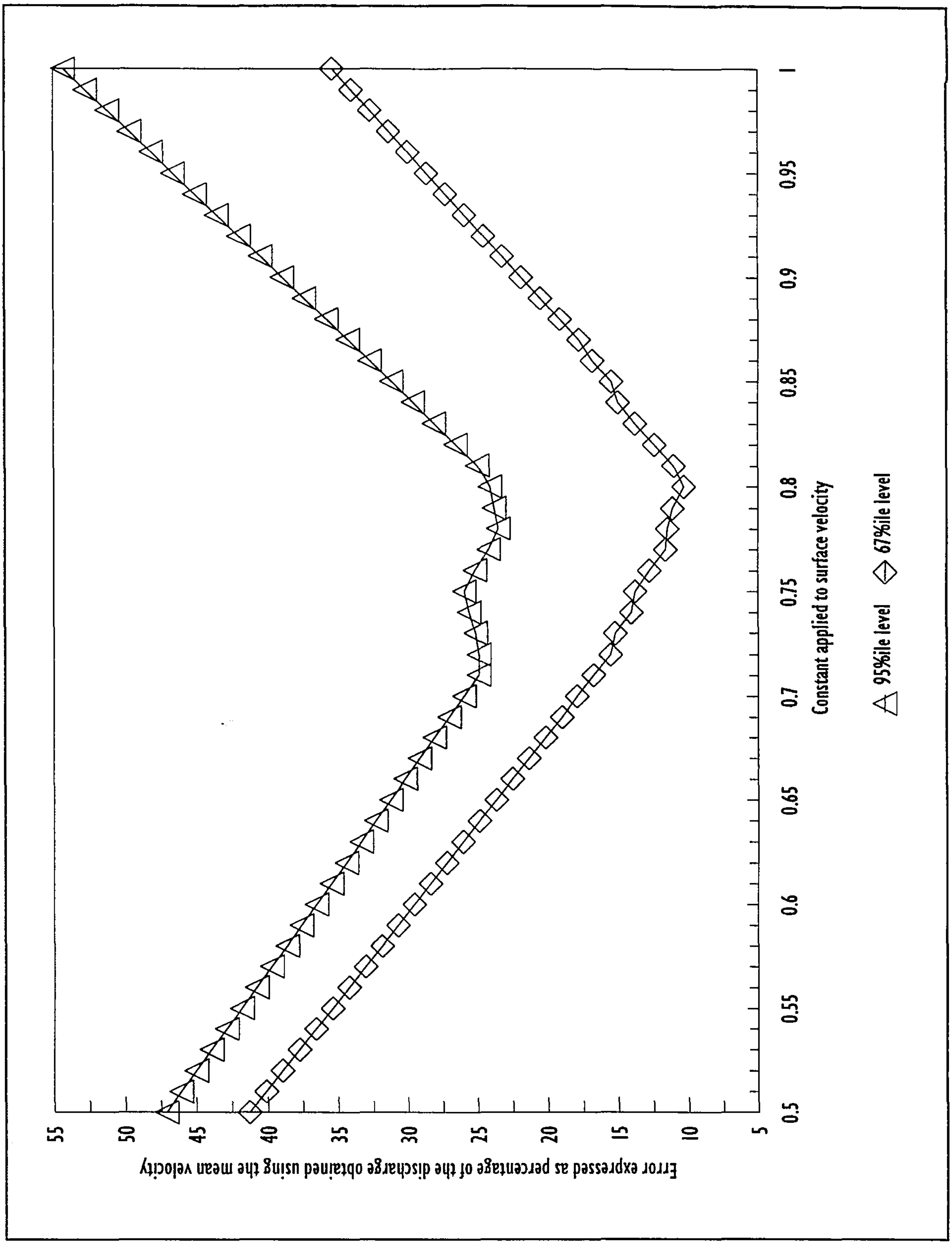

Figure 2.11 Error in discharge using the surface velocity multiplied by a constant

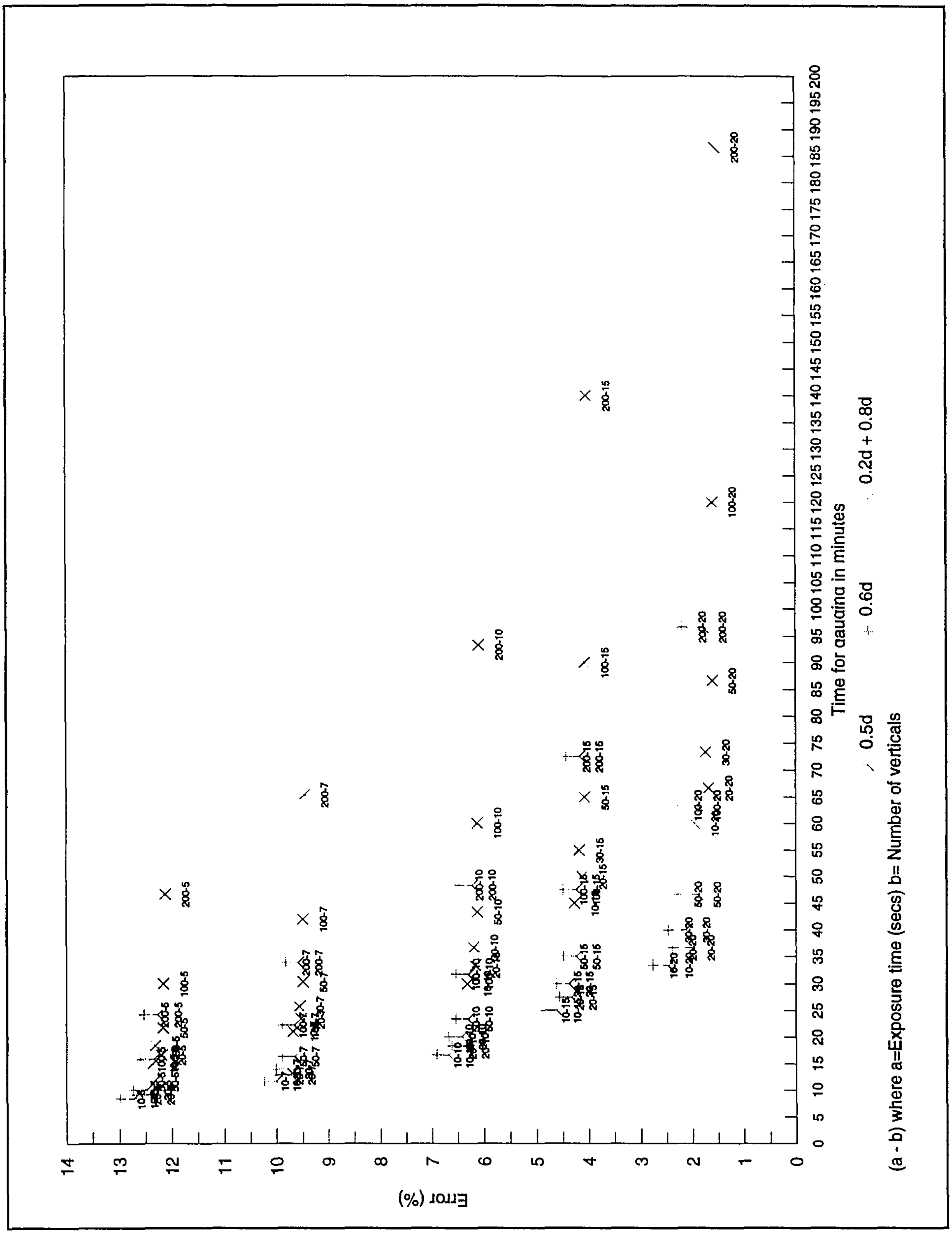

Figure 2.12 Combined error in gauging using error in reduced number of verticals obtained from whole rivers analysis and reduced exposure time error based on the flume data analysis

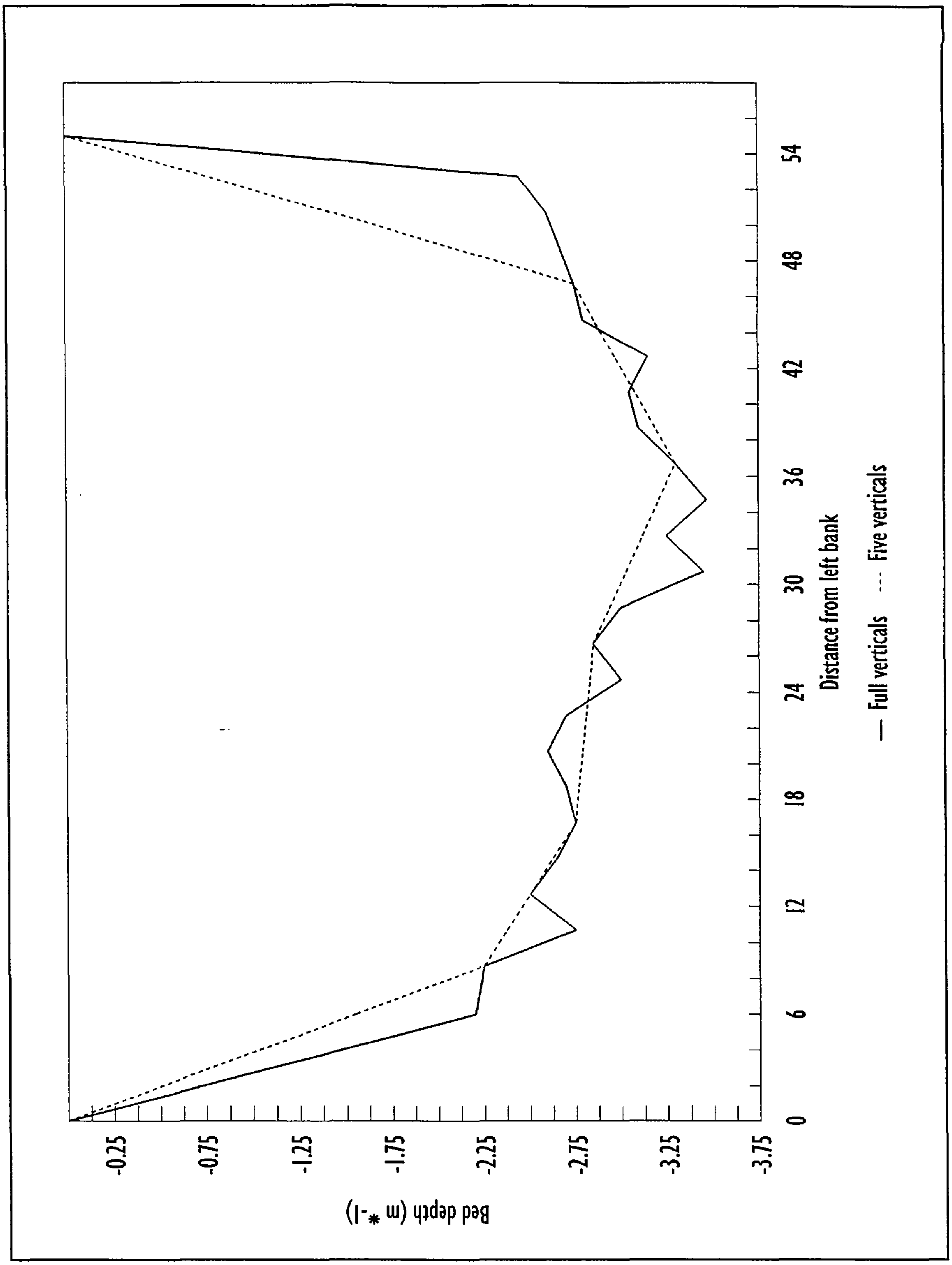

Figure 2.13 Edge effect on flow area for the River Thames at Reading Bridge (18 November 1992)

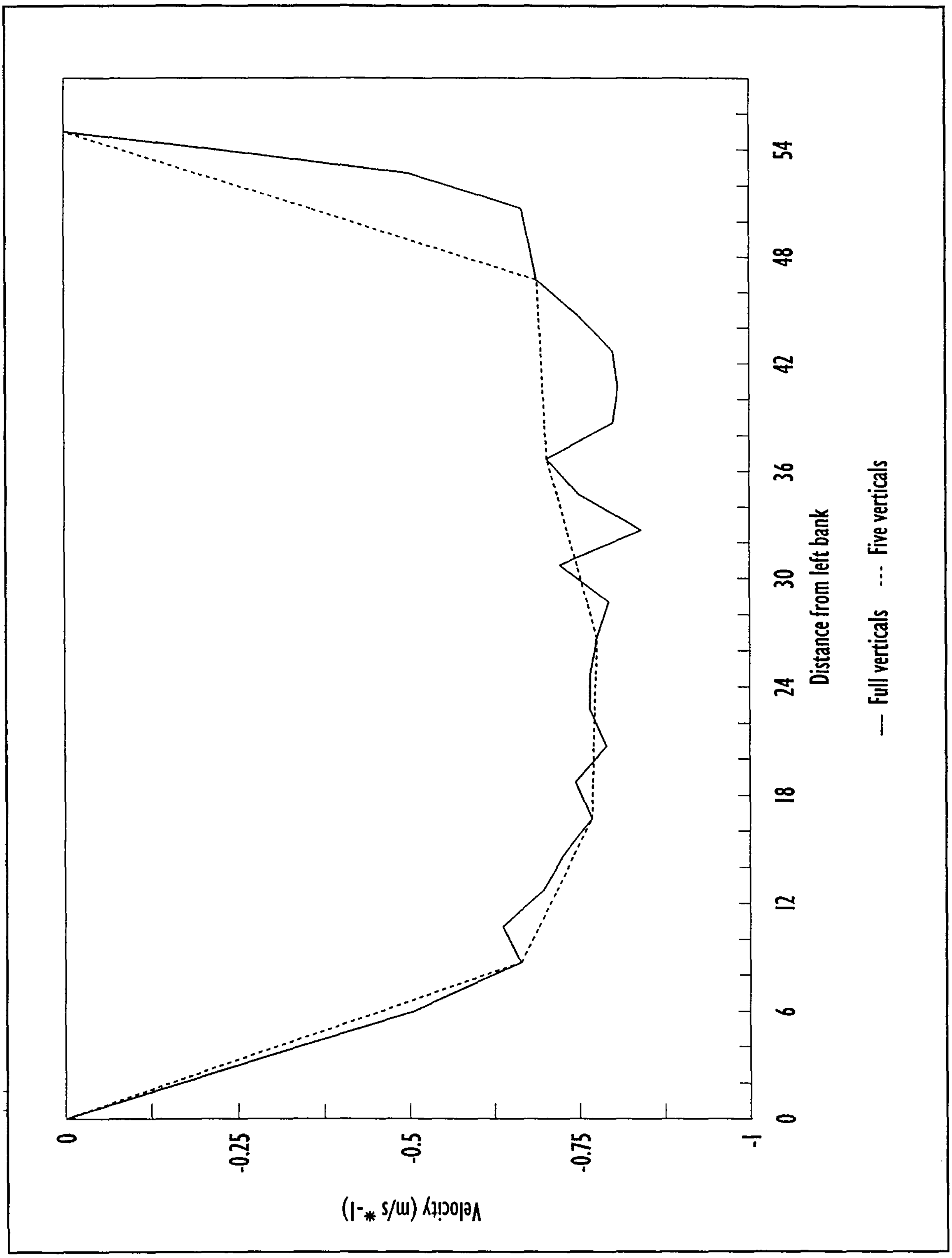

Figure 2.14 Edge effect on velocity for the River Thames at Reading Bridge (18 November 1992)

3 FLOW MEASUREMENT IN SMALL STREAMS

3.1 Background

The objective of this part of the research is to determine standard techniques and best practices of flow measurement in small streams for non-standard situations not adequately covered by the current British and International Standards. Small streams are widespread throughout the United Kingdom and take a variety of forms. These include spring seepages on hillsides, natural stream courses with gravel beds, vegetated drainage systems and concrete lined intake or outfall channels. Measurement of flows in small streams is of importance to hydrometry for a number of reasons, including spot measurements for abstraction licence and discharge consent determination and compliance, to calibration of gauging stations on small streams, and in the planning, development and management of catchment water resources.

British Standard (BS) 3680 Part 3A "Measurement of Liquid Flow in Open Channels" covers most aspects of stream flow measurement. The standard provides wide ranging guidelines for current metering including, for example, current meter exposure time, number and depth of velocity measurements and methods of calculation. However, the Standard is not applicable to very small streams, and no guidelines exist for acceptable techniques under these circumstances.

The objective of the research is to define standard procedures and best practice for gauging small streams. The research included both laboratory and field investigations. The objective of the laboratory tests was to determine a suitable gauging technique. Trials were then carried out near gauging stations on small streams to test the method in the field and identify modifications to the techniques developed in the laboratory in order to take account of field conditions.

Factors which were taken into account in the determination of the optimum procedure include the following:

- Number of verticals
- Type of current meter
- Minimum water depth for current meter measurement
- Method of measuring stream width and depth
- Current meter exposure time
- Method of calculating discharge

The laboratory investigations and results are covered in Section 3.3. The method of calculating discharge is discussed in Section 3.4, and the accuracy of the method is considered in Section 3.5. The optimum procedure determined from the laboratory investigations is described in Section 3.6, and the field trials are covered in Section 3.7. Current meter requirements are given in Section 3.8.

3.2 Definition of a small stream

For the purpose of this research, small streams are defined as having a depth of less than 0.1 metres and/or a width of less than 2.0 metres. The laboratory tests covered small streams up to 2.0 m wide and 0.25m deep.

3.3 Laboratory research

3.3.1 Introduction

The laboratory facilities used in the development of the gauging methodology for small streams were

- a tilting flume with a working length of 24 metres, breadth of 0.915 metres and depth of 0.30 metres.
- a general purpose flume with a working length of 15 metres, breadth of 2.3 metres and depth of 0.61 metres.

The discharge capacity of both flumes was 0.17 m^3/s. Water was delivered to the flumes by centrifugal pumps via constant head systems. The discharge in the tilting flume was measured by a BS V-notch and in the general purpose flume by a BS thin plate weir complemented by a volumetric measurement of the flow. Downstream water level was controlled by hinged tailgate.

Five channel configurations were tested. These were four rectangular channels with channel widths of 0.5m, 0.915m, 1.5m and 2m respectively each with a channel depth of up to 0.25m, and a trapezoidal channel section with a top width of 2m, channel depth of up to 0.25m and 1 in 2 side slopes. Figure 3.1 shows the rectangular channel used in the laboratory.

Flow depths were measured using piezometric tappings set flush with the channel wall. Polythene tubes were used to make connections to 0.15m internal diameter stilling wells where the flow depths were measured using micrometer screw gauges reading to 0.01mm.

Rotating element current meters are most commonly used by the Environment Agency for gauging small streams, and an Ott C2 rotating element meter with a Type 6 impeller (diameter 30mm) was used for most of the tests, see Figure 3.2 In addition, an Aqua Data - Sensa RV1 electromagnetic current meter was also used to assess the suitability of this type of current meter for measuring velocities in small streams, see Figure 3.2. The current meters were calibrated in the towing tank facility at HR Wallingford prior to undertaking the small stream research and a check calibration of the meters was undertaken during the test programme.

Flow measurements were taken within the following range of conditions

- bed slope - 0.001 - 0.01
- flow depth - 0.05m - 0.25m

- flow velocity - 0.10m/s - 1.40m/s
- discharge - 0.01m^3/s - 0.11m^3/s
- current meter exposure time 10s - 100s
- number of verticals 1 - 20
- depth of velocity measurement 0.6d where d is the depth below the water surface

The maximum exposure time used for the electromagnetic current meter was 60s.

Deviation of the metered discharge from the facility discharge within limits of ±5% was taken as the guideline for an accurate gauging.

3.3.2 Number of verticals

The object of investigating the number of verticals to be used in current meter gauging of small streams is to identify the minimum number of verticals which should be used under any circumstances, the maximum number which should be used, and the accuracy which can be achieved with different numbers of verticals.

The five channel sections were divided into panels which ranged between 1 and 20 in number. The minimum panel width tested was 0.0915 metre. The current meter was located centrally within each panel at a point below the water surface equivalent to 0.6 of the flow depth. The exposure time used in optimising the number of verticals was 100s for the rotating element current meter. Subsequent tests carried out using an electromagnetic current meter used an exposure time of 60s.

The Ott C2 flow measurement data for a current meter exposure time of 100s is summarised in Table L.1. The deviation of the metered discharge from the facility discharge for the Ott C2 is summarised and analysed statistically in Table L.2

The Sensa RV1 flow measurement data for a current meter exposure time of 60s is summarised in Table L.3. The deviation of the metered discharge from the facility discharge for the Sensa RV1 is summarised and analysed statistically in Table L.4, which also includes results for an exposure time of 10s.

The deviation of the metered discharge from the facility discharge is plotted against the non-dimensional parameter, water surface width over maximum flow depth (W/D). The Ott C2 data for rectangular and trapezoidal cross sections with an exposure time of 100s is shown on Figures L.1 and L.2 respectively. The Sensa RV1 data for flow measurements with a 60s exposure times in rectangular channels is shown on Figure L.3.

The data shows that inaccuracy in the measured flow increases

- with a reduction in the number of verticals.
- for channels with smaller W/D ratios, ie narrow deep channels.

Analysis of the deviation of the metered discharge from the facility discharge for the Ott C2 indicates that the minimum number of verticals required for a flow measurement accuracy of ±5% is five. Using an increased number of verticals resulted in a negligible improvement in the accuracy of the gauging exercise. A reduction in the number of verticals to 2 or 1 resulted in inaccuracies of approximately 10% and 15% between the metered discharge and the facility discharge. Analysis of the Sensa RV1 electromagnetic current meter data indicates that the meter generally gave an accuracy within the ±5% guidelines for five or more verticals.

It was noted during the experimental work that the measured discharge for the facility using the weir differed from current metered results for full gaugings by about 2%. The error in the weir discharge was assumed for the purposes of the analysis to be zero, although the reason for this difference was not established.

3.3.3 Effect of stream slope

The effect of stream slope on the number of verticals required to give an accurate gauging was investigated. The tests were undertaken in the tilting flume for bed slopes ranging between 0.001 and 0.01. The flow velocity was measured using the Ott C2 rotating element current meter with an exposure time of 100 seconds. Flow measurements were taken for flow depths of 0.05 metre and 0.10 metre with the number of verticals ranging between 1 and 10.

The flow measurement data and deviation of the metered discharge from the facility discharge is summarised in Table L.5 and shown on Figure L.4. The slope data shows a similar trend to that shown by the more comprehensive data set used for optimising the number of verticals. The conclusion that can be drawn is that the accuracy of gauging using five verticals across the channel width is not compromised by the effect of channel slope.

3.3.4 Current meter exposure time

Reducing current meter exposure time can speed up a gauging exercise but could introduce errors in discharge measurement. In order to define the effect of reduced exposure time on gauging accuracy two series of tests were undertaken

- a set of comprehensive complementary tests to those used to optimise the number of verticals but with a current meter exposure time of 10 seconds.
- sensitivity test with exposure times of 10 seconds, 50 seconds and 100 seconds for a number of verticals ranging between 1 and 10 in number in a 0.915 metre rectangular channel with a flow depth of 0.05 metre.

The flow measurement data for the Ott C2 meter is summarised in Table L.6 and plotted in Figures L.5 and L.6. A statistical summary is given in Table L.7. The data set for the Sensa RV1 is too limited to be analysed statistically, but is summarised in Table L.8 and shown in Figure L.7. Table L.4 shows the analysis of the combined data for exposure times of 10 seconds and 60 seconds.

It was concluded that the metered flow using five verticals and a reduced exposure time of ten seconds maintains an accuracy of ±5% when compared with the facility discharge.

Sensitivity tests undertaken with exposure times of 10 seconds, 50 seconds and 100 seconds and shown on Figure L.8 show that the gauged flow accuracy remains within ±5% of the flume discharge for each exposure time.

It should be noted, however, that the experimental channel sections used to develop the small stream gauging procedure are uniform and the flow is relatively uniformly distributed across the channel width. In field situations this may not always be the case, and as there is no need to save time in order to achieve a quick gauging a minimum exposure time of 30 seconds as defined by BS 3680 Part 3A and ISO748 is proposed for adoption.

3.3.5 Waded current meter gauging

Small streams wider than approximately 1m cannot be gauged using rods without the use of a temporary bridge or wading. Some initial waded gaugings were undertaken in the laboratory to determine whether wading has a significant effect on flow measurement.

Gaugings were undertaken using a 2m rectangular cross section channel with flow depths of 0.05m, 0.10m and 0.25m. Velocity measurements were taken with both the Ott C2 and the Sensa RV1 current meters, with a 30s exposure time for panels ranging between 1 and 20 in number. The gaugings were taken with the operator stood behind the meter.

The Ott C2 flow measurement data, and deviation of the metered discharge from the facility discharge, are summarised in Tables L.9 and L.10 respectively, and plotted in Figure L.9. The equivalent tables and figures for the Sensa RV1 are shown in Tables L.11 and L.12 and Figure L.10 respectively.

The data shows that:

- There is a reduction in accuracy compared with results obtained without wading, and there is a greater scatter of results.
- waded gaugings using the Ott C2 increase in inaccuracy as the stream becomes shallower.
- waded gaugings using the Sensa RV1 show an inaccuracy throughout the range of flow depths tested.

These results indicated that wading influences the flow measurement procedure. A programme of further tests was then undertaken to check and clarify these conclusions. The aim of the investigation was to:

- confirm or disprove the earlier findings that suggested wading influenced the flow measurement procedure for small streams.
- consider the various ways in which metering may be done whilst wading and investigate their relative effects on flow measurement.
- develop a recommended method for wading that minimises any adverse effects on the flow measurement procedure.

The scope of the investigation did not cover estimation of the actual magnitude of errors in the flow measurement procedure. The aim was to provide a practical working procedure so that, for situations where wading is the only feasible technique, the errors caused by wading are minimised. Full details of the investigation are given in Appendix N. A summary of the investigation, along with the conclusions and recommendations derived, is given below.

Test Programme

A number of tests were undertaken to achieve the aims listed above. Prior to developing any test programme consideration was first given to the way in which metering may be done. For example, when holding the current meter would the operator face forwards or sideways? Would he or she stand with legs apart or together? It was concluded that the operator would have the ability to place the current meter anywhere within an approximate 0.5m radius (ie. an arm length) from his standing position and that he may stand with legs together or apart when facing upstream, or together if facing towards the bank.

All tests were undertaken by simulating the presence of an operator in the channel by using a pair of size 8 wellington boots filled with concrete. These were positioned according to the required test posture and accurate measurements of flow and depth, both with and without the boots, noted at key locations across a specified 'test grid'.

Test Series 1 - Tests

The first series of tests looked at the effect on flow measurement within a 'test grid' 0.45m (arms reach) square, upstream of the assumed location of the operator. The three boot postures detailed above were considered, with the boots being placed centrally within a 2m wide channel.

Test Series 1 - Conclusions

It was concluded that the boots did have a measurable effect on the flow measurement calculations under certain conditions. To minimise the effect it was found that facing upstream whilst standing with feet apart, and the current meter held at arms length in front of you, resulted in the least impact on flow estimation.

Test Series 2 - Tests

Test Series 1 looked only at a symmetrical distribution of effect, with the boots placed centrally in the channel. Test series 2 looked at what happened as the boots moved closer to the banks to see if any interaction effects occurred. Within the 2m wide channel, two offsets were considered. These were offsets from the centreline of 0.2 m and 0.4 m. This placed the right boot 0.5m and 0.3m respectively from the left bank. It was considered feasible at these distances that the operator may stand with one foot in the channel and one resting on the bank. As such, these scenarios were also tested. Since the conclusions of Test Series 1 were that the boots apart posture gave the least effect, only this posture was considered for further testing during Series 2.

Test Series 2 - Conclusions

It was concluded that there is an interaction effect when the boots are close to the bank, however the effect is minimal if recording is undertaken at arms length, as recommended by the Series 1 test conclusions. Any effects were also found to be significantly reduced by placing only one boot in the channel, rather than two. This would therefore be recommended if at all possible.

Test Series 3 - Tests

A brief investigation was made into the effect that the current meter, and support staff, had on recorded water level or depth. By accurately recording flow depths (non intrusively) both with and without the current meter in position, we were able to assess the impact of the meter itself on the data collected. Variations in the water level, at the point of flow measurement, were recorded at the four centreline grid positions for the flow conditions used during Stage 2. These conditions were depth = 0.06m and velocity = 0.5m/s.

Test Series 3 - Conclusions

As would be expected the water level rises when the current meter is placed in the channel. The average increase in water level was +1.5mm for an average flow depth of 61.8mm. This amounts to an increase of 2.4% in the flow depth value. Without undertaking a detailed comparison of flow calculated by use of the current meter against flow measured by a non intrusive method it was not possible to translate this effect into a percentage effect on the discharge estimate.

It was concluded that whilst the increase was measurable, it remained small in comparison to the effects generated by wading itself. It was also noted that this was an effect which cannot be altered or minimised, unlike the effects of wading.

Conclusions and Recommendations

It was concluded that:

1. Wading whilst current metering within small streams will affect the flow discharge estimation.
2. The effect of wading on flow velocity and depth reduces upstream, and hence further away, from the boots. To minimise effect on the flow measurement calculation the meter should therefore be held in a position upstream of the operator, at arms length.
3. Of the three boot positions investigated (boots together facing upstream, boots together facing the bank, boots apart facing upstream), the 'boots apart, facing upstream' posture has the least effect on flow depths and velocity.
4. An interaction between bank and boots occurs if the operator stands too close to the banks (ie. ≤300mm). The operator should therefore stand as far from the bank as possible.
5. Effects are considerably reduced if the operator is able to stand with one foot on the bank and only one foot in the channel.
6. The current meter, and staff, itself affect the water depth and hence velocity. The effects

are small in comparison to those caused by wading and cannot be avoided.

A revised procedure for flow measurement in small streams may now be recommended:

- If it is at all possible to undertake the flow measurement without wading then this should always be done.

Given that wading is the only viable option, then:

1. Where possible take readings close to the bank, whilst stood on the bank.
2. Where possible take readings whilst standing with one foot in the channel and one on the bank

This should allow data to be collected for locations up to at least 500mm from the bank. For mid channel readings (> 500mm from either bank) the operator should stand facing upstream with feet apart. The current meter should be held centrally at arms length. This posture should be maintained for each 'step' across the channel until the meter is within 500mm of the bank.

3.4 Comparison of discharge calculation methods

The object of comparing methods for calculating the discharge within a small stream was to establish whether the simple summation of the product of panel velocity and area ("mid-section method") gave as accurate a measure of total flow as an analysis using the BS 3680 Part 3A/ISO748 mean-section method. The comparison of calculation methods was undertaken using the data obtained with the Ott C2 rotating element meter from the five channel sections tested, for flow depths of 0.05 m, 0.10 m and 0.25 m. The current meter exposure time was 100 seconds. The number of verticals used to measure the flow velocity ranged between 1 and 20. Each channel section tested was divided equally into an equivalent number of verticals with each vertical being centrally located within the panel. The current meter was positioned at a point equivalent to 0.6 of the flow depth as measured from the water surface.

The two methods of discharge calculation were

- Mid-section method, as outlined in BS3680 Part 3A/ISO748 Section 9.2.2.2
- Mean-section method, as outlined in BS3680 Part 3A/ISO748 Section 9.2.2.1

The measured discharges using the two methods are summarised in Table L.13. Comparison of the data shows that for gauging exercises undertaken with verticals ranging in number between 10 and 20 both methods of calculating discharge are equally as appropriate. For flow measurement exercises using five verticals summating the mid-section method is a slightly more accurate method of calculating the discharge.

The average difference between the metered and facility flow using the mid-section and mean-section methods are approximately 2% and 1.2% respectively for 10 to 20 verticals, with a standard deviation about the average of 1.7% and 2% respectively. With five verticals the average difference between metered and facility discharge for the two calculation methods are approximately 3% and 3.5% respectively. The standard deviation about the average for the mid-section method is approximately 2.7% compared to 5.2% for the mean-section method.

3.5 Uncertainty of a velocity area measurement

The overall uncertainty in the gauging of discharge depends upon both random and systematic uncertainties, as discussed in Section 2.6.

The random uncertainty in discharge measurements by means of current meters (X_Q) is calculated using the equation below

$$X_Q = \sqrt{X_m^2 + \frac{1}{m}[X_b^2 + X_d^2 + X_p^2 + \frac{1}{p}(X_e^2 + X_c^2)]}$$

Where

X_m = Uncertainty due to number of verticals, m
X_b = Uncertainty in width measurement
X_d = Uncertainty in depth
X_p = Uncertainty due to number of points in vertical, p
X_e = Uncertainty due to exposure time
X_c = Uncertainty in current meter rating

The above equation was used to estimate the uncertainty in discharge measurement with a value of X_m of 5% and values of other uncertainties as given in Annex E of ISO 748, as follows:

X_b	(Uncertainty in width measurement)	0.3%
X_d	(Uncertainty in depth)	3.0%
X_p	(Uncertainty due to number of points in vertical)	15.0%
X_e	(Uncertainty due to exposure time)	4.0%
X_c	(Uncertainty in current meter rating)	1.0%

The resulting uncertainty in discharge measurement is about 9%. The errors obtained in the flume tests for five verticals were within 5%. An analysis was therefore carried out to estimate values of individual uncertainties in order to achieve an overall uncertainty of 5%. The results are shown in Tables L.14, L.15 and L.16. Table L.14 shows results obtained using values taken from Annex E of ISO748 only, including X_m of 15% for 5 verticals, reducing to 9% for 10 verticals and 5% for 20 verticals.

It was found that an overall error of 5% was achieved with values of X_m and X_p of 3.5%, as shown in Table L.16.

Suggested values of uncertainties

The following values of uncertainties are suggested for velocity area measurements based on the results obtained in the laboratory flumes.

Uncertainties in width (X_b)

The uncertainty in the measurement of width should not be greater than ±1%

Table 3.1 Uncertainties in width (X_b)

Type of channel	Width (m)	Absolute error (%)
Flume	0.5	0.2
	2.0	0.1
Concrete	0.5/2.0	0.5
Natural stream	0.5/2.0	1.0

Uncertainties in depth (X_d)

For flumes the uncertainty should not exceed ±2%; for concrete channels the uncertainty should not exceed ±3%; for natural streams the uncertainty should not exceed ±5%.

Table 3.2 Uncertainties in depth (X_d)

Type of channel	Depth (m)	Absolute error (%)
Flume	0.05	2.0
	0.25	1.0
Concrete	0.05	2.0
	0.25	3.0
Natural stream	0.05	2.0
	0.25	5.0

The following values for uncertainties in determination of the mean velocity are proposed.

Times of exposure (X_e)

The following values are given as a guide and have been taken from ISO748 for a single point in the vertical at 0.6D.

Table 3.3 Times of exposure (X_e)

	Exposure time (seconds)			
Velocity (m/s)	30	60	120	180
	Uncertainty (± %)			
0.05	50	40	30	20
0.10	27	22	16	13
0.20	15	12	9	7
0.30	10	7	6	5
0.40	8	6	6	5
0.50	8	6	6	4
1.00	7	6	6	4
>1.000	7	6	5	4

Number of points in the vertical (X_p) and number of verticals (X_m)

The following values were derived from the flume tests as discussed above. The values given are for a single point in the vertical at 0.6D.

Table 3.4 Number of points in the vertical (Xp) and number of verticals (Xm)

Type of channel	Number of verticals	Uncertainty (± %)
All types	10/20	2.5
	5	3.5

Current meter rating (X_c)

The following values are given as a guide. Values for individual meters should be verified when the meter is calibrated. The uncertainties are for individual ratings at the 95% confidence level.

Table 3.5 Current meter rating (X_c)

Velocity (m/s)	Uncertainty (± %)	
	Rotating element	Electromagnetic
0.03	20.0	0.5 throughout velocity range
0.1	5.0	
0.15	2.5	
0.25	2.0	
0.5	1.0	
>0.50	1.0	

3.6 Optimum procedure for current meter gauging

The proposed practice should adopt the following recommendations :

1. Number of verticals

    - Number of verticals should not be less than 5.
    - Spacing of verticals should not be less than 1.5 times the current meter impeller diameter

2. Current meter exposure time

    - Exposure time should not be less than 30 seconds.

3. Channel section

    - Section should ideally have a rectangular profile with uniform bed and banks.
    - Section should be perpendicular to the flow.
    - The existing section at the measurement site should be adapted to provide a rectangular shape if initially unsuitable.

4. Approach conditions

    - The approach channel to the measuring site should be straight for a distance of 5 channel widths, if possible.
    - When the length of straight channel is restricted either naturally or through adaptation of the channel at the measurement site then it is recommended that the straight length upstream of the measuring section should be twice that

downstream.

5. Flow conditions

- Water surface should be tranquil.
- Flow depth should not be less than twice the diameter of the impeller of a rotating element current meter or twice the depth of the head of an electromagnetic flowmeter.
- If the section profile has been adapted then allow the flow to stabilize before starting measurements.

6. Bed conditions

- The bed should be smooth at the measuring section. Objects such as stones which are significant in size compared with the water depth should be removed.
- Significant errors will occur where the bed material particle size is of the same order of magnitude as the water depth.

7. Measurement of cross section

- The channel depth at the gauging site should be measured using a steel rule, graduated in mm, with the water surface as datum, at not greater than 0.10 metre intervals across the width.

8. Range of suitable meters

- Small diameter rotating element meters (eg; Ott C2, BFM-002 and BFM-004) and shallow profile electromagnetic current meter (eg; Aqua Data - Sensa RV1) are suitable for measuring flows in small streams.

9. Wading

- If it is at all possible to undertake the flow measurement without wading then this should always be done.

Given that wading is the only viable option, then:

- Where possible take readings close to the bank, whilst stood on the bank.
- Where possible take readings whilst standing with one foot in the channel and one on the bank. This should allow data to be collected for locations up to at least 500mm from the bank.
- For mid channel readings (> 500mm from either bank) the operator should stand facing upstream with feet apart. The current meter should be held centrally at arms length. This posture should be maintained for each 'step' across the channel until the meter is within 500mm of the bank.

10. Method of calculating discharge

- Mid-section method

11. Attainable accuracy

- If the above recommendations are adopted an accuracy of ±5% in the measurement of discharge should be attainable.

In order to achieve a gauging section which satisfies the above criteria, adaptation of the section is required. It will be necessary to provide suitable equipment and materials to the gauging teams, and it is recommended that further consideration is given to the best method of adapting sections. For example, a portable flume may be suitable for very small streams with rough beds for use in conjunction with a temporary dam to raise the water level. A rod for water level measurement would also be required, to determine when the water level has stabilised after adaptation of the section.

3.7 Field trials

The procedure detailed in Section 3.6 was tested in the field in Ewelme Brook, Environment Agency - Thames Region on 9 March 1995. The brook is gauged by a 2m wide Flat V weir, as shown on Figure 3.3. The mean flow for the station is 0.05 m^3/s with a peak flow to date of 0.3 m^3/s (14/08/1980). The channel upstream of the weir ranges between approximately 0.9m and 1.3m wide and is rectangular in section. The vertical sides of the channel are brick lined. The channel bed in the upper reach is formed of coarse flint gravel with a D_{50} of approximately 0.03m. D_{50} is the particle size which is exceeded by 50% of the particles. Closer to the weir the channel is rectangular with brick sides and a bed consisting of sand and fine gravel interspersed with occasional coarser gravel. Downstream of the weir the flow passes through redundant cress beds before emerging into a stream with a natural section. The water surface width of this section was 2.1 metres with a maximum depth of approximately 0.27 metre.

Discharge measurements were taken on the upper brick lined section, the lower brick lined section, and the natural section. Velocity measurements were undertaken using the Ott C2 meter with an exposure time of 30 seconds. In addition, flow in the lower reach of the brick lined channel were measured using the Aqua Data - Sensa RV1 electromagnetic current meter. Below the weir the brook is joined by two ungauged springs upstream of the natural measuring section. Consequently, the accuracy of measured discharges for the natural section could only be compared on a relative basis using a full current metering undertaken using 19 verticals.

During the field trials the flow depth in the upper brick lined reach was approximately 0.18 metre with a turbulent water surface, see Figure 3.4 and in the lower brick lined reach approximately 0.3 metre deep with a tranquil water surface, see Figure 3.5. The transect was measured using a steel rule with the water surface as datum. Flow measurement in the natural section is shown on Figure 3.6. Wading was used in this case, although for the recommended procedure wading should generally be avoided. The number of verticals used in the transects were 1, 2, 5 and 10 with the sections being divided into verticals of equal width. Velocity measurements were taken with the current meter located centrally within each panel with the meter located at 0.6 of the depth as measured from the water surface. Three velocity readings were taken at each position measured and the values averaged.

The metered discharges are shown on Table M.1. The deviation of the metered discharge from the weir discharge/full current metering is shown in Table M.2 and on Figures M.1 and M.2 for the rectangular and natural sections respectively.

The following conclusions were made from the field trials

- Good agreement was achieved between the weir discharge and the current metered discharge for the lower brick lined channel using both the Ott C2 and Sensa-RV1 meters. Flow in the reach was tranquil with a relatively smooth, sandy gravel bed. The deviation of the metered discharge from the weir discharge was 3.3%, -1.0%, -6.0% and 26.0% for the Ott C2 with 10, 5,2 and 1 verticals respectively, and 4.2%, -2.2% and -9.8% for the Sensa RV1 with 10, 5 and 2 verticals respectively.
- Poor agreement was achieved between weir and metered flow for the upper reach of the brick lined channel where the flow was turbulent. The deviation between the metered discharge and weir discharge was 20%, 14%, 25% and 36% for 10,5,2 and 1 verticals respectively.
- For the natural section, the deviation between the metered discharge and the full gauging was 0.6%, 4.5%, 12.6% and 19% for 10,5,2 and 1 verticals respectively.
- Where good agreement is achieved between the metered and weir discharge the optimum number of verticals that should be used for a metering is confirmed as being 5. Using less than 5 verticals produces a metered discharge with an accuracy outside the ±5% guideline.

3.8 Suitability of current meter

Current meters currently used in the gauging of small streams are listed in Table 3.6. The Ott C2 rotating element meter with Type 6 impeller and Aqua Data - Sensa RV1 electromagnetic current meter were used during the course of the laboratory and field work. The following observations can be made in respect of the laboratory and field tests involving the two meters and the implications for other types of flowmeter.

3.8.1 Performance of current meters

Both types of current meter measured the discharge accurately using the procedure determined for the gauging of small streams. This will give some confidence in the ability of the current meter detailed in the table but not tested during the course of the study to perform satisfactorily.

3.8.2 Shallow depth performance

Both current meters performed well in shallow depths. Performance of the rotating element meters detailed in the table but not tested in the study can be expected to perform as satisfactorily as the Ott C2 due to the physical similarity of the meters. However, it is anticipated that the shallow depth performance of electromagnetic current meters will be related to individual probe size and shape and would require investigation before being used for gauging small streams.

3.8.3 Environmental consideration in use of meters

The lack of moving parts in an electromagnetic current meter gives an advantage to this type of meter compared to a rotating element meter when measuring flows containing solids, weed etc. Rotating element meters have the advantage in the presence of extraneous magnetic fields and other ambient environmental electrical effects.

3.8.4 Calibration of current meters

The calibration of a rotating element meter is applied externally compared to the internal calibration characteristic embedded in the electronics of the electromagnetic current meters. This enables the electromagnetic current meter to give an instantaneous readout of flow velocity but the method whereby measured electrical potential is transformed into velocity is not visible.

The calibration of the electromagnetic current meter provided for the duration of this study was in error by 31% at 0.1 m/s reducing to 1.7% at 0.6 m/s when it was received. Re-calibration is normally undertaken by the meter manufacturer, but for the purposes of the study the meter was checked in the HR current meter rating tank and a conversion table was produced to convert meter readings to velocity.

Table 3.6 Specification of current meters for use in small streams

Meter type	Impeller type	Impeller diameter/ head depth (m)	Impeller pitch (m)	Minimum flow depth for use of current meter (m)	Range of flow velocity for use of current meter (m/s)	Approx. accuracy at minimum velocity (%)
Aqua Data - Sensa RV1 (Electromagnetic)		0.02	n/a	0.05	0.00 - 4.00	±0.5
Braystoke BFM-002 (Rotating element)	1178 -	0.05	0.1	0.1	0.04 - 2.00	±20
Braystoke BFM-004 (Rotating element)	911	0.019	0.04	0.04	0.07 - 1.50	±5
	912	0.028	0.04	0.06	0.05 - 1.50	±10 - ±20
Seba M1 (Rotating element)	50	0.030/0.050	0.05	0.060/0.100	0.03 - 0.60	±10 - ±20
	100	0.030/0.050	0.1	0.060/0.100	0.03 - 1.20	±10 - ±20
	250	0.05	0.25	0.1	0.03 - 2.50	±20
	500	0.05	0.5	0.1	0.04 - 5.00	±5
Ott C2 (Rotating element)	1	0.05	0.05	0.1	0.03 - 0.60	±20
	2	0.05	0.1	0.1	0.04 - 1.20	±20
	3	0.05	0.25	0.1	0.04 - 2.50	±20
	4	0.05	0.5	0.1	0.08 - 5.00	±5
	5	0.03	0.05	0.06	0.06 - 0.60	±10 - ±20
	6	0.03	0.1	0.06	0.06 - 1.20	±10 - ±20

4 CONCLUSIONS AND RECOMMENDATIONS

1. The procedure described in Section 5.1 is recommended for use in conditions of rapidly varying flow. The procedure has not been applied in the field, and it is recommended that the procedure is applied for river gauging during the winter of 1995/96. Feedback should be provided on the use of the procedure and possible improvements.

2. More data on the effects of reducing current meter exposure time at high velocities are required to check the accuracy of the results given in this report.

3. Where small numbers of verticals are used the effects of errors at the edge of the channel become significant. The magnitude of these effects should be investigated and, if necessary, a modification should be made to the calculation procedure.

4. The procedure described in Section 5.2 is recommended for use for flow measurement in small streams.

   Although some testing of the procedure has been carried out in the field, it is recommended that the procedure is applied for stream gauging by the Environment Agency and RPBs. Feedback should be provided on the use of the procedure and possible improvements.

5. It is recommended that more consideration is given to the optimum ways of adapting small streams for flow gauging purposes, and a list of suitable equipment is prepared for use by gauging teams.

5 RECOMMENDED METHODS

5.1 Measurement of flow where the stage is changing rapidly

The recommended procedure for current meter gauging of rapidly varying flow is as follows

1. When to use the recommended procedure

   On arrival at the site read the Gauge Board. From a plot of the site rating curve, determine the water level rise or fall from the current Gauge Board reading which corresponds to a 10% change in flow. The rise or fall should be calculated in mm.

   From an on-site water level chart, estimate the current rate of rise and fall in mm/hr. Calculate the time available to carry out the gauging ie how long before the flow will have changed by 10%. If a water level chart is not available, calculate the rate of change of water level by taking a second Gauge Board reading 10 minutes after the first reading.

$$Time\ (minutes) = \frac{A}{B} \times 60$$

   where A is the rise or fall for a 10% change in flow (mm) and B is the current rate of rise or fall (mm/hr).

   If the time available to carry out the gauging is more than one hour, use normal procedures. If the time is less than one hour, proceed to step 2.

2. Recommended flow gauging procedure

   Using the time available for the gauging, decide the number of verticals. The table below is given for guidance purposes but times may vary from site to site. Gauging staff should use their experience when deciding the number of verticals at each site.

Time for gauging (mins)	No. of verticals	Uncertainty (%)
10 - 15	5	12.6
15 - 20	7	9.9
20 - 30	10	6.6
30 - 40	15	4.5
>40	20	2.3

The uncertainties do not include the systematic and base random errors. The effect of these errors will be to increase the overall uncertainties by about 4-5%.

In all cases

- Exposure time is 40 seconds including a 30 second measurement period. NOTE THAT THIS SHORT EXPOSURE TIME SHOULD NOT BE USED FOR NORMAL FLOW GAUGINGS WHERE TIME IS NOT A CRITICAL FACTOR.

- One velocity measurement is taken in the vertical, at 0.5d

$$V_m = 0.96 \ V_{0.5}$$

Further reduction of the exposure time is generally not recommended except where trash is a problem. The measurement period could be reduced to 10 seconds in this case to avoid the meter being affected by the accumulation of trash. If this procedure is adopted it is recommended that the average velocity from three measurements each with a 10 second exposure time is taken.

3. Position of verticals

If possible, the position of verticals should be predetermined from inspection of cross section profiles obtained from recent full gaugings at the site. The objective will be to identify locations which permit the best coverage using a small number of verticals, and may include the following:

- Lowest point in channel
- Points where there is a change in the lateral slope across the bed

The bed profile may change during a flood event and it is therefore still necessary to measure the depth at each vertical during the gauging. This procedure will however minimise errors caused by the selection of vertical locations.

If no information is available on cross section profiles, the verticals should be evenly spaced. The distance between the water edge and the nearest vertical should be half the distance between verticals. Thus, if the water surface width is B and the number of verticals is X, the spacing between verticals is B/X and the spacing between the water edge and the first vertical is B/2X.

4. Use of surface velocities

In cases where it is not possible to get the current meter into the water a surface velocity measurement should be taken. The mean velocity for the vertical should be calculated using the formula:

$v_m = 0.80 v_{SURF}$

The cross section of the river channel at the site should be based on measurements taken either before or after the event. In this case the errors will be of the order of 25% excluding systematic and base random errors.

5. Water level variation

The water level should be recorded when each velocity measurement is taken. This is used in the calculation of mean stage.

6. Flow calculation method

The flow should be calculated using the following formula

$$Q = \sum v_i \, d_i \, b_i$$

Where

Q = Total discharge (m^3/s)
v_i =Velocity at the ith vertical (m/s)
d_i = Depth at the ith vertical (m)
b_i = Width of the ith segment (m)
Where the verticals are evenly spaced , $b_i = B/X$

7. Calculation of mean stage

The mean stage ($\bar{z}$) should be calculated using the following formula

$$\bar{z} = \frac{\sum q_i \, z_i}{Q}$$

where

q_i = Discharge in the ith segment = [$v_i \, d_i \, b_i$] (m^3/s)
z_i = Water level when the velocity in the ith segment was taken (m)
Q = Total discharge (m^3/s)

5.2 Flow measurement in small streams

1. Number of verticals

- Number of verticals should not be less than 5.
- Spacing of verticals should not be less than 1.5 times the current meter impeller diameter

- Spacing between verticals should not exceed 0.10m

2. Location of verticals

Verticals should be evenly spaced and the distance between the water edge and the nearest vertical should be half the distance between verticals. Thus if the water surface width is B and the number of verticals is X, the spacing between verticals is B/X and the spacing between the water edge and the first vertical is B/2X .

3. Current meter exposure time

- Exposure time should not be less than 30 seconds. Generally the exposure time should be 100 seconds unless there are particular reasons why a shorter period should be used.

4. Channel section

The most important aspect of flow measurement in small streams is the selection of the best available site.

- Section should ideally have a rectangular profile with uniform bed and banks.
- Section should be perpendicular to the flow.
- The existing section at the measurement site should be adapted to provide a rectangular shape if initially unsuitable. Ideally the measurement section should have the following characteristics:

  Tranquil flow
  Adequate flow depth (see 6 below)
  Smooth bed (see 7 below)

The adaptation of the section may require portable equipment and materials which must be provided to the gauging team.

5. Approach conditions

- The approach channel to the measuring site should be straight for a distance of 5 channel widths, if possible.
- When the length of straight channel is restricted either naturally or through adaptation of the channel at the measurement site then it is recommended that the straight length upstream of the measuring section should be twice the straight length downstream.

6. Flow conditions

- Water surface should be tranquil.
- Water depth should not be less than twice the diameter of the impeller of a

rotating element current meter or twice the thickness of the head of an electromagnetic flowmeter.

- If the section profile has been adapted the flow and water level should be allowed to stabilize before starting measurements.

7. Bed conditions

- The bed should be smooth at the measuring section. Objects such as stones which are significant in size compared with the water depth should be removed.
- Significant errors will occur where the bed material particle size is of the same order of magnitude as the water depth.

8. Measurement of cross section

- The channel depth at the gauging site should be measured using a steel rule, graduated in mm, with the water surface as datum, at the same verticals where the velocity is measured.

9. Range of suitable meters

- Small diameter rotating element meters (eg; Ott C2, BFM-002 and BFM-004) and shallow profile electromagnetic current meters (eg; Aqua Data - Sensa RV1) are suitable for measuring flows in small streams. A table of suitable current meters together with their operating ranges is given in Table 5.1.

10. Wading

- If it is at all possible to undertake the flow measurement without wading then this should always be done.

Given that wading is the only viable option, then:

- Where possible take readings close to the bank, whilst stood on the bank.
- Where possible take readings whilst standing with one foot in the channel and one on the bank. This should allow data to be collected for locations up to at least 500mm from the bank.
- For mid channel readings (> 500mm from either bank) the operator should stand facing upstream with feet apart. The current meter should be held centrally at arms length. This posture should be maintained for each 'step' across the channel until the meter is within 500mm of the bank.

11. Method of calculating discharge

The mid-section method should be used, as follows

$$Q = \sum v_i \, d_i \, b_i$$

Where

Q = Total discharge (m^3/s)
v_i =Velocity at the ith vertical (m/s), measured at 0.6 of the depth
d_i = Depth at the ith vertical (m)
b_i = Width of the ith segment (m)

12. Attainable accuracy

- If the above recommendations are adopted an accuracy of ±5% in the measurement of discharge should be attainable.

Table 5.1 Guidelines for current meters for use in small streams

Meter type	Impeller type/pitch (m)	Impeller diameter/ head depth (m)	Minimum flow depth for use of current meter (m)	Range of flow velocity for use of current meter (m/s)
Aqua Data - Sensa RV1 (Electromagnetic)	n/a	0.02	0.05	0.00 - 4.00
Braystoke BFM-002 (Rotating element)	1178 -/0.1	0.05	0.1	0.04 - 2.00
Braystoke BFM-004 (Rotating element)	911/0.04	0.019	0.04	0.07 - 1.50
	912/0.04	0.028	0.06	0.05 - 1.50
Seba M1 (Rotating element)	50/0.05	0.030/0.050	0.060/0.100	0.03 - 0.60
	100/0.10	0.030/0.050	0.060/0.100	0.03 - 1.20
	250/0.25	0.05	0.1	0.03 - 2.50
	500/0.50	0.05	0.1	0.04 - 5.00
Ott C2 (Rotating element)	1/0.05	0.05	0.1	0.03 - 0.60
	2/0.10	0.05	0.1	0.04 - 1.20
	3/0.25	0.05	0.1	0.04 - 2.50
	4/0.50	0.05	0.1	0.08 - 5.00
	5/0.05	0.03	0.06	0.06 - 0.60
	6/0.10	0.03	0.06	0.06 - 1.20

6 REFERENCES

British Standard 3680,

Part 3A,	1980:	Velocity area methods
Part 3B,	1983:	Establishment and operation of a gauging station
Part 3C,	1983:	Stage-discharge relation
Part 3D,	1980:	Moving boat method
Part 3E,	1986:	Ultrasonic method
Part 3F,	1986:	Data for the determination of errors
Part 3G,	1990:	Guide for the selection of methods
Part 3H,	1988:	Electromagnetic method (ISO)
Part 3I,	1986:	Stage-Fall Discharge method (ISO)
Part 3J,	1989:	Three vertical method
Part 3K,	1989:	Wet line correction (ISO)
Part 3L,	* :	Measurement under ice conditions
Part 3M,	1990:	Guide to the methods of measuring high discharges in rivers
Part 3N,	* :	Measurement in meandering rivers
Part 3P,	* :	Measurement of flow in unstable channels
Part 3Q,	* :	Measurement in arid and semi-arid regions (ISO)
Part 3R,	* :	Guide for safe practice in stream gauging

ISO748	* :	Measurement of liquid flow in open channels - Velocity area methods (in draft)
ISO7178	1983:	Investigation of the total error in measurement of flow by the velocity area methods

APPENDIX A. TERMS OF REFERENCE

R&D PROJECT PLAN

A.1 R&D Commission

R&D Commission: B - Water Resources
Topic: B01 - Hydrometric Data

Title: CURRENT METER STANDARDS (INSTRUMENT DEVELOPMENT)

Proposal No: BO1(93)02 Project No: 529

R&D Classification: Applied Strategic

Primary purpose: Operational Effectiveness

A.2 Project Manager

Project Manager: John Adams

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Contract signatory:	Dr Rodney White
Project Manager:	David Ramsbottom

A.4 Contract details

Type:	Single Tender Action	
Start Date:	04/94	Status: As proposed
End Date:	03/95	Status: As proposed

A.5 Objectives

To develop standard meter gauging methodologies that can be applied to rapid changes under flood conditions and to gaugings where BSI standards are currently inapplicable in order to provide more consistent data to the Environment Agency.

Specific Objectives

(a) To examine the effect of a reduction of the number of verticals on the accuracy of a gauging under the rapidly changing stage of a flood event.
(b) To examine the effect of a reduction of the current meter exposure time on the accuracy of a gauging under rapidly varying stage.
(c) To examine the optimum depth, and/or depths, of the current meter on the accuracy of a gauging under rapidly varying stage.
(d) To examine the balance to be achieved between accuracy of individual gaugings (fewer verticals, short exposure time, single point versus many verticals, longer exposure time, multi point) against gauging time.
(e) To define a standard practice(s) for current meter gaugings on shallow (<0.1 m) and narrow (<2.0 m) streams where BS 3680 Part 3A cannot be applied.
(f) To produce a final Project Report, R&D Note and Digest.
(g) To produce a synopsis for field use. (R&D Note B).

A.6 Background

The programme of work in the Topic B1 - Hydrometric Data is directed towards improving the efficiency and accuracy of hydrometric data collection, processing and presentation. It targets areas where improvements in techniques or instrumentation are required to enable the Hydrometrician to better fulfill the requirements of internal and external customers.

Hydrometric data is a cornerstone of the Environment Agency operations, being used by all functions in fulfilling corporate plan objectives. It is both an operational and planning tool for Water Resources, Flood Defence, Pollution Control and Fisheries. R&D in this Topic will, therefore, ultimately have widespread application through the use of data.

Current meter stream flow gauging is a technique of primary importance to hydrometry. It is used to provide data to calibrate river gauging stations and to make spot measurements for abstraction license and discharge consent determination and compliance. Its importance can be judged by the fact that the instrumentation, calibration, gauging practices, flow calculation, etc. are covered by BS 3680 Parts 3A to R. The application of the full technique, giving the highest degree of accuracy, is limited to larger streams and rivers whose change in stage is relatively slow.

The overall aim of this project is to determine standard techniques and best practices for non-standard situations not adequately covered by BS 3680 Part 3. This will give increased confidence of both users and indirect recipients of information from the current meter gaugings.

The option chosen to carry out this study reflects the Environment Agency's need to employ methodologies that fit within the existing British Standards framework and are also compatible with existing equipment and data processing capabilities. This option, which has the support of the National Hydrometry group, ensures no additional costs will be incurred during implementation and is looked upon as the most favourable economic option. The only alternative option would have involved the development of new technology, which (though a worthy R&D aim in itself) was thought to be too risky and time consuming given the urgent problems which would need to be solved in the short term with the applied solutions.

Context

One of the principal aims of the Environment Agency Water resources Strategy is to "manage water resources to achieve a right balance between the needs of the environment and those of the abstractors". For effective management decision to be made it is essential that accurate, quantitative information is provided.

The British standard 3680 "Measurement of Liquid Flow in Open Channels" covers most aspects of stream flow measurement. There is, however, a wide range of acceptable method variants e.g. current meter exposure time, number and depth of velocity measurements and methods of calculation. No guidelines exist as to the choice of appropriate methods for particular river conditions, or acceptable techniques where the standard cannot be applied.

There is related work being undertaken in the Review of Low Velocity Measurement Techniques (Project BO1(90)2) which is evaluating ultra-sonic and electromagnetic current meters. Investigative work is also being carried out regarding calculation methods as part of the WAMS project. This project supports the Continuing Activity-Hydrometry.

A.7 Method

Overall Approach

A review of techniques used "world-wide", a review of "non-standard" techniques used in the UK and analysis of any appropriate data that is available. The Environment Agency Project Manager will facilitate the appropriate links with the various Environment Agency Regions.

Contractor

The Hydraulics Research Laboratory, Wallingford, are considered uniquely placed to meet the requirements of this project given their in depth practical knowledge and expertise, together with international contacts in the field.

Project Organisation

The Project Manager reports to the Topic Leader. He will also liaise with the National Hydrometric Group, whose Chairman is the Environment Agency representative on The British Standards Institute's PCL3 Hydrometry Committee.

The output will be of use to the National Hydrometric Group, The Institute of Hydrology, The British Standards Institute and other organisations working in the UK Water Regulatory Organisations (e.g. River Purification Boards).

Project Monitoring

Project Monitoring will be by the Project Manager through monthly and by-monthly Progress Reports and Final report.

Undertake Research

(a) Contact key Environment Agency and RPB staff to identify what techniques are currently used under rapidly changing stage conditions and shallow/narrow streams. Also if comparative data is available.
(b) Obtain information (including comparative data) regarding techniques applied in other countries.
(c) Critically review these methods.
(d) Analyse available data.
(e) Produce draft Progress Report indicating techniques.
(f) Assess field data collection from recommended techniques, amend recommendations if necessary. Define accuracy of techniques. Produce summary report.
(g) Complete Progress Report and draft Project Report.
(h) Complete R&D Note A.
(i) Produce R&D Note B (Field Guide).

Uptake

Internal dissemination via the Topic Leader to the Functional Managers Group.

Internal dissemination via the Project Manager to the National Hydrometric Group.

The R&D Notes will be released to the Public Domain with agreement from the Water Resources Managers.

Implementation

National implementation to be arranged by Hydrometric Group and proposed, to the Water resources Manager, for adoption as policy. Possible inclusion in BS 3680.

A.8 Targets and Timescales

Works Item	Completion date	Month
Review existing methodologies (Objectives d & e)	31/5/94	2
Selection of study site/data availability (Objective d)	30/6/94	3
Progress and/or Interim reports at Quarterly Intervals	See outputs	See outputs
Define data needs	31/7/94	4
Completion of Objective e	31/1/95	10
Completion of Objective d	31/1/95	10
Draft Project Record & R&D Note A	28/2/95	11
Draft Field Synopsis (R&D Note B)	28/2/95	11

A.9 Outputs

Deliverables

A. Short Term

Type	Status Int	Ext	No	Completion	Produced by
Methodology Review Report (Objectives a, b & c)	LR	R	10	31/5/94	Contractor
Quarterly Report	LR	R	10	30/6/94	Contractor
Study Site and Data Availability Report (Objective d)	LR	R	10	30/6/94	Contractor
Interim Report	LR	R	10	30/9/94	Contractor
Quarterly Report	LR	R	10	31/12/94	Contractor
Draft Project Record and R&D Note A (Objectives d, e & f)	LR	R	10	28/2/95	Contractor
Draft R&D Note B (Field User Guide)	LR	R	10	28/2/95	Contractor

B. Project Outputs

Type	Status Int	Ext	No	Completion	Produced by
Project Record	LR	R	10	31/3/95	Contractor
R&D Note A	RR	PD	60	31/3/95	Contractor
R&D Note B (User Guide)	RR	PD	200	31/3/95	Contractor
R&D Digest	RR	PD	100	31/3/95	Contractor

Project Outputs

Item	Designation	Acceptance Level	Uptake
R&D Project Record	O,G	Topic Leader	(C)

R&D Note A	O,G	Functional Managers Group	(C)
R&D Note B (USER Guide)	O,G	Topic Leader	(C)
R&D Digest	-	Topic Leader	

A.10 Costs (£)

Outline Cost Plan

Project Stage	**Environment Agency Management**		**In-House**	**External Contractor**
	Function	R&D		
Project	-	-	-	-
Planning	-	-	-	-
R&D	-	-	-	62,000
Uptake	-	-	-	-
TOTAL	-	-	-	62,000

Budget Provision (£)	1994/95
Contractor	62,000
Environment Agency	-

A.11 Benefits

The benefits of this project will be standard techniques and best practices for current meter gauging situations not adequately covered by BS 3680 Part 3. This will give increased confidence of both the users and indirect recipients of information from the current meter gaugings.

Do Nothing Option

Environment Agency will continue to be unable to take a consistent and standardised approach to current meter gaugings on small rivers and streams and in conditions of relatively rapid changes in flow.

A.12 Assumptions and Risks

The success of the project will be dependent to a large extent on the support of the regions in providing information and the availability of data.

A wide range of sites need to be considered if guidelines are to be applicable on a national basis.

A.13 Overall Appraisal

This project will enable the Environment Agency to take a standardised approach, based on best practices, to current meter gauging in conditions not covered by BS 3680. It will be valuable in underpinning, increasing confidence and establishing a defensible decision on resource management and abstraction control.

APPENDIX B. QUESTIONNAIRE

Letter 1

Mr J S Waters
Environment Agency Severn Trent Region
Sapphire East
550 Streetsbrook Road
Solihull
West Midlands
B91 1QT

Our Ref : R/S/210

29 September 1994

Dear Jim

Environment Agency R&D PROJECT 529
CURRENT METERING STANDARDS (INSTRUMENT DEVELOPMENT)

HR Wallingford has been appointed by the Environment Agency to undertake the above Research and Development Project. The specific objectives are listed below.

(a) To examine the effect of a reduction of the number of verticals on the accuracy of a gauging under the rapidly changing stage of a flood event.

(b) To examine the effect of a reduction of the current meter exposure time on the accuracy of a gauging under rapidly changing stage.

(c) To examine the optimum depth, and/or depths, of the current meter on the accuracy of a gauging under rapidly changing state.

(d) To examine the balance to be achieved between accuracy of individual gaugings (fewer verticals, short exposure time, single point versus many verticals, longer exposure time, multi point) against gauging time.

(e) To define a standard practice(s) for current meter gaugings on shallow (<0.1 m) and narrow (<2.0 m) streams where BS 3680 Part 3A cannot be applied.

(f) To produce a final Project report, R&D Note and Digest.

(g) To produce a synopsis for field use.

The first stage in the study is to visit the Environment Agency Regions to discuss techniques currently used in each Region for gauging flows where the stage is rapidly changing, and for gauging flows in shallow and/or narrow streams. We would also like to collect current metering data for analysis, particularly for objectives (a) and (c) above. We would therefore be grateful if we could visit you in the near future, and will phone you shortly to discuss a date. The visits will be undertaken by John Forty and Phil Hollinrake , who both work in our Rivers Group.

The specific objectives of our visit are as follows:

1. To find out the techniques used in your Region to gauge flood flows where the stage is changing rapidly.

2. To collect current meter data which we can use to assess the effects of reducing the number of verticals and to examine the optimum depths for current metering. The data we require will be copies of the actual measurements for individual flow gaugings. In order to gain the maximum benefit from the project we require these data for a range of different rivers in preference to a large number of gaugings at one site.

3. To find out the techniques used in your Region to gauge narrow and/or shallow streams.

4. To find out whether any work has been undertaken in your Region which may be relevant to the research. This might include, for example, any of the following.

   Assessments of the accuracy of flood flow or small stream gauging techniques.

   Any research carried out concerning the effect of current meter exposure time on the accuracy of flood flow gauging.

   Methods used to calibrate thin plate weirs.

5. To find out the types of current meter in use in the Region, and what they are used for.

It would be a great help if data could be prepared in advance so that it could be handed over when we meet. Thank you for your cooperation on this matter, and we look forward to meeting you in due course.

Yours sincerely

D M Ramsbottom
Rivers Group Manager

Letter 2

CURRENT METERING STANDARDS

DATA REQUIREMENTS

Further to our letter of 29 September and following discussions with John Adams, the Environment Agency Project Manager, a more detailed list of the data we require for the above project has evolved and is given below. We would be grateful if all the information listed under items 1(a), 1(b), 1(c)i), 1(d)i), 2(a), 3(a), and 3(b) could be provided when we meet. If you have any queries please contact John Forty or Phil Hollinrake at this office.

1. Research into measurement of Rapidly Varying Flow

a) What techniques do you currently use to measure flow where the stage is varying rapidly? (e.g. number of verticals, current meter exposure time, etc.)

b) Full data for current meter gauging of rivers with high discharges (above the 20 percentile). The data will be used to assess the effects of reducing the number of verticals on the accuracy of flow gauging, and the flow should be reasonably steady. Data to include:

River name

Gauging site

Brief description including: Width, Depth, Bed material; Whether the section is natural or controlled by a structure downstream

Field sheets for at least three gaugings at the site

Corresponding current meter calibration data for these gaugings

Cross section of the river at the gauging site, if this is not available from the field sheets

A measure of river slope if available (e.g. water surface slope, bed slope, longitudinal section)

Data from a minimum of four sites per Environment Agency Area or equivalent RPB geographical area is desirable. This will provide at least 12 sites per Environment Agency Region, and should cover a representative range of rivers in each Region.

c) Effect of reducing exposure time

i) Part of the research involves assessing the effect of current meter exposure time on the accuracy of gauging. Any existing data on velocities obtained for different exposure times during the same gauging would therefore be useful if it is available.

ii) Since it is unlikely that a significant amount of data involving different exposure times during the same gauging will be readily available, it would be useful for this study if a limited number of gaugings (say one per area) could be carried out in this way in the next month or so. We would be grateful if exposure times could be varied during gaugings of reasonably steady high velocities (e.g. >1.0m/s). The sequence might be 100s, 50s, 30s, 20s, 10s, 10s, 20s, 30s, 50s, 100s. We will be quite happy to discuss the possibility of you assisting our study in this way when we visit your region.

d) Multi point gaugings

i) We also require, if available from your region, data for gaugings with several points in the vertical, preferably five or more to obtain a reasonable profile. Data to include:

River name

Gauging site

Brief description including: Width; Depth; Bed material; Whether the section is natural or controlled by a structure downstream and, in the latter case, the type of structure and distance downstream

A measure of river slope if available (e.g. water surface slope, bed slope, longitudinal section)

Velocity profile data including depths of measurement, measured velocities, and position of each vertical in cross section. Plots of profiles should be provided if available.

ii) In addition, we would be grateful if a current metering could be carried out (one per area) using six measurement points in each vertical during a gauging which you are planning to carry out in the next month or so. This would clearly involve additional work for the hydrometric team and is therefore optional. The procedure would be as follows.

Undertake a full river gauging at a site with a reasonably steady flow with single velocity measurements in each vertical.

Repeat the gauging but with six velocity measurements in each vertical (e.g. surface, 0.2D, 0.4D, 0.6D, 0.8D and near the bed where D is the depth). Again we will be happy to discuss the possibility of you assisting our study in this way when we make our visit to your region.

e) A recommended method for measuring flows where the stage is varying rapidly will be developed during the research and will be tested in the field. We would be pleased to hear from any Environment Agency Regions who would be willing to participate in these field trials, which are likely to commence in March 1995.

2. Research into flow measurement in small streams

a) What techniques do you currently use to measure flow in small streams? (e.g. number of verticals, current meter type, etc.). Our definition of small streams is less than 2m wide and/or less than 0.1 m deep.

b) Data for small stream flow gaugings in connection with calibration of structures (e.g. thin plate weirs), measurement of abstraction and discharges, etc. Data to include:

Stream

Site

Purpose of gauging

Brief description including: Width; Depth; bed material; Whether the section is natural or controlled by a structure downstream

Field sheet(s)

Corresponding current meter type, propeller diameter and calibration data

Cross section of the stream at the gauging site, if this is not available from the field sheets

Corresponding structure rating curve if available.

c) A recommended method for measuring flows in small streams will be developed during the research and will be tested in the field. Again we would be pleased to hear from Environment Agency Regions who would be willing to participate in these filed trials, which are likely to commence in March 1995.

3. General

a) Any other data which may be relevant to our research. This may include, for example, details of work carried out in the development of flood flow and small stream flow gauging procedures.

b) Types of current meters you use to measure flood flows and small stream flows.

Letter 3

Service Hydrologique et Geologique National
CH-3003 Bern
Switzerland

Our Ref : R/S/210

For the attention of Dr B Schadler

9 November 1994

Dear Sirs

Environment Agency R&D PROJECT 529
CURRENT METERING STANDARDS (INSTRUMENT DEVELOPMENT)

HR Wallingford has been appointed by the Environment Agency to undertake the above Research and Development (R&D) Project. The specific objectives are listed below.

(a) To examine the effect of a reduction of the number of verticals on the accuracy of a gauging under the rapidly changing stage of a flood event.

(b) To examine the effect of a reduction of the current meter exposure time on the accuracy of a gauging under rapidly changing stage.

(c) To examine the optimum depth, and/or depths, of the current meter on the accuracy of a gauging under rapidly changing state.

(d) To examine the balance to be achieved between accuracy of individual gaugings (fewer verticals, short exposure time, single point versus many verticals, longer exposure time, multi point) against gauging time.

(e) To define a standard practice(s) for current meter gaugings on shallow (<0.1 m) and narrow (<2.0 m) streams where BS 3680 Part 3A cannot be applied.

(f) To produce a final Project Report, R&D Note and Digest by March 1995.

(g) To produce a synopsis for field use.

To assist us in our research, we would be grateful if you would provide details of the methods you use in Switzerland to measure flows under conditions of rapidly changing stage, such as in a flood event, and flows in small streams.

We look forward to hearing from you in due course, and would be pleased to discuss our research with you in more detail if required.

Yours faithfully

D M Ramsbottom
Rivers Group Manager

APPENDIX C. SCHEDULE OF VISITS TO ENVIRONMENT AGENCY REGIONAL OFFICES AND CLYDE RIVER PURIFICATION BOARD

Region	Date	Venue	Those present	
			Environment Agency/RPB	HR Wallingford
Anglian	6 January 1995	Brampton	Mark Whiteman Dennis Glenn	John Forty
North West	31 October 1994	Warrington	John Adams Alison Hamer Ray Moore Alan Payn Wally Ball	David Ramsbottom John Forty Phil Hollinrake
Northumbria/ Yorks	15 December 1994	Leeds	Peter Towlson David Shields David Stewart Philip Proctor	Rodney White
Severn Trent	13 January 1995	Solihull	Richard Iredale Andrew Pimperton	John Forty
Southern	9 February 1995	Worthing	Steve Fairall Sean Key Joe Pearce Max Pope	John Forty
South West	12 December 1994	Bridgwater	Ann Riley Sheila Turner Geoff Hardwicke Andy Gardiner Keith Garrett	Rodney White
Thames	12 January 1995	Reading	George Merrick Barry Ambrose John Gill	Phil Hollinrake

Welsh	15 December 1994	Shrewsbury	John Arrowsmith Hywel Perrott Ray Renshaw John Williams Martin Richards	Phil Hollinrake
Clyde RPB	13 January 1995	East Kilbride	Tom Poodle	Rodney White David Ramsbottom

APPENDIX D: SUMMARY OF INFORMATION PROVIDED BY THE NRA REGIONS (TO 31/1/95)

Table D.1 Summary of information provided by the Environment Agency Regions and the Clyde River Purification Board

Region	River	Site	Date	Flow (m^3/s)
Anglian	Asheldam Brook	Asheldam	30 March 1994	0.014
Anglian	Asheldam Brook	Asheldam	27 May 1994	0.012
Anglian	Asheldam Brook	Asheldam	11 November 1994	0.003
Anglian	Asheldam Brook	Asheldam	6 December 1994	0.002
Anglian	Bentley Brook	Thorrington	14 May 1994	0.042
Anglian	Bentley Brook	Thorrington	28 June 1994	0.013
Anglian	Bentley Brook	Thorrington	21 July 1994	0.010
Anglian	Bentley Brook	Thorrington	25 August 1994	0.016
Anglian	Bentley Brook	Thorrington	21 September 1994	0.025
Anglian	Bentley Brook	Thorrington	20 October 1994	0.012
Anglian	Bentley Brook	Thorrington	18 November 1994	0.017
Anglian	Bentley Brook	Thorrington	15 December 1994	0.019
Anglian	Bentley Brook	Thorrington	13 January 1995	0.072
Anglian	Bradwell Brook	Tillingham	7 January 1994	0.001
Anglian	Bradwell Brook	Tillingham	7 January 1994	0.014
Anglian	Bradwell Brook	Tillingham	21 May 1994	0.006
Anglian	Bradwell Brook	Tillingham	27 May 1994	0.001
Anglian	Bradwell Brook	Tillingham	24 September 1994	0.014
Anglian	Bradwell Brook	Tillingham	11 November 1994	0.004
Anglian	Bramsfield Stream	Wenhaston	12 January 1994	1.222
Anglian	Bramsfield Stream	Wenhaston	12 May 1994	0.070
Anglian	Bramsfield Stream	Wenhaston	22 June 1994	0.057
Anglian	Bramsfield Stream	Wenhaston	19 July 1994	0.056
Anglian	Bramsfield Stream	Wenhaston	24 August 1994	0.040
Anglian	Bramsfield Stream	Wenhaston	22 September 1994	0.098
Anglian	Bramsfield Stream	Wenhaston	18 October 1994	0.044
Anglian	Bramsfield Stream	Wenhaston	16 November 1994	0.124
Anglian	Bramsfield Stream	Wenhaston	14 December 1994	0.062
Anglian	Burn	Abbey Farm	18 February 1993	0.025

Table D.1 continued Summary of information provided by the Environment Agency Regions and the Clyde River Purification Board

Region	River	Site	Date	Flow (m^3/s)
Anglian	Burn	Abbey Farm	18 March 1993	0.397
Anglian	Burn	Abbey Farm	16 April 1993	0.486
Anglian	Burn	Abbey Farm	14 May 1993	0.561
Anglian	Burn	Abbey Farm	16 June 1993	0.095
Anglian	Burn	Abbey Farm	16 July 1993	0.059
Anglian	Burn	Abbey Farm	17 August 1993	0.063
Anglian	Burn	Abbey Farm	16 September 1993	0.017
Anglian	Burn	Abbey Farm	16 October 1993	0.039
Anglian	Burn	Abbey Farm	17 November 1993	0.087
Anglian	Burn	Abbey Farm	16 December 1993	0.194
Anglian	Burn	Abbey Farm	22 January 1994	0.535
Anglian	Burn	Abbey Farm	29 January 1994	0.493
Anglian	Burn	Abbey Farm	5 February 1994	0.620
Anglian	Burn	Abbey Farm	3 March 1994	0.451
Anglian	Burn	Abbey Farm	30 March 1994	0.390
Anglian	Burn	Abbey Farm	28 April 1994	0.300
Anglian	Burn	Abbey Farm	26 May 1994	0.285
Anglian	Burn	Abbey Farm	24 June 1994	0.132
Anglian	Burn	Abbey Farm	22 July 1994	0.353
Anglian	Burn	Abbey Farm	19 August 1994	0.111
Anglian	Burn	Abbey Farm	21 September 1994	0.185
Anglian	Burn	Abbey Farm	11 November 1994	0.077
Anglian	Burn	Abbey Farm	6 December 1994	0.080
Anglian	Burn	Abbey Farm	7 January 1995	0.125
Anglian	Burn	Abbey Farm	7 January 1995	0.063
Anglian	Burn	Abbey Meadow	18 February 1993	0.024
Anglian	Burn	Abbey Meadow	18 March 1993	0.026
Anglian	Burn	Abbey Meadow	16 April 1993	0.045
Anglian	Burn	Abbey Meadow	14 May 1993	0.044
Anglian	Burn	Abbey Meadow	16 June 1993	0.057
Anglian	Burn	Abbey Meadow	16 July 1993	0.040
Anglian	Burn	Abbey Meadow	17 August 1993	0.046
Anglian	Burn	Abbey Meadow	16 September 1993	0.026

Table D.1 continued Summary of information provided by the Environment Agency Regions and the Clyde River Purification Board

Region	River	Site	Date	Flow (m^3/s)
Anglian	Burn	Abbey Meadow	16 October 1993	0.036
Anglian	Burn	Abbey Meadow	17 November 1993	0.064
Anglian	Burn	Abbey Meadow	22 January 1994	0.505
Anglian	Burn	Abbey Meadow	29 January 1994	0.379
Anglian	Burn	Abbey Meadow	5 February 1994	0.482
Anglian	Burn	Abbey Meadow	3 March 1994	0.359
Anglian	Burn	Abbey Meadow	30 March 1994	0.282
Anglian	Burn	Abbey Meadow	28 April 1994	0.240
Anglian	Burn	Abbey Meadow	26 May 1994	0.223
Anglian	Burn	Abbey Meadow	24 June 1994	0.106
Anglian	Burn	Abbey Meadow	22 July 1994	0.126
Anglian	Burn	Abbey Meadow	19 August 1994	0.065
Anglian	Burn	Abbey Meadow	21 September 1994	0.051
Anglian	Burn	Abbey Meadow	15 October 1994	0.083
Anglian	Burn	Easter Cornhill	3 March 1994	0.238
Anglian	Burn	Easter Cornhill	30 March 1994	0.184
Anglian	Burn	Easter Cornhill	28 April 1994	0.153
Anglian	Burn	Easter Cornhill	26 May 1994	0.109
Anglian	Burn	Easter Cornhill	24 June 1994	0.081
Anglian	Burn	Easter Cornhill	22 July 1994	0.054
Anglian	Burn	Easter Cornhill	19 August 1994	0.048
Anglian	Burn	Easter Cornhill	21 September 1994	0.088
Anglian	Burn	Easter Cornhill	15 October 1994	0.064
Anglian	Burn	Easter Cornhill	11 November 1994	0.059
Anglian	Burn	Easter Cornhill	6 December 1994	0.043
Anglian	Burn	Easter Cornhill	7 January 1995	0.061
Anglian	Burn	Easter Cornhill	5 February 1995	0.261
Anglian	Burn	Forge House	26 February 1993	0.032
Anglian	Burn	Forge House	18 March 1993	0.032
Anglian	Burn	Forge House	16 April 1993	0.042
Anglian	Burn	Forge House	14 May 1993	0.043
Anglian	Burn	Forge House	16 June 1993	0.056
Anglian	Burn	Forge House	16 July 1993	0.028

Table D.1 continued Summary of information provided by the Environment Agency Regions and the Clyde River Purification Board

Region	River	Site	Date	Flow (m^3/s)
Anglian	Burn	Forge House	17 August 1993	0.024
Anglian	Burn	Forge House	16 September 1993	0.026
Anglian	Burn	Forge House	16 October 1993	0.038
Anglian	Burn	Forge House	17 November 1993	0.073
Anglian	Burn	Forge House	16 December 1993	0.161
Anglian	Burn	Forge House	3 March 1994	0.234
Anglian	Burn	Forge House	30 March 1994	0.194
Anglian	Burn	Forge House	28 April 1994	0.182
Anglian	Burn	Forge House	26 May 1994	1.600
Anglian	Burn	Forge House	24 June 1994	0.112
Anglian	Burn	Forge House	22 July 1994	0.098
Anglian	Burn	Forge House	19 August 1994	0.066
Anglian	Burn	Forge House	21 September 1994	0.080
Anglian	Burn	Forge House	15 October 1994	0.081
Anglian	Burn	Forge House	11 November 1994	0.061
Anglian	Burn	Forge House	6 December 1994	0.052
Anglian	Burn	Forge House	7 January 1995	0.078
Anglian	Burn	Leicester Square	18 February 1993	0.036
Anglian	Burn	Leicester Square	18 March 1993	0.034
Anglian	Burn	Leicester Square	16 April 1993	0.022
Anglian	Burn	Leicester Square	14 May 1993	0.028
Anglian	Burn	Leicester Square	16 June 1993	0.023
Anglian	Burn	Leicester Square	16 July 1993	0.023
Anglian	Burn	Leicester Square	17 August 1993	0.019
Anglian	Burn	Leicester Square	16 September 1993	0.020
Anglian	Burn	Leicester Square	16 October 1993	0.028
Anglian	Burn	Leicester Square	17 November 1993	0.048
Anglian	Burn	Leicester Square	16 December 1993	0.101
Anglian	Burn	Leicester Square	5 February 1994	0.188
Anglian	Burn	Leicester Square	3 March 1994	0.150
Anglian	Burn	Leicester Square	30 March 1994	0.128
Anglian	Burn	Leicester Square	28 April 1994	0.116
Anglian	Burn	Leicester Square	26 May 1994	0.119

Table D.1 continued Summary of information provided by the Environment Agency Regions and the Clyde River Purification Board

Region	River	Site	Date	Flow (m^3/s)
Anglian	Burn	Leicester Square	24 June 1994	0.094
Anglian	Burn	Leicester Square	22 July 1994	0.046
Anglian	Burn	Leicester Square	19 August 1994	0.035
Anglian	Burn	Leicester Square	21 September 1994	0.072
Anglian	Burn	Leicester Square	11 November 1994	0.052
Anglian	Burn	Leicester Square	6 December 1994	0.047
Anglian	Burn	Leicester Square	7 January 1995	0.050
Anglian	Burn	North Creake	16 December 1993	0.045
Anglian	Burn	North Creake	22 January 1994	0.263
Anglian	Burn	North Creake	29 January 1994	0.236
Anglian	Burn	North Creake	5 February 1994	0.301
Anglian	Burn	North Creake	3 March 1994	0.206
Anglian	Burn	North Creake	30 March 1994	0.134
Anglian	Burn	North Creake	28 April 1994	0.090
Anglian	Burn	North Creake	26 May 1994	0.063
Anglian	Burn	North Creake	24 June 1994	0.027
Anglian	Burn	North Creake	22 July 1994	0.000
Anglian	Burn	North Creake	19 August 1994	0.002
Anglian	Burn	North Creake	21 September 1994	0.055
Anglian	Burn	North Creake	15 October 1994	0.035
Anglian	Burn	North Creake	11 November 1994	0.022
Anglian	Burn	North Creake	6 December 1994	0.028
Anglian	Burn	North Creake	7 January 1995	0.036
Anglian	Burn	Sly's Farm	16 October 1993	0.006
Anglian	Burn	Sly's Farm	17 November 1993	0.004
Anglian	Burn	Sly's Farm	16 December 1993	0.137
Anglian	Burn	Sly's Farm	22 January 1994	0.289
Anglian	Burn	Sly's Farm	29 January 1994	0.235
Anglian	Burn	Sly's Farm	5 February 1994	0.317
Anglian	Burn	Sly's Farm	3 March 1994	0.234
Anglian	Burn	Sly's Farm	30 March 1994	0.205
Anglian	Burn	Sly's Farm	28 April 1994	0.142
Anglian	Burn	Sly's Farm	26 May 1994	0.126

Table D.1 continued Summary of information provided by the Environment Agency Regions and the Clyde River Purification Board

Region	River	Site	Date	Flow (m^3/s)
Anglian	Burn	Sly's Farm	24 June 1994	0.058
Anglian	Burn	Sly's Farm	22 July 1994	0.027
Anglian	Burn	Sly's Farm	19 August 1994	0.013
Anglian	Burn	Sly's Farm	21 September 1994	0.074
Anglian	Burn	Sly's Farm	15 October 1994	0.041
Anglian	Burn	Sly's Farm	11 November 1994	0.036
Anglian	Burn	Sly's Farm	6 December 1994	0.030
Anglian	Burn	Sly's Farm	7 January 1995	0.052
Anglian	Burn	Vicarage S. Creake	16 December 1993	0.121
Anglian	Burn	Vicarage S. Creake	22 January 1994	0.227
Anglian	Can	High Easter	15 September 1993	0.015
Anglian	Can	High Easter	31 March 1994	0.027
Anglian	Can	High Easter	29 April 1994	0.096
Anglian	Can	High Easter	28 May 1994	0.118
Anglian	Can	High Easter	25 June 1994	0.025
Anglian	Can	High Easter	20 August 1994	0.028
Anglian	Can	High Easter	15 September 1994	0.017
Anglian	Can	High Easter	14 October 1994	0.003
Anglian	Can	High Easter	14 November 1994	0.016
Anglian	Can	High Easter	7 December 1994	0.047
Anglian	Dunwich	Dunwich	12 May 1994	0.038
Anglian	Dunwich	Dunwich	22 June 1994	0.023
Anglian	Dunwich	Dunwich	19 July 1994	0.018
Anglian	Dunwich	Dunwich	24 August 1994	0.015
Anglian	Dunwich	Dunwich	22 September 1994	0.038
Anglian	Dunwich	Dunwich	18 October 1994	0.022
Anglian	Dunwich	Dunwich	16 November 1994	0.056
Anglian	Dunwich	Dunwich	14 December 1994	0.031
Anglian	Dunwich	Dunwich	12 January 1995	0.203
Anglian	Glaven	Bayfield	25 November 1993	0.553
Anglian	Glaven	Bayfield	3 February 1994	0.475
Anglian	Glaven	Bayfield	16 March 1994	1.356
Anglian	Glaven	Bayfield	26 April 1994	0.548

Table D.1 continued Summary of information provided by the Environment Agency Regions and the Clyde River Purification Board

Region	River	Site	Date	Flow (m^3/s)
Anglian	Glaven	Bayfield	25 May 1994	0.578
Anglian	Glaven	Bayfield	21 June 1994	0.401
Anglian	Glaven	Bayfield	20 July 1994	0.247
Anglian	Glaven	Bayfield	17 August 1994	0.287
Anglian	Glaven	Bayfield	22 October 1994	0.331
Anglian	Glaven	Bayfield	22 November 1994	0.450
Anglian	Glaven	Bayfield	20 December 1994	0.582
Anglian	Hiz	Mill Farm	16 July 1994	0.022
Anglian	Hiz	Priory Park	16 July 1994	0.041
Anglian	Hiz	Priory Park	26 August 1994	0.014
Anglian	Hiz	Priory Park	21 September 1994	0.012
Anglian	Hiz	Wellhead	16 July 1994	0.004
Anglian	Hiz	Westmill Lane	16 July 1994	0.019
Anglian	Hiz	Westmill Lane	26 August 1994	0.013
Anglian	Hiz	Westmill Lane	21 September 1994	0.018
Anglian	Hiz	Windmill Pub	16 July 1994	0.032
Anglian	Hiz	Windmill Pub	26 August 1994	0.019
Anglian	Hiz	Windmill Pub	21 September 1994	0.006
Anglian	Lark	Grundisburgh	12 January 1994	0.845
Anglian	Lark	Grundisburgh	13 May 1994	0.018
Anglian	Lark	Grundisburgh	13 May 1994	0.051
Anglian	Lark	Grundisburgh	23 June 1994	0.012
Anglian	Lark	Grundisburgh	23 June 1994	0.029
Anglian	Lark	Grundisburgh	20 July 1994	0.007
Anglian	Lark	Grundisburgh	20 July 1994	0.021
Anglian	Lark	Grundisburgh	23 August 1994	0.017
Anglian	Lark	Grundisburgh	23 August 1994	0.002
Anglian	Lark	Grundisburgh	20 September 1994	0.028
Anglian	Lark	Grundisburgh	20 September 1994	0.005
Anglian	Lark	Grundisburgh	19 October 1994	0.020
Anglian	Lark	Grundisburgh	19 October 1994	0.003
Anglian	Lark	Grundisburgh	17 November 1994	0.074
Anglian	Lark	Grundisburgh	17 November 1994	0.021

Table D.1 continued Summary of information provided by the Environment Agency Regions and the Clyde River Purification Board

Region	River	Site	Date	Flow (m^3/s)
Anglian	Lark	Grundisburgh	14 December 1994	0.105
Anglian	Lark	Grundisburgh	14 December 1994	0.034
Anglian	Lark	Grundisburgh	12 January 1995	0.229
Anglian	Mardyke	Bulphan	31 March 1994	0.005
Anglian	Mardyke	Bulphan	29 April 1994	0.002
Anglian	Mardyke	Bulphan	28 May 1994	0.008
Anglian	Mardyke	Bulphan	25 June 1994	0.005
Anglian	Mardyke	Bulphan	15 September 1994	0.010
Anglian	Mardyke	Bulphan	15 September 1994	0.024
Anglian	Ore	Broadwater	12 January 1994	1.136
Anglian	Ore	Broadwater	12 May 1994	0.038
Anglian	Ore	Broadwater	23 June 1994	0.009
Anglian	Ore	Broadwater	19 July 1994	0.019
Anglian	Ore	Broadwater	23 August 1994	0.015
Anglian	Ore	Broadwater	22 September 1994	0.084
Anglian	Ore	Broadwater	18 October 1994	0.023
Anglian	Ore	Broadwater	16 November 1994	0.124
Anglian	Ore	Broadwater	14 December 1994	0.081
Anglian	Oughton	Oughton Common	21 September 1994	0.001
Anglian	Oughton	Oughton Head	26 August 1994	0.018
Anglian	Oughton	Oughton Head	21 September 1994	0.015
Anglian	Oughton	Westmill Farm	16 July 1994	0.109
Anglian	Oughton	Westmill Farm	26 August 1994	0.088
Anglian	Oughton	Westmill Farm	21 September 1994	0.073
Anglian	Roxwell Brook	Roxwell	15 September 1993	0.142
Anglian	Roxwell Brook	Roxwell	29 March 1994	0.111
Anglian	Roxwell Brook	Roxwell	1 May 1994	0.024
Anglian	Roxwell Brook	Roxwell	28 May 1994	0.072
Anglian	Roxwell Brook	Roxwell	25 June 1994	0.024
Anglian	Roxwell Brook	Roxwell	20 August 1994	0.016
Anglian	Roxwell Brook	Roxwell	20 August 1994	0.016
Anglian	Roxwell Brook	Roxwell	15 September 1994	0.046
Anglian	Roxwell Brook	Roxwell	15 September 1994	0.046

Table D.1 continued Summary of information provided by the Environment Agency Regions and the Clyde River Purification Board

Region	River	Site	Date	Flow (m^3/s)
Anglian	Roxwell Brook	Roxwell	14 October 1994	0.011
Anglian	Roxwell Brook	Roxwell	15 October 1994	0.010
Anglian	Roxwell Brook	Roxwell	7 December 1994	0.020
Anglian	Salcott Creek	Salcott	10 September 1993	0.004
Anglian	Salcott Creek	Salcott	30 March 1994	0.026
Anglian	Salcott Creek	Salcott	27 May 1994	0.053
Anglian	Salcott Creek	Salcott	16 June 1994	0.002
Anglian	Salcott Creek	Salcott	19 August 1994	0.001
Anglian	Salcott Creek	Salcott	14 October 1994	0.083
Anglian	Salcott Creek	Salcott	11 November 1994	0.042
Anglian	Sixpenny Brook	Alresfield	14 May 1994	0.039
Anglian	Sixpenny Brook	Alresfield	28 June 1994	0.021
Anglian	Sixpenny Brook	Alresfield	21 July 1994	0.014
Anglian	Sixpenny Brook	Alresfield	25 August 1994	0.015
Anglian	Sixpenny Brook	Alresfield	21 September 1994	0.036
Anglian	Sixpenny Brook	Alresfield	20 October 1994	0.011
Anglian	Sixpenny Brook	Alresfield	18 November 1994	0.029
Anglian	Sixpenny Brook	Alresfield	15 December 1994	0.024
Anglian	Sixpenny Brook	Alresfield	13 January 1995	0.041
Anglian	Tenpenney Brook	Alresfield	14 May 1994	0.120
Anglian	Tenpenney Brook	Alresfield	28 June 1994	0.036
Anglian	Tenpenney Brook	Alresfield	21 July 1994	0.020
Anglian	Tenpenney Brook	Alresfield	25 August 1994	0.022
Anglian	Tenpenney Brook	Alresfield	21 September 1994	0.082
Anglian	Tenpenney Brook	Alresfield	20 October 1994	0.026
Anglian	Tenpenney Brook	Alresfield	18 November 1994	0.085
Anglian	Tenpenney Brook	Alresfield	15 December 1994	0.080
Anglian	Tenpenney Brook	Alresfield	13 January 1995	0.202
Clyde	Clyde	Daldowie	31 July 1985	89.679
Clyde	Clyde	Daldowie	31 July 1985	93.246
Clyde	Clyde	Daldowie	15 January 1986	225.137
Clyde	Clyde	Daldowie	15 January 1986	228.058
Clyde	Clyde	Daldowie	11 February 1987	142.132

Table D.1 continued Summary of information provided by the Environment Agency Regions and the Clyde River Purification Board

Region	River	Site	Date	Flow (m^3/s)
Clyde	Clyde	Daldowie	11 February 1987	147.804
Clyde	Clyde	Daldowie	18 November 1987	83.555
Clyde	Clyde	Daldowie	18 November 1987	98.534
Clyde	Clyde	Daldowie	7 February 1990	172.138
Clyde	Clyde	Daldowie	7 February 1990	158.732
Clyde	Clyde	Daldowie	24 December 1991	417.250
Clyde	Clyde	Daldowie	24 December 1991	399.878
Clyde	Doon	Auchendrane	19 August 1988	17.989
Clyde	Doon	Auchendrane	19 August 1988	16.512
Clyde	Doon	Auchendrane	15 April 1989	18.189
Clyde	Doon	Auchendrane	15 April 1989	18.303
Clyde	Doon	Auchendrane	3 February 1990	18.600
Clyde	Doon	Auchendrane	3 February 1990	17.844
Clyde	Doon	Auchendrane	5 October 1990	19.854
Clyde	Doon	Auchendrane	5 October 1990	19.729
Clyde	Doon	Auchendrane	9 January 1992	76.556
Clyde	Doon	Auchendrane	9 January 1992	77.550
Clyde	Doon	Auchendrane	1 April 1993	15.515
Clyde	Doon	Auchendrane	1 April 1993	14.878
Clyde	Falloch	Glenfalloch	1 November 1989	21.884
Clyde	Falloch	Glenfalloch	1 November 1989	20.253
Clyde	Falloch	Glenfalloch	23 January 1990	9.757
Clyde	Falloch	Glenfalloch	23 January 1990	10.176
Clyde	Falloch	Glenfalloch	6 February 1990	65.214
Clyde	Falloch	Glenfalloch	6 February 1990	66.191
Clyde	Falloch	Glenfalloch	5 April 1991	33.592
Clyde	Falloch	Glenfalloch	5 April 1991	37.683
Clyde	Falloch	Glenfalloch	29 November 1991	19.376
Clyde	Falloch	Glenfalloch	29 November 1991	19.171
Clyde	Falloch	Glenfalloch	10 March 1992	34.370
Clyde	Falloch	Glenfalloch	10 March 1992	36.575
Clyde	Irwine	Shewalton	15 March 1989	15.107
Clyde	Irwine	Shewalton	15 March 1989	15.282

Table D.1 continued Summary of information provided by the Environment Agency Regions and the Clyde River Purification Board

Region	River	Site	Date	Flow (m^3/s)
Clyde	Irwine	Shewalton	17 January 1990	35.551
Clyde	Irwine	Shewalton	17 January 1990	36.082
Clyde	Irwine	Shewalton	14 February 1990	18.491
Clyde	Irwine	Shewalton	14 February 1990	18.566
Clyde	Irwine	Shewalton	10 November 1992	69.878
Clyde	Irwine	Shewalton	11 November 1992	64.302
Clyde	Irwine	Shewalton	27 January 1994	31.313
Clyde	Irwine	Shewalton	27 January 1994	30.697
Clyde	Irwine	Shewalton	14 March 1994	19.746
Clyde	Irwine	Shewalton	14 March 1994	20.683
Clyde	Kelvin	Dryfield	26 March 1987	13.396
Clyde	Kelvin	Dryfield	26 March 1987	14.419
Clyde	Kelvin	Dryfield	20 November 1987	17.314
Clyde	Kelvin	Dryfield	20 November 1987	15.209
Clyde	Kelvin	Dryfield	14 July 1988	10.440
Clyde	Kelvin	Dryfield	14 July 1988	10.063
Clyde	Kelvin	Dryfield	20 October 1988	15.915
Clyde	Kelvin	Dryfield	20 October 1988	14.732
Clyde	Kelvin	Dryfield	1 December 1988	22.290
Clyde	Kelvin	Dryfield	1 December 1988	22.784
Clyde	Kelvin	Dryfield	20 March 1991	68.548
Clyde	Kelvin	Dryfield	20 March 1991	66.445
Clyde	Luggie	Dondurrant	23 December 1984	4.695
Clyde	Luggie	Dondurrant	23 December 1984	4.780
Clyde	Luggie	Dondurrant	4 October 1985	2.545
Clyde	Luggie	Dondurrant	4 October 1985	2.428
Clyde	Luggie	Dondurrant	21 March 1986	1.898
Clyde	Luggie	Dondurrant	21 March 1986	1.949
Clyde	Luggie	Dondurrant	22 August 1987	2.727
Clyde	Luggie	Dondurrant	22 September 1987	2.938
Clyde	Luggie	Dondurrant	28 October 1987	1.342
Clyde	Luggie	Dondurrant	28 October 1987	1.279

Table D.1 continued Summary of information provided by the Environment Agency Regions and the Clyde River Purification Board

Region	River	Site	Date	Flow (m^3/s)
Clyde	Luggie	Dondurrant	20 January 1988	5.438
Clyde	Luggie	Dondurrant	20 January 1988	6.039
Northumbria/Yorks	Aire	Armley	20 December 1988	67.277
Northumbria/Yorks	Aire	Armley	30 January 1990	68.463
Northumbria/Yorks	Aire	Armley	7 January 1992	136.905
Northumbria/Yorks	Aire	Armley	19 December 1992	50.435
Northumbria/Yorks	Aire	Armley	17 December 1993	108.885
Northumbria/Yorks	Aire	Armley	27 January 1994	89.904
Northumbria/Yorks	Aire	Kildwick	23 March 1989	50.091
Northumbria/Yorks	Aire	Kildwick	24 March 1989	26.304
Northumbria/Yorks	Aire	Kildwick	26 January 1990	45.491
Northumbria/Yorks	Aire	Kildwick	19 November 1991	31.565
Northumbria/Yorks	Aire	Kildwick	9 December 1993	21.730
Northumbria/Yorks	Aire	Kildwick	26 January 1994	41.034
Northumbria/Yorks	Calder	Mytholmroyd	3 December 1992	59.645
Northumbria/Yorks	Calder	Mytholmroyd	14 September 1993	41.945
Northumbria/Yorks	Calder	Mytholmroyd	14 September 1993	49.740
Northumbria/Yorks	Coquet	Rothbury	5 November 1991	38.189
Northumbria/Yorks	Coquet	Rothbury	5 November 1991	36.752
Northumbria/Yorks	Coquet	Rothbury	1 April 1992	129.003
Northumbria/Yorks	Coquet	Rothbury	1 April 1992	149.078
Northumbria/Yorks	Don	Doncaster	1 December 1988	47.216
Northumbria/Yorks	Don	Doncaster	13 April 1989	51.041
Northumbria/Yorks	Don	Doncaster	10 February 1990	51.324
Northumbria/Yorks	Eastburn Beck	Driffield	16 October 1986	0.085
Northumbria/Yorks	Eastburn Beck	Driffield	21 November 1986	0.044
Northumbria/Yorks	Eastburn Beck	Driffield	16 December 1986	0.079
Northumbria/Yorks	Kelleythorpe A	Kellythorpe	14 May 1993	0.103
Northumbria/Yorks	Kelleythorpe A	Kellythorpe	27 August 1993	0.055
Northumbria/Yorks	Kelleythorpe A	Kellythorpe	18 November 1993	0.087
Northumbria/Yorks	Ouse	Skelton	31 May 1991	9.837
Northumbria/Yorks	Ouse	Skelton	7 September 1991	4.896
Northumbria/Yorks	Ouse	Skelton	20 August 1992	8.623

Table D.1 continued Summary of information provided by the Environment Agency Regions and the Clyde River Purification Board

Region	River	Site	Date	Flow (m^3/s)
Northumbria/Yorks	Ouse	Skelton	4 December 1992	443.062
Northumbria/Yorks	Ouse	Skelton	17 September 1993	332.049
Northumbria/Yorks	Ouse	Skelton	21 December 1993	339.520
Northumbria/Yorks	Ouse Burn	Cragg Hall	22 March 1994	0.085
Northumbria/Yorks	Ouse Burn	Cragg Hall	13 December 1994	0.132
Northumbria/Yorks	Ouse Burn	Woolsington	22 March 1994	0.020
Northumbria/Yorks	Rother	Whittington	28 April 1981	17.645
Northumbria/Yorks	Rother	Whittington	21 October 1988	31.449
Northumbria/Yorks	Rother	Whittington	11 April 1989	19.071
Northumbria/Yorks	Rother	Whittington	8 February 1990	17.498
Northumbria/Yorks	Rother	Whittington	8 February 1990	21.670
Northumbria/Yorks	Southburn Beck	Driffield	21 November 1990	0.000
Northumbria/Yorks	Southburn Beck	Driffield	28 August 1991	0.017
Northumbria/Yorks	Southburn Beck	Southburn	19 November 1992	0.048
Northumbria/Yorks	Swale	Catterick Bridge	5 March 1993	4.182
Northumbria/Yorks	Swale	Catterick Bridge	15 May 1993	174.137
Northumbria/Yorks	Swale	Catterick Bridge	24 July 1993	2.601
Northumbria/Yorks	Swale	Catterick Bridge	8 September 1993	1.404
Northumbria/Yorks	Swale	Catterick Bridge	16 September 1993	103.670
Northumbria/Yorks	Swale	Catterick Bridge	30 December 1993	12.724
Northumbria/Yorks	Swale	Leckby	12 March 1981	121.838
Northumbria/Yorks	Swale	Leckby	25 March 1981	171.729
Northumbria/Yorks	Swale	Leckby	5 January 1982	208.479
Northumbria/Yorks	Tees	Low Moor	24 February 1991	408.282
Northumbria/Yorks	Tees	Low Moor	6 March 1991	209.750
Northumbria/Yorks	Tees	Low Moor	6 March 1991	238.980
Northumbria/Yorks	Tees	Low Moor	14 December 1991	424.415
Northumbria/Yorks	Tees	Low Moor	24 December 1991	424.415
Northumbria/Yorks	Tees	Middleton	1 November 1991	104.352
Northumbria/Yorks	Tees	Middleton	16 January 1993	201.347
Northumbria/Yorks	Tees	Middleton	16 January 1993	169.656
Northumbria/Yorks	Tyne	Bywell	12 November 1991	302.299
Northumbria/Yorks	Tyne	Bywell	23 December 1991	496.316

Table D.1 continued Summary of information provided by the Environment Agency Regions and the Clyde River Purification Board

Region	River	Site	Date	Flow (m^3/s)
Northumbria/Yorks	Tyne	Bywell	23 December 1991	496.316
Northumbria/Yorks	Tyne	Bywell	24 December 1991	873.399
Northumbria/Yorks	Tyne	Bywell	24 December 1991	873.399
Northumbria/Yorks	Unnamed stream	Grid ref:TA064560	27 August 1993	0.017
Northumbria/Yorks	Unnamed stream	Kellythorpe	22 April 1993	0.036
Northumbria/Yorks	Unnamed stream	Kellythorpe	14 May 1993	0.046
Northumbria/Yorks	Ure	Kilgram Bridge	28 December 1979	233.076
Northumbria/Yorks	Ure	Kilgram Bridge	31 January 1980	112.935
Northumbria/Yorks	Ure	Kilgram Bridge	13 November 1982	159.613
Northumbria/Yorks	Ure	Kilgram Bridge	18 December 1986	51.442
Northumbria/Yorks	Ure	Kilgram Bridge	14 January 1993	146.465
Northumbria/Yorks	Ure	Kilgram Bridge	14 January 1993	94.359
Northumbria/Yorks	Ure	Westwick	13 August 1983	2.497
Northumbria/Yorks	Ure	Westwick	14 June 1988	3.479
Northumbria/Yorks	Ure	Westwick	1 September 1989	2.741
Northumbria/Yorks	Wansbeck	Mitford	1 April 1992	74.290
Northumbria/Yorks	Wansbeck	Mitford	2 April 1992	167.487
Northumbria/Yorks	Wansbeck	Mitford	1 May 1992	175.460
Northumbria/Yorks	Wansbeck	Mitford	7 April 1993	65.326
Northumbria/Yorks	Wear	Whitton Park	20 December 1991	94.420
Northumbria/Yorks	Wear	Whitton Park	20 December 1991	94.421
Northumbria/Yorks	Wear	Whitton Park	24 December 1991	205.377
Northumbria/Yorks	Wear	Whitton Park	24 December 1991	205.377
Northumbria/Yorks	Wharfe	Ilkley	11 February 1977	70.687
Northumbria/Yorks	Wharfe	Ilkley	4 January 1978	137.950
Northumbria/Yorks	Wharfe	Ilkley	3 March 1979	191.492
North West	Alt	Kirkby	10 August 1992	3.877
North West	Alt	Kirkby	10 August 1993	8.023
North West	Alt	Kirkby	10 August 1993	3.534
North West	Alt	Kirkby	10 August 1993	7.409
North West	Alt	Kirkby	10 August 1993	6.336
North West	Alt	Kirkby	10 August 1993	5.584
North West	Alt	Kirkby	10 August 1993	5.004

Table D.1 continued Summary of information provided by the Environment Agency Regions and the Clyde River Purification Board

Region	River	Site	Date	Flow (m^3/s)
North West	Calder	Whalley	23 December 1991	68.323
North West	Calder	Whalley	23 December 1991	73.845
North West	Calder	Whalley	14 March 1992	42.196
North West	Calder	Whalley	14 March 1992	39.533
North West	Irt	Galesyke	11 January 1995	5.000
North West	Kent	Sedgwick	11 November 1989	127.925
North West	Kent	Sedgwick	11 November 1989	156.986
North West	Kent	Sedgwick	12 November 1989	235.317
North West	Kent	Sedgwick	12 November 1989	174.645
North West	Kent	Sedgwick	19 March 1992	31.327
North West	Kent	Sedgwick	19 March 1992	14.525
North West	Kent	Sedgwick	19 March 1992	27.032
North West	Kent	Sedgwick	9 December 1993	28.086
North West	Kent	Sedgwick	30 December 1993	42.393
North West	Kent	Sedgwick	30 December 1993	44.533
North West	Kent	Sedgwick	13 January 1994	17.619
North West	Old Brook	Magerscough	10 August 1994	0.005
North West	Woodplumpton	Woodplumpton	10 August 1994	0.020
North West	Woodplumpton	Newmid Brook	10 August 1994	0.031
North West	Wyre	St Michaels	29 December 1994	71.765
North West	Wyre	St Michaels	29 December 1994	104.620
North West	Wyre	St Michaels	29 December 1994	111.050
Severn Trent	Amber	Wingfield Park	11 June 1994	0.546
Severn Trent	Amber	Wingfield Park	19 August 1994	0.078
Severn Trent	Amber	Wingfield Park	30 September 1994	0.783
Severn Trent	Amber	Wingfield Park	8 November 1994	1.999
Severn Trent	Arrow	Studley	21 July 1994	0.223
Severn Trent	Arrow	Studley	16 September 1994	7.360
Severn Trent	Arrow	Studley	16 September 1994	6.728
Severn Trent	Avon	Lilbourne	16 December 1993	4.407
Severn Trent	Avon	Lilbourne	4 February 1994	9.642
Severn Trent	Avon	Lilbourne	18 February 1994	1.023
Severn Trent	Avon	Lilbourne	21 July 1994	0.039

Table D.1 continued Summary of information provided by the Environment Agency Regions and the Clyde River Purification Board

Region	River	Site	Date	Flow (m^3/s)
Severn Trent	Badsey Brook	Offenham	21 July 1994	0.085
Severn Trent	Badsey Brook	Offenham	8 September 1994	0.096
Severn Trent	Badsey Brook	Offenham	23 November 1994	0.441
Severn Trent	Blythe	Castle Farm	11 August 1994	0.398
Severn Trent	Blythe	Castle Farm	25 August 1994	0.444
Severn Trent	Blythe	Castle Farm	15 September 1994	0.913
Severn Trent	Blythe	Castle Farm	25 October 1994	0.774
Severn Trent	Bourne Brook	Fillongey Lodge	17 December 1994	0.134
Severn Trent	Bourne Brook	Fillongey Lodge	24 December 1994	0.122
Severn Trent	Bourne Brook	Fillongey Lodge	14 January 1995	0.157
Severn Trent	Brocton Brook	Brocton	6 July 1989	0.027
Severn Trent	Derwent	Chatsworth	19 July 1994	1.866
Severn Trent	Derwent	Chatsworth	17 August 1994	1.622
Severn Trent	Derwent	Chatsworth	15 September 1994	2.735
Severn Trent	Derwent	Chatsworth	11 November 1994	18.887
Severn Trent	Derwent	Whatstandwell	10 December 1993	94.043
Severn Trent	Derwent	Whatstandwell	14 April 1994	31.085
Severn Trent	Derwent	Whatstandwell	25 May 1994	8.943
Severn Trent	Derwent	Whatstandwell	15 July 1994	4.581
Severn Trent	Henmore Brook	Carsington	21 July 1989	0.022
Severn Trent	Henmore Brook	Carsington	9 August 1989	0.013
Severn Trent	Henmore Brook	Carsington	14 September 1989	0.022
Severn Trent	Henmore Brook	Carsington	7 October 1989	0.026
Severn Trent	Independance level	Whitecroft	19 July 1991	0.011
Severn Trent	Manifold	Ilam	6 August 1994	0.972
Severn Trent	Manifold	Ilam	15 September 1994	1.836
Severn Trent	Manifold	Ilam	19 October 1994	1.464
Severn Trent	Manifold	Ilam	19 November 1994	3.800
Severn Trent	Mease	Stone Bridge	17 August 1994	0.204
Severn Trent	Mease	Stone Bridge	31 August 1994	0.213
Severn Trent	Mease	Stone Bridge	10 September 1994	0.337
Severn Trent	Mease	Stone Bridge	28 September 1994	0.590
Severn Trent	Meden	Church Warsop	15 April 1994	0.856

Table D.1 continued Summary of information provided by the Environment Agency Regions and the Clyde River Purification Board

Region	River	Site	Date	Flow (m^3/s)
Severn Trent	Meden	Church Warsop	17 June 1994	0.430
Severn Trent	Meden	Church Warsop	30 July 1994	0.257
Severn Trent	Meden	Church Warsop	23 September 1994	0.576
Severn Trent	Oldacre Brook	Brocton	21 July 1994	0.006
Severn Trent	Pontford Brook	Sandyford Bridge	16 November 1993	0.519
Severn Trent	Pontford Brook	Sandyford Bridge	22 July 1994	0.046
Severn Trent	Pontford Brook	Sandyford Bridge	27 July 1994	0.080
Severn Trent	Pontford Brook	Sandyford Bridge	29 September 1994	0.069
Severn Trent	Poulter	Cuckney	5 October 1994	0.314
Severn Trent	Poulter	Cuckney	3 November 1994	0.293
Severn Trent	Poulter	Cuckney	3 November 1994	0.284
Severn Trent	Poulter	Cuckney	17 November 1994	0.298
Severn Trent	Rea	Calthorpe Park	28 May 1994	0.547
Severn Trent	Rea	Calthorpe Park	27 August 1994	0.232
Severn Trent	Rea	Calthorpe Park	20 September 1994	3.557
Severn Trent	Rea Brook	Hook-a-gate	28 September 1994	0.910
Severn Trent	Rea Brook	Hook-a-gate	30 September 1994	0.742
Severn Trent	Rea Brook	Hook-a-gate	1 October 1994	0.683
Severn Trent	Severn	Saxons Lodge	4 July 1995	47.511
Severn Trent	Severn	Montford	5 July 1994	7.735
Severn Trent	Severn	Montford	14 July 1994	6.485
Severn Trent	Severn	Montford	1 October 1994	14.600
Severn Trent	Severn	Montford	4 November 1994	55.644
Severn Trent	Stour	Shipston	23 June 1994	0.679
Severn Trent	Stour	Shipston	21 July 1994	0.387
Severn Trent	Stour	Shipston	12 August 1994	0.403
Severn Trent	Tanat	Llanyblodwell	20 May 1994	1.834
Severn Trent	Tanat	Llanyblodwell	1 June 1994	1.185
Severn Trent	Tanat	Llanyblodwell	14 June 1994	1.229
Severn Trent	Tanat	Llanyblodwell	14 July 1994	0.697
Severn Trent	Teme	Tenbury	5 August 1994	2.507
Severn Trent	Teme	Tenbury	8 September 1994	1.735
Severn Trent	Teme	Tenbury	5 October 1994	6.072

Table D.1 continued Summary of information provided by the Environment Agency Regions and the Clyde River Purification Board

Region	River	Site	Date	Flow (m^3/s)
Severn Trent	Trent	Stoke	27 April 1994	0.484
Severn Trent	Trent	Stoke	23 June 1994	0.135
Severn Trent	Trent	Stoke	20 July 1994	0.094
Severn Trent	Trent	Stoke	16 September 1994	3.231
Severn Trent	York/Slade Brook	Whitecroft	13 July 1991	0.002
South West	Avon	Fordingbridge	10 December 1992	67.271
South West	Avon	Fordingbridge	10 December 1992	65.137
South West	Avon	Fordingbridge	22 December 1992	54.915
South West	Brue	Lovington	27 November 1992	7.532
South West	Brue	Lovington	27 November 1992	7.330
South West	Brue	Lovington	2 December 1992	7.545
South West	Brue	Lovington	8 December 1992	32.905
South West	Camel	Denby	4 December 1976	17.161
South West	Camel	Denby	4 December 1976	22.083
South West	Camel	Denby	4 December 1984	25.358
South West	Cerne	Fish Farm	21 October 1994	0.001
South West	Coleford Water	Broomhill	31 December 1993	0.384
South West	Copse Spring	Bramblecombe	18 October 1994	0.003
South West	Copse Spring	Bramblecombe	20 October 1994	0.009
South West	Copse Spring	Bramblecombe	20 October 1994	0.004
South West	Copse Spring	Bramblecombe	21 October 1994	0.008
South West	Copse Spring	Bramblecombe	21 October 1994	0.004
South West	Dart	Austins Bridge	20 December 1982	145.445
South West	Dart	Austins Bridge	22 January 1985	187.666
South West	Dart	Austins Bridge	4 February 1994	68.076
South West	Devils Brook	Court Street Bridge	18 October 1994	0.006
South West	Doniford	Swill Bridge	3 December 1992	7.729
South West	Doniford	Swill Bridge	14 December 1993	1.946
South West	Doniford	Swill Bridge	22 December 1993	5.504
South West	Doniford	Swill Bridge	6 January 1994	10.232
South West	Exe	Thorverton	10 March 1981	272.983
South West	Exe	Thorverton	1 December 1992	192.358
South West	Exe	Thorverton	8 December 1992	49.780

Table D.1 continued Summary of information provided by the Environment Agency Regions and the Clyde River Purification Board

Region	River	Site	Date	Flow (m^3/s)
South West	Hicks mill stream	Trehaddle	4 February 1994	0.515
South West	Hicks mill stream	Trehaddle	17 June 1994	0.115
South West	Hicks mill stream	Trehaddle	7 July 1994	0.097
South West	Hicks mill stream	Trehaddle	10 September 1994	0.072
South West	Hicks mill stream	Trehaddle	4 November 1994	0.534
South West	Hicks mill stream	Trehaddle	2 December 1994	0.282
South West	Inny	Beals Mill	30 January 1990	26.991
South West	Inny	Beals Mill	30 January 1990	28.175
South West	Inny	Beals Mill	30 January 1990	25.221
South West	Inny	Beals Mill	30 January 1990	29.046
South West	Lox Yeo	Windcombe Hill	20 November 1991	0.043
South West	Nadder	Court Street Bridge	6 January 1994	13.205
South West	Nadder	Court Street Bridge	6 January 1994	8.380
South West	Nadder	Court Street Bridge	4 February 1994	9.059
South West	Okement	Jacobstone	1 December 1992	61.554
South West	Okement	Jacobstone	19 December 1992	53.968
South West	Okement	Jacobstone	14 January 1993	38.865
South West	Ottery	Werrington	22 January 1980	37.023
South West	Ottery	Werrington	16 March 1982	22.595
South West	Ottery	Werrington	24 February 1994	40.292
South West	Peartwater	Ashford Dam	13 September 1991	0.019
South West	Piddle	Baggs Mill	4 December 1992	6.126
South West	Piddle	Baggs Mill	20 December 1992	7.364
South West	Piddle	Baggs Mill	12 January 1993	7.609
South West	Stour	Blackwater Bridge	16 October 1993	107.401
South West	Stour	Blackwater Bridge	23 December 1993	115.431
South West	Stour	Blackwater Bridge	12 November 1994	125.616
South West	Tamar	Gunnislake	16 December 1993	130.780
South West	Tamar	Gunnislake	21 December 1993	202.837
South West	Tamar	Gunnislake	1 November 1994	283.693
South West	Tavy	Ludbrook	16 December 1986	83.969
South West	Tavy	Ludbrook	16 December 1986	81.483
South West	Tavy	Ludbrook	16 December 1986	81.087

Table D.1 continued Summary of information provided by the Environment Agency Regions and the Clyde River Purification Board

Region	River	Site	Date	Flow (m^3/s)
South West	Till	Poultry Farm	19 October 1994	0.027
South West	Tone	Bishops Hull	10 January 1992	11.476
South West	Tone	Bishops Hull	11 November 1992	4.263
South West	Tone	Bishops Hull	3 December 1992	21.980
South West	Tone	Bishops Hull	3 December 1992	27.395
South West	Torridge	Torrington	19 October 1978	0.666
South West	Torridge	Torrington	20 October 1978	0.677
South West	Torridge	Torrington	20 October 1978	0.652
South West	Torridge	Torrington	20 October 1978	0.660
South West	Torridge	Torrington	20 October 1978	0.658
South West	Torridge	Torrington	20 October 1978	0.654
South West	Torridge	Torrington	20 October 1978	0.685
South West	Torridge	Torrington	28 March 1987	124.328
South West	Torridge	Torrington	3 January 1991	214.854
South West	Torridge	Torrington	13 January 1993	78.713
South West	Winterbourne	Ashton Farm	24 November 1994	0.007
South West	Winterbourne	Cress beds	28 October 1994	0.017
South West	Winterbourne	Martinstown	28 October 1994	0.006
South West	Wolf	Roadford	9 November 1990	7.464
South West	Wolf	Roadford	4 November 1994	3.047
South West	Wolf	Roadford	4 November 1994	8.602
South West	Yeo	Penmill	10 January 1992	15.410
South West	Yeo	Penmill	1 December 1992	52.451
South West	Yeo	Penmill	21 December 1993	75.093
South West	Yeo	Penmill	21 December 1993	77.614
South West	Yeo	Penmill	10 November 1994	46.807
Southern	Arun	Pallingham	7 October 1992	0.780
Southern	Arun	Pallingham	23 October 1992	6.360
Southern	Arun	Pallingham	29 October 1992	7.439
Southern	Arun	Pallingham	13 November 1992	15.210
Southern	Arun	Pallingham	27 November 1992	67.165
Southern	Arun	Pallingham	13 January 1993	26.135
Southern	Arun	Pallingham	17 July 1993	0.671

Table D.1 continued Summary of information provided by the Environment Agency Regions and the Clyde River Purification Board

Region	River	Site	Date	Flow (m^3/s)
Southern	Bevern Stream	Holmans Bridge	26 July 1990	0.012
Southern	Bevern Stream	Holmans Bridge	27 July 1990	0.016
Southern	Bevern Stream	Holmans Bridge	27 July 1990	0.016
Southern	Bevern Stream	Holmans Bridge	27 July 1990	0.015
Southern	Bevern Stream	Holmans Bridge	31 August 1990	0.029
Southern	Bevern Stream	Holmans Bridge	31 August 1990	0.029
Southern	Bevern Stream	Holmans Bridge	19 September 1990	0.009
Southern	Blackwater	Ower	3 April 1993	3.151
Southern	Blackwater	Ower	3 April 1993	3.151
Southern	Blackwater	Ower	13 August 1994	7.469
Southern	Blackwater	Ower	12 September 1994	8.202
Southern	Blackwater	Ower	29 September 1994	3.065
Southern	Blackwater	Ower	1 November 1994	7.730
Southern	Blackwater	Ower	9 December 1994	7.469
Southern	Blackwater	Ower	3 February 1995	4.113
Southern	Blackwater	Ower	3 February 1995	4.113
Southern	Blackwater	Ower	1 November 1995	7.730
Southern	Blackwater	Ower	2 December 1995	0.886
Southern	Blackwater	Sherfield English	25 July 1992	0.044
Southern	Blackwater	Sherfield English	26 August 1992	0.036
Southern	Blackwater	Sherfield English	26 September 1992	0.047
Southern	Blackwater	Sherfield English	27 October 1992	0.037
Southern	Blackwater	Sherfield English	20 February 1993	0.032
Southern	Blackwater	Sherfield English	20 March 1993	0.025
Southern	Blackwater	Sherfield English	20 April 1993	0.042
Southern	Cant STW Outfall	Outflow Channel	10 December 1991	0.341
Southern	Cant STW Outfall	Outflow Channel	18 December 1991	0.241
Southern	Cant STW Outfall	Outflow Channel	21 February 1992	0.263
Southern	Cant STW Outfall	Outflow Channel	17 March 1993	0.292
Southern	Cuckmere	Arlington	1 November 1994	18.386
Southern	Cuckmere	Arlington	1 November 1994	19.207
Southern	Cuckmere	Arlington	15 November 1994	10.443
Southern	Cuckmere	Arlington	15 November 1994	9.750

Table D.1 continued Summary of information provided by the Environment Agency Regions and the Clyde River Purification Board

Region	River	Site	Date	Flow (m^3/s)
Southern	Cuckmere	Arlington	15 November 1994	9.750
Southern	Cuckmere	Arlington	15 November 1994	10.443
Southern	Cuckmere	Arlington	10 December 1994	17.527
Southern	Cuckmere	Arlington	10 December 1994	16.154
Southern	Cuckmere	Arlington	21 January 1995	15.501
Southern	Cuckmere	Arlington	21 January 1995	14.601
Southern	Cuckmere	Arlington	24 January 1995	15.288
Southern	Cuckmere	Arlington	24 January 1995	14.229
Southern	Cuckmere	Arlington	24 January 1995	14.299
Southern	Cuckmere	Arlington	16 February 1995	9.822
Southern	Cuckmere	Arlington	16 February 1995	9.745
Southern	Cuckmere	Arlington	16 February 1995	9.437
Southern	Cuckmere	Arlington	16 February 1995	9.490
Southern	Cuckmere	Arlington	16 February 1995	9.798
Southern	Cuckmere	Arlington	16 February 1995	10.203
Southern	Dour	Crabble Mill	3 January 1988	1.267
Southern	Dour	Crabble Mill	23 February 1988	1.320
Southern	Dour	Crabble Mill	18 November 1989	0.083
Southern	Dour	Crabble Mill	7 December 1989	0.051
Southern	Dour	Crabble Mill	21 August 1990	0.114
Southern	Dour	Crabble Mill	21 August 1990	0.104
Southern	Dour	Crabble Mill	22 August 1990	0.087
Southern	Dour	Crabble Mill	20 September 1990	0.049
Southern	Dour	Crabble Mill	27 January 1994	0.984
Southern	Dour	Crabble Mill	11 February 1994	0.965
Southern	Dour	Crabble Mill	11 March 1994	0.838
Southern	Dour	Crabble Mill	24 March 1994	0.818
Southern	Durlock	Wingham	22 December 1993	0.091
Southern	Great Stour	Ashford	9 October 1993	4.387
Southern	Great Stour	Horton	22 December 1993	14.057
Southern	Great Stour	Horton	22 December 1993	13.890
Southern	Great Stour	Horton	1 January 1994	25.220
Southern	Great Stour	Horton	8 January 1994	14.758

Table D.1 continued Summary of information provided by the Environment Agency Regions and the Clyde River Purification Board

Region	River	Site	Date	Flow (m^3/s)
Southern	Great Stour	Horton	8 January 1994	14.538
Southern	Great Stour	Wye	18 March 1989	11.050
Southern	Great Stour	Wye	18 March 1989	11.420
Southern	Great Stour	Wye	7 April 1989	17.305
Southern	Great Stour	Wye	7 April 1989	17.459
Southern	Great Stour	Wye	22 December 1989	10.630
Southern	Great Stour	Wye	13 February 1990	17.936
Southern	Great Stour	Wye	13 February 1990	11.421
Southern	Great Stour	Wye	1 February 1991	15.823
Southern	Great Stour	Wye	11 February 1991	11.740
Southern	Great Stour	Wye	11 February 1991	11.230
Southern	Great Stour	Wye	10 December 1991	11.107
Southern	Great Stour	Wye	10 December 1991	10.899
Southern	Great Stour	Wye	14 October 1993	11.486
Southern	Lavant	Lavant A	12 December 1992	0.310
Southern	Lavant	Lavant A	23 December 1992	0.810
Southern	Lavant	Lavant A	30 December 1992	0.930
Southern	Lavant	Lavant A	12 January 1993	1.200
Southern	Lavant	Lavant A	16 January 1993	1.090
Southern	Lavant	Lavant A	19 January 1993	1.370
Southern	Lavant	Lavant A	26 January 1993	1.200
Southern	Lavant	Lavant A	3 February 1993	1.300
Southern	Lavant	Lavant A	9 February 1993	1.200
Southern	Lavant	Lavant A	5 March 1993	0.780
Southern	Lavant	Lavant A	16 March 1993	0.583
Southern	Lavant	Lavant A	26 March 1993	0.329
Southern	Lavant	Lavant B	12 December 1992	0.410
Southern	Lavant	Lavant B	23 December 1992	0.740
Southern	Lavant	Lavant B	30 December 1992	0.760
Southern	Lavant	Lavant B	12 January 1993	0.990
Southern	Lavant	Lavant B	19 January 1993	1.200
Southern	Lavant	Lavant B	26 January 1993	1.060
Southern	Lavant	Lavant B	3 February 1993	1.100

Table D.1 continued Summary of information provided by the Environment Agency Regions and the Clyde River Purification Board

Region	River	Site	Date	Flow (m^3/s)
Southern	Lavant	Lavant B	9 February 1993	1.000
Southern	Lavant	Lavant B	16 February 1993	0.850
Southern	Lavant	Lavant B	5 March 1993	0.485
Southern	Lavant	Lavant B	16 March 1993	0.369
Southern	Lavant	Lavant B	26 March 1993	0.207
Southern	Lavant	Lavant C	12 December 1992	0.300
Southern	Lavant	Lavant C	23 December 1992	0.510
Southern	Lavant	Lavant C	30 December 1992	0.460
Southern	Lavant	Lavant C	12 January 1993	0.660
Southern	Lavant	Lavant C	19 January 1993	0.940
Southern	Lavant	Lavant C	26 January 1993	0.805
Southern	Lavant	Lavant C	3 February 1993	0.810
Southern	Lavant	Lavant C	9 February 1993	0.710
Southern	Lavant	Lavant C	16 February 1993	0.560
Southern	Lavant	Lavant C	4 March 1993	0.390
Southern	Lavant	Lavant C	16 March 1993	0.292
Southern	Lavant	Lavant C	26 March 1993	0.153
Southern	Lavant	Lavant D	12 December 1992	1.929
Southern	Lavant	Lavant D	24 December 1992	0.570
Southern	Lavant	Lavant D	30 December 1992	0.600
Southern	Lavant	Lavant D	12 January 1993	0.690
Southern	Lavant	Lavant D	16 January 1993	0.690
Southern	Lavant	Lavant D	19 January 1993	0.910
Southern	Lavant	Lavant D	26 January 1993	0.820
Southern	Lavant	Lavant D	26 January 1993	0.817
Southern	Lavant	Lavant D	2 February 1993	0.868
Southern	Lavant	Lavant D	9 February 1993	0.750
Southern	Lavant	Lavant D	4 March 1993	0.465
Southern	Lavant	Lavant D	16 March 1993	0.435
Southern	Lavant	Lavant D	26 March 1993	0.260
Southern	Lavant	Lavant E	19 January 1991	0.650
Southern	Lavant	Lavant E	12 December 1992	0.420
Southern	Lavant	Lavant E	24 December 1992	0.340

Table D.1 continued Summary of information provided by the Environment Agency Regions and the Clyde River Purification Board

Region	River	Site	Date	Flow (m^3/s)
Southern	Lavant	Lavant E	30 December 1992	0.330
Southern	Lavant	Lavant E	12 January 1993	0.480
Southern	Lavant	Lavant E	26 January 1993	0.550
Southern	Lavant	Lavant E	2 February 1993	0.620
Southern	Lavant	Lavant E	9 February 1993	0.560
Southern	Lavant	Lavant E	16 February 1993	0.450
Southern	Lavant	Lavant E	4 March 1993	0.325
Southern	Lavant	Lavant E	16 March 1993	0.255
Southern	Lavant	Lavant E	26 March 1993	0.129
Southern	Lavant	Lavant F	12 December 1992	0.288
Southern	Lavant	Lavant F	24 December 1992	0.170
Southern	Lavant	Lavant F	30 December 1992	0.200
Southern	Lavant	Lavant F	12 January 1993	0.340
Southern	Lavant	Lavant F	19 January 1993	0.370
Southern	Lavant	Lavant F	26 January 1993	0.330
Southern	Lavant	Lavant F	2 February 1993	0.360
Southern	Lavant	Lavant F	9 February 1993	0.178
Southern	Lavant	Lavant F	16 February 1993	0.320
Southern	Lavant	Lavant F	4 March 1993	0.303
Southern	Lavant	Lavant F	16 March 1993	0.265
Southern	Lavant	Lavant F	26 March 1993	0.118
Southern	Lavant	Lavant Sewer Work	23 December 1992	0.031
Southern	Lavant	Lavant Sewer Work	31 December 1992	0.043
Southern	Lavant	Lavant Sewer Work	13 January 1993	0.640
Southern	Lavant	Lavant Sewer Work	19 January 1993	0.770
Southern	Lavant	Lavant Sewer Work	27 January 1993	0.890
Southern	Lavant	Lavant Sewer Work	3 February 1993	0.950
Southern	Lavant	Lavant Sewer Work	9 February 1993	0.940
Southern	Lavant	Lavant Sewer Work	16 February 1993	0.810
Southern	Little Stour	Seaton Mill	24 August 1989	0.024
Southern	Little Stour	Seaton Mill	20 October 1989	0.009
Southern	Little Stour	Seaton Mill	23 January 1990	0.032
Southern	Little Stour	Seaton Mill	21 February 1990	0.097

Table D.1 continued Summary of information provided by the Environment Agency Regions and the Clyde River Purification Board

Region	River	Site	Date	Flow (m^3/s)
Southern	Little Stour	Seaton Mill	21 March 1990	0.115
Southern	Little Stour	Seaton Mill	21 April 1990	0.139
Southern	Little Stour	Seaton Mill	19 May 1990	0.093
Southern	Little Stour	Seaton Mill	24 August 1991	0.021
Southern	Little Stour	Seaton Mill	9 January 1993	0.079
Southern	Little Stour	Seaton Mill	25 June 1993	0.119
Southern	Little Stour	Seaton Mill	17 August 1993	0.031
Southern	Little Stour	Seaton Mill	16 September 1993	0.037
Southern	Little Stour	Seaton Mill	3 February 1994	0.775
Southern	Little Stour	Seaton Mill	26 July 1994	0.155
Southern	Monks Brook	Stoneham Lane	2 July 1992	3.600
Southern	Monks Brook	Stoneham Lane	3 December 1992	5.498
Southern	Monks Brook	Stoneham Lane	4 February 1994	6.393
Southern	Monks Brook	Stoneham Lane	9 December 1994	7.339
Southern	Nailbourne	Derringstone	21 January 1994	0.803
Southern	Nailbourne	Derringstone	3 February 1994	0.668
Southern	Nailbourne	Derringstone	3 March 1994	0.391
Southern	Ouse	Goldbridge	14 October 1993	28.535
Southern	Ouse	Goldbridge	22 December 1993	16.807
Southern	Ouse	Goldbridge	22 December 1993	15.027
Southern	Ouse	Goldbridge	5 January 1994	27.814
Southern	Ouse	Goldbridge	5 January 1994	31.999
Southern	Ouse	Goldbridge	6 January 1994	25.503
Southern	Ouse	Goldbridge	6 January 1994	25.005
Southern	Ouse	Goldbridge	4 February 1994	14.774
Southern	Ouse	Goldbridge	4 February 1994	16.254
Southern	Ouse	Goldbridge	14 October 1994	14.108
Southern	Ouse	Goldbridge	31 January 1995	10.501
Southern	Ouse	Pilstye Comp.	26 July 1990	0.014
Southern	Sarre Penn	Calcott	22 February 1975	0.259
Southern	Sarre Penn	Calcott	14 February 1976	0.464
Southern	Sarre Penn	Calcott	1 December 1976	1.220
Southern	Sarre Penn	Calcott	27 November 1990	0.976

Table D.1 continued Summary of information provided by the Environment Agency Regions and the Clyde River Purification Board

Region	River	Site	Date	Flow (m^3/s)
Southern	Sarre Penn	Calcott	27 November 1990	0.976
Southern	Sarre Penn	Calcott	10 January 1991	1.400
Southern	Sarre Penn	Calcott	10 January 1991	1.400
Southern	Sarre Penn	Calcott	9 June 1992	0.033
Southern	Sarre Penn	Calcott	22 December 1993	0.792
Southern	Sarre Penn	Calcott	22 December 1993	0.792
Southern	Sarre Penn	Tyler Hill	22 December 1993	0.348
Southern	Sheppey	Fenney Castle	19 February 1992	
Southern	Tanyard Fish Farm		31 October 1991	0.360
Southern	Test	Broadlands	7 January 1993	11.372
Southern	Test	Broadlands	10 January 1993	6.399
Southern	Test	Broadlands	5 June 1995	15.970
Southern	Uckfield	Industrial Estate	25 July 1990	0.087
Southern	Uckfield	Industrial Estate	25 July 1990	0.087
Southern	Uckfield	Industrial Estate	29 August 1990	0.085
Southern	Wick Stream	Camberlot Road	20 February 1992	0.032
Southern	Wick Stream	Camberlot Road	20 February 1992	0.033
Thames	Brent	Costons Lane	4 February 1994	5.571
Thames	Brent	Costons Lane	4 February 1994	6.654
Thames	Brent	Costons Lane	4 February 1994	7.410
Thames	Brent	Costons Lane	4 February 1994	10.308
Thames	Brent	Costons Lane	4 February 1994	11.791
Thames	Brent	Costons Lane	4 February 1994	12.300
Thames	Brent	Costons Lane	4 February 1994	12.617
Thames	Brent	Costons Lane	4 February 1994	13.641
Thames	Brent	Costons Lane	4 February 1994	15.883
Thames	Coln	Fairford	27 November 1991	2.281
Thames	Kennet	Newbury	4 February 1993	10.857
Thames	Kingclere Brook	Kingsclere	29 November 1994	0.111
Thames	New River	New Gauge	1 March 1995	1.249
Thames	Quaggy	Manor House Gdns	28 June 1991	0.260
Thames	Quaggy	Manor House Gdns	28 June 1991	0.314
Thames	Quaggy	Manor House Gdns	28 June 1991	0.447

Table D.1 continued Summary of information provided by the Environment Agency Regions and the Clyde River Purification Board

Region	River	Site	Date	Flow (m^3/s)
Thames	Quaggy	Manor House Gdns	28 June 1991	0.472
Thames	Quaggy	Manor House Gdns	28 June 1991	0.773
Thames	Quaggy	Manor House Gdns	28 June 1991	1.031
Thames	Quaggy	Manor House Gdns	28 June 1991	1.216
Thames	Quaggy	Manor House Gdns	28 June 1991	1.470
Thames	Shalbourne	Smitham Bridge	29 November 1994	0.122
Thames	Thames	Reading Bridge	19 November 1992	101.730
Thames	Thames	Sutton Courtney	19 January 1995	66.359
Thames	Ver	Premill site	21 December 1994	0.037
Thames	Ver	Premill site	21 December 1994	0.078
Thames	Ver	Premill site	21 December 1994	0.151
Welsh	Afon Barllwd	Barllwyd	14 March 1995	0.329
Welsh	Castroggy	Fish Farm	14 March 1992	0.004
Welsh	Conwy	Conwy Hut	16 February 1995	22.849
Welsh	Dee	Bala cableway	16 November 1994	52.870
Welsh	Dee	Bala cableway	22 November 1994	37.660
Welsh	Dee	Bala cableway	24 November 1994	30.000
Welsh	Dee	Bala cableway	2 December 1994	4.794
Welsh	Dee	Ironbridge	4 August 1994	102.260
Welsh	Dee	Ironbridge	14 September 1994	49.977
Welsh	Dee	Ironbridge	12 October 1994	12.617
Welsh	Dee	Ironbridge	28 October 1994	41.203
Welsh	Dee	Ironbridge	11 November 1994	45.940
Welsh	Dee	Ironbridge	13 January 1995	97.939
Welsh	Dee	Ironbridge	13 January 1995	98.489
Welsh	Dee	Ironbridge	13 January 1995	101.762
Welsh	Dee	Ironbridge	13 January 1995	102.804
Welsh	Dee	Ironbridge	13 January 1995	103.559
Welsh	Dee	Ironbridge	13 January 1995	102.218
Welsh	Dee	Ironbridge	13 January 1995	101.994
Welsh	Dee	Ironbridge	13 January 1995	103.961
Welsh	Dyfi	Dyfi Hut	15 February 1995	59.206
Welsh	Elwy	Pont-y-Gyddel	1 November 1994	10.158

Table D.1 continued Summary of information provided by the Environment Agency Regions and the Clyde River Purification Board

Region	River	Site	Date	Flow (m^3/s)
Welsh	Elwy	Pont-y-Gyddel	16 November 1994	12.781
Welsh	Garth Tonmawr	Blaenpelenna	9 June 1994	0.298
Welsh	Garth Tonmawr	Blaenpelenna	21 July 1994	0.016
Welsh	Garth Tonmawr	Blaenpelenna	25 August 1994	0.012
Welsh	Garth Tonmawr	Blaenpelenna	22 September 1994	0.019
Welsh	Tawe	Ynstanglws	10 March 1994	76.685
Welsh	Tawe	Ynstanglws	10 March 1994	82.685
Welsh	Tawe	Ynstanglws	22 June 1994	36.030
Welsh	Tawe	Ynstanglws	22 June 1994	32.521

APPENDIX E: SUMMARY OF INFORMATION PROVIDED BY INTERNATIONAL INSTITUTES

Letters were sent to thirteen European institutes requesting information on methods used to measure flows where the stage is changing rapidly, and in small streams (see Appendix B, letter 3). The responses received are given below.

Hydrographisches Zentralburo
Marxergasse 2
A-1030 Wien
Austria
Contact: Dr Nobilis

Information was provided for rapidly varying stage only, as follows.

- The number of measuring points is reduced
- Kreps method used: Two measurement points in the vertical to obtain mean velocity, near the surface and at 0.38 of the depth.
- Plotting of discharge results on the stage discharge curve for control
- Use of telemetry to estimate when and where floods will occur, and alert hydrometry groups.
- No verification of the hysteresis phenomenon
- Rates of change occur which are sometimes greater than 0.5m/minute in connection with hydropower utilisation. Problems of measurement of these flows by current meter have not been resolved.

Institute for Land and Water Management
Vital Decosterstraat 102
3000 Leuven
Belgium
Contact: Prof J Feyen

Information on small stream gauging was provided, as follows:

- Distance between verticals 1.5 times the propeller diameter
- At least 11 verticals taken where the width of the section is greater than 16 times the propeller diameter
- Discharge not greater than 11% of total discharge for each panel
- A 50mm diameter propeller is generally used
- For flow depths up to 0.17m, one measurement point is used at a depth of 0.5d. For flow depths between 0.18 and 0.24m, two measurement points are used at about 0.28d and 0.71d (exact positions specified for each depth). For depths of 0.25 to 0.32m, three measurement points are used, and for depths between 0.33 and 0.40m four measurement points are used. A table of exact positions is given.
- For depths greater than 0.40m, between one and five measurement points are used

depending on depth and method (either rod or cableway). A table of exact positions is given.
- Minimum exposure time is either 30 seconds, or the lesser of a specified minimum number of revolutions or an exposure time of 10 seconds.

Directorate-General for Public Works and
Water Management
Institute for Inland Water Management
PO Box 17
8200 AA Lelystad
The Netherlands
Contact: J P Bakker

Reply received, but no useful information provided

Swedish Meteorological and
Hydrological Institute (SMHI)
S-60176 Norrkoping
Sweden
Contact: Maja Brandt

Rapidly Varying Stage

Normal method is measurement at 0.2 and 0.8d with 40 second exposure time. For rapid gaugings the number of verticals is reduced, and sometimes velocities are measured in every second vertical in one gauging and the alternate verticals for the next gauging.

Small streams

Use is made of the JOMEX CM90 micro current meter, propeller diameter 21mm. An illustration is enclosed. Measurements are made at 0.2 and 0.8d.

Sweden has no other manuals other than the Standards.

SMHI are involved in standardisation work in hydrometry, and are interested in the development of techniques for international use.

Service Hydrologique et Geologique
National
CH-3003 Bern
Switzerland
Contact: Dr B Schadler

The following documents were provided:

- Velocity distribution in Swiss rivers

- Manual on discharge measurements
- Guidance on measurement of discharge with continuously changing water level. This report included velocity profiles for the River Rhone where water levels can vary by 0.5m in one hour (30% of the flow depth). It was not particularly helpful for the current research.
- Report on the effect of non-immersion of a current meter on the accuracy of the measurement. The report showed the effect on accuracy of recorded velocities with the propeller at 50, 75 and 100% immersion, and immersed at a depth of 0.15m. Accuracies were obtained by comparison with the velocity recorded at a depth of 0.3m. Different propellers were used, with diameters ranging from 100mm to 127mm. For complete immersion errors were generally less than 2% for velocities greater than 0.2 m/s.

No response was received from the following organisations

Hydrometrical Survey
Danish Land Development Service
Ringstedvej 20
PO Box 9
DK-4000 Roskilde
Denmark
Contact: Ole Ekstrand

National Board of Waters & Environment
Hydrological Office
PO Box 436
SF-00101 Helsinki
Finland
Contact: Dr P Seuna

DIREN Midi-Pyrenees
2 Port St Etienne
31079 - Toulouse Cedex
France
Contact: M Bouziges

Servizio Idrografico e
Mareografico Italiano
c/o Presidenza de Consiglio
via V Veneto 56
00187 Roma
Italy
Contact: Dott Ing G Batini

NVE Norwegian Water Resources
& Energy Administration
Hydrology Department

Box 5091- Majorstua
N-301 Oslo
Norway
Contact: L A Roald

Office of Public Works
17/19 Lower Hatch Street
Dublin 2
Ireland
Contact: T Bolger

Direccion General de Obras
Hidraulicas
MOPTMA
Avda de Portugal 81
28011 Madrid
Spain
Contact: J M Santafe Martinez

APPENDIX F: REDUCTION IN NUMBER OF VERTICALS (RAPIDLY VARYING FLOW)

Table F.1 Data used in reduced number of verticals analysis

Region	River	Station	Flow (m^3s^{-1})	Width (m)	No of Vert	Refer.
Clyde	Luggie	Dondurrant	6.039	6.50	17	Luggie
South West	Piddle	Baggs Mill	7.610	7.70	15	Piddle
Severn Trent	Arrow	Studley	7.360	8.50	25	Arrow
Thames	Kennet	Newbury	10.583	8.50	9	Kennet
Severn Trent	Avon	Lilbourne	9.640	9.00	16	Avon2
Yorkshire	Rother	Whittington	21.670	9.50	11	Rother
North West	Alt	Kirkby	7.400	9.75	15	Alt
South West	Nadder	Court Street	13.305	10.50	17	Nadder
South West	Camel	Denby	22.083	11.15	15	Camel
South West	Brue	Lovington	32.905	12.60	9	Brue
Yorkshire	Calder	Mytholmroyd	49.740	17.40	17	Calder2
Yorkshire	Aire	Kildwick	45.491	18.00	17	Aire2
Clyde	Doon	Auchendrane	18.600	18.40	17	Doon
South West	Yeo	Pen Mill	46.807	18.85	24	Yeo
Welsh	Elwy	PontGwyddel	12.781	19.00	17	Elwy
South West	Okement	Jacobstone	60.811	19.80	19	Okement
South West	Ottery	Werrington	37.023	22.20	18	Ottery
Yorkshire	Aire	Armley	136.902	24.00	17	Aire1
Welsh	Dee	Bala Cable	52.870	26.30	28	Dee1
Clyde	Falloch	Glenfalloch	21.884	27.30	16	Falloch
Yorkshire	Wansbeck	Mitford	175.460	28.00	15	Wansbec
Yorkshire	Swale	Catterick br.	12.724	28.00	18	Swale2
Severn Trent	Severn	Montford	55.644	28.10	17	Severn
South West	Torridge	Torrington	214.854	28.40	16	Torridge
Severn Trent	Derwent	Chatsworth	18.887	28.50	28	Derwent
Severn Trent	Derwent	Whatstandwe	31.085	29.35	27	Derwent

Table F.1 cont Data used in reduced number of verticals analysis

Region	River	Station	Flow (m^3s^{-1})	Width (m)	No of Vert	Refer.
North West	Kent	Sedgewick	31.327	33.50	18	Kent
South West	Dart	Austin's Br.	187.666	34.00	17	Dart
Thames	Thames	Sutton Court.	66.359	37.00	19	Thames2
North West	Calder	Whalley	73.845	23.50	24	Calder1
Yorkshire	Don	Doncaster	51.324	24.00	18	Don
Southern	Arun	Pallingham	67.165	38.00	37	Arun
South West	Avon	Fordingbridge	62.271	39.00	18	Avon1
Welsh	Dee	Ironbridge	102.260	42.80	21	Dee2
South West	Stour	Blackwater	107.401	50.00	24	Stour
Clyde	Clyde	Daldowie	172.138	51.70	15	Clyde
Yorkshire	Ure	Kilgram Br.	112.935	31.50	21	Ure
South West	Tamar	Gunnislake	283.693	32.24	18	Tamar2
South West	Exe	Thorverton	49.780	33.00	18	Exe
Thames	Thames	Reading	101.730	55.00	23	Thames1
Yorkshire	Ouse	Skelton	339.520	67.50	23	Ouse1
South West	Tamar	Gunnislake	202.837	33.26	18	Tamar1
Yorkshire	Ouse	Skelton	443.062	70.50	31	Ouse2
Yorkshire	Swale	Leckby	228.434	93.50	36	Swale1

Table F.2 Discharges calculated for reduced number of verticals (m^3s^{-1})

River Ref.	Width (m)	Number of verticals									
		Full	20	15	10	7	5	4	3	2	1
Kennet	8.50	10.848				9.901	8.556	9.631	8.378	7.643	8.613
Brue	12.60	29.770				30.365	30.842	27.227	29.764	25.683	21.095
Derwent1	29.35	31.149	31.356	30.382	29.720	31.290	28.129	28.306	26.221	21.543	14.821
Kent	33.50	31.028		30.746	29.171	28.098	27.798	26.300	24.396	21.113	13.661
Dee1	26.30	52.556	53.252	51.575	53.856	50.107	50.927	47.168	43.425	37.699	17.072
Okement	19.80	61.196		61.450	59.159	61.702	59.114	56.693	53.874	55.616	30.213
Calder1	23.50	73.452	72.347	70.959	71.036	67.630	68.180	64.131	61.446	55.951	38.594
Avon	39.00	63.294		63.317	63.309	61.884	59.056	57.773	53.989	53.492	29.270
Aire1	24.00	136.937		136.138	135.664	134.809	131.264	122.411	120.460	104.211	74.546
Ure	31.50	112.848	112.657	113.432	110.560	110.862	106.972	105.011	101.871	90.754	62.118
Dee2	42.80	102.486	102.600	101.337	100.553	95.012	93.758	88.806	78.251	63.457	33.680
Stour	50.00	107.546	108.522	107.988	106.226	105.976	106.387	98.435	102.230	91.726	65.794
Wansbeck	28.00	185.149		185.149	179.728	184.993	176.417	177.216	157.416	134.949	86.213
Dart	34.00	183.294		182.712	185.292	179.321	176.882	184.773	153.699	133.019	82.056
Torridge	28.40	215.664		214.994	209.942	212.948	193.992	186.673	156.321	144.961	92.225
Tamar1	33.26	202.475		203.692	205.469	197.754	201.375	181.291	180.165	166.723	86.758
Tamar2	32.24	288.282		289.373	281.767	265.679	252.900	266.888	246.939	235.783	154.500

Table F.2 cont Discharges calculated for reduced number of verticals (m^3s^{-1})

River Ref.	Width (m)	Number of verticals									
		Full	20	15	10	7	5	4	3	2	1
Ouse1	67.50	326.040	323.404	322.020	317.817	320.863	305.859	307.328	297.113	243.427	269.874
Ouse2	70.50	425.055	421.614	418.241	412.765	387.124	377.036	389.308	428.450	336.399	339.992
Swale1	93.50	237.902	234.901	201.637	220.659	212.153	219.697	159.198	151.902	153.678	36.602
Thame1	55.00	100.675	100.160	99.664	98.511	92.477	92.029	90.323	79.834	66.075	42.540
Don	24.00	49.096		48.929	48.792	47.159	49.112	43.468	39.872	40.855	24.948
Calder2	17.40	48.455		46.550	47.471	43.901	45.749	46.150	37.342	34.344	18.098
Aire2	18.00	43.416		43.104	43.238	42.660	41.635	40.227	36.829	34.340	20.058
Nadder	7.60	13.234		13.019	12.871	12.638	12.124	11.821	10.508	10.513	7.979
Exe	33.00	52.368		50.169	49.095	47.759	46.484	42.243	43.394	34.893	25.335
Ottery	22.20	39.071		38.623	38.675	38.557	37.633	37.569	35.491	28.798	20.422
Camel	11.15	23.292		23.292	22.290	22.929	21.611	20.337	19.415	17.380	8.658
Swale2	28.00	12.142		12.206	11.714	12.265	11.449	11.108	9.937	8.600	4.465
Arun	38.00	64.347	64.531	65.059	66.979	59.913	63.018	67.108	45.661	55.928	16.950
Yeo	18.85	47.112	47.016	47.804	46.492	48.078	42.074	41.164	39.621	39.744	26.721
Elwy	19.00	13.402		13.303	12.896	12.916	12.105	12.125	11.577	10.504	5.830
Thames2	37.00	66.281		66.667	64.021	64.174	61.000	61.279	58.009	51.431	39.543

Table F.3 Error in discharge produced for each gauging (%)

RIVER	Percentage error for number of verticals								
	20	15	10	7	5	4	3	2	1
Kennet	-	-	-	-8.730	-21.128	-11.219	-22.769	-29.545	-20.603
Brue	-	-	-	1.999	3.601	-8.542	-0.020	-13.729	-29.140
Derwent1	0.665	-2.462	-4.588	0.453	-9.695	-9.127	-15.821	-30.839	-52.419
Kent	-	-0.909	-5.985	-9.443	-10.410	-15.238	-21.374	-31.955	-55.972
Dee1	1.324	-1.867	2.474	-4.660	-3.100	-10.252	-17.374	-28.269	-67.517
Okement	-	0.415	-3.329	0.827	-3.402	-7.358	-11.965	-9.118	-50.629
Calder1	-1.504	-3.394	-3.289	-7.926	-7.177	-12.690	-16.345	-23.826	-47.457
Avon	-	0.036	0.024	-2.228	-6.696	-8.723	-14.701	-15.486	-53.755
Aire1	-	-0.583	-0.930	-1.554	-4.143	-10.608	-12.033	-23.899	-45.562
Ure	-0.169	0.518	-2.028	-1.760	-5.207	-6.945	-9.727	-19.579	-44.954
Dee2	0.111	-1.121	-1.886	-7.293	-8.516	-13.348	-23.647	-38.082	-67.137
Stour	0.908	0.411	-1.227	-1.460	-1.078	-8.472	-4.943	-14.710	-38.822
Wansbeck	-	0.000	-2.928	-0.084	-4.716	-4.285	-14.979	-27.113	-53.436
Dart	-	-0.318	1.090	-2.168	-3.498	0.807	-16.146	-27.429	-55.233
Torridge	-	-0.311	-2.653	-1.259	-10.049	-13.443	-27.516	-32.784	-57.237
Tamar1	-	0.601	1.479	-2.332	-0.543	-10.463	-11.019	-17.657	-57.151
Tamar2	-	0.378	-2.260	-7.841	-12.273	-7.421	-14.341	-18.211	-46.407

Table F.3 cont Error in discharge produced for each gauging (%)

RIVER	Percentage error for number of verticals								
	20	15	10	7	5	4	3	2	1
Ouse1	-0.808	-1.233	-2.522	-1.588	-6.190	-5.739	-8.872	-25.338	-17.227
Ouse2	-0.810	-1.603	-2.891	-8.924	-11.297	-8.410	0.799	-20.858	-20.012
Swale1	-1.261	-15.244	-7.248	-10.823	-7.652	-33.083	-36.149	-35.403	-84.615
Thame1	-0.512	-1.004	-2.149	-8.143	-8.588	-10.283	-20.701	-34.368	-57.745
Don	-	-0.340	-0.619	-3.945	0.033	-11.463	-18.788	-16.785	-49.185
Calder2	-	-3.931	-2.031	-9.398	-5.585	-4.757	-22.935	-29.122	-62.650
Aire2	-	-0.719	-0.410	-1.741	-4.102	-7.345	-15.172	-20.905	-53.800
Nadder	-	-1.625	-2.743	-4.504	-8.387	-10.677	-20.598	-20.561	-39.708
Exe	-	-4.199	-6.250	-8.801	-11.236	-19.334	-17.136	-33.370	-51.621
Ottery	-	-1.147	-1.014	-1.316	-3.680	-3.844	-9.163	-26.293	-47.731
Camel	-	0.000	-4.302	-1.558	-7.217	-12.687	-16.645	-25.382	-62.828
Yeo	-0.204	1.469	-1.316	2.050	-10.694	-12.625	-15.900	-15.639	-43.282
Elwy	-	-0.739	-3.776	-3.626	-9.678	-9.528	-13.617	-21.624	-56.499
Thames2	-	0.582	-3.410	-3.179	-7.968	-7.547	-12.480	-22.405	-40.340
Swale2	-	0.527	-3.525	1.013	-5.707	-8.516	-18.160	-29.171	-63.227

Table F.4 Error in discharge with reduced number of verticals (%)

Number of verticals	95% level	67% level
Twenty verticals	1.486	0.879
Fifteen verticals	4.012	1.214
Ten verticals	6.064	2.979
Seven verticals	9.434	4.579
Five verticals	12.099	8.169
Four verticals	18.515	10.641
Three verticals	28.735	17.751
Two verticals	35.043	29.351
One vertical	69.071	57.192

Table F.5 Error in discharge with reduced number of verticals by river width band (%)

Number of verticals	River width									
	0-10m		10-20m		20-30m		30-50m		>50m	
	95%ile	67%ile	95%ile	67%ile	95%ile	67%ile	95%ile	67%ile	95%ile	67%ile
20			0.194	0.137	1.499	1.428	0.783	0.249	1.171	0.809
15	1.609	1.522	1.250	0.719	2.882	1.413	2.506	0.715	12.516	1.485
10	4.912	1.541	4.118	2.926	5.050	2.888	6.104	2.685	6.159	2.651
7	10.466	6.242	7.253	3.626	7.706	4.158	9.090	7.039	10.348	8.416
5	18.341	8.067	11.117	9.678	10.158	6.751	11.703	8.171	10.620	7.980
4	17.332	11.078	12.662	9.528	13.564	10.505	17.081	9.366	27.383	9.551
3	22.612	19.010	20.419	15.900	30.082	17.932	26.074	16.513	32.287	19.629
2	29.950	28.914	31.516	25.382	32.910	30.355	35.490	24.263	35.355	34.663
1	61.845	52.036	66.807	62.650	65.993	57.110	70.070	55.506	79.853	60.483

APPENDIX G: REDUCTION IN EXPOSURE TIME (RAPIDLY VARYING FLOW)

Table G.1 Velocity in m/s recorded using current metering in the flume

Date	Depth (m)	Time of exposure in seconds						
		200	100	50	30	20	10	5
1/12/94	0.245	0.109	0.111	0.113	0.109	0.115	0.109	0.099
1/12/94	0.245	0.109	0.112	0.109	0.109	0.109	0.120	0.120
1/12/94	0.245	0.111	0.112	0.111	0.116	0.109	0.120	0.099
1/12/94	0.225	0.261	0.265	0.265	0.262	0.264	0.259	0.270
1/12/94	0.225	0.262	0.262	0.261	0.270	0.264	0.281	0.248
1/12/94	0.225	0.264	0.266	0.270	0.262	0.264	0.259	0.248
30/11/94	0.225	0.534	0.551	0.545	0.569	0.530	0.502	0.514
30/11/94	0.225	0.539	0.545	0.531	0.554	0.541	0.547	0.536
30/11/94	0.225	0.536	0.532	0.549	0.539	0.558	0.525	0.469
30/11/94	0.225	0.540	0.545	0.545	0.543	0.536	0.523	0.514
30/11/94	0.225	0.541	0.541	0.542	0.551	0.541	0.523	0.536
30/11/94	0.225	0.542	0.545	0.545	0.539	0.547	0.547	0.491
30/11/94	0.180	0.705	0.707	0.704	0.698	0.696	0.702	0.691
30/11/94	0.180	0.714	0.720	0.711	0.702	0.713	0.713	0.691
30/11/94	0.180	0.704	0.707	0.700	0.691	0.707	0.713	0.691
30/11/94	0.140	1.024	1.025	1.017	1.029	1.016	1.000	0.978
30/11/94	0.140	1.024	1.028	1.024	1.029	1.016	1.011	0.978
30/11/94	0.140	1.020	1.028	1.024	1.021	1.016	1.000	0.978
30/11/94	0.140	1.169	1.170	1.171	1.173	1.130	1.114	1.130
30/11/94	0.140	1.177	1.169	1.186	1.192	1.146	1.141	1.108
30/11/94	0.140	1.178	1.178	1.180	1.202	1.173	1.130	1.152
30/11/94	0.100	1.396	1.393	1.384	1.387	1.369	1.380	1.325
30/11/94	0.100	1.394	1.394	1.382	1.394	1.380	1.358	1.325
30/11/94	0.100	1.395	1.395	1.388	1.383	1.380	1.369	1.325
30/11/94	0.080	1.628	1.627	1.625	1.640	1.608	1.597	1.586
30/11/94	0.080	1.637	1.632	1.603	1.633	1.630	1.597	1.543
30/11/94	0.080	1.625	1.630	1.625	1.630	1.630	1.586	1.608

Table G.1 cont Velocity in m/s recorded using current metering in the flume

Date	Depth (m)	Time of exposure in seconds						
		200	100	50	30	20	10	5
30/11/94	0.080	1.840	1.842	1.832	1.836	1.809	1.792	1.738
30/11/94	0.080	1.847	1.844	1.834	1.829	1.820	1.771	1.738
30/11/94	0.080	1.940	1.930	1.921	1.916	1.912	1.868	1.825
30/11/94	0.080	1.935	1.923	1.921	1.916	1.912	1.879	1.847
30/11/94	0.080	1.926	1.934	1.925	1.912	1.928	1.868	1.847
30/11/94	0.080	1.835	1.840	1.832	1.840	1.803	1.782	1.760

Table G.2 Velocities calculated using varying exposure times for Shipston-on-Stour (m/s)

Reference	200 secs	100 secs	50 secs	10 secs	5 secs
Shipston1	0.554	0.638	0.602	0.549	0.644
Shipston2	0.603	0.602	0.554	0.549	0.644
Shipston3	0.600	0.596	0.628	0.501	0.598
Shipston4	0.454	0.450	0.448	0.428	0.501
Shipston5	0.449	0.450	0.448	0.452	0.452
Shipston6	0.446	0.438	0.457	0.501	0.404
Shipston7	0.204	0.165	0.177	0.138	0.162
Shipston8	0.189	0.179	0.186	0.186	0.162
Shipston9	0.188	0.174	0.181	0.186	0.259
Shipston10	0.454	0.455	0.462	0.428	0.501
Shipston11	0.445	0.438	0.467	0.428	0.501
Shipston12	0.446	0.433	0.433	0.477	0.452
Shipston13	0.327	0.339	0.336	0.380	0.356
Shipston14	0.324	0.331	0.351	0.380	0.356
Shipston15	0.330	0.344	0.341	0.356	0.452

Table G.3 Flows calculated using varying exposure times: Environment Agency field data (m^3/s)

Reference	Actual flow	100 secs	50 secs	10 secs	5 secs
Ward's Bridge	19.300	17.740	17.807	17.740	-
Besford	31.130	34.267	35.247	34.730	-
Llanyblodwell	255.177	256.734		285.694	-
Hookagate	68.555	79.733	77.592	77.787	-
Coleshill	26.852	28.785	29.320	30.070	-
Wingfield Park	36.500	34.475	40.850	43.779	-
Church Warsop	41.060	42.347	41.702	41.712	-
Thames1	4.765	5.006	4.936	4.694	-
Thames2	4.765	4.847	4.904	4.674	-

Table G.4 Percentage error with reduced exposure time for flume data

Date	Exposure time (seconds)					
	100	50	30	20	10	5
1/12/94	1.835	3.670	0.000	5.505	0.000	-9.174
1/12/94	2.752	0.000	0.000	0.000	10.092	10.092
1/12/94	0.901	0.000	4.505	-1.802	8.108	-10.811
1/12/94	1.533	1.533	0.383	1.149	-0.766	3.448
1/12/94	0.000	-0.382	3.053	0.763	7.252	-5.344
1/12/94	0.758	2.273	-0.758	0.000	-1.894	-6.061
30/11/94	3.184	2.060	6.554	-0.749	-5.993	-3.745
30/11/94	1.113	-1.484	2.783	0.371	1.484	-0.557
30/11/94	-0.746	2.425	0.560	4.104	-2.052	-12.500
30/11/94	0.926	0.926	0.556	-0.741	-3.148	-4.815
30/11/94	0.000	0.185	1.848	0.000	-3.327	-0.924
30/11/94	0.554	0.554	-0.554	0.923	0.923	-9.410
30/11/94	0.284	-0.142	-0.993	-1.277	-0.426	-1.986
30/11/94	0.840	-0.420	-1.681	-0.140	-0.140	-3.221
30/11/94	0.426	-0.568	-1.847	0.426	1.278	-1.847
30/11/94	0.098	-0.684	0.488	-0.781	-2.344	-4.492

Table G.4 cont **Percentage error with reduced exposure time for flume data**

Date	Exposure time (seconds)					
	100	50	30	20	10	5
30/11/94	-0.515	-0.979	-1.237	-1.443	-3.711	-5.928
30/11/94	-0.620	-0.724	-0.982	-1.189	-2.894	-4.548
30/11/94	0.415	-0.052	-0.727	0.104	-3.011	-4.102
30/11/94	0.272	-0.163	0.272	-1.744	-2.888	-4.087
30/11/94	0.391	0.000	0.488	-0.781	-1.270	-4.492
30/11/94	0.784	0.392	0.098	-0.392	-1.961	-4.118
30/11/94	0.086	0.171	0.342	-3.336	-4.705	-3.336
30/11/94	-0.680	0.765	1.274	-2.634	-3.059	-5.862
30/11/94	0.000	0.170	2.037	-0.424	-4.075	-2.207
30/11/94	-0.215	-0.860	-0.645	-1.934	-1.146	-5.086
30/11/94	0.000	-0.861	0.000	-1.004	-2.583	-4.950
0.0290135	0.000	-0.502	-0.860	-1.075	-1.864	-5.018
30/11/94	-0.061	-0.184	0.737	-1.229	-1.904	-2.580
30/11/94	-0.305	-2.077	-0.244	-0.428	-2.443	-5.742
30/11/94	0.308	0.000	0.308	0.308	-2.400	-1.046
30/11/94	0.109	-0.435	-0.217	-1.685	-2.609	-5.543
30/11/94	-0.162	-0.704	-0.975	-1.462	-4.115	-5.901

Table G.5 Error in velocity with reduced exposure time for Shipston-on-Stour (%)

Date	Exposure time (seconds)			
	100	50	10	5
Shipston1	15.234	8.583	-0.873	16.184
Shipston2	-0.218	-8.105	-8.908	6.767
Shipston3	-0.658	4.604	-16.568	-0.448
Shipston4	-0.800	-1.333	-5.599	10.398
Shipston5	0.270	-0.270	0.809	0.809
Shipston6	-1.897	2.439	12.193	-9.484
Shipston7	-19.520	-13.605	-32.534	-20.703
Shipston8	-5.126	-1.282	-1.282	-14.098
Shipston9	-7.094	-3.225	-0.645	38.051
Shipston10	0.267	1.866	-5.599	10.398
Shipston11	-1.630	4.891	-3.804	12.498
Shipston12	-2.981	-2.981	6.774	1.355
Shipston13	3.703	2.962	16.293	8.887
Shipston14	2.238	8.207	17.161	9.699
Shipston15	4.028	3.296	7.691	36.989

Table G.6 Error in flows with reduced exposure times: Environment Agency field data (%)

Date	Exposure time (seconds)			
	100	50	10	5
Ward's Bridge	-8.083	-7.736	-8.083	-
Besford	10.077	13.225	11.564	-
Llanyblodwell	0.610		11.959	-
Hookagate	16.305	13.182	13.467	-
Coleshill	7.199	9.191	11.984	-
Wingfield Park	-5.548	11.918	19.942	-
Church Warsop	3.134	1.564	1.588	-
Thames1	5.058	3.589	-1.490	-
Thames2	1.721	2.917	-1.910	-

Table G.7 Error in velocity with reduced exposure time for flume data (%)

Exposure time	95%ile error	67%ile error
100 secs	2.925	0.709
50 secs	2.923	0.860
30 secs	5.092	1.100
20 secs	4.316	1.250
10 secs	7.594	3.032
5 secs	10.379	5.432

Table G.8 Error in velocity with reduced exposure time for Shipston-on-Stour data (%)

Exposure time	95%ile error	67%ile error
100 secs	16.305	3.719
50 secs	9.838	4.618
10 secs	21.004	9.072
5 secs	37.785	12.578

APPENDIX H: LOCATION OF POINTS IN VERTICAL (RAPIDLY RISING STAGE)

Table H.1 Data used in points in vertical analysis

Region	River	Location	Discharge	Reference	No of verts
Yorkshire	Aire	Armley	67.277	Aire 1	14
Yorkshire	Aire	Kildwick	31.565	Aire 2	15
Yorkshire	Aire	Armley	108.885	Aire 3	15
Yorkshire	Aire	Kildwick	45.491	Aire 4	16
Welsh	Conwy	Conwy Hut	22.787	Conwy	17
Southern	Cuckmere	Arlington	10.203	Cuckmere	15
Yorkshire	Don	Doncaster	47.216	Don 1	16
Yorkshire	Don	Doncaster	51.324	Don 2	18
Welsh	Dyfi	Dyfi Hut	59.283	Dyfi	9
North West	Irt	Galeskye	5.658	Irt	21
Yorkshire	Ouse	Skelton	443.062	Ouse 1	31
Yorkshire	Ouse	Skelton	339.520	Ouse 2	23
Yorkshire	Ouse	Skelton	9.837	Ouse 3	20
Yorkshire	Rother	Whittington	17.645	Rother 1	11
Yorkshire	Rother	Whittington	17.498	Rother 2	9
Yorkshire	Rother	Whittington	31.449	Rother 3	11
South West	Sheppey	FennyCastle	-	Sheppey	16
Yorkshire	Swale	Catterick Bri	103.670	Swale 1	14
Yorkshire	Swale	Catterick Bri	174.137	Swale 2	13
Yorkshire	Ure	Kigram	51.442	Ure 1	13
Yorkshire	Ure	Kilgram Bri	94.359	Ure 2	10
Yorkshire	Ure	Kilgram Bri	159.613	Ure 3	16
Yorkshire	Wharfe	Ilkley	137.950	Wharfe	12

Table H.2 Mean velocities in ms^{-1} produced using methods outlined in Table 2.3

Reference	Method Number 1	2	3	4	5	6	8	9	10
Aire1 - A	0.265	0.279	0.266	0.265	0.263	0.265	0.260	0.253	0.263
Aire1 - B	0.352	0.361	0.352	0.352	0.351	0.352	0.354	0.345	0.353
Aire1 - C	0.835	0.837	0.794	0.814	0.776	0.807	0.768	0.745	0.780
Aire1 - D	0.949	0.974	0.953	0.951	0.923	0.951	0.954	0.955	0.966
Aire1 - E	1.110	1.123	1.121	1.115	1.078	1.117	1.085	1.065	1.097
Aire1 - F	1.464	1.418	1.448	1.456	1.394	1.453	1.439	1.420	1.437
Aire1 - G	1.614	1.519	1.561	1.588	1.510	1.579	1.583	1.565	1.568
Aire1 - H	1.447	1.456	1.557	1.502	1.462	1.520	1.514	1.509	1.520
Aire1 - I	1.472	1.442	1.431	1.452	1.392	1.445	1.451	1.445	1.454
Aire1 - J	1.338	1.328	1.409	1.374	1.323	1.385	1.363	1.353	1.370
Aire1 - K	1.595	1.465	1.520	1.558	1.468	1.545	1.517	1.478	1.496
Aire1 - L	1.349	1.345	1.442	1.396	1.344	1.411	1.379	1.363	1.383
Aire1 - M	1.091	1.009	0.878	0.984	0.896	0.949	0.869	0.817	0.876
Aire1 - N	0.320	0.317	0.396	0.358	0.357	0.370	0.352	0.335	0.346
Aire2 - A	0.134	0.152	0.152	0.143	0.150	0.146	0.152	0.151	0.153
Aire2 - B	0.127	0.155	0.202	0.164	0.189	0.177	0.202	0.203	0.194
Aire2 - C	0.645	0.596	0.604	0.624	0.591	0.617	0.613	0.599	0.604
Aire2 - D	0.953	0.891	0.865	0.909	0.848	0.894	0.866	0.845	0.865
Aire2 - E	1.064	1.034	0.965	1.015	0.959	0.998	0.981	0.966	0.988
Aire2 - F	1.021	1.011	0.959	0.990	0.945	0.979	0.976	0.970	0.984
Aire2 - G	1.013	1.035	1.010	1.012	0.979	1.011	1.003	1.000	1.017
Aire2 - H	0.886	0.974	1.013	0.950	0.943	0.971	0.976	0.995	1.003
Aire2 - I	1.054	1.056	1.089	1.072	1.036	1.077	1.055	1.041	1.062
Aire2 - J	1.082	1.032	1.045	1.064	1.016	1.057	1.054	1.039	1.047
Aire2 - K	1.085	1.042	0.998	1.041	0.975	1.027	1.005	0.994	1.013
Aire2 - L	1.023	0.993	0.841	0.932	0.856	0.902	0.854	0.834	0.876
Aire2 - M	0.712	0.682	0.635	0.673	0.625	0.660	0.599	0.564	0.607
Aire2 - N	0.421	0.318	0.351	0.386	0.347	0.374	0.350	0.316	0.326
Aire2 - O	0.087	0.077	0.137	0.112	0.120	0.120	0.149	0.157	0.137
Aire3 - A	0.609	0.634	0.561	0.585	0.572	0.577	0.581	0.576	0.590
Aire3 - B	0.897	0.882	0.851	0.874	0.842	0.866	0.860	0.843	0.860

Table H.2 cont Mean velocities in ms^{-1} produced using methods outlined in Table 2.3

Reference	Method Number								
	1	2	3	4	5	6	8	9	10
Aire3 - C	1.498	1.439	1.254	1.376	1.288	1.335	1.239	1.163	1.248
Aire3 - D	1.761	1.735	1.674	1.717	1.628	1.703	1.647	1.616	1.666
Aire3 - E	2.029	1.933	1.895	1.962	1.851	1.940	1.929	1.911	1.929
Aire3 - F	2.011	1.978	1.925	1.968	1.883	1.954	1.939	1.920	1.949
Aire3 - G	2.143	2.090	2.096	2.120	2.025	2.112	2.083	2.056	2.088
Aire3 - H	1.782	1.831	1.893	1.837	1.798	1.856	1.921	1.963	1.938
Aire3 - I	1.521	1.588	1.747	1.634	1.625	1.671	1.678	1.678	1.687
Aire3 - J	1.578	1.589	1.671	1.625	1.596	1.640	1.663	1.657	1.660
Aire3 - K	1.611	1.631	1.694	1.653	1.615	1.666	1.676	1.673	1.682
Aire3 - L	1.552	1.557	1.587	1.570	1.530	1.575	1.597	1.596	1.599
Aire3 - M	1.144	1.219	1.209	1.177	1.158	1.187	1.147	1.125	1.171
Aire3 - N	0.694	0.787	0.740	0.717	0.743	0.725	0.743	0.735	0.753
Aire3 - O	0.213	0.221	0.146	0.179	0.173	0.168	0.169	0.164	0.173
Aire4 - A	0.670	0.658	0.625	0.648	0.617	0.640	0.619	0.602	0.623
Aire4 - B	0.387	0.449	0.477	0.432	0.464	0.447	0.472	0.468	0.470
Aire4 - C	0.748	0.756	0.696	0.722	0.702	0.713	0.729	0.727	0.733
Aire4 - D	0.952	0.927	0.944	0.948	0.907	0.947	0.923	0.903	0.924
Aire4 - E	1.085	1.061	1.078	1.082	1.043	1.080	1.054	1.025	1.052
Aire4 - F	1.053	1.105	1.068	1.060	1.031	1.063	1.036	1.028	1.060
Aire4 - G	1.148	1.117	1.148	1.148	1.120	1.148	1.159	1.138	1.145
Aire4 - H	1.115	1.111	1.103	1.109	1.074	1.107	1.097	1.080	1.100
Aire4 - I	1.139	1.128	1.156	1.148	1.120	1.150	1.159	1.145	1.153
Aire4 - J	1.101	1.060	1.118	1.109	1.070	1.112	1.112	1.096	1.102
Aire4 - K	1.085	1.055	1.079	1.082	1.037	1.081	1.053	1.028	1.052
Aire4 - L	0.928	0.861	0.851	0.889	0.831	0.876	0.829	0.791	0.824
Aire4 - M	0.615	0.589	0.585	0.600	0.584	0.595	0.574	0.539	0.563
Aire4 - N	0.241	0.351	0.446	0.344	0.397	0.378	0.412	0.426	0.418
Aire4 - O	0.586	0.594	0.586	0.586	0.573	0.586	0.580	0.568	0.582
Aire4 - P	0.287	0.285	0.290	0.288	0.287	0.289	0.288	0.276	0.283
Aire4 - Q	0.211	0.219	0.200	0.206	0.203	0.204	0.201	0.195	0.203
Conwy - A	0.316	0.308	0.216	0.266	0.248	0.249	0.261	0.262	0.265

Table H.2 cont Mean velocities in ms^{-1} produced using methods outlined in Table 2.3

Reference	Method Number								
	1	2	3	4	5	6	8	9	10
Conwy - B	0.352	0.404	0.429	0.390	0.392	0.403	0.406	0.417	0.420
Conwy - C	0.429	0.416	0.411	0.420	0.407	0.417	0.427	0.424	0.423
Conwy - D	0.403	0.414	0.470	0.436	0.435	0.447	0.445	0.440	0.444
Conwy - E	0.454	0.451	0.500	0.477	0.470	0.485	0.485	0.479	0.481
Conwy - F	0.511	0.490	0.485	0.498	0.475	0.493	0.495	0.490	0.493
Conwy - G	0.454	0.463	0.500	0.477	0.469	0.485	0.485	0.484	0.487
Conwy - H	0.464	0.466	0.477	0.471	0.457	0.473	0.475	0.474	0.477
Conwy - I	0.449	0.441	0.411	0.430	0.410	0.423	0.427	0.427	0.430
Conwy - J	0.403	0.409	0.426	0.414	0.404	0.418	0.415	0.412	0.418
Conwy - K	0.393	0.409	0.362	0.377	0.362	0.372	0.375	0.379	0.385
Conwy - L	0.382	0.360	0.362	0.372	0.355	0.369	0.378	0.377	0.374
Conwy - M	0.346	0.338	0.331	0.339	0.327	0.336	0.342	0.340	0.340
Conwy - N	0.300	0.313	0.313	0.307	0.302	0.309	0.315	0.318	0.319
Conwy - O	0.290	0.298	0.264	0.277	0.263	0.273	0.277	0.282	0.284
Conwy - P	0.234	0.232	0.211	0.222	0.214	0.218	0.224	0.224	0.225
Conwy - Q	0.234	0.227	0.239	0.236	0.231	0.237	0.240	0.236	0.237
Cuckmere-D	0.353	0.355	0.355	0.354	0.340	0.355	0.354	0.355	0.358
Cuckmere-E	0.159	0.195	0.231	0.195	0.212	0.207	0.220	0.225	0.222
Cuckmere-F	0.429	0.412	0.393	0.411	0.391	0.405	0.394	0.381	0.393
Cuckmere-G	0.446	0.434	0.435	0.441	0.424	0.439	0.435	0.428	0.434
Cuckmere-H	0.450	0.436	0.440	0.445	0.429	0.443	0.437	0.425	0.434
Cuckmere-I	0.438	0.434	0.431	0.434	0.420	0.433	0.430	0.424	0.431
Cuckmere-J	0.421	0.416	0.425	0.423	0.408	0.424	0.421	0.418	0.422
Cuckmere-K	0.400	0.392	0.448	0.424	0.417	0.432	0.441	0.440	0.435
Cuckmere-L	0.433	0.428	0.427	0.430	0.417	0.429	0.425	0.416	0.424
Cuckmere-M	0.459	0.455	0.450	0.454	0.440	0.453	0.445	0.433	0.445
Cuckmere-N	0.471	0.469	0.459	0.465	0.450	0.463	0.449	0.435	0.450
Cuckmere-O	0.501	0.471	0.452	0.477	0.446	0.469	0.457	0.446	0.456
Cuckmere-P	0.425	0.414	0.393	0.409	0.383	0.404	0.395	0.393	0.401
Cuckmere-Q	0.227	0.234	0.273	0.250	0.251	0.258	0.266	0.268	0.264
Cuckmere-R	0.438	0.420	0.433	0.435	0.415	0.435	0.435	0.434	0.435

Table H.2 cont Mean velocities in ms^{-1} produced using methods outlined in Table 2.3

Reference	Method Number								
	1	2	3	4	5	6	8	9	10
Don1 - A	0.524	0.475	0.325	0.425	0.365	0.391	0.341	0.313	0.351
Don1 - B	0.675	0.702	0.659	0.667	0.657	0.664	0.670	0.665	0.677
Don1 - C	0.934	0.956	0.914	0.924	0.888	0.920	0.895	0.885	0.913
Don1 - D	1.142	1.128	1.087	1.114	1.065	1.105	1.096	1.086	1.104
Don1 - E	1.302	1.245	1.221	1.261	1.203	1.248	1.250	1.233	1.243
Don1 - F	1.198	1.217	1.204	1.201	1.176	1.202	1.219	1.214	1.223
Don1 - G	1.163	1.196	1.233	1.198	1.171	1.209	1.218	1.224	1.230
Don1 - H	1.134	1.159	1.100	1.117	1.087	1.111	1.105	1.092	1.117
Don1 - I	1.086	1.082	1.099	1.092	1.067	1.094	1.115	1.112	1.112
Don1 - J	1.052	1.049	1.093	1.072	1.039	1.079	1.065	1.053	1.069
Don1 - K	1.032	0.991	0.980	1.006	0.960	0.997	0.986	0.966	0.982
Don1 - L	0.968	0.975	1.018	0.993	0.962	1.001	0.957	0.931	0.965
Don1 - M	0.727	0.771	0.763	0.745	0.741	0.751	0.755	0.750	0.763
Don1 - N	0.670	0.648	0.616	0.643	0.613	0.634	0.630	0.619	0.630
Don1 - O	0.721	0.712	0.532	0.627	0.604	0.595	0.600	0.574	0.599
Don1 - P	0.588	0.550	0.510	0.549	0.509	0.536	0.532	0.527	0.533
Don2 - A	0.154	0.165	0.163	0.159	0.156	0.160	0.173	0.184	0.177
Don2 - B	0.537	0.556	0.564	0.550	0.547	0.555	0.541	0.522	0.542
Don2 - C	0.539	0.606	0.594	0.567	0.581	0.576	0.601	0.609	0.610
Don2 - D	0.841	0.823	0.844	0.842	0.816	0.843	0.834	0.817	0.830
Don2 - E	1.069	1.037	1.060	1.064	1.019	1.063	1.058	1.048	1.057
Don2 - F	1.319	1.278	1.212	1.265	1.207	1.247	1.245	1.227	1.244
Don2 - G	1.167	1.213	1.163	1.165	1.143	1.164	1.133	1.105	1.148
Don2 - H	1.169	1.186	1.190	1.180	1.151	1.183	1.166	1.146	1.172
Don2 - I	1.150	1.152	1.163	1.156	1.125	1.158	1.152	1.137	1.155
Don2 - J	1.104	1.095	1.146	1.125	1.095	1.132	1.124	1.108	1.122
Don2 - K	1.050	1.065	1.085	1.068	1.040	1.073	1.078	1.077	1.085
Don2 - L	1.047	1.048	1.049	1.048	1.012	1.048	1.042	1.035	1.049
Don2 - M	0.958	0.959	0.978	0.968	0.941	0.971	0.973	0.967	0.975
Don2 - N	0.773	0.792	0.825	0.799	0.788	0.807	0.806	0.797	0.808
Don2 - O	0.754	0.771	0.799	0.776	0.757	0.784	0.781	0.781	0.789

Table H.2 cont Mean velocities in ms^{-1} produced using methods outlined in Table 2.3

Reference	Method Number								
	1	2	3	4	5	6	8	9	10
Don2 - P	0.615	0.634	0.625	0.620	0.613	0.622	0.633	0.630	0.635
Don2 - Q	0.575	0.570	0.583	0.579	0.563	0.580	0.587	0.584	0.586
Don2 - R	0.053	0.192	0.248	0.150	0.198	0.183	0.202	0.229	0.227
Dyfi - A	0.152	0.128	0.110	0.131	0.122	0.124	0.125	0.117	0.119
Dyfi - B	0.582	0.557	0.385	0.484	0.441	0.451	0.435	0.417	0.443
Dyfi - C	0.885	0.859	0.787	0.836	0.775	0.820	0.784	0.771	0.799
Dyfi - D	1.044	1.002	0.967	1.005	0.942	0.993	0.965	0.951	0.973
Dyfi - E	1.070	1.032	1.072	1.071	1.037	1.071	1.064	1.040	1.054
Dyfi - F	1.085	1.105	1.118	1.102	1.082	1.107	1.109	1.098	1.113
Dyfi - G	1.100	1.093	1.049	1.075	1.023	1.066	1.050	1.043	1.063
Dyfi - H	0.423	0.438	0.505	0.464	0.459	0.478	0.464	0.458	0.467
Dyfi - I	0.259	0.264	0.254	0.257	0.248	0.256	0.245	0.238	0.249
Irt-A	0.252	0.247	0.299	0.275	0.295	0.283	0.284	0.257	0.265
Irt-B	0.556	0.571	0.514	0.535	0.511	0.528	0.533	0.540	0.546
Irt-C	0.603	0.591	0.477	0.540	0.526	0.519	0.543	0.531	0.537
Irt-D	0.624	0.647	0.653	0.638	0.630	0.643	0.667	0.677	0.671
Irt-E	0.577	0.581	0.705	0.641	0.652	0.662	0.683	0.675	0.667
Irt-F	0.671	0.669	0.629	0.650	0.642	0.643	0.665	0.655	0.658
Irt-G	0.671	0.679	0.715	0.693	0.693	0.701	0.720	0.713	0.712
Irt-H	0.676	0.661	0.697	0.687	0.677	0.690	0.708	0.700	0.697
Irt-I	0.702	0.734	0.745	0.723	0.715	0.730	0.743	0.748	0.751
Irt-J	0.760	0.762	0.731	0.746	0.730	0.741	0.765	0.764	0.764
Irt-K	0.739	0.744	0.745	0.742	0.727	0.743	0.752	0.746	0.751
Irt-L	0.755	0.768	0.755	0.755	0.738	0.755	0.775	0.780	0.779
Irt-M	0.770	0.752	0.776	0.773	0.759	0.774	0.780	0.762	0.769
Irt-N	0.729	0.750	0.737	0.733	0.721	0.734	0.762	0.771	0.766
Irt-O	0.692	0.719	0.690	0.691	0.679	0.690	0.711	0.718	0.719
Irt-P	0.729	0.727	0.726	0.727	0.704	0.727	0.723	0.715	0.725
Irt-Q	0.723	0.704	0.726	0.724	0.698	0.725	0.733	0.731	0.730
Irt-R	0.623	0.613	0.661	0.642	0.627	0.648	0.657	0.653	0.652
Irt-S	0.639	0.611	0.561	0.600	0.558	0.587	0.580	0.577	0.586

Table H.2 cont Mean velocities in ms^{-1} produced using methods outlined in Table 2.3

Reference	Method Number								
	1	2	3	4	5	6	8	9	10
Irt-T	0.545	0.516	0.430	0.488	0.439	0.468	0.443	0.433	0.453
Irt-U	0.346	0.370	0.330	0.338	0.323	0.336	0.335	0.344	0.350
Ouse1 - A	0.079	0.132	0.107	0.093	0.098	0.097	0.089	0.095	0.106
Ouse1 - B	0.060	0.082	0.213	0.136	0.161	0.162	0.166	0.163	0.157
Ouse1 - C	0.146	0.167	0.116	0.131	0.128	0.126	0.128	0.131	0.137
Ouse1 - D	0.164	0.184	0.292	0.228	0.254	0.249	0.275	0.278	0.263
Ouse1 - E	0.203	0.230	0.273	0.238	0.243	0.250	0.267	0.282	0.272
Ouse1 - F	0.345	0.330	0.360	0.352	0.342	0.355	0.380	0.390	0.375
Ouse1 - G	0.485	0.437	0.580	0.532	0.515	0.548	0.531	0.513	0.515
Ouse1 - H	0.767	0.714	0.830	0.799	0.755	0.809	0.777	0.761	0.771
Ouse1 - I	1.247	1.140	1.167	1.207	1.127	1.194	1.133	1.083	1.121
Ouse1 - J	1.508	1.448	1.401	1.455	1.379	1.437	1.412	1.384	1.412
Ouse1 - K	1.587	1.544	1.644	1.616	1.558	1.625	1.597	1.568	1.591
Ouse1 - L	1.430	1.502	1.517	1.473	1.441	1.488	1.482	1.489	1.510
Ouse1 - M	1.563	1.504	1.518	1.540	1.480	1.533	1.551	1.540	1.541
Ouse1 - N	1.561	1.517	1.491	1.526	1.461	1.514	1.519	1.505	1.518
Ouse1 - O	1.430	1.427	1.426	1.428	1.377	1.427	1.406	1.387	1.415
Ouse1 - P	1.435	1.400	1.413	1.424	1.350	1.420	1.347	1.307	1.358
Ouse1 - Q	1.349	1.388	1.215	1.282	1.220	1.260	1.217	1.200	1.252
Ouse1 - R	1.268	1.231	1.126	1.197	1.123	1.173	1.117	1.079	1.129
Ouse1 - S	1.043	1.110	1.035	1.039	1.002	1.038	0.970	0.945	1.005
Ouse1 - T	1.006	0.939	0.884	0.945	0.894	0.925	0.903	0.867	0.893
Ouse1 - U	0.847	0.833	0.755	0.801	0.770	0.786	0.800	0.793	0.800
Ouse1 - V	0.640	0.619	0.605	0.623	0.599	0.617	0.604	0.584	0.601
Ouse1 - W	0.508	0.502	0.546	0.527	0.513	0.533	0.525	0.515	0.523
Ouse1 - X	0.444	0.440	0.385	0.415	0.382	0.405	0.380	0.373	0.392
Ouse1 - Y	0.451	0.431	0.394	0.422	0.390	0.413	0.391	0.380	0.397
Ouse1 - Z	0.493	0.484	0.498	0.495	0.471	0.496	0.485	0.481	0.489
Ouse1 - AA	0.679	0.669	0.621	0.650	0.622	0.640	0.638	0.629	0.641
Ouse1 - AB	0.684	0.717	0.667	0.676	0.649	0.673	0.660	0.661	0.679
Ouse1 - AC	0.684	0.711	0.653	0.669	0.646	0.663	0.673	0.682	0.688

Table H.2 cont Mean velocities in ms^{-1} produced using methods outlined in Table 2.3

Reference	Method Number								
	1	2	3	4	5	6	8	9	10
Ouse1 - AD	0.400	0.423	0.375	0.388	0.378	0.383	0.388	0.390	0.397
Ouse1 - AE	0.102	0.131	0.131	0.116	0.126	0.121	0.128	0.131	0.132
Ouse2 - A	0.047	0.079	0.078	0.063	0.069	0.068	0.069	0.075	0.077
Ouse2 - B	0.122	0.131	0.112	0.117	0.117	0.115	0.135	0.144	0.136
Ouse2 - C	0.138	0.168	0.137	0.137	0.143	0.137	0.154	0.164	0.161
Ouse2 - D	0.376	0.390	0.335	0.356	0.336	0.349	0.323	0.312	0.335
Ouse2 - E	0.638	0.615	0.549	0.594	0.564	0.579	0.569	0.551	0.569
Ouse2 - F	0.924	0.947	0.718	0.821	0.771	0.786	0.794	0.800	0.821
Ouse2 - G	1.131	1.107	1.024	1.077	1.021	1.059	1.018	0.986	1.027
Ouse2 - H	1.108	1.143	1.024	1.066	1.029	1.052	1.049	1.045	1.070
Ouse2 - I	1.142	1.179	1.198	1.170	1.140	1.179	1.120	1.085	1.136
Ouse2 - J	1.178	1.214	1.198	1.188	1.151	1.191	1.181	1.180	1.201
Ouse2 - K	1.292	1.268	1.273	1.282	1.226	1.279	1.247	1.223	1.252
Ouse2 - L	1.219	1.224	1.165	1.192	1.137	1.183	1.149	1.133	1.168
Ouse2 - M	1.183	1.138	1.136	1.160	1.100	1.152	1.110	1.079	1.111
Ouse2 - N	1.035	1.051	0.976	1.005	0.952	0.995	0.962	0.954	0.987
Ouse2 - O	0.960	0.943	0.925	0.943	0.895	0.937	0.876	0.839	0.885
Ouse2 - P	0.693	0.697	0.531	0.612	0.578	0.585	0.558	0.533	0.571
Ouse2 - Q	0.467	0.496	0.574	0.520	0.520	0.538	0.514	0.502	0.519
Ouse2 - R	0.265	0.288	0.257	0.261	0.252	0.259	0.239	0.232	0.250
Ouse2 - S	0.223	0.195	0.201	0.212	0.206	0.208	0.222	0.216	0.211
Ouse2 - T	0.145	0.161	0.147	0.146	0.144	0.146	0.142	0.141	0.148
Ouse2 - U	0.158	0.136	0.174	0.166	0.170	0.169	0.178	0.168	0.164
Ouse2 - V	0.127	0.133	0.145	0.136	0.137	0.139	0.137	0.133	0.137
Ouse2 - W	0.062	0.072	0.064	0.063	0.065	0.063	0.065	0.065	0.067
Ouse3 - A	0.030	0.040	0.033	0.031	0.035	0.032	0.036	0.038	0.037
Ouse3 - B	0.051	0.048	0.035	0.043	0.043	0.040	0.045	0.044	0.043
Ouse3 - C	0.067	0.066	0.060	0.064	0.060	0.062	0.062	0.061	0.062
Ouse3 - D	0.081	0.075	0.078	0.079	0.076	0.079	0.079	0.076	0.077
Ouse3 - E	0.074	0.073	0.070	0.072	0.068	0.071	0.068	0.066	0.069
Ouse3 - F	0.079	0.079	0.075	0.077	0.075	0.076	0.073	0.069	0.073

Table H.2 cont Mean velocities in ms^{-1} produced using methods outlined in Table 2.3

Reference	Method Number							
	1	2	3	4	5	6	8	9	10

Reference	1	2	3	4	5	6	8	9	10
Ouse3 - G	0.076	0.080	0.075	0.075	0.074	0.075	0.073	0.072	0.074
Ouse3 - H	0.081	0.082	0.084	0.082	0.080	0.083	0.083	0.083	0.083
Ouse3 - I	0.083	0.083	0.083	0.083	0.080	0.083	0.082	0.081	0.083
Ouse3 - J	0.076	0.079	0.085	0.080	0.079	0.082	0.082	0.083	0.083
Ouse3 - K	0.090	0.086	0.086	0.088	0.084	0.087	0.089	0.088	0.088
Ouse3 - L	0.076	0.078	0.081	0.079	0.078	0.079	0.084	0.085	0.084
Ouse3 - M	0.083	0.083	0.087	0.085	0.083	0.086	0.087	0.087	0.087
Ouse3 - N	0.072	0.078	0.089	0.081	0.081	0.083	0.084	0.085	0.085
Ouse3 - O	0.088	0.085	0.080	0.084	0.080	0.083	0.083	0.083	0.084
Ouse3 - P	0.095	0.091	0.088	0.092	0.086	0.090	0.089	0.089	0.090
Ouse3 - Q	0.086	0.078	0.083	0.085	0.079	0.084	0.080	0.077	0.079
Ouse3 - R	0.090	0.080	0.081	0.086	0.079	0.084	0.082	0.080	0.081
Ouse3 - S	0.074	0.073	0.065	0.070	0.063	0.068	0.062	0.061	0.065
Ouse3 - T	0.049	0.040	0.021	0.035	0.025	0.030	0.029	0.031	0.031
Rother1 -A	0.135	0.111	0.154	0.144	0.130	0.147	0.130	0.123	0.127
Rother1 -B	0.413	0.362	0.233	0.323	0.280	0.293	0.264	0.238	0.265
Rother1 -C	0.854	0.840	0.869	0.862	0.845	0.864	0.851	0.821	0.842
Rother1 -D	0.956	0.930	0.951	0.954	0.922	0.953	0.888	0.831	0.883
Rother1 -E	1.356	1.348	1.261	1.309	1.254	1.293	1.291	1.282	1.302
Rother1 -F	1.412	1.429	1.356	1.384	1.340	1.375	1.358	1.336	1.371
Rother1 -G	1.453	1.486	1.410	1.432	1.393	1.424	1.381	1.341	1.396
Rother1 -H	1.571	1.550	1.441	1.506	1.437	1.484	1.444	1.407	1.455
Rother1 -I	1.397	1.420	1.287	1.342	1.275	1.323	1.228	1.176	1.259
Rother1 -J	1.279	1.238	1.184	1.232	1.162	1.216	1.135	1.080	1.143
Rother1 -K	0.854	0.840	0.744	0.799	0.761	0.780	0.744	0.708	0.748
Rother2 -A	0.618	0.564	0.401	0.510	0.444	0.473	0.416	0.382	0.427
Rother2 -B	0.827	0.803	0.719	0.773	0.734	0.755	0.756	0.744	0.758
Rother2 -C	0.871	0.915	0.895	0.883	0.873	0.887	0.857	0.830	0.868
Rother2 -D	1.183	1.169	1.119	1.151	1.113	1.140	1.120	1.087	1.120
Rother2 -E	1.395	1.380	1.420	1.408	1.360	1.412	1.402	1.389	1.405
Rother2 -F	1.207	1.240	1.346	1.276	1.267	1.299	1.306	1.297	1.306

Table H.2 cont Mean velocities in ms^{-1} produced using methods outlined in Table 2.3

Reference	Method Number								
	1	2	3	4	5	6	8	9	10
Rother2 -G	1.269	1.287	1.310	1.290	1.262	1.296	1.313	1.313	1.318
Rother2 -H	1.234	1.187	1.140	1.187	1.117	1.171	1.162	1.155	1.168
Rother2 -I	0.797	0.802	0.701	0.749	0.713	0.733	0.695	0.666	0.707
Rother3 -A	0.367	0.414	0.499	0.433	0.461	0.455	0.485	0.489	0.480
Rother3 -B	0.821	0.890	0.935	0.878	0.875	0.897	0.886	0.884	0.903
Rother3 -C	0.611	0.779	1.111	0.861	0.947	0.944	1.016	1.057	1.019
Rother3 -D	1.109	1.173	1.253	1.181	1.174	1.205	1.231	1.249	1.244
Rother3 -E	1.515	1.424	1.496	1.505	1.443	1.502	1.493	1.459	1.471
Rother3 -F	1.548	1.546	1.513	1.531	1.459	1.525	1.541	1.563	1.562
Rother3 -G	1.595	1.552	1.609	1.602	1.524	1.604	1.592	1.590	1.599
Rother3 -H	1.658	1.561	1.593	1.625	1.531	1.614	1.608	1.599	1.603
Rother3 -I	1.574	1.439	1.327	1.451	1.366	1.409	1.411	1.366	1.385
Rother3 -J	1.411	1.393	1.368	1.390	1.324	1.382	1.362	1.352	1.375
Rother3 -K	0.952	0.996	0.936	0.944	0.909	0.941	0.925	0.927	0.951
Sheppey-A	0.046	0.054	0.056	0.051	0.054	0.053	0.053	0.052	0.054
Sheppey-B	0.107	0.108	0.101	0.104	0.102	0.103	0.104	0.103	0.104
Sheppey-C	0.208	0.199	0.131	0.169	0.161	0.157	0.160	0.152	0.159
Sheppey-D	0.244	0.242	0.249	0.246	0.242	0.247	0.236	0.224	0.234
Sheppey-E	0.256	0.266	0.257	0.257	0.253	0.257	0.260	0.259	0.262
Sheppey-F	0.336	0.332	0.327	0.331	0.323	0.330	0.331	0.325	0.330
Sheppey-G	0.331	0.340	0.352	0.342	0.341	0.345	0.349	0.343	0.347
Sheppey-H	0.394	0.389	0.382	0.388	0.377	0.386	0.388	0.381	0.386
Sheppey-I	0.419	0.429	0.415	0.417	0.404	0.417	0.415	0.414	0.421
Sheppey-J	0.424	0.415	0.413	0.418	0.405	0.417	0.418	0.412	0.416
Sheppey-K	0.382	0.399	0.390	0.386	0.378	0.387	0.388	0.388	0.394
Sheppey-L	0.357	0.374	0.386	0.371	0.368	0.376	0.379	0.380	0.383
Sheppey-M	0.310	0.312	0.307	0.309	0.303	0.308	0.312	0.308	0.311
Sheppey-N	0.306	0.308	0.262	0.284	0.278	0.277	0.279	0.271	0.279
Sheppey-O	0.232	0.248	0.226	0.229	0.227	0.228	0.221	0.214	0.225
Sheppey-P	0.095	0.089	0.050	0.073	0.065	0.065	0.064	0.061	0.065
Swale1 - A	0.051	0.068	0.062	0.056	0.056	0.058	0.055	0.057	0.061

Table H.2 cont Mean velocities in ms^{-1} produced using methods outlined in Table 2.3

Reference	Method Number							
	1	2	3	4	5	6	8	9	10
Swale1 - B	0.083	0.118	0.171	0.127	0.153	0.141	0.178	0.191	0.173
Swale1 - C	0.674	0.628	0.560	0.617	0.575	0.598	0.562	0.528	0.560
Swale1 - D	1.427	1.503	1.367	1.397	1.336	1.387	1.325	1.311	1.373
Swale1 - E	1.940	1.918	2.007	1.974	1.937	1.985	2.007	1.982	1.990
Swale1 - F	2.074	2.029	2.042	2.058	1.994	2.053	2.071	2.048	2.060
Swale1 - G	1.927	1.912	1.943	1.935	1.888	1.938	1.955	1.935	1.948
Swale1 - H	1.994	1.948	2.070	2.032	1.974	2.045	2.033	1.999	2.019
Swale1 - I	1.948	1.943	1.949	1.948	1.888	1.948	1.954	1.941	1.959
Swale1 - J	1.498	1.449	1.381	1.439	1.343	1.420	1.339	1.299	1.358
Swale1 - K	0.539	0.542	0.583	0.561	0.541	0.568	0.561	0.562	0.567
Swale1 - L	0.335	0.339	0.322	0.329	0.316	0.326	0.301	0.284	0.306
Swale1 - M	0.152	0.173	0.152	0.152	0.156	0.152	0.156	0.155	0.159
Swale1 - N	0.030	0.062	0.067	0.048	0.059	0.054	0.059	0.064	0.065
Swale2 - A	0.280	0.263	0.252	0.266	0.254	0.261	0.251	0.237	0.247
Swale2 - B	0.348	0.362	0.334	0.341	0.330	0.338	0.327	0.321	0.335
Swale2 - C	0.493	0.519	0.486	0.489	0.478	0.488	0.482	0.478	0.492
Swale2 - D	1.232	1.261	1.194	1.213	1.160	1.206	1.187	1.188	1.214
Swale2 - E	2.236	2.196	2.105	2.171	2.050	2.149	2.134	2.136	2.160
Swale2 - F	2.957	2.840	2.849	2.903	2.754	2.885	2.869	2.848	2.870
Swale2 - G	2.669	2.757	2.812	2.741	2.687	2.764	2.801	2.819	2.828
Swale2 - H	2.856	2.867	2.848	2.852	2.775	2.850	2.899	2.901	2.907
Swale2 - I	2.610	2.556	2.574	2.592	2.514	2.586	2.613	2.587	2.600
Swale2 - J	2.771	2.696	2.645	2.708	2.577	2.687	2.683	2.671	2.693
Swale2 - K	1.941	1.878	1.749	1.845	1.719	1.813	1.702	1.644	1.728
Swale2 - L	0.698	0.684	0.535	0.616	0.570	0.589	0.538	0.503	0.551
Swale2 - M	0.094	0.120	0.116	0.105	0.111	0.108	0.113	0.117	0.118
Ure1 - A	0.047	0.055	0.034	0.041	0.036	0.038	0.037	0.040	0.042
Ure1 - B	0.134	0.117	0.168	0.151	0.156	0.157	0.170	0.166	0.158
Ure1 - C	0.212	0.191	0.244	0.228	0.231	0.233	0.238	0.226	0.224
Ure1 - D	0.369	0.379	0.373	0.371	0.358	0.372	0.358	0.353	0.365
Ure1 - E	0.619	0.615	0.626	0.622	0.607	0.623	0.609	0.591	0.608

Table H.2 cont   Mean velocities in ms^{-1} produced using methods outlined in Table 2.3

Reference	Method Number								
	1	2	3	4	5	6	8	9	10
Ure1 - F	0.624	0.652	0.664	0.644	0.643	0.650	0.647	0.632	0.648
Ure1 - G	0.768	0.787	0.804	0.786	0.775	0.792	0.801	0.798	0.804
Ure1 - H	0.809	0.833	0.885	0.847	0.846	0.860	0.874	0.867	0.871
Ure1 - I	0.898	0.898	0.858	0.878	0.850	0.871	0.869	0.856	0.872
Ure1 - J	0.687	0.642	0.602	0.645	0.606	0.630	0.637	0.630	0.632
Ure1 - K	0.478	0.444	0.398	0.438	0.396	0.424	0.375	0.348	0.381
Ure1 - L	0.280	0.298	0.260	0.270	0.249	0.266	0.230	0.220	0.246
Ure1 - M	0.086	0.103	0.117	0.101	0.102	0.106	0.106	0.111	0.112
Ure2 - A	0.395	0.420	0.375	0.385	0.362	0.382	0.364	0.367	0.383
Ure2 - B	1.022	1.006	0.903	0.963	0.899	0.943	0.917	0.909	0.935
Ure2 - C	1.188	1.249	1.216	1.202	1.174	1.206	1.189	1.182	1.213
Ure2 - D	1.328	1.398	1.435	1.381	1.373	1.399	1.423	1.429	1.436
Ure2 - E	1.391	1.428	1.419	1.405	1.362	1.410	1.396	1.392	1.417
Ure2 - F	1.378	1.286	1.137	1.257	1.143	1.217	1.157	1.128	1.172
Ure2 - G	0.952	0.904	0.838	0.895	0.829	0.876	0.850	0.837	0.858
Ure2 - H	0.589	0.551	0.460	0.524	0.469	0.503	0.461	0.442	0.472
Ure2 - I	0.078	0.069	0.069	0.074	0.074	0.072	0.082	0.081	0.077
Ure2 - J	0.000	0.018	0.021	0.011	0.017	0.014	0.017	0.021	0.021
Ure3 - A	0.059	0.075	0.088	0.073	0.081	0.078	0.085	0.087	0.085
Ure3 - B	0.069	0.081	0.109	0.089	0.093	0.095	0.090	0.088	0.091
Ure3 - C	0.322	0.253	0.329	0.325	0.284	0.326	0.287	0.270	0.281
Ure3 - D	0.740	0.622	0.514	0.627	0.534	0.589	0.538	0.510	0.538
Ure3 - E	1.087	1.021	0.835	0.961	0.866	0.919	0.854	0.820	0.872
Ure3 - F	1.056	1.055	1.098	1.077	1.043	1.084	1.057	1.037	1.061
Ure3 - G	1.487	1.365	1.385	1.436	1.350	1.419	1.397	1.362	1.378
Ure3 - H	1.758	1.736	1.466	1.612	1.501	1.563	1.546	1.544	1.581
Ure3 - I	1.941	1.936	1.761	1.851	1.769	1.821	1.780	1.742	1.800
Ure3 - J	1.763	1.670	1.599	1.681	1.605	1.654	1.665	1.633	1.647
Ure3 - K	1.458	1.348	1.403	1.431	1.349	1.421	1.404	1.378	1.389
Ure3 - L	1.173	1.106	1.009	1.091	1.006	1.063	1.013	0.983	1.022
Ure3 - M	0.902	0.853	0.768	0.835	0.765	0.813	0.804	0.807	0.816

Table H.2 cont   Mean velocities in ms^{-1} produced using methods outlined in Table 2.3

Reference	Method Number								
	1	2	3	4	5	6	8	9	10
Ure3 - N	0.745	0.683	0.581	0.663	0.600	0.635	0.609	0.590	0.613
Ure3 - O	0.596	0.481	0.493	0.544	0.495	0.527	0.502	0.464	0.477
Ure3 - P	0.327	0.259	0.270	0.299	0.267	0.289	0.271	0.250	0.258
Wharfe - A	0.928	0.905	0.835	0.881	0.828	0.866	0.834	0.815	0.844
Wharfe - B	1.857	1.851	1.730	1.793	1.709	1.772	1.713	1.673	1.736
Wharfe - C	2.465	2.428	2.391	2.428	2.335	2.415	2.371	2.321	2.377
Wharfe - D	2.048	2.053	2.075	2.061	2.005	2.066	2.035	1.997	2.041
Wharfe - E	1.799	1.752	1.689	1.744	1.671	1.726	1.688	1.640	1.687
Wharfe - F	1.881	1.865	1.936	1.908	1.859	1.917	1.875	1.825	1.871
Wharfe - G	1.842	1.867	1.910	1.876	1.842	1.887	1.885	1.861	1.887
Wharfe - H	1.933	1.939	1.979	1.956	1.917	1.963	1.952	1.913	1.948
Wharfe - I	2.053	2.100	2.053	2.053	2.010	2.053	2.042	2.014	2.056
Wharfe - J	1.938	1.992	1.919	1.929	1.899	1.925	1.910	1.868	1.919
Wharfe - K	2.149	2.212	2.204	2.176	2.130	2.185	2.174	2.157	2.196
Wharfe - L	2.225	2.187	2.104	2.164	2.069	2.144	2.070	2.007	2.080

Table H.3 Error in mean velocity using the methods outlined in Table 2.3 (%)

Reference	Method number							
	1	2	3	4	5	6	8	9
Aire1 - A	0.646	6.100	36.000	0.741	-0.076	0.772	-1.139	-3.785
Aire1 - B	-0.170	2.507	-0.170	-0.170	-0.525	-0.170	0.312	-2.203
Aire1 - C	7.079	7.351	1.757	4.418	-0.455	3.531	-1.577	-4.527
Aire1 - D	-1.790	0.789	-1.428	-1.609	-4.486	-1.549	-1.294	-1.135
Aire1 - E	1.176	2.335	2.133	1.654	-1.777	1.814	-1.085	-2.911
Aire1 - F	1.886	-1.287	0.738	1.312	-2.958	1.120	0.174	-1.188
Aire1 - G	2.953	-3.094	-0.427	1.263	-3.674	0.700	0.944	-0.172
Aire1 - H	-4.828	-4.215	2.407	-1.210	-3.858	-0.004	-0.434	-0.728
Aire1 - I	1.252	-0.817	-1.568	-0.158	-4.230	-0.628	-0.165	-0.582
Aire1 - J	-2.350	-3.103	2.832	0.241	-3.416	1.104	-0.496	-1.255
Aire1 - K	6.618	-2.043	1.604	4.111	-1.872	3.275	1.397	-1.214
Aire1 - L	-2.487	-2.779	4.236	0.875	-2.873	1.995	-0.318	-1.475
Aire1 - M	24.586	15.272	0.206	12.396	2.347	8.332	-0.742	-6.760
Aire1 - N	-7.514	-8.301	14.306	3.396	3.107	7.033	1.676	-3.276
Aire2 - A	-12.189	-0.288	-0.721	-6.455	-1.802	-4.543	-0.393	-1.048
Aire2 - B	-34.637	-20.453	3.706	-15.466	-2.522	-9.075	3.809	4.478
Aire2 - C	6.753	-1.410	-0.116	3.318	-2.218	2.174	1.490	-0.861
Aire2 - D	10.122	3.000	-0.104	5.009	-2.057	3.305	0.092	-2.396
Aire2 - E	7.703	4.658	-2.318	2.693	-2.890	1.022	-0.658	-2.234
Aire2 - F	3.718	2.690	-2.631	0.543	-3.987	-0.515	-0.863	-1.446
Aire2 - G	-0.432	1.765	-0.727	-0.580	-3.774	-0.629	-1.386	-1.759
Aire2 - H	-11.639	-2.822	1.027	-5.306	-5.969	-3.195	-2.643	-0.751
Aire2 - I	-0.781	-0.548	2.513	0.866	-2.457	1.415	-0.659	-2.036
Aire2 - J	3.333	-1.488	-0.201	1.566	-2.999	0.977	0.688	-0.805
Aire2 - K	7.097	2.813	-1.540	2.779	-3.761	1.339	-0.790	-1.852
Aire2 - L	16.821	13.409	-3.963	6.429	-2.290	2.965	-2.444	-4.724
Aire2 - M	17.279	12.351	4.513	10.896	2.981	8.768	-1.268	-7.182
Aire2 - N	29.181	-2.350	7.702	18.441	6.459	14.861	7.303	-3.140
Aire2 - O	-36.681	-44.105	-0.655	-18.668	-12.773	-12.664	8.079	14.144
Aire3 - A	3.255	7.508	-4.883	-0.814	-3.052	-2.170	-1.543	-2.368
Aire3 - B	4.351	2.634	-1.059	1.646	-2.053	0.745	-0.012	-1.951

Table H.3 cont **Error in mean velocity using the methods outlined in Table 2.3 (%)**

Reference	Method number							
	1	2	3	4	5	6	8	9
Aire3 - C	20.022	15.298	0.473	10.248	3.225	6.989	-0.713	-6.858
Aire3 - D	5.721	4.172	0.468	3.095	-2.236	2.219	-1.147	-2.994
Aire3 - E	5.211	0.231	-1.737	1.737	-4.006	0.579	0.000	-0.890
Aire3 - F	3.186	1.473	-1.226	0.980	-3.402	0.245	-0.487	-1.491
Aire3 - G	2.629	0.110	0.378	1.504	-3.039	1.129	-0.268	-1.553
Aire3 - H	-8.045	-5.531	-2.343	-5.194	-7.237	-4.243	-0.877	1.312
Aire3 - I	-9.824	-5.861	3.545	-3.139	-3.682	-0.911	-0.510	-0.536
Aire3 - J	-4.923	-4.243	0.681	-2.121	-3.820	-1.187	0.169	-0.143
Aire3 - K	-4.244	-3.053	0.689	-1.777	-4.033	-0.955	-0.404	-0.559
Aire3 - L	-2.951	-2.661	-0.763	-1.857	-4.337	-1.492	-0.156	-0.211
Aire3 - M	-2.289	4.093	3.263	0.487	-1.055	1.412	-2.058	-3.898
Aire3 - N	-7.835	4.542	-1.726	-4.781	-1.301	-3.763	-1.301	-2.390
Aire3 - O	22.908	27.409	-16.042	3.433	-0.462	-3.058	-2.424	-5.559
Aire4 - A	7.561	5.571	0.337	3.949	-0.971	2.745	-0.658	-3.436
Aire4 - B	-17.625	-4.470	1.533	-8.046	-1.149	-4.853	0.490	-0.348
Aire4 - C	2.074	3.166	-5.022	-1.474	-4.224	-2.656	-0.587	-0.814
Aire4 - D	3.041	0.323	2.176	2.609	-1.829	2.464	-0.108	-2.226
Aire4 - E	3.156	0.901	2.491	2.824	-0.865	2.713	0.200	-2.532
Aire4 - F	-0.698	4.247	0.670	-0.014	-2.801	0.214	-2.263	-3.087
Aire4 - G	0.236	-2.433	0.192	0.214	-2.205	0.207	1.170	-0.608
Aire4 - H	1.382	0.993	0.246	0.814	-2.305	0.624	-0.227	-1.815
Aire4 - I	-1.223	-2.218	0.252	-0.486	-2.875	-0.240	0.468	-0.702
Aire4 - J	-0.100	-3.835	1.397	0.649	-2.904	0.898	0.853	-0.523
Aire4 - K	3.127	0.234	2.509	2.818	-1.440	2.715	0.086	-2.307
Aire4 - L	12.594	4.421	3.191	7.893	0.880	6.325	0.607	-3.988
Aire4 - M	9.236	4.696	3.819	6.528	3.757	5.625	1.865	-4.292
Aire4 - N	-42.317	-15.902	6.750	-17.784	-4.871	-9.606	-1.436	1.883
Aire4 - O	0.722	2.056	0.636	0.679	-1.573	0.665	-0.378	-2.315
Aire4 - P	1.413	0.580	2.297	1.855	1.237	2.002	1.625	-2.356
Aire4 - Q	4.198	8.326	-1.235	1.481	0.272	0.576	-0.790	-3.868
Conwy - A	19.349	16.436	-18.392	0.478	-6.071	-5.812	-1.163	-0.965

Table H.3 cont Error in mean velocity using the methods outlined in Table 2.3 (%)

Reference	Method number							
	1	2	3	4	5	6	8	9
Conwy - B	-16.349	-3.883	1.952	-7.199	-6.623	-4.148	-3.416	-0.691
Conwy - C	1.211	-1.674	-3.028	-0.908	-3.970	-1.615	0.848	0.202
Conwy - D	-9.242	-6.773	5.776	-1.733	-1.939	0.770	0.347	-0.963
Conwy - E	-5.647	-6.352	3.942	-0.852	-2.374	0.746	0.852	-0.497
Conwy - F	3.536	-0.606	-1.664	0.936	-3.773	0.069	0.312	-0.624
Conwy - G	-6.740	-4.910	2.738	-2.001	-3.663	-0.421	-0.316	-0.597
Conwy - H	-2.582	-2.348	0.108	-1.237	-4.172	-0.789	-0.430	-0.610
Conwy - I	4.412	2.525	-4.531	-0.060	-4.744	-1.550	-0.596	-0.755
Conwy - J	-3.560	-2.114	1.964	-0.798	-3.226	0.123	-0.614	-1.309
Conwy - K	1.998	6.232	-5.995	-1.998	-5.899	-3.331	-2.665	-1.554
Conwy - L	2.333	-3.736	-3.157	-0.412	-4.911	-1.327	1.235	0.961
Conwy - M	1.808	-0.817	-2.712	-0.452	-3.960	-1.206	0.452	-0.201
Conwy - N	-5.792	-1.838	-1.770	-3.781	-5.354	-3.110	-1.126	-0.161
Conwy - O	1.983	4.828	-7.032	-2.524	-7.353	-4.027	-2.705	-0.721
Conwy - P	3.876	3.004	-6.384	-1.254	-4.738	-2.964	-0.228	-0.304
Conwy - Q	-1.300	-4.208	0.867	-0.217	-2.227	0.144	1.516	-0.217
Cuckmere-D	-1.412	-0.837	-0.824	-1.118	-5.165	-1.020	-1.294	-0.824
Cuckmere-E	-28.140	-11.849	4.183	-11.978	-4.449	-6.591	-0.570	1.331
Cuckmere-F	9.228	4.859	0.107	4.668	-0.472	3.148	0.215	-3.112
Cuckmere-G	2.719	0.008	0.291	1.505	-2.466	1.100	0.194	-1.489
Cuckmere-H	3.790	0.572	1.361	2.575	-1.011	2.171	0.680	-2.041
Cuckmere-I	1.566	0.791	0.098	0.832	-2.632	0.587	-0.294	-1.696
Cuckmere-J	-0.399	-1.509	0.599	0.100	-3.533	0.266	-0.299	-1.065
Cuckmere-K	-8.229	-10.041	2.904	-2.662	-4.201	-0.807	1.259	1.129
Cuckmere-L	2.187	0.962	0.696	1.441	-1.729	1.193	0.099	-1.955
Cuckmere-M	3.128	2.188	1.232	2.180	-0.986	1.864	0.000	-2.559
Cuckmere-N	4.682	4.090	1.873	3.277	0.010	2.809	-0.187	-3.433
Cuckmere-O	9.797	3.187	-0.832	4.483	-2.255	2.711	0.092	-2.218
Cuckmere-P	6.106	3.377	-1.790	2.158	-4.253	0.842	-1.368	-1.965
Cuckmere-Q	-14.196	-11.503	3.350	-5.423	-4.928	-2.499	0.638	1.489
Cuckmere-R	0.679	-3.348	-0.291	0.194	-4.549	0.032	0.194	-0.129

Table H.3 cont **Error in mean velocity using the methods outlined in Table 2.3 (%)**

Reference	Method number							
	1	2	3	4	5	6	8	9
Don1 - A	49.118	35.094	-7.513	20.803	3.913	11.364	-2.931	-11.070
Don1 - B	-0.281	3.744	-2.718	-1.499	-2.962	-1.906	-0.990	-1.783
Don1 - C	2.345	4.721	0.099	1.222	-2.712	0.847	-1.907	-3.061
Don1 - D	3.433	2.208	-1.594	0.919	-3.559	0.082	-0.752	-1.624
Don1 - E	4.713	0.100	-1.842	1.436	-3.245	0.343	0.547	-0.810
Don1 - F	-2.036	-0.460	-1.586	-1.811	-3.815	-1.736	-0.360	-0.701
Don1 - G	-5.447	-2.790	0.203	-2.622	-4.837	-1.680	-1.008	-0.488
Don1 - H	1.531	3.787	-1.513	0.009	-2.677	-0.498	-1.039	-2.200
Don1 - I	-2.347	-2.714	-1.223	-1.785	-4.078	-1.598	0.252	-0.039
Don1 - J	-1.553	-1.808	2.237	0.342	-2.770	0.973	-0.328	-1.507
Don1 - K	5.102	0.898	-0.244	2.429	-2.276	1.538	0.367	-1.619
Don1 - L	0.321	1.034	5.451	2.886	-0.342	3.741	-0.777	-3.565
Don1 - M	-4.768	1.043	-0.118	-2.443	-2.882	-1.668	-1.127	-1.712
Don1 - N	6.400	2.906	-2.176	2.112	-2.660	0.683	0.048	-1.673
Don1 - O	20.387	18.858	-11.170	4.608	0.793	-0.651	0.100	-4.213
Don1 - P	10.381	3.173	-4.261	3.060	-4.543	0.619	-0.225	-1.070
Don2 - A	-13.043	-7.036	-7.962	-10.503	-12.140	-9.656	-2.146	3.708
Don2 - B	-0.904	2.572	3.986	1.541	0.849	2.356	-0.258	-3.611
Don2 - C	-11.697	-0.682	-2.687	-7.192	-4.849	-5.690	-1.556	-0.257
Don2 - D	1.325	-0.877	1.627	1.476	-1.729	1.526	0.470	-1.627
Don2 - E	1.174	-1.874	0.274	0.724	-3.525	0.574	0.123	-0.830
Don2 - F	5.995	2.681	-2.644	1.676	-3.034	0.236	0.008	-1.438
Don2 - G	1.655	5.659	1.307	1.481	-0.479	1.423	-1.280	-3.789
Don2 - H	-0.290	1.167	1.501	0.606	-1.834	0.904	-0.571	-2.294
Don2 - I	-0.390	-0.217	0.693	0.152	-2.568	0.332	-0.225	-1.545
Don2 - J	-1.596	-2.408	2.148	0.276	-2.398	0.900	0.196	-1.269
Don2 - K	-3.208	-1.814	0.018	-1.595	-4.153	-1.057	-0.673	-0.765
Don2 - L	-0.172	-0.046	-0.029	-0.100	-3.533	-0.076	-0.677	-1.363
Don2 - M	-1.774	-1.716	0.226	-0.774	-3.486	-0.441	-0.195	-0.868
Don2 - N	-4.320	-2.027	2.055	-1.133	-2.482	-0.070	-0.260	-1.370
Don2 - O	-4.400	-2.259	1.243	-1.579	-4.038	-0.638	-0.938	-1.019

Table H.3 cont Error in mean velocity using the methods outlined in Table 2.3 (%)

Reference	Method number 1	2	3	4	5	6	8	9
Don2 - P	-3.150	-0.220	-1.575	-2.362	-3.472	-2.100	-0.346	-0.787
Don2 - Q	-1.877	-2.689	-0.512	-1.195	-3.951	-0.967	0.137	-0.284
Don2 - R	-76.662	-15.456	8.983	-33.840	-12.946	-19.566	-11.185	0.983
Dyfi - A	27.753	8.122	-7.698	10.028	2.992	4.119	5.618	-1.643
Dyfi - B	31.496	25.680	-13.085	9.206	-0.496	1.776	-1.853	-5.944
Dyfi - C	10.715	7.518	-1.476	4.620	-3.033	2.588	-1.925	-3.507
Dyfi - D	7.329	3.036	-0.580	3.374	-3.178	2.056	-0.791	-2.250
Dyfi - E	1.509	-2.084	1.752	1.630	-1.620	1.671	1.022	-1.249
Dyfi - F	-2.489	-0.637	0.507	-0.991	-2.755	-0.492	-0.323	-1.337
Dyfi - G	3.472	2.806	-1.350	1.061	-3.823	0.257	-1.254	-1.913
Dyfi - H	-9.335	-6.109	8.236	-0.549	-1.788	2.379	-0.659	-2.013
Dyfi - I	4.333	6.103	2.270	3.302	-0.367	2.958	-1.444	-4.265
Irt-A	-5.092	-7.006	12.599	3.753	11.139	6.702	7.303	-3.156
Irt-B	1.850	4.674	-5.868	-2.009	-6.238	-3.295	-2.299	-1.056
Irt-C	12.201	10.053	-11.215	0.493	-2.040	-3.410	1.076	-1.141
Irt-D	-7.058	-3.698	-2.814	-4.936	-6.187	-4.229	-0.685	0.833
Irt-E	-13.532	-12.891	5.650	-3.941	-2.263	-0.744	2.293	1.204
Irt-F	1.932	1.647	-4.448	-1.258	-2.526	-2.321	0.972	-0.478
Irt-G	-5.793	-4.642	0.448	-2.672	-2.750	-1.632	1.039	0.073
Irt-H	-3.017	-5.106	0.039	-1.489	-2.831	-0.980	1.592	0.371
Irt-I	-6.466	-2.149	-0.803	-3.635	-4.734	-2.691	-0.973	-0.375
Irt-J	-0.471	-0.178	-4.269	-2.370	-4.361	-3.003	0.210	0.096
Irt-K	-1.659	-0.930	-0.928	-1.293	-3.276	-1.171	0.013	-0.757
Irt-L	-3.056	-1.448	-3.120	-3.088	-5.220	-3.099	-0.475	0.154
Irt-M	0.101	-2.237	0.816	0.459	-1.368	0.578	1.425	-0.884
Irt-N	-4.868	-2.158	-3.889	-4.378	-5.866	-4.215	-0.535	0.657
Irt-O	-3.721	0.116	-4.055	-3.888	-5.527	-3.943	-1.087	-0.078
Irt-P	0.439	0.220	0.081	0.260	-2.913	0.200	-0.350	-1.492
Irt-Q	-0.979	-3.580	-0.678	-0.829	-4.389	-0.778	0.360	0.080
Irt-R	-4.439	-5.905	1.313	-1.563	-3.787	-0.604	0.721	0.224
Irt-S	9.100	4.326	-4.303	2.399	-4.798	0.165	-0.990	-1.457

Table H.3 cont **Error in mean velocity using the methods outlined in Table 2.3 (%)**

Reference	Method number 1	2	3	4	5	6	8	9
Irt-T	20.203	13.701	-5.161	7.521	-3.154	3.294	-2.404	-4.426
Irt-U	-1.084	5.817	-5.531	-3.307	-7.562	-4.048	-4.064	-1.565
Ousel - A	-25.260	24.428	0.757	-12.252	-7.474	-7.915	-16.272	-10.123
Ousel - B	-61.783	-48.025	35.350	-13.217	2.548	2.972	5.414	3.503
Ousel - C	6.803	21.843	-15.143	-4.170	-6.657	-7.827	-6.145	-3.926
Ousel - D	-37.690	-30.152	10.942	-13.374	-3.666	-5.268	4.369	5.433
Ousel - E	-25.258	-15.346	0.515	-12.371	-10.530	-8.076	-1.657	3.768
Ousel - F	-7.951	-11.889	-4.082	-6.017	-8.738	-5.372	1.361	4.100
Ousel - G	-5.770	-15.135	12.590	3.410	-0.019	6.470	3.186	-0.330
Ousel - H	-0.570	-7.472	7.597	3.513	-2.178	4.874	0.739	-1.327
Ousel - I	11.240	1.738	4.103	7.672	0.531	6.482	1.053	-3.360
Ousel - J	6.769	2.498	-0.807	2.981	-2.358	1.718	0.000	-1.987
Ousel - K	-0.251	-2.974	3.331	1.540	-2.071	2.137	0.390	-1.467
Ousel - L	-5.285	-0.522	0.444	-2.421	-4.554	-1.466	-1.828	-1.356
Ousel - M	1.441	-2.368	-1.512	-0.036	-3.930	-0.528	0.681	-0.063
Ousel - N	2.867	-0.015	-1.746	0.560	-3.713	-0.209	0.066	-0.802
Ousel - O	1.074	0.831	0.792	0.933	-2.679	0.886	-0.622	-1.941
Ousel - P	5.647	3.082	4.027	4.837	-0.644	4.567	-0.825	-3.801
Ousel - Q	7.722	10.811	-2.979	2.372	-2.583	0.588	-2.795	-4.150
Ousel - R	12.322	9.019	-0.301	6.010	-0.509	3.906	-1.098	-4.420
Ousel - S	3.750	10.439	2.954	3.352	-0.313	3.220	-3.501	-5.998
Ousel - T	12.704	5.239	-0.963	5.870	0.151	3.593	1.176	-2.887
Ousel - U	5.822	4.048	-5.672	0.075	-3.811	-1.841	-0.087	-0.904
Ousel - V	6.578	3.114	0.749	3.664	-0.192	2.692	0.649	-2.720
Ousel - W	-2.831	-4.055	4.342	0.756	-1.808	1.951	0.421	-1.428
Ousel - X	13.208	12.106	-1.836	5.686	-2.575	3.179	-3.162	-4.980
Ousel - Y	13.717	8.563	-0.782	6.467	-1.639	4.051	-1.362	-4.102
Ousel - Z	0.818	-0.957	1.738	1.278	-3.701	1.431	-0.900	-1.636
Ousel - AA	5.978	4.436	-3.153	1.413	-2.856	-0.109	-0.437	-1.878
Ousel - AB	0.677	5.552	-1.825	-0.574	-4.416	-0.991	-2.914	-2.708
Ousel - AC	-0.552	3.425	-5.060	-2.806	-6.034	-3.557	-2.152	-0.892

Table H.3 cont **Error in mean velocity using the methods outlined in Table 2.3 (%)**

Reference	Method number 1	2	3	4	5	6	8	9
Ouse1 - AD	0.654	6.532	-5.637	-2.491	-4.806	-3.540	-2.315	-1.778
Ouse1 - AE	-22.610	-0.941	-0.986	-11.798	-4.173	-8.194	-2.656	-0.733
Ouse2 - A	-39.119	1.969	1.036	-19.041	-10.039	-12.349	-10.104	-2.418
Ouse2 - B	-10.360	-3.718	-17.708	-14.034	-13.887	-15.258	-1.176	5.805
Ouse2 - C	-14.126	4.841	-15.059	-14.592	-10.952	-14.748	-4.045	1.950
Ouse2 - D	12.205	16.312	-0.030	6.088	0.254	4.049	-3.730	-7.043
Ouse2 - E	12.225	8.243	-3.430	4.398	-0.712	1.788	0.123	-3.108
Ouse2 - F	12.559	15.308	-12.596	-0.018	-6.121	-4.211	-3.338	-2.505
Ouse2 - G	10.159	7.809	-0.312	4.924	-0.584	3.178	-0.857	-3.997
Ouse2 - H	3.580	6.886	-4.319	-0.369	-3.809	-1.686	-1.944	-2.340
Ouse2 - I	0.510	3.799	5.395	2.953	0.356	3.767	-1.426	-4.506
Ouse2 - J	-1.891	1.141	-0.267	-1.079	-4.135	-0.808	-1.666	-1.696
Ouse2 - K	3.170	1.228	1.613	2.392	-2.084	2.132	-0.455	-2.353
Ouse2 - L	4.375	4.803	-0.248	2.064	-2.680	1.293	-1.601	-2.974
Ouse2 - M	6.442	2.401	2.213	4.328	-1.035	3.623	-0.117	-2.960
Ouse2 - N	4.916	6.559	-1.115	1.901	-3.467	0.895	-2.514	-3.294
Ouse2 - O	8.499	6.546	4.543	6.521	1.096	5.862	-0.995	-5.176
Ouse2 - P	21.345	22.122	-7.109	7.118	1.182	2.376	-2.259	-6.701
Ouse2 - Q	-10.037	-4.481	10.480	0.222	0.087	3.641	-0.905	-3.326
Ouse2 - R	5.873	15.062	2.477	4.175	0.679	3.609	-4.395	-7.444
Ouse2 - S	5.938	-7.192	-4.513	0.713	-2.162	-1.029	5.321	2.613
Ouse2 - T	-1.762	8.943	-0.745	-1.253	-2.710	-1.084	-3.794	-4.246
Ouse2 - U	-3.482	-17.019	6.292	1.405	3.543	3.034	8.674	2.423
Ouse2 - V	-6.960	-2.242	5.861	-0.549	0.293	1.587	0.147	-2.564
Ouse2 - W	-7.463	7.463	-4.478	-5.970	-3.433	-5.473	-2.985	-2.488
Ouse3 - A	-19.571	6.810	-12.869	-16.220	-6.166	-15.103	-2.949	0.536
Ouse3 - B	18.329	11.369	-18.794	-0.232	0.464	-6.419	5.336	0.928
Ouse3 - C	7.544	5.554	-3.692	1.926	-3.451	0.054	-0.963	-2.087
Ouse3 - D	5.332	-2.003	0.780	3.056	-0.845	2.297	2.211	-0.954
Ouse3 - E	7.872	7.055	1.312	4.592	-0.364	3.499	-1.166	-4.276
Ouse3 - F	8.516	8.791	2.335	5.426	2.885	4.396	-0.000	-5.220

Table H.3 cont Error in mean velocity using the methods outlined in Table 2.3 (%)

Reference	Method number							
	1	2	3	4	5	6	8	9
Ouse3 - G	2.151	7.097	0.134	1.142	-0.538	0.806	-1.478	-3.898
Ouse3 - H	-2.878	-1.583	0.120	-1.379	-3.717	-0.879	-0.480	-0.879
Ouse3 - I	0.484	0.533	-0.121	0.182	-3.027	0.081	-0.484	-1.533
Ouse3 - J	-8.213	-4.928	2.053	-3.080	-4.589	-1.369	-0.845	-0.362
Ouse3 - K	2.273	-1.818	-2.841	-0.284	-4.205	-1.136	0.795	0.189
Ouse3 - L	-8.982	-6.874	-2.994	-5.988	-6.766	-4.990	0.120	1.996
Ouse3 - M	-4.598	-4.552	0.000	-2.299	-4.138	-1.533	0.345	0.192
Ouse3 - N	-15.094	-8.302	4.953	-5.071	-4.009	-1.730	-0.708	-0.157
Ouse3 - O	5.263	2.201	-4.306	0.478	-4.426	-1.116	-0.239	-0.718
Ouse3 - P	5.909	1.672	-1.895	2.007	-4.125	0.706	-0.557	-1.338
Ouse3 - Q	8.861	-1.570	5.063	6.962	-0.380	6.329	1.266	-2.532
Ouse3 - R	11.524	-1.264	0.372	5.948	-1.673	4.089	2.107	-1.074
Ouse3 - S	14.374	13.509	0.464	7.419	-2.009	5.100	-4.019	-6.234
Ouse3 - T	57.051	29.231	-32.692	12.179	-19.231	-2.778	-6.731	-0.641
Rother1 -A	5.965	-12.967	20.487	13.226	2.276	15.646	2.355	-3.715
Rother1 -B	56.026	36.728	-12.165	21.930	5.742	10.565	-0.151	-10.087
Rother1 -C	1.485	-0.235	3.268	2.377	0.404	2.674	1.093	-2.397
Rother1 -D	8.316	5.398	7.750	8.033	4.453	7.939	0.634	-5.846
Rother1 -E	4.147	3.558	-3.149	0.499	-3.706	-0.717	-0.822	-1.575
Rother1 -F	3.006	4.278	-1.080	0.963	-2.218	0.282	-0.934	-2.514
Rother1 -G	4.083	6.453	1.003	2.543	-0.233	2.030	-1.103	-3.964
Rother1 -H	7.980	6.531	-0.990	3.495	-1.213	2.000	-0.735	-3.327
Rother1 -I	10.970	12.784	2.192	6.581	1.271	5.118	-2.447	-6.559
Rother1 -J	11.928	8.333	3.614	7.771	1.702	6.385	-0.683	-5.487
Rother1 -K	14.110	12.175	-0.655	6.728	1.744	4.267	-0.615	-5.398
Rother2 -A	44.900	32.127	-5.979	19.461	4.021	10.981	-2.556	-10.551
Rother2 -B	9.175	6.012	-5.149	2.013	-3.069	-0.374	-0.251	-1.760
Rother2 -C	0.380	5.493	3.146	1.763	0.582	2.224	-1.245	-4.345
Rother2 -D	5.672	4.447	-0.045	2.814	-0.581	1.861	0.009	-2.918
Rother2 -E	-0.683	-1.751	1.096	0.206	-3.211	0.503	-0.178	-1.146
Rother2 -F	-7.545	-5.029	3.064	-2.241	-2.968	-0.472	0.008	-0.664

Table H.3 cont **Error in mean velocity using the methods outlined in Table 2.3 (%)**

Reference	Method number							
	1	2	3	4	5	6	8	9
Rother2 -G	-3.703	-2.346	-0.592	-2.148	-4.219	-1.629	-0.341	-0.377
Rother2 -H	5.624	1.604	-2.465	1.579	-4.357	0.231	-0.522	-1.124
Rother2 -I	12.730	13.380	-0.849	5.941	0.898	3.678	-1.754	-5.752
Rother3 -A	-23.462	-13.610	3.962	-9.750	-3.848	-5.179	1.105	2.016
Rother3 -B	-9.051	-1.363	3.523	-2.764	-3.041	-0.668	-1.872	-2.090
Rother3 -C	-40.016	-23.566	9.071	-15.472	-7.073	-7.291	-0.255	3.770
Rother3 -D	-10.866	-5.713	0.707	-5.080	-5.654	-3.151	-1.045	0.359
Rother3 -E	2.998	-3.178	1.672	2.335	-1.887	2.114	1.475	-0.843
Rother3 -F	-0.909	-1.032	-3.149	-2.029	-6.609	-2.403	-1.351	0.019
Rother3 -G	-0.256	-2.925	0.588	0.166	-4.671	0.306	-0.450	-0.569
Rother3 -H	3.418	-2.605	-0.667	1.375	-4.507	0.694	0.312	-0.262
Rother3 -I	13.654	3.909	-4.181	4.737	-1.368	1.764	1.885	-1.353
Rother3 -J	2.611	1.299	-0.516	1.047	-3.745	0.526	-0.938	-1.668
Rother3 -K	0.105	4.782	-1.630	-0.762	-4.395	-1.052	-2.702	-2.506
Sheppey-A	-13.632	1.000	5.115	-4.258	1.580	-1.134	-0.765	-3.441
Sheppey-B	2.286	3.803	-3.461	-0.587	-2.211	-1.545	-0.010	-1.556
Sheppey-C	30.873	25.638	-17.464	6.704	1.304	-1.352	0.762	-4.470
Sheppey-D	4.142	3.294	6.084	5.113	3.067	5.437	0.725	-4.561
Sheppey-E	-2.193	1.478	-1.849	-2.021	-3.340	-1.964	-0.778	-1.286
Sheppey-F	1.728	0.716	-0.804	0.462	-2.145	0.040	0.379	-1.370
Sheppey-G	-4.615	-2.046	1.431	-1.592	-1.831	-0.584	0.360	-1.156
Sheppey-H	2.140	0.667	-1.111	0.515	-2.307	-0.027	0.435	-1.250
Sheppey-I	-0.344	1.897	-1.331	-0.837	-4.024	-1.002	-1.397	-1.604
Sheppey-J	1.765	-0.369	-0.746	0.509	-2.611	0.091	0.505	-1.012
Sheppey-K	-3.110	1.190	-0.990	-2.050	-4.020	-1.697	-1.490	-1.472
Sheppey-L	-6.921	-2.235	0.742	-3.090	-3.964	-1.813	-0.984	-0.860
Sheppey-M	-0.364	0.182	-1.487	-0.926	-2.671	-1.113	0.270	-0.956
Sheppey-N	9.613	10.282	-6.143	1.735	-0.587	-0.891	0.000	-2.911
Sheppey-O	2.901	10.089	0.417	1.659	0.605	1.245	-1.983	-5.031
Sheppey-P	45.032	36.291	-22.966	11.033	0.083	-0.300	-1.241	-6.334
Swale1 - A	-16.118	11.316	1.151	-7.484	-7.730	-4.605	-10.197	-5.702

Table H.3 cont Error in mean velocity using the methods outlined in Table 2.3 (%)

Reference	Method number							
	1	2	3	4	5	6	8	9
Swale1 - B	-52.134	-32.180	-1.672	-26.903	-11.995	-18.493	2.422	10.342
Swale1 - C	20.422	12.260	-0.036	10.193	2.698	6.783	0.411	-5.634
Swale1 - D	3.925	9.452	-0.444	1.741	-2.713	1.012	-3.539	-4.523
Swale1 - E	-2.517	-3.619	0.849	-0.834	-2.686	-0.273	0.849	-0.415
Swale1 - F	0.685	-1.479	-0.869	-0.092	-3.182	-0.351	0.519	-0.586
Swale1 - G	-1.073	-1.851	-0.252	-0.662	-3.083	-0.525	0.359	-0.662
Swale1 - H	-1.233	-3.520	2.531	0.649	-2.217	1.276	0.688	-1.010
Swale1 - I	-0.577	-0.830	-0.551	-0.564	-3.621	-0.560	-0.276	-0.917
Swale1 - J	10.350	6.749	1.694	6.022	-1.053	4.580	-1.378	-4.297
Swale1 - K	-4.905	-4.305	2.858	-1.023	-4.614	0.271	-1.059	-0.847
Swale1 - L	9.620	10.890	5.366	7.493	3.387	6.784	-1.440	-6.959
Swale1 - M	-4.403	8.679	-4.717	-4.560	-2.075	-4.612	-2.201	-2.830
Swale1 - N	-53.560	-3.406	2.941	-25.310	-9.056	-15.893	-9.288	-1.187
Swale2 - A	13.177	6.128	1.859	7.518	2.526	5.632	1.496	-4.136
Swale2 - B	3.974	8.276	-0.359	1.808	-1.554	1.086	-2.301	-4.143
Swale2 - C	0.203	5.561	-1.321	-0.559	-2.795	-0.813	-2.053	-2.879
Swale2 - D	1.474	3.899	-1.697	-0.111	-4.444	-0.640	-2.207	-2.177
Swale2 - E	3.514	1.684	-2.551	0.481	-5.090	-0.529	-1.227	-1.123
Swale2 - F	3.021	-1.050	-0.760	1.131	-4.057	0.501	-0.045	-0.771
Swale2 - G	-5.632	-2.534	-0.576	-3.104	-5.001	-2.262	-0.983	-0.317
Swale2 - H	-1.761	-1.398	-2.054	-1.907	-4.554	-1.956	-0.279	-0.219
Swale2 - I	0.404	-1.655	-1.000	-0.298	-3.299	-0.532	0.531	-0.481
Swale2 - J	2.893	0.114	-1.805	0.544	-4.317	-0.239	-0.368	-0.827
Swale2 - K	12.352	8.720	1.210	6.781	-0.486	4.924	-1.459	-4.820
Swale2 - L	26.656	24.115	-3.012	11.822	3.502	6.877	-2.377	-8.758
Swale2 - M	-20.474	1.523	-2.284	-11.379	-5.838	-8.347	-4.146	-1.156
Ure1 - A	11.905	30.286	-19.048	-3.571	-13.452	-8.730	-12.381	-5.556
Ure1 - B	-15.082	-25.779	6.464	-4.309	-1.331	-0.718	7.858	5.408
Ure1 - C	-5.442	-14.790	8.608	1.583	2.810	3.925	6.289	0.877
Ure1 - D	0.985	3.777	2.080	1.533	-2.121	1.715	-1.916	-3.394
Ure1 - E	1.826	1.227	2.895	2.361	-0.214	2.539	0.230	-2.780

Table H.3 cont Error in mean velocity using the methods outlined in Table 2.3 (%)

Reference	Method number 1	2	3	4	5	6	8	9
Ure1 - F	-3.689	0.608	2.408	-0.641	-0.687	0.376	-0.216	-2.403
Ure1 - G	-4.430	-2.041	0.050	-2.190	-3.571	-1.444	-0.324	-0.697
Ure1 - H	-7.076	-4.287	1.654	-2.711	-2.774	-1.256	0.345	-0.452
Ure1 - I	2.970	2.979	-1.674	0.648	-2.488	-0.126	-0.378	-1.865
Ure1 - J	8.651	1.496	-4.792	1.929	-4.120	-0.311	0.759	-0.311
Ure1 - K	25.591	16.658	4.440	15.016	4.007	11.491	-1.524	-8.653
Ure1 - L	13.867	21.025	5.531	9.699	1.322	8.310	-6.669	-10.533
Ure1 - M	-22.870	-7.444	4.484	-9.193	-8.610	-4.634	-4.753	-0.299
Ure2 - A	3.187	9.718	-2.038	0.575	-5.408	-0.296	-4.990	-4.084
Ure2 - B	9.258	7.556	-3.464	2.897	-3.849	0.777	-1.967	-2.858
Ure2 - C	-2.037	2.990	0.231	-0.903	-3.204	-0.525	-1.996	-2.504
Ure2 - D	-7.502	-2.609	-0.084	-3.793	-4.353	-2.556	-0.871	-0.455
Ure2 - E	-1.821	0.824	0.155	-0.833	-3.878	-0.503	-1.496	-1.727
Ure2 - F	17.577	9.761	-3.029	7.274	-2.457	3.840	-1.271	-3.768
Ure2 - G	10.917	5.306	-2.365	4.276	-3.402	2.062	-0.932	-2.443
Ure2 - H	24.815	16.669	-2.628	11.093	-0.583	6.520	-2.310	-6.301
Ure2 - I	1.563	-10.625	-10.156	-4.297	-3.711	-6.250	7.161	5.686
Ure2 - J	-100.00	-13.366	2.439	-48.780	-18.049	-31.707	-15.610	2.439
Ure3 - A	-30.670	-12.009	2.820	-13.925	-4.700	-8.343	-0.470	1.841
Ure3 - B	-24.342	-11.579	18.969	-2.686	1.919	4.532	-0.987	-3.692
Ure3 - C	14.795	-9.647	17.112	15.954	1.337	16.340	2.353	-3.743
Ure3 - D	37.444	15.453	-4.625	16.410	-0.882	9.398	-0.074	-5.213
Ure3 - E	24.670	17.096	-4.232	10.219	-0.728	5.402	-2.064	-5.914
Ure3 - F	-0.490	-0.580	3.421	1.465	-1.743	2.117	-0.443	-2.328
Ure3 - G	7.879	-0.998	0.443	4.161	-2.039	2.921	1.364	-1.190
Ure3 - H	11.167	9.756	-7.297	1.935	-5.103	-1.142	-2.251	-2.344
Ure3 - I	7.809	7.549	-2.216	2.797	-1.769	1.126	-1.139	-3.272
Ure3 - J	7.024	1.373	-2.932	2.046	-2.541	0.386	1.081	-0.888
Ure3 - K	5.005	-2.894	1.044	3.025	-2.874	2.365	1.109	-0.732
Ure3 - L	14.809	8.243	-1.292	6.758	-1.507	4.075	-0.861	-3.820
Ure3 - M	10.580	4.568	-5.848	2.366	-6.252	-0.372	-1.398	-1.026

Table H.3 cont Error in mean velocity using the methods outlined in Table 2.3 (%)

Reference	Method number							
	1	2	3	4	5	6	8	9
Ure3 - N	21.633	11.438	-5.224	8.204	-2.090	3.728	-0.588	-3.619
Ure3 - O	24.948	0.931	3.249	14.099	3.700	10.482	5.157	-2.795
Ure3 - P	26.793	0.504	4.692	15.743	3.529	12.059	4.924	-3.128
Wharfe - A	9.927	7.178	-1.149	4.389	-1.960	2.543	-1.256	-3.498
Wharfe - B	7.001	6.676	-0.346	3.328	-1.530	2.103	-1.320	-3.592
Wharfe - C	3.715	2.172	0.581	2.148	-1.769	1.626	-0.240	-2.337
Wharfe - D	0.343	0.610	1.641	0.992	-1.769	1.209	-0.279	-2.148
Wharfe - E	6.664	3.906	0.142	3.403	-0.907	2.316	0.053	-2.793
Wharfe - F	0.561	-0.279	3.475	2.018	-0.636	2.504	0.257	-2.450
Wharfe - G	-2.400	-1.065	1.176	-0.612	-2.408	-0.016	-0.127	-1.411
Wharfe - H	-0.750	-0.456	1.587	0.418	-1.556	0.808	0.216	-1.759
Wharfe - I	-0.160	2.102	-0.160	-0.160	-2.256	-0.160	-0.676	-2.065
Wharfe - J	0.974	3.763	-0.016	0.479	-1.052	0.314	-0.500	-2.690
Wharfe - K	-2.118	0.766	0.364	-0.877	-2.963	-0.463	-0.961	-1.776
Wharfe - L	6.956	5.123	1.115	4.035	-0.548	3.062	-0.510	-3.540

Table H.4 Percentage error in velocity with reduced points in vertical for individual verticals

Method type	95%limit	67% limit
Method 1	30.998	8.132
Method 2	21.899	6.057
Method 3	12.597	3.151
Method 4	14.677	3.787
Method 5	7.377	3.799
Method 6	9.821	3.081
Method 8	5.455	1.373
Method 9	6.308	2.787

Table H.5 Percentage error in velocity with reduced points in vertical for whole rivers

Method type	95%limit	67% limit
Method 1	7.219	1.896
Method 2	4.496	1.855
Method 3	1.750	0.812
Method 4	3.332	1.378
Method 5	3.970	2.857
Method 6	2.036	1.198
Method 8	1.207	0.510
Method 9	3.181	1.918

Table H.6 Error in velocity with reduced points in vertical and reduced number of verticals for the whole river (%)

Method Number	Full verticals		Ten verticals		Seven verticals		Five verticals	
	95%	67%	95%	67%	95%	67%	95%	67%
1	7.068	2.081	7.679	5.651	12.591	5.787	16.284	8.423
2	5.262	1.826	7.690	5.628	12.912	6.297	16.942	9.284
3	1.814	1.011	8.067	4.721	12.579	7.108	20.011	8.904
4	3.724	1.551	6.993	4.131	11.050	6.380	18.091	9.554
5	4.172	2.872	10.392	6.938	15.052	8.915	21.456	11.710
6	1.932	1.236	7.236	4.588	10.617	6.496	19.301	9.114
8	1.308	0.454	9.200	5.724	12.498	8.250	20.078	10.011
9	3.101	1.753	10.953	6.303	14.226	8.632	20.744	12.024
10	0.000	0.000	8.975	5.088	12.542	7.521	18.539	9.578

Table H.7 Error in discharge using a single surface velocity value

Surface Velocity Constant	Percentage error 95%ile	Percentage error 67%ile	Surface Velocity Constant	Percentage error 95%ile	Percentage error 67%ile
0.500	47.105	41.285	0.750	25.921	13.776
0.510	46.047	40.111	0.760	25.160	12.794
0.520	44.989	38.937	0.770	24.176	11.646
0.530	43.931	37.762	0.780	23.490	11.510
0.540	42.873	36.588	0.790	23.791	11.150
0.550	41.815	35.414	0.800	24.092	10.347
0.560	40.757	34.239	0.810	24.974	11.039
0.570	39.699	33.065	0.820	26.517	12.410
0.580	38.642	31.891	0.830	28.060	13.781
0.590	37.584	30.716	0.840	29.603	15.021
0.600	36.526	29.542	0.850	31.146	15.471
0.610	35.468	28.368	0.860	32.689	16.810
0.620	34.410	27.194	0.870	34.232	17.771
0.630	33.352	26.019	0.880	35.774	19.124
0.640	32.294	24.845	0.890	37.317	20.478
0.650	31.236	23.671	0.900	38.860	21.832
0.660	30.178	22.496	0.910	40.403	23.185
0.670	29.120	21.322	0.920	41.946	24.539
0.680	28.063	20.148	0.930	43.489	25.893
0.690	27.005	18.974	0.940	45.032	27.247
0.700	25.947	17.910	0.950	46.575	28.600
0.710	24.889	16.738	0.960	48.118	29.954
0.720	24.885	15.565	0.970	49.660	31.308
0.730	25.115	15.227	0.980	51.203	32.661
0.740	25.576	14.066	0.990	52.746	34.015
0.750	25.921	13.776	1.000	54.289	35.369

APPENDIX I Error analysis data (Rapidly varying flow)

Table I.1 Combined error from reduced number of verticals with reduced points in vertical for individual verticals for 200 second exposure time error from flume data (%)

Method Number	Number of verticals								
	20	15	10	7	5	4	3	2	1
1	7.089	8.953	11.526	15.042	18.400	24.146	33.853	41.333	75.708
2	5.117	6.933	9.205	12.550	15.566	21.510	31.394	38.312	72.459
3	3.185	5.165	7.255	10.567	13.346	19.557	29.641	36.157	70.210
4	3.603	5.519	7.636	10.944	13.765	19.916	29.958	36.547	70.613
5	2.220	4.441	6.497	9.837	12.541	18.879	29.049	35.429	69.464
6	2.652	4.746	6.813	10.138	12.872	19.155	29.289	35.724	69.766
8	1.923	4.252	6.305	9.657	12.343	18.715	28.907	35.255	69.286
9	2.049	4.330	6.384	9.731	12.424	18.782	28.965	35.326	69.358
10	1.486	4.012	6.064	9.434	12.099	18.515	28.735	35.043	69.071

Table I.2 Combined error from reduced number of verticals with reduced points in vertical for individual verticals for 100 second exposure time error from flume data (%)

Method Number	Number of verticals								
	20	15	10	7	5	4	3	2	1
1	7.119	8.985	11.564	15.083	18.446	24.190	33.895	41.385	75.764
2	5.159	6.974	9.251	12.599	15.621	21.560	31.439	38.368	72.518
3	3.218	5.192	7.285	10.596	13.378	19.584	29.665	36.187	70.241
4	3.622	5.536	7.655	10.963	13.785	19.934	29.974	36.567	70.633
5	2.252	4.463	6.519	9.858	12.563	18.898	29.065	35.449	69.484
6	2.678	4.766	6.834	10.158	12.894	19.174	29.305	35.744	69.786
8	1.941	4.263	6.316	9.667	12.354	18.724	28.915	35.265	69.296
9	2.066	4.341	6.395	9.741	12.435	18.791	28.973	35.336	69.369
10	1.510	4.024	6.076	9.445	12.111	18.525	28.743	35.053	69.081

Table I.3 Combined error from reduced number of verticals with reduced points in vertical for individual verticals for 50 second exposure time error from flume data (%)

Method Number	Number of verticals 20	15	10	7	5	4	3	2	1
1	7.119	8.985	11.563	15.083	18.446	24.190	33.895	41.385	75.764
2	5.159	6.974	9.251	12.599	15.621	21.560	31.439	38.368	72.518
3	3.218	5.192	7.285	10.596	13.378	19.584	29.665	36.187	70.241
4	3.622	5.536	7.655	10.963	13.785	19.934	29.974	36.567	70.633
5	2.252	4.463	6.519	9.858	12.563	18.898	29.065	35.449	69.484
6	2.678	4.766	6.834	10.158	12.894	19.174	29.305	35.744	69.786
8	1.941	4.263	6.316	9.667	12.354	18.724	28.915	35.265	69.296
9	2.066	4.341	6.395	9.741	12.435	18.791	28.973	35.336	69.369
10	1.510	4.024	6.076	9.445	12.111	18.525	28.743	35.053	69.081

Table I.4 Combined error from reduced number of verticals with reduced points in vertical for individual verticals for 30 second exposure time error from flume data (%)

Method Number	Number of verticals 20	15	10	7	5	4	3	2	1
1	7.180	9.049	11.638	15.165	18.540	24.280	33.980	41.490	75.879
2	5.242	7.057	9.345	12.697	15.732	21.661	31.531	38.481	72.638
3	3.285	5.248	7.344	10.655	13.443	19.640	29.714	36.247	70.303
4	3.662	5.571	7.693	11.000	13.827	19.970	30.006	36.607	70.674
5	2.315	4.506	6.563	9.900	12.609	18.936	29.098	35.490	69.526
6	2.732	4.807	6.876	10.199	12.939	19.211	29.338	35.785	69.828
8	1.978	4.286	6.339	9.689	12.377	18.744	28.932	35.285	69.317
9	2.101	4.363	6.417	9.762	12.458	18.810	28.990	35.356	69.390
10	1.557	4.048	6.100	9.467	12.135	18.544	28.760	35.074	69.102

Table I.5 **Combined error from reduced number of verticals with reduced points in vertical for individual verticals for 20 second exposure time error from flume data (%)**

Method Number	Number of verticals 20	15	10	7	5	4	3	2	1
1	7.154	9.022	11.607	15.130	18.501	24.242	33.944	41.446	75.831
2	5.207	7.022	9.305	12.656	15.685	21.618	31.492	38.433	72.588
3	3.257	5.225	7.319	10.630	13.416	19.616	29.693	36.222	70.277
4	3.645	5.556	7.677	10.985	13.810	19.955	29.993	36.590	70.657
5	2.289	4.488	6.545	9.882	12.590	18.920	29.085	35.473	69.509
6	2.709	4.790	6.858	10.182	12.920	19.196	29.324	35.768	69.810
8	1.962	4.276	6.329	9.680	12.368	18.736	28.925	35.277	69.308
9	2.086	4.354	6.408	9.753	12.448	18.802	28.983	35.348	69.381
10	1.537	4.038	6.090	9.457	12.125	18.536	28.753	35.065	69.093

Table I.6 **Combined error from reduced number of verticals with reduced points in vertical for individual verticals for 10 second exposure time error from flume data (%)**

Method Number	Number of verticals 20	15	10	7	5	4	3	2	1
1	7.289	9.165	11.774	15.314	18.711	24.443	34.135	41.681	76.088
2	5.392	7.205	9.513	12.874	15.932	21.843	31.698	38.686	72.856
3	3.404	5.348	7.451	10.761	13.561	19.740	29.803	36.356	70.415
4	3.734	5.634	7.761	11.069	13.904	20.037	30.065	36.679	70.749
5	2.427	4.583	6.644	9.976	12.693	19.006	29.159	35.565	69.602
6	2.827	4.879	6.953	10.273	13.020	19.280	29.398	35.859	69.903
8	2.044	4.327	6.380	9.728	12.420	18.779	28.962	35.323	69.355
9	2.163	4.403	6.459	9.801	12.501	18.846	29.020	35.394	69.428
10	1.640	4.091	6.143	9.506	12.178	18.580	28.791	35.112	69.141

Table I.7 **Combined error from reduced number of verticals with reduced points in vertical for individual verticals for 5 second exposure time error from flume data (%)**

Method Number	Number of verticals 20	15	10	7	5	4	3	2	1
1	7.459	9.345	11.985	15.545	18.976	24.697	34.379	41.980	76.416
2	5.619	7.433	9.772	13.149	16.243	22.128	31.960	39.008	73.199
3	3.583	5.501	7.618	10.925	13.744	19.898	29.942	36.528	70.593
4	3.844	5.732	7.868	11.176	14.023	20.140	30.157	36.792	70.867
5	2.593	4.703	6.768	10.095	12.824	19.115	29.254	35.682	69.722
6	2.971	4.992	7.072	10.388	13.148	19.388	29.493	35.975	70.023
8	2.143	4.391	6.445	9.789	12.487	18.834	29.010	35.382	69.416
9	2.257	4.466	6.523	9.862	12.567	18.901	29.068	35.453	69.488
10	1.762	4.158	6.210	9.569	12.246	18.636	28.839	35.171	69.201

Table I.8 **Combined error from reduced number of verticals with reduced points in vertical for whole rivers for 200 second exposure time error from flume data (%)**

Method Number	Number of verticals 20	15	10	7	5	4	3	2	1
1	2.194	4.424	6.479	9.821	12.522	18.864	29.036	35.413	69.447
2	1.794	4.177	6.228	9.586	12.265	18.651	28.852	35.187	69.217
3	1.537	4.037	6.089	9.457	12.124	18.536	28.753	35.065	69.093
4	1.662	4.103	6.155	9.518	12.190	18.590	28.799	35.122	69.151
5	1.731	4.141	6.193	9.553	12.229	18.621	28.826	35.155	69.185
6	1.554	4.046	6.098	9.465	12.133	18.543	28.759	35.073	69.101
8	1.510	4.024	6.076	9.445	12.111	18.525	28.743	35.053	69.082
9	1.647	4.095	6.147	9.510	12.182	18.583	28.794	35.115	69.144
10	1.486	4.012	6.064	9.434	12.099	18.515	28.735	35.043	69.071

Table I.9 Combined error from reduced number of verticals with reduced points in vertical for whole rivers for 100 second exposure time error from flume data (%)

Method Number	Number of verticals								
	20	15	10	7	5	4	3	2	1
1	2.289	4.488	6.545	9.883	12.590	18.920	29.085	35.473	69.509
2	1.910	4.244	6.297	9.649	12.334	18.708	28.901	35.248	69.279
3	1.605	4.073	6.124	9.489	12.160	18.564	28.778	35.095	69.124
4	1.705	4.126	6.178	9.539	12.214	18.609	28.816	35.142	69.172
5	1.772	4.164	6.216	9.574	12.252	18.640	28.843	35.176	69.206
6	1.599	4.070	6.121	9.487	12.157	18.562	28.776	35.093	69.122
8	1.534	4.036	6.088	9.456	12.123	18.534	28.752	35.064	69.092
9	1.669	4.107	6.158	9.521	12.194	18.593	28.802	35.125	69.155
10	1.510	4.024	6.076	9.445	12.111	18.525	28.743	35.053	69.081

Table I.10 Combined error from reduced number of verticals with reduced points in vertical for whole rivers for 50 second exposure time error from flume data (%)

Method Number	Number of verticals								
	20	15	10	7	5	4	3	2	1
1	2.289	4.488	6.545	9.883	12.590	18.920	29.085	35.473	69.509
2	1.909	4.244	6.297	9.649	12.334	18.708	28.901	35.248	69.279
3	1.605	4.072	6.124	9.489	12.159	18.564	28.778	35.095	69.124
4	1.705	4.126	6.178	9.539	12.214	18.609	28.816	35.142	69.172
5	1.772	4.164	6.216	9.574	12.252	18.640	28.843	35.176	69.206
6	1.599	4.070	6.121	9.487	12.157	18.562	28.776	35.093	69.122
8	1.534	4.036	6.088	9.456	12.123	18.534	28.752	35.064	69.092
9	1.669	4.107	6.158	9.521	12.194	18.593	28.802	35.125	69.155
10	1.510	4.024	6.076	9.445	12.111	18.525	28.743	35.053	69.081

Table I.11 Combined error from reduced number of verticals with reduced points in vertical for whole rivers for 30 second exposure time error from flume data (%)

Method Number	Number of verticals								
	20	15	10	7	5	4	3	2	1
1	2.472	4.615	6.677	10.007	12.728	19.035	29.184	35.595	69.634
2	2.125	4.379	6.433	9.777	12.475	18.824	29.001	35.371	69.404
3	1.735	4.143	6.195	9.555	12.231	18.623	28.828	35.157	69.187
4	1.788	4.173	6.225	9.582	12.261	18.648	28.849	35.184	69.214
5	1.852	4.210	6.262	9.617	12.299	18.679	28.876	35.217	69.247
6	1.687	4.117	6.169	9.530	12.204	18.601	28.809	35.134	69.164
8	1.580	4.060	6.111	9.478	12.147	18.554	28.769	35.084	69.113
9	1.712	4.130	6.182	9.543	12.218	18.612	28.819	35.146	69.175
10	1.557	4.048	6.100	9.467	12.135	18.544	28.760	35.074	69.102

Table I.12 Combined error from reduced number of verticals with reduced points in vertical for whole rivers for 20 second exposure time error from flume data (%)

Method Number	Number of verticals								
	20	15	10	7	5	4	3	2	1
1	2.397	4.562	6.622	9.955	12.670	18.987	29.142	35.544	69.581
2	2.037	4.323	6.376	9.724	12.416	18.775	28.959	35.319	69.352
3	1.681	4.114	6.165	9.527	12.201	18.598	28.807	35.131	69.161
4	1.753	4.153	6.205	9.564	12.241	18.632	28.835	35.166	69.196
5	1.818	4.191	6.243	9.599	12.279	18.663	28.862	35.199	69.230
6	1.651	4.097	6.149	9.512	12.184	18.585	28.795	35.117	69.146
8	1.561	4.050	6.102	9.468	12.137	18.546	28.761	35.076	69.104
9	1.694	4.120	6.172	9.534	12.208	18.604	28.812	35.137	69.167
10	1.537	4.038	6.090	9.457	12.125	18.536	28.753	35.065	69.093

Table I.13 Combined error from reduced number of verticals with reduced points in vertical for whole rivers for 10 second exposure time error from flume data (%)

Method Number	Number of verticals 20	15	10	7	5	4	3	2	1
1	2.774	4.839	6.910	10.232	12.975	19.242	29.365	35.818	69.861
2	2.470	4.614	6.675	10.006	12.726	19.034	29.183	35.594	69.633
3	1.950	4.269	6.322	9.672	12.360	18.729	28.919	35.270	69.302
4	1.930	4.257	6.309	9.661	12.347	18.719	28.910	35.259	69.290
5	1.989	4.293	6.346	9.695	12.385	18.750	28.937	35.292	69.324
6	1.838	4.202	6.254	9.609	12.291	18.672	28.870	35.209	69.240
8	1.662	4.103	6.155	9.517	12.190	18.590	28.799	35.122	69.151
9	1.787	4.173	6.225	9.582	12.261	18.648	28.849	35.183	69.214
10	1.640	4.091	6.143	9.506	12.178	18.580	28.791	35.112	69.141

Table I.14 Combined error from reduced number of verticals with reduced points in vertical for whole rivers for 5 second exposure time error from flume data (%)

Method Number	Number of verticals 20	15	10	7	5	4	3	2	1
1	3.194	5.172	7.263	10.575	13.355	19.564	29.648	36.165	70.219
2	2.933	4.962	7.040	10.357	13.114	19.359	29.468	35.944	69.991
3	2.248	4.460	6.516	9.856	12.561	18.895	29.063	35.447	69.482
4	2.135	4.385	6.440	9.783	12.482	18.830	29.006	35.377	69.410
5	2.189	4.420	6.476	9.817	12.519	18.861	29.033	35.410	69.444
6	2.052	4.332	6.386	9.733	12.426	18.783	28.966	35.328	69.360
8	1.783	4.170	6.222	9.580	12.258	18.646	28.847	35.181	69.211
9	1.900	4.239	6.291	9.644	12.329	18.704	28.897	35.243	69.274
10	1.762	4.158	6.210	9.569	12.246	18.636	28.839	35.171	69.201

Table I.15 Combined error from reduced number of verticals with reduced points in vertical for individual verticals for 200 second exposure time error from field data (%)

Method Number	Number of verticals 20	15	10	7	5	4	3	2	1
1	7.089	8.953	11.526	15.042	18.400	24.146	33.853	41.333	75.708
2	5.117	6.933	9.205	12.550	15.566	21.510	31.394	38.312	72.459
3	3.185	5.165	7.255	10.567	13.346	19.557	29.641	36.157	70.210
4	3.603	5.519	7.636	10.944	13.765	19.916	29.958	36.547	70.613
5	2.220	4.441	6.497	9.837	12.541	18.879	29.049	35.429	69.464
6	2.652	4.746	6.813	10.138	12.872	19.155	29.289	35.724	69.766
8	1.923	4.252	6.305	9.657	12.343	18.715	28.907	35.255	69.286
9	2.049	4.330	6.384	9.731	12.424	18.782	28.965	35.326	69.358
10	1.486	4.012	6.064	9.434	12.099	18.515	28.735	35.043	69.071

Table I.16 Combined error from reduced number of verticals with reduced points in vertical for individual verticals for 100 second exposure time error from field data (%)

Method Number	Number of verticals 20	15	10	7	5	4	3	2	1
1	7.971	9.893	12.627	16.256	19.792	25.485	35.137	42.911	77.444
2	6.283	8.111	10.551	13.982	17.189	23.003	32.775	40.009	74.271
3	4.097	5.961	8.120	11.431	14.308	20.389	30.379	37.065	71.151
4	4.173	6.030	8.196	11.508	14.394	20.465	30.447	37.149	71.238
5	3.059	5.063	7.147	10.461	13.229	19.457	29.553	36.049	70.099
6	3.386	5.332	7.435	10.744	13.543	19.725	29.789	36.339	70.398
8	2.431	4.586	6.647	9.979	12.696	19.008	29.161	35.567	69.605
9	2.532	4.659	6.722	10.051	12.775	19.074	29.219	35.638	69.677
10	2.103	4.365	6.419	9.764	12.460	18.812	28.991	35.358	69.391

Table I.17 Combined error from reduced number of verticals with reduced points in vertical for individual verticals for 50 second exposure time error from field data (%)

Method Number	Number of verticals								
	20	15	10	7	5	4	3	2	1
1	7.422	9.306	11.939	15.495	18.919	24.642	34.326	41.915	76.344
2	5.570	7.384	9.716	13.090	16.176	22.066	31.903	38.938	73.124
3	3.544	5.468	7.582	10.890	13.704	19.864	29.912	36.490	70.554
4	3.820	5.710	7.845	11.153	13.997	20.118	30.137	36.768	70.841
5	2.558	4.677	6.741	10.069	12.795	19.091	29.233	35.656	69.696
6	2.94	4.968	7.0458	10.363	13.12	19.365	29.472	35.95	69.997
8	2.122	4.377	6.4312	9.7753	12.473	18.822	29	35.369	69.402
9	2.237	4.452	6.5088	9.8483	12.553	18.889	29.058	35.44	69.475
10	1.736	4.144	6.1956	9.5554	12.232	18.624	28.828	35.158	69.188

Table I.18 Combined error from reduced number of verticals with reduced points in vertical for individual verticals for 10 second exposure time error from field data (%)

Method Number	Number of verticals								
	20	15	10	7	5	4	3	2	1
1	8.504	10.467	13.303	17.009	20.659	26.331	35.959	43.921	78.567
2	6.946	8.802	11.351	14.850	18.181	23.937	33.654	41.090	75.442
3	4.601	6.433	8.643	11.966	14.908	20.919	30.856	37.652	71.764
4	4.509	6.345	8.545	11.865	14.795	20.819	30.766	37.540	71.647
5	3.505	5.434	7.545	10.853	13.663	19.829	29.881	36.452	70.514
6	3.793	5.686	7.818	11.126	13.967	20.092	30.114	36.739	70.812
8	2.715	4.794	6.863	10.186	12.925	19.200	29.328	35.772	69.815
9	2.806	4.863	6.936	10.256	13.002	19.265	29.385	35.842	69.886
10	2.426	4.582	6.643	9.975	12.692	19.005	29.158	35.564	69.601

Table I.19 Combined error from reduced number of verticals with reduced points in vertical for individual verticals for 5 second exposure time error from field data (%)

Method Number	Number of verticals 20	15	10	7	5	4	3	2	1
1	11.029	13.241	16.602	20.742	24.982	30.659	40.273	49.217	84.613
2	9.878	11.969	15.083	19.012	22.975	28.629	38.229	46.708	81.719
3	6.770	8.618	11.137	14.617	17.914	23.684	33.415	40.796	75.122
4	6.064	7.886	10.291	13.703	16.872	22.708	32.498	39.670	73.906
5	5.360	7.173	9.477	12.836	15.889	21.803	31.662	38.642	72.809
6	5.552	7.366	9.696	13.068	16.151	22.043	31.882	38.913	73.097
8	3.949	5.826	7.971	11.280	14.140	20.242	30.248	36.903	70.982
9	4.012	5.883	8.034	11.344	14.210	20.304	30.303	36.971	71.053
10	3.756	5.653	7.782	11.090	13.928	20.057	30.084	36.701	70.773

Table I.20 Combined error from reduced number of verticals with reduced points in vertical for whole rivers for 200 second exposure time error from field data (%)

Method Number	Number of verticals 20	15	10	7	5	4	3	2	1
1	2.194	4.424	6.479	9.821	12.522	18.864	29.036	35.413	69.447
2	1.794	4.177	6.228	9.586	12.265	18.651	28.852	35.187	69.217
3	1.537	4.037	6.089	9.457	12.124	18.536	28.753	35.065	69.093
4	1.662	4.103	6.155	9.518	12.190	18.590	28.799	35.122	69.151
5	1.731	4.141	6.193	9.553	12.229	18.621	28.826	35.155	69.185
6	1.554	4.046	6.098	9.465	12.133	18.543	28.759	35.073	69.101
8	1.510	4.024	6.076	9.445	12.111	18.525	28.743	35.053	69.082
9	1.647	4.095	6.147	9.510	12.182	18.583	28.794	35.115	69.144
10	1.486	4.012	6.064	9.434	12.099	18.515	28.735	35.043	69.070

Table I.21 Combined error from reduced number of verticals with reduced points in vertical for whole rivers for 100 second exposure time error from field data (%)

Method Number	Number of verticals 20	15	10	7	5	4	3	2	1
1	4.255	6.107	8.281	11.594	14.491	20.550	30.524	37.242	71.336
2	4.063	5.930	8.086	11.396	14.269	20.355	30.349	37.028	71.112
3	3.001	5.016	7.097	10.413	13.175	19.411	29.513	36.000	70.049
4	2.682	4.769	6.837	10.161	12.897	19.176	29.308	35.747	69.789
5	2.725	4.802	6.871	10.194	12.933	19.207	29.334	35.780	69.823
6	2.617	4.720	6.786	10.112	12.843	19.131	29.268	35.699	69.739
8	2.120	4.376	6.430	9.774	12.472	18.821	28.999	35.368	69.402
9	2.220	4.441	6.497	9.837	12.541	18.879	29.049	35.429	69.464
10	2.103	4.365	6.419	9.764	12.460	18.812	28.991	35.358	69.391

Table I.22 Combined error from reduced number of verticals with reduced points in vertical for whole rivers for 50 second exposure time error from field data (%)

Method Number	Number of verticals 20	15	10	7	5	4	3	2	1
1	3.107	5.101	7.188	10.501	13.273	19.494	29.586	36.090	70.141
2	2.839	4.888	6.962	10.282	13.030	19.289	29.406	35.868	69.913
3	2.187	4.419	6.474	9.816	12.517	18.859	29.032	35.408	69.442
4	2.092	4.357	6.412	9.757	12.452	18.805	28.985	35.351	69.384
5	2.147	4.393	6.448	9.791	12.490	18.836	29.012	35.384	69.418
6	2.007	4.304	6.357	9.706	12.396	18.759	28.945	35.302	69.334
8	1.757	4.156	6.207	9.566	12.244	18.633	28.837	35.168	69.198
9	1.876	4.224	6.277	9.631	12.314	18.691	28.887	35.230	69.261
10	1.736	4.144	6.196	9.555	12.232	18.624	28.828	35.158	69.188

Table I.23 Combined error from reduced number of verticals with reduced points in vertical for whole rivers for 10 second exposure time error from field data (%)

Method Number	Number of verticals 20	15	10	7	5	4	3	2	1
1	5.184	6.999	9.279	12.628	15.654	21.590	31.466	38.401	72.554
2	5.028	6.845	9.106	12.446	15.449	21.404	31.297	38.193	72.334
3	3.659	5.568	7.690	10.998	13.824	19.968	30.004	36.604	70.671
4	3.181	5.161	7.252	10.564	13.342	19.554	29.638	36.154	70.207
5	3.217	5.191	7.284	10.595	13.377	19.583	29.664	36.186	70.240
6	3.125	5.116	7.204	10.517	13.290	19.509	29.599	36.106	70.157
8	2.441	4.593	6.654	9.986	12.704	19.015	29.167	35.574	69.612
9	2.528	4.655	6.718	10.047	12.772	19.071	29.216	35.635	69.674
10	2.426	4.582	6.643	9.975	12.692	19.005	29.158	35.564	69.601

Table I.24 Combined error from reduced number of verticals with reduced points in vertical for whole rivers for 5 second exposure time error from field data (%)

Method Number	Number of verticals 20	15	10	7	5	4	3	2	1
1	8.729	10.712	13.592	17.332	21.032	26.698	36.318	44.361	79.061
2	8.637	10.612	13.475	17.200	20.880	26.548	36.171	44.181	78.859
3	6.169	7.993	10.415	13.835	17.023	22.848	32.629	39.831	74.079
4	5.153	6.969	9.245	12.593	15.614	21.554	31.433	38.360	72.511
5	5.176	6.991	9.270	12.619	15.643	21.581	31.458	38.391	72.543
6	5.120	6.935	9.207	12.553	15.569	21.513	31.396	38.315	72.463
8	3.765	5.662	7.792	11.100	13.938	20.066	30.092	36.711	70.783
9	3.823	5.713	7.847	11.155	14.000	20.120	30.140	36.770	70.844
10	3.756	5.653	7.782	11.090	13.928	20.057	30.084	36.701	70.773

APPENDIX J: GAUGING TIMES

Table J.1 Summary of data used to calculate time of gauging

Agency Region	River	Gauging Station	River Discharge (m^3s^{-1})	Width of River (m)	Gauging Time (secs)	Number of verticals	Exposure time (secs)	Number of points in vertical	Method of metering	Time for moving the current meter (secs)
Severn Trent	Amber	Wingfield Park	0.780	5.00	2100	12	50	1	Waded	125.000
Severn Trent	Arrow	Studley	0.220	5.60	2100	17	50	1	Waded	73.529
Severn Trent	Avon	Lilbourne	4.410	7.80	3000	16	100	1	Cableway	87.500
Severn Trent	Blythe	Castle Farm	0.770	10.76	2640	20	100	1	Waded	32.000
Severn Trent	Blythe	Castle Farm	0.910	11.29	3360	22	100	1	Cableway	52.727
Severn Trent	Derwent	Chatsworth	2.730	27.40	5100	26	100	1	Cableway	96.154
Severn Trent	Derwent	Chatsworth	2.730	23.00	8700	21	100	2	Cableway	214.286
Severn Trent	Manifold	Ilam	1.840	12.50	2640	22	100	1	Waded	20.000
Severn Trent	Manifold	Ilam	3.800	13.10	2880	22	100	1	Waded	30.909
Severn Trent	Mease	Stones Br.	0.590	6.80	2100	20	100	1	Waded	16.667
Severn Trent	Rea	Calthorpe Park	0.550	9.10	2700	18	100	1	Waded	42.105
Severn Trent	Rea	Calthorpe Park	3.560	9.20	3000	16	100	1	Cableway	66.667
Severn Trent	Severn	Saxon's Lode	47.500	59.20	7200	17	50	2	Cableway	323.529
Severn Trent	Stour	Shipston	0.679	9.00	2700	15	100	1	Waded	58.824
Severn Trent	Tanat	Llanyblodwell	0.700	17.65	4200	17	100	1	Waded	147.059
Severn Trent	Tanat	Llanyblodwell	1.180	16.00	2400	14	100	1	Waded	71.429
Severn Trent	Teme	Tenbury	6.070	17.00	2700	16	50	2	Cableway	68.750

Table J.1 cont **Summary of data used to calculate time of gauging**

Agency Region	River	Gauging Station	River Discharge (m^3s^{-1})	Width of River (m)	Gauging Time (secs)	Number of verticals	Exposure time (secs)	Number of points in vertical	Method of metering	Time for moving the current meter (secs)
Severn Trent	Trent	Stoke	3.230	7.20	1860	15	100	1	Cableway	24.000
South West	Avon	Fordingbridge	65.140	39.00	3300	18	50	1	Cableway	133.333
South West	Brue	Lovington	7.530	9.27	900	9	60	1	Cableway	40.000
South West	Brue	Lovington	32.900	12.60	1500	11	60	1	Cableway	76.364
South West	Camel	Denby	22.080	11.15	2400	14	60	1	Cableway	111.429
South West	Dart	Austin's Br.	145.440	33.40	2400	19	60	1	Cableway	66.316
South West	Doniford	Swill Br.	1.950	5.55	1800	12	60	1	Waded	90.000
South West	Doniford	Swill Br.	7.730	5.50	1200	12	60	1	Waded	40.000
South West	Exe	Thorverton	49.780	32.50	2100	17	50	1	Cableway	73.529
South West	Inny	Beal's Mill	29.050	13.01	1200	8	50	1	Cableway	100.000
South West	Nadder	Ct St Br.	8.380	10.20	2160	15	50	1	Cableway	94.000
South West	Okement	Jacobstone	38.860	15.75	1380	12	50	1	Cableway	65.000
South West	Ottery	Werrington	37.020	22.20	1800	18	50	1	Cableway	50.000
South West	Piddle	Bagg's Mill	7.610	6.80	2460	15	50	1	Cableway	139.231
South West	Stour	Blackwater Br.	115.430	55.00	4140	28	50	2	Cableway	47.857
South West	Stour	Blackwater Br.	125.620	60.00	4800	24	50	2	Cableway	100.000
South West	Tamar	Gunnislake	283.690	32.24	2220	17	50	1	Cableway	80.588

Table J.1 cont **Summary of data used to calculate time of gauging**

Agency Region	River	Gauging Station	River Discharge (m^3s^{-1})	Width of River (m)	Gauging Time (secs)	Number of verticals	Exposure time (secs)	Number of points in vertical	Method of metering	Time for moving the current meter (secs)
South West	Tavy	Ludbrook	83.970	22.65	1380	13	50	1	Cableway	56.154
South West	Till	Ct St Br.	0.261	5.23	1500	13	50	1	Waded	65.385
South West	Tone	Bishop's Hull	11.480	12.00	3300	11	60	1	Cableway	240.000
South West	Tone	Bishop's Hull	27.390	12.00	1500	7	60	1	Cableway	154.286
South West	Torridge	Torrington	214.850	28.40	1500	15	50	1	Cableway	50.000
South West	Wolf	Roadford	3.047	8.25	1200	15	50	1	Cableway	30.000
South West	Wolf	Roadford	7.460	8.25	1500	9	50	1	Cableway	116.667
South West	Yeo	Pen Mill	15.410	14.80	2820	12	60	1	Cableway	175.000
South West	Yeo	Pen Mill	46.080	18.85	5400	23	60	1	Cableway	174.783
South West	Yeo	Pen Mill	52.450	17.70	1740	10	60	1	Cableway	114.000
Southern	Arlington	Cuckmere	9.440	19.00	3000	18	50	2	Cableway	66.667
Southern	Arlington	Cuckmere	9.490	19.00	3000	20	50	1	Cableway	116.667
Southern	Arlington	Cuckmere	9.750	19.00	5400	18	50	5	Cableway	50.000
Southern	Arlington	Cuckmere	10.440	19.90	3000	19	50	2	Cableway	57.895
Southern	Blackwater	Ower	7.730	6.00	1200	9	100	1	Waded	71.429
Southern	Gt Stour	Hoston	13.890	12.50	2700	12	50	2	Cableway	125.000

Table J.1 cont **Summary of data used to calculate time of gauging**

Agency Region	River	Gauging Station	River Discharge (m^3s^{-1})	Width of River (m)	Gauging Time (secs)	Number of verticals	Exposure time (secs)	Number of points in vertical	Method of metering	Time for moving the current meter (secs)
Southern	Gt Stour	Wye	11.050	12.30	3900	13	50	2	Cableway	200.000
Southern	Gt Stour	Wye	11.420	12.25	2100	12	50	1	Cableway	125.000
Southern	Ouse	Goldbridge	16.810	14.00	5400	16	50	2	Cableway	237.500
Southern	Ouse	Goldbridge	25.000	16.20	2100	16	50	2	Waded	31.250
Southern	Tanyard Fish Farm		0.360	16.00	4380	15	50	1	Waded	242.000
Thames	New RIver	New Gauge	1.220	7.51	5400	10	60	6	Waded	180.000
Thames	New RIver	New Gauge	1.250	7.51	5400	10	60	1	Waded	480.000
Welsh	Conwy	Conwy	22.850	34.98	9600	17	50	6	Cableway	264.706
Welsh	Dee	IronBr.	101.670	41.20	7200	20	100	2	Cableway	160.000
Welsh	Dee	Bala	30.000	24.50	5100	25	100	2	Cableway	4.000
Welsh	Dee	Bala	52.870	26.30	6900	26	100	2	Cableway	65.385
Welsh	Dee	Ironbridge	140.000	42.20	7200	19	100	2	Cableway	178.947
Welsh	Elwy	Pont-y-Gwyddel	10.160	17.23	3000	17	100	1	Cableway	76.471
Welsh	Elwy	Pont-y-Gwyddel	12.780	17.73	3300	17	100	1	Cableway	94.118
Welsh	Dyfi	Dyfi	59.210	33.06	10800	9	50	6	Cableway	900.000
Welsh	Tawe	Ynystanglws	40.370	27.83	1500	13	50	1	Cableway	65.385
Welsh	Tawe	Ynystanglws	82.680	29.40	2100	14	50	1	Cableway	100.000

Table J.1 cont Summary of data used to calculate time of gauging

Agency Region	River	Gauging Station	River Discharge (m^3s^{-1})	Width of River (m)	Gauging Time (secs)	Number of verticals	Exposure time (secs)	Number of points in vertical	Method of metering	Time for moving the current meter (secs)
Yorkshire	Aire	Armley	67.270	20.50	12000	13	100	5	Cableway	423.077
Yorkshire	Aire	Armley	108.880	22.50	9000	13	100	5	Cableway	192.308
Yorkshire	Aire	Kildwick	21.730	14.00	2100	13	100	1	Cableway	61.538
Yorkshire	Aire	Kildwick	41.030	17.80	6600	10	100	5	Cableway	160.000
Yorkshire	Calder	Mytholmroyd	49.740	16.00	2400	15	100	1	Cableway	60.000
Yorkshire	Don	Doncaster	51.041	24.50	3000	16	100	1	Cableway	87.500
Yorkshire	Rother	Whittington	19.070	9.00	11400	8	200	5	Cableway	425.000
Yorkshire	Rother	Whittington	21.670	9.50	1800	9	100	1	Cableway	100.000
Yorkshire	Ure	Kilgram Br.	146.465	33.00	7500	9	100	5	Cableway	333.333

Table J.2 Combined percentage error using whole river and flume data errors with total time taken to complete a gauging

Number of verticals	Meter position	Exposure time (secs)	Percentage Error	Total time for gauging (secs)	Totatl time for gauging (mins)
20	0.5	200	1.794	5800	96.667
20	0.5	100	1.91	3800	63.333
20	0.5	50	1.909	2800	46.667
20	0.5	30	2.125	2400	40.000
20	0.5	20	2.037	2200	36.667
20	0.5	10	2.47	2000	33.333
15	0.5	200	4.177	4350	72.500
15	0.5	100	4.244	2850	47.500
15	0.5	50	4.244	2100	35.000
15	0.5	30	4.379	1800	30.000
15	0.5	20	4.323	1650	27.500
15	0.5	10	4.614	1500	25.000
10	0.5	200	6.228	2900	48.333
10	0.5	100	6.297	1900	31.667
10	0.5	50	6.297	1400	23.333
10	0.5	30	6.433	1200	20.000
10	0.5	20	6.376	1100	18.333
10	0.5	10	6.675	1000	16.667
7	0.5	200	9.586	2030	33.833
7	0.5	100	9.649	1330	22.167
7	0.5	50	9.649	980	16.333
7	0.5	30	9.777	840	14.000
7	0.5	20	9.724	770	12.833
7	0.5	10	10.006	700	11.667
5	0.5	200	12.265	1450	24.167
5	0.5	100	12.334	950	15.833
5	0.5	50	12.334	700	11.667
5	0.5	30	12.475	600	10.000

Table J.2 cont **Combined percentage error using whole river and flume data errors with total time taken to complete a gauging**

Number of verticals	Meter position	Exposure time (secs)	Percentage Error	Total time for gauging (secs)	Totatl time for gauging (mins)
5	0.5	20	12.416	550	9.167
5	0.5	10	12.726	500	8.333
20	0.6	200	2.194	5800	96.667
20	0.6	100	2.289	3800	63.333
20	0.6	50	2.289	2800	46.667
20	0.6	30	2.472	2400	40.000
20	0.6	20	2.397	2200	36.667
20	0.6	10	2.774	2000	33.333
15	0.6	200	4.424	4350	72.500
15	0.6	100	4.488	2850	47.500
15	0.6	50	4.488	2100	35.000
15	0.6	30	4.615	1800	30.000
15	0.6	20	4.562	1650	27.500
15	0.6	10	4.839	1500	25.000
10	0.6	200	6.479	2900	48.333
10	0.6	100	6.545	1900	31.667
10	0.6	50	6.545	1400	23.333
10	0.6	30	6.677	1200	20.000
10	0.6	20	6.622	1100	18.333
10	0.6	10	6.91	1000	16.667
7	0.6	200	9.821	2030	33.833
7	0.6	100	9.883	1330	22.167
7	0.6	50	9.883	980	16.333
7	0.6	30	10.007	840	14.000
7	0.6	20	9.955	770	12.833
7	0.6	10	10.232	700	11.667
5	0.6	200	12.522	1450	24.167
5	0.6	100	12.59	950	15.833
5	0.6	50	12.59	700	11.667

Table J.2 cont **Combined percentage error using whole river and flume data errors with total time taken to complete a gauging**

Number of verticals	Meter position	Exposure time (secs)	Percentage Error	Total time for gauging (secs)	Totatl time for gauging (mins)
5	0.6	30	12.728	600	10.000
5	0.6	20	12.67	550	9.167
5	0.6	10	12.975	500	8.333
20	0.8 + 0.2	200	1.537	11200	186.667
20	0.8 + 0.2	100	1.605	7200	120.000
20	0.8 + 0.2	50	1.605	5200	86.667
20	0.8 + 0.2	30	1.735	4400	73.333
20	0.8 + 0.2	20	1.681	4000	66.667
20	0.8 + 0.2	10	1.95	3600	60.000
15	0.8 + 0.2	200	4.037	8400	140.000
15	0.8 + 0.2	100	4.073	5400	90.000
15	0.8 + 0.2	50	4.072	3900	65.000
15	0.8 + 0.2	30	4.173	3300	55.000
15	0.8 + 0.2	20	4.114	3000	50.000
15	0.8 + 0.2	10	4.269	2700	45.000
10	0.8 + 0.2	200	6.089	5600	93.333
10	0.8 + 0.2	100	6.124	3600	60.000
10	0.8 + 0.2	50	6.124	2600	43.333
10	0.8 + 0.2	30	6.195	2200	36.667
10	0.8 + 0.2	20	6.165	2000	33.333
10	0.8 + 0.2	10	6.322	1800	30.000
7	0.8 + 0.2	200	9.457	3920	65.333
7	0.8 + 0.2	100	9.489	2520	42.000
7	0.8 + 0.2	50	9.489	1820	30.333
7	0.8 + 0.2	30	9.555	1540	25.667
7	0.8 + 0.2	20	9.527	1400	23.333
7	0.8 + 0.2	10	9.672	1260	21.000

Table J.2 cont **Combined percentage error using whole river and flume data errors with total time taken to complete a gauging**

Number of verticals	Meter position	Exposure time (secs)	Percentage Error	Total time for gauging (secs)	Totatl time for gauging (mins)
5	0.8 + 0.2	200	12.124	2800	46.667
5	0.8 + 0.2	100	12.16	1800	30.000
5	0.8 + 0.2	50	12.159	1300	21.667
5	0.8 + 0.2	30	12.321	1100	18.333
5	0.8 + 0.2	20	12.201	1000	16.667
5	0.8 + 0.2	10	12.36	900	15.000

APPENDIX K CALCULATION PROCEDURE WHERE DEPTH CHANGES BY MORE THAN 5% DURING GAUGING

9.4 Determination of discharge for variations of water-level

If the fluctuation of water-level during the period of velocity measurement is less than 5 % of the mean depth, the mean value shall be adopted for the computation of the discharge. If the fluctuation is more than this amount, then this discharge shall be computed as shown in 9.4.1. and the mean water-level corresponding to this discharge computed as shown in 9.4.2.

If the independant vertical method described in 8.1.4.4-f has been used, the computation of discharge is given in 9.4.3.

9.4.1 Computation of discharge

The water level is flotted separately for each segment to form a serie of steps as shown in Fig.4. Alternatively, the level can be joined by a smooth curve. A curve of mean water surface line ; the area enclosed representating the total discharge.

Corrected water level

Gauge datum

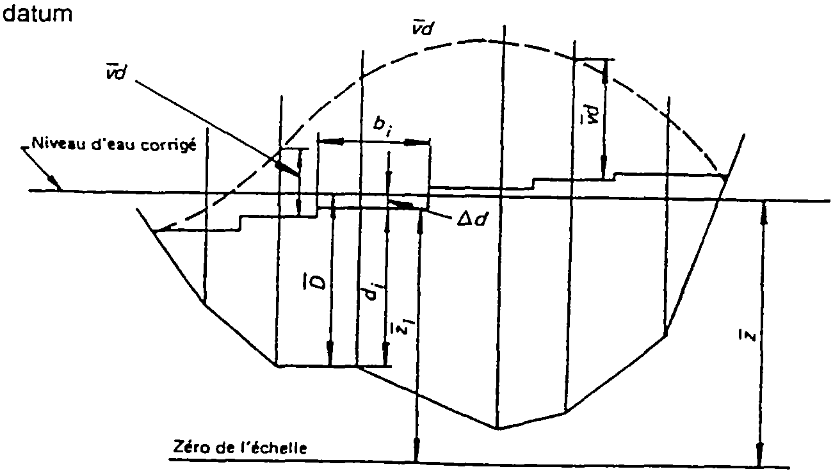


Figure 4 - Computation of discharge and mean water-level for variations of water-level

9.4.2 Computation of mean water-level

The mean water-level representative of the discharge measurement shall be computed from the equations :

$$\bar{z} = \frac{\sum q_i \bar{z}_i}{Q}$$

$$q_i = b_i d_i \bar{v}_i$$

where

$\bar{z}$ is the mean water-level above the gauge datum ;

q_i is the partial discharge in the ith segment ;

$\bar{z}_i$ is the mean water-level corresponding to the partial discharge q_i ;

Q is the total discharge and equal to the sum of the partial discharge $\sum q_i$;

b_i is the width of the ith segment ;

d_i is the depth of the ith segment ;

$\bar{v}_i$ is the mean velocity in the ith segment.

The method is indicated in figure 4.

9.4.3 Computation of discharge for independent vertical method

By employing this gauging technique over a period of time, if a sufficiently large range in flow has been covered, it will be possible to derive a relationship between level and unit-width discharge for each vertical. A family of curves can then be constructed, each curve representating an independant stage/discharge relationship for the corresponding segment of channel width. This assumes of course that the channel geometry remains constant and that no change occurs in the position of a vertical relative to the zero reference point.

Then, for a given value of river stage, total flow in the cross section is obtained with an arithmetical method by summation of all segment discharges (Fig.5a) ; or with a graphical method (Fig.5b) by plotting the unit width discharge for all verticals and determining the area under this curve.

Total flow in the cross section for any given value of stage (Fig.5c) can be obtained by either of these methods.

APPENDIX L: LABORATORY RESULTS (SMALL STREAMS)

Table L.1 Summary of flume data. Ott C2 rotating element meter with Type 6 impeller. 100 seconds exposure time.

Chan. type	Chan. top width (m)	Flow depth (m)	Weir flow (m^3/s)	Number of verticals									
				20	15	14	12	10	7	5	3	2	1
				Metered discharge (m^3/s)[1]									
Rect.	0.500	0.050	0.01296							0.012 49		0.013 23	0.013 25
		0.100	0.03626							0.037 53		0.038 22	0.038 55
		0.250	0.03626							0.038 86		0.040 12	0.041 48
Rect.	0.915	0.050	0.01751					0.017 35		0.017 78		0.017 91	0.018 05
		0.100	0.04315					0.044 40		0.044 37		0.045 12	0.045 69
		0.250	0.05910					0.061 55		0.062 72		0.062 45	0.065 00
Rect.	1.500	0.050	0.02656		0.026 24			0.026 88		0.026 85		0.027 68	0.027 91
		0.100	0.05790		0.059 88			0.060 18		0.062 19		0.060 72	0.062 79
		0.250	0.09073		0.092 49			0.092 97		0.093 91		0.093 44	0.102 10
Rect.	2.000	0.050	0.03123	0.031 77				0.031 75		0.031 89		0.031 46	0.030 13
		0.100	0.05595	0.057 11				0.057 49		0.058 14		0.060 14	0.059 22
		0.250	0.11176	0.112 27				0.115 03		0.114 76		0.117 97	0.116 18
Trap.	2.000	0.050	0.01907				0.019 39		0.019 40		0.019 60		0.019 77
1:2 side slopes		0.100	0.06196			0.064 66			0.063 88		0.059 75		0.059 52
		0.250	0.10438	0.110 06					0.108 62		0.102 22		0.100 56

Note : [1] Metered discharge calculated using velocity-area method.

Table L.2 Summary of flume data. Ott C2 rotating element meter with Type 6 impeller. 100 seconds exposure time. Statistical analysis of deviation of metered discharge from weir discharge (%)

Chan. type	Chan. top width (m)	Flow depth (m)	Weir flow (m^3/s)	Number of verticals									
				20	15	14	12	10	7	5	3	2	1
				Deviation of metered discharge[1] from weir discharge (%)									
Rect.	0.500	0.050	0.01296							-3.64		2.05	2.24
		0.100	0.03626							3.51		5.40	6.31
		0.250	0.03626							7.18		10.64	14.40
Rect.	0.915	0.050	0.01751					-0.92		1.56		2.26	3.08
		0.100	0.04315					2.90		2.84		4.57	5.89
		0.250	0.05910					4.15		6.12		5.67	9.98
Rect.	1.500	0.050	0.02656		-1.20			1.60		1.47		4.62	5.48
		0.100	0.05790		3.43			3.94		5.85		4.87	8.44
		0.250	0.09073		1.95			2.47		3.51		2.99	12.55
Rect.	2.000	0.050	0.03123	1.73				1.65		2.11		0.75	-3.52
		0.100	0.05595	2.08				2.76		3.91		7.49	5.85
		0.250	0.11176	0.45				2.93		2.69		5.55	3.96
Trap.	2.000	0.050	0.01907				1.69		1.73		2.76		3.70
		0.100	0.06196			4.35			3.11		-3.57		-3.90
		0.250	0.10438	5.44					4.06		-2.07		-3.70
Statistical analysis													
Average				2.42	1.29			2.39	2.97	3.09	-0.96	4.74	4.72
Standard Deviation				1.84	2.07			1.43	0.96	2.68	2.70	2.53	5.33
Deviation about the average - min				0.58	-0.78			0.96	2.01	0.41	-3.40	2.21	-0.61
Deviation about the average - max				4.26	3.36			3.82	3.93	5.77	1.74	7.27	10.05

Note : [1] Metered discharge calculated using velocity-area method.

Table L.3 Summary of flume data. Aqua Data - Sensa RV1 electromagnetic flowmeter. 60 seconds exposure time.

Chan. type	Chan. top width (m)	Flow depth (m)	Weir flow (m^3/s)	Number of verticals									
				20	15	14	12	10	7	5	3	2	1
				Metered discharge (m^3/s)[1]									
Rect.	0.500	0.050	0.01296							0.01186		0.01255	0.01267
		0.100	0.03626							0.03638		0.03697	0.03741
		0.250	0.03626							0.03653		0.03758	0.03978
Rect.	0.915	0.050	0.01751										
		0.100	0.04315										
		0.250	0.05910										
Rect.	1.500	0.050	0.02656										
		0.100	0.05790										
		0.250	0.09073										
Rect.	2.000	0.050	0.03123	0.02934				0.03015		0.03097		0.03167	0.03162
		0.100	0.05595	0.05329				0.05577		0.05668		0.06038	0.05903
		0.250	0.11176	0.11034				0.10698		0.11199		0.11399	0.11503
Trap.	2.000	0.050	0.01907										
1:2 side slopes		0.100	0.06196										
		0.250	0.10438										

Note: [1] Metered discharge calculated using velocity-area method.

Table L.4 Summary of flume data. Aqua Data - Sensa RV1 electromagnetic flowmeter. 10 and 60 seconds exposure time. Statistical analysis of deviation of metered discharge from weir discharge (%)

Chan. type	Chan. top width (m)	Flow depth (m)	Timing period (secs)	Weir flow (m^3/s)	Number of verticals									
					20	15	14	12	10	7	5	3	2	1
					Deviation of metered discharge from weir discharge (%)									
Rect.	0.500	0.050	10	0.01296							-8.30		-2.50	-2.20
		0.100		0.03626							-0.26		1.46	3.17
		0.250		0.03626							-1.14		5.50	7.00
Rect.	0.915	0.050		0.01751										
		0.100		0.04315										
		0.250		0.05910										
Rect.	1.500	0.050		0.02656										
		0.100		0.05790										
		0.250		0.09073										
Rect.	2.000	0.050		0.03123					-1.06		-0.60		-0.50	1.00
		0.100		0.05595	0.90				-1.84		0.10		6.50	6.50
		0.250		0.11176	-1.50				-1.74		0.20		3.60	-4.60
Trap.	2.000	0.050		0.01907										
		0.100		0.06196										
		0.250		0.10438										
Rect.	0.500	0.050	60	0.01296							-8.50		-3.20	-2.20
		0.100		0.03626							0.30		1.95	3.17
		0.250		0.03626							0.75		3.60	9.70
Rect.	0.915	0.050		0.01751										
		0.100		0.04315										
		0.250		0.05910										
Rect.	1.500	0.050		0.02656										
		0.100		0.05790										
		0.250		0.09073										
Rect.	2.000	0.050		0.03123	-6.06				-3.45		-0.80		1.42	1.26
		0.100		0.05595	-4.75				-0.30		1.30		7.90	5.50
		0.250		0.11176	-1.27				-4.27		0.20		2.00	2.90
Trap.	2.000	0.050		0.01907										
		0.100		0.06196										
		0.250		0.10438										
					Statistical analysis									
Average					-1.58				-0.70		-0.70		1.16	1.04
Standard Deviation					2.34				1.27		2.37		2.56	2.86
Deviation about the average - min					-3.92				-1.97		-3.07		-1.40	-1.82
Deviation about the average - max					0.75				0.57		1.67		3.72	3.90

Table H.3 cont **Error in mean velocity using the methods outlined in Table 2.3 (%)**

Reference	Method number							
	1	2	3	4	5	6	8	9
Aire3 - C	20.022	15.298	0.473	10.248	3.225	6.989	-0.713	-6.858
Aire3 - D	5.721	4.172	0.468	3.095	-2.236	2.219	-1.147	-2.994
Aire3 - E	5.211	0.231	-1.737	1.737	-4.006	0.579	0.000	-0.890
Aire3 - F	3.186	1.473	-1.226	0.980	-3.402	0.245	-0.487	-1.491
Aire3 - G	2.629	0.110	0.378	1.504	-3.039	1.129	-0.268	-1.553
Aire3 - H	-8.045	-5.531	-2.343	-5.194	-7.237	-4.243	-0.877	1.312
Aire3 - I	-9.824	-5.861	3.545	-3.139	-3.682	-0.911	-0.510	-0.536
Aire3 - J	-4.923	-4.243	0.681	-2.121	-3.820	-1.187	0.169	-0.143
Aire3 - K	-4.244	-3.053	0.689	-1.777	-4.033	-0.955	-0.404	-0.559
Aire3 - L	-2.951	-2.661	-0.763	-1.857	-4.337	-1.492	-0.156	-0.211
Aire3 - M	-2.289	4.093	3.263	0.487	-1.055	1.412	-2.058	-3.898
Aire3 - N	-7.835	4.542	-1.726	-4.781	-1.301	-3.763	-1.301	-2.390
Aire3 - O	22.908	27.409	-16.042	3.433	-0.462	-3.058	-2.424	-5.559
Aire4 - A	7.561	5.571	0.337	3.949	-0.971	2.745	-0.658	-3.436
Aire4 - B	-17.625	-4.470	1.533	-8.046	-1.149	-4.853	0.490	-0.348
Aire4 - C	2.074	3.166	-5.022	-1.474	-4.224	-2.656	-0.587	-0.814
Aire4 - D	3.041	0.323	2.176	2.609	-1.829	2.464	-0.108	-2.226
Aire4 - E	3.156	0.901	2.491	2.824	-0.865	2.713	0.200	-2.532
Aire4 - F	-0.698	4.247	0.670	-0.014	-2.801	0.214	-2.263	-3.087
Aire4 - G	0.236	-2.433	0.192	0.214	-2.205	0.207	1.170	-0.608
Aire4 - H	1.382	0.993	0.246	0.814	-2.305	0.624	-0.227	-1.815
Aire4 - I	-1.223	-2.218	0.252	-0.486	-2.875	-0.240	0.468	-0.702
Aire4 - J	-0.100	-3.835	1.397	0.649	-2.904	0.898	0.853	-0.523
Aire4 - K	3.127	0.234	2.509	2.818	-1.440	2.715	0.086	-2.307
Aire4 - L	12.594	4.421	3.191	7.893	0.880	6.325	0.607	-3.988
Aire4 - M	9.236	4.696	3.819	6.528	3.757	5.625	1.865	-4.292
Aire4 - N	-42.317	-15.902	6.750	-17.784	-4.871	-9.606	-1.436	1.883
Aire4 - O	0.722	2.056	0.636	0.679	-1.573	0.665	-0.378	-2.315
Aire4 - P	1.413	0.580	2.297	1.855	1.237	2.002	1.625	-2.356
Aire4 - Q	4.198	8.326	-1.235	1.481	0.272	0.576	-0.790	-3.868
Conwy - A	19.349	16.436	-18.392	0.478	-6.071	-5.812	-1.163	-0.965

Table H.3 cont Error in mean velocity using the methods outlined in Table 2.3 (%)

Reference	Method number							
	1	2	3	4	5	6	8	9
Conwy - B	-16.349	-3.883	1.952	-7.199	-6.623	-4.148	-3.416	-0.691
Conwy - C	1.211	-1.674	-3.028	-0.908	-3.970	-1.615	0.848	0.202
Conwy - D	-9.242	-6.773	5.776	-1.733	-1.939	0.770	0.347	-0.963
Conwy - E	-5.647	-6.352	3.942	-0.852	-2.374	0.746	0.852	-0.497
Conwy - F	3.536	-0.606	-1.664	0.936	-3.773	0.069	0.312	-0.624
Conwy - G	-6.740	-4.910	2.738	-2.001	-3.663	-0.421	-0.316	-0.597
Conwy - H	-2.582	-2.348	0.108	-1.237	-4.172	-0.789	-0.430	-0.610
Conwy - I	4.412	2.525	-4.531	-0.060	-4.744	-1.550	-0.596	-0.755
Conwy - J	-3.560	-2.114	1.964	-0.798	-3.226	0.123	-0.614	-1.309
Conwy - K	1.998	6.232	-5.995	-1.998	-5.899	-3.331	-2.665	-1.554
Conwy - L	2.333	-3.736	-3.157	-0.412	-4.911	-1.327	1.235	0.961
Conwy - M	1.808	-0.817	-2.712	-0.452	-3.960	-1.206	0.452	-0.201
Conwy - N	-5.792	-1.838	-1.770	-3.781	-5.354	-3.110	-1.126	-0.161
Conwy - O	1.983	4.828	-7.032	-2.524	-7.353	-4.027	-2.705	-0.721
Conwy - P	3.876	3.004	-6.384	-1.254	-4.738	-2.964	-0.228	-0.304
Conwy - Q	-1.300	-4.208	0.867	-0.217	-2.227	0.144	1.516	-0.217
Cuckmere-D	-1.412	-0.837	-0.824	-1.118	-5.165	-1.020	-1.294	-0.824
Cuckmere-E	-28.140	-11.849	4.183	-11.978	-4.449	-6.591	-0.570	1.331
Cuckmere-F	9.228	4.859	0.107	4.668	-0.472	3.148	0.215	-3.112
Cuckmere-G	2.719	0.008	0.291	1.505	-2.466	1.100	0.194	-1.489
Cuckmere-H	3.790	0.572	1.361	2.575	-1.011	2.171	0.680	-2.041
Cuckmere-I	1.566	0.791	0.098	0.832	-2.632	0.587	-0.294	-1.696
Cuckmere-J	-0.399	-1.509	0.599	0.100	-3.533	0.266	-0.299	-1.065
Cuckmere-K	-8.229	-10.041	2.904	-2.662	-4.201	-0.807	1.259	1.129
Cuckmere-L	2.187	0.962	0.696	1.441	-1.729	1.193	0.099	-1.955
Cuckmere-M	3.128	2.188	1.232	2.180	-0.986	1.864	0.000	-2.559
Cuckmere-N	4.682	4.090	1.873	3.277	0.010	2.809	-0.187	-3.433
Cuckmere-O	9.797	3.187	-0.832	4.483	-2.255	2.711	0.092	-2.218
Cuckmere-P	6.106	3.377	-1.790	2.158	-4.253	0.842	-1.368	-1.965
Cuckmere-Q	-14.196	-11.503	3.350	-5.423	-4.928	-2.499	0.638	1.489
Cuckmere-R	0.679	-3.348	-0.291	0.194	-4.549	0.032	0.194	-0.129

Table H.3 cont Error in mean velocity using the methods outlined in Table 2.3 (%)

Reference	Method number							
	1	2	3	4	5	6	8	9
Don1 - A	49.118	35.094	-7.513	20.803	3.913	11.364	-2.931	-11.070
Don1 - B	-0.281	3.744	-2.718	-1.499	-2.962	-1.906	-0.990	-1.783
Don1 - C	2.345	4.721	0.099	1.222	-2.712	0.847	-1.907	-3.061
Don1 - D	3.433	2.208	-1.594	0.919	-3.559	0.082	-0.752	-1.624
Don1 - E	4.713	0.100	-1.842	1.436	-3.245	0.343	0.547	-0.810
Don1 - F	-2.036	-0.460	-1.586	-1.811	-3.815	-1.736	-0.360	-0.701
Don1 - G	-5.447	-2.790	0.203	-2.622	-4.837	-1.680	-1.008	-0.488
Don1 - H	1.531	3.787	-1.513	0.009	-2.677	-0.498	-1.039	-2.200
Don1 - I	-2.347	-2.714	-1.223	-1.785	-4.078	-1.598	0.252	-0.039
Don1 - J	-1.553	-1.808	2.237	0.342	-2.770	0.973	-0.328	-1.507
Don1 - K	5.102	0.898	-0.244	2.429	-2.276	1.538	0.367	-1.619
Don1 - L	0.321	1.034	5.451	2.886	-0.342	3.741	-0.777	-3.565
Don1 - M	-4.768	1.043	-0.118	-2.443	-2.882	-1.668	-1.127	-1.712
Don1 - N	6.400	2.906	-2.176	2.112	-2.660	0.683	0.048	-1.673
Don1 - O	20.387	18.858	-11.170	4.608	0.793	-0.651	0.100	-4.213
Don1 - P	10.381	3.173	-4.261	3.060	-4.543	0.619	-0.225	-1.070
Don2 - A	-13.043	-7.036	-7.962	-10.503	-12.140	-9.656	-2.146	3.708
Don2 - B	-0.904	2.572	3.986	1.541	0.849	2.356	-0.258	-3.611
Don2 - C	-11.697	-0.682	-2.687	-7.192	-4.849	-5.690	-1.556	-0.257
Don2 - D	1.325	-0.877	1.627	1.476	-1.729	1.526	0.470	-1.627
Don2 - E	1.174	-1.874	0.274	0.724	-3.525	0.574	0.123	-0.830
Don2 - F	5.995	2.681	-2.644	1.676	-3.034	0.236	0.008	-1.438
Don2 - G	1.655	5.659	1.307	1.481	-0.479	1.423	-1.280	-3.789
Don2 - H	-0.290	1.167	1.501	0.606	-1.834	0.904	-0.571	-2.294
Don2 - I	-0.390	-0.217	0.693	0.152	-2.568	0.332	-0.225	-1.545
Don2 - J	-1.596	-2.408	2.148	0.276	-2.398	0.900	0.196	-1.269
Don2 - K	-3.208	-1.814	0.018	-1.595	-4.153	-1.057	-0.673	-0.765
Don2 - L	-0.172	-0.046	-0.029	-0.100	-3.533	-0.076	-0.677	-1.363
Don2 - M	-1.774	-1.716	0.226	-0.774	-3.486	-0.441	-0.195	-0.868
Don2 - N	-4.320	-2.027	2.055	-1.133	-2.482	-0.070	-0.260	-1.370
Don2 - O	-4.400	-2.259	1.243	-1.579	-4.038	-0.638	-0.938	-1.019

Table H.3 cont Error in mean velocity using the methods outlined in Table 2.3 (%)

Reference	Method number							
	1	2	3	4	5	6	8	9
Don2 - P	-3.150	-0.220	-1.575	-2.362	-3.472	-2.100	-0.346	-0.787
Don2 - Q	-1.877	-2.689	-0.512	-1.195	-3.951	-0.967	0.137	-0.284
Don2 - R	-76.662	-15.456	8.983	-33.840	-12.946	-19.566	-11.185	0.983
Dyfi - A	27.753	8.122	-7.698	10.028	2.992	4.119	5.618	-1.643
Dyfi - B	31.496	25.680	-13.085	9.206	-0.496	1.776	-1.853	-5.944
Dyfi - C	10.715	7.518	-1.476	4.620	-3.033	2.588	-1.925	-3.507
Dyfi - D	7.329	3.036	-0.580	3.374	-3.178	2.056	-0.791	-2.250
Dyfi - E	1.509	-2.084	1.752	1.630	-1.620	1.671	1.022	-1.249
Dyfi - F	-2.489	-0.637	0.507	-0.991	-2.755	-0.492	-0.323	-1.337
Dyfi - G	3.472	2.806	-1.350	1.061	-3.823	0.257	-1.254	-1.913
Dyfi - H	-9.335	-6.109	8.236	-0.549	-1.788	2.379	-0.659	-2.013
Dyfi - I	4.333	6.103	2.270	3.302	-0.367	2.958	-1.444	-4.265
Irt-A	-5.092	-7.006	12.599	3.753	11.139	6.702	7.303	-3.156
Irt-B	1.850	4.674	-5.868	-2.009	-6.238	-3.295	-2.299	-1.056
Irt-C	12.201	10.053	-11.215	0.493	-2.040	-3.410	1.076	-1.141
Irt-D	-7.058	-3.698	-2.814	-4.936	-6.187	-4.229	-0.685	0.833
Irt-E	-13.532	-12.891	5.650	-3.941	-2.263	-0.744	2.293	1.204
Irt-F	1.932	1.647	-4.448	-1.258	-2.526	-2.321	0.972	-0.478
Irt-G	-5.793	-4.642	0.448	-2.672	-2.750	-1.632	1.039	0.073
Irt-H	-3.017	-5.106	0.039	-1.489	-2.831	-0.980	1.592	0.371
Irt-I	-6.466	-2.149	-0.803	-3.635	-4.734	-2.691	-0.973	-0.375
Irt-J	-0.471	-0.178	-4.269	-2.370	-4.361	-3.003	0.210	0.096
Irt-K	-1.659	-0.930	-0.928	-1.293	-3.276	-1.171	0.013	-0.757
Irt-L	-3.056	-1.448	-3.120	-3.088	-5.220	-3.099	-0.475	0.154
Irt-M	0.101	-2.237	0.816	0.459	-1.368	0.578	1.425	-0.884
Irt-N	-4.868	-2.158	-3.889	-4.378	-5.866	-4.215	-0.535	0.657
Irt-O	-3.721	0.116	-4.055	-3.888	-5.527	-3.943	-1.087	-0.078
Irt-P	0.439	0.220	0.081	0.260	-2.913	0.200	-0.350	-1.492
Irt-Q	-0.979	-3.580	-0.678	-0.829	-4.389	-0.778	0.360	0.080
Irt-R	-4.439	-5.905	1.313	-1.563	-3.787	-0.604	0.721	0.224
Irt-S	9.100	4.326	-4.303	2.399	-4.798	0.165	-0.990	-1.457

Table H.3 cont **Error in mean velocity using the methods outlined in Table 2.3 (%)**

Reference	Method number							
	1	2	3	4	5	6	8	9
Irt-T	20.203	13.701	-5.161	7.521	-3.154	3.294	-2.404	-4.426
Irt-U	-1.084	5.817	-5.531	-3.307	-7.562	-4.048	-4.064	-1.565
Ouse1 - A	-25.260	24.428	0.757	-12.252	-7.474	-7.915	-16.272	-10.123
Ouse1 - B	-61.783	-48.025	35.350	-13.217	2.548	2.972	5.414	3.503
Ouse1 - C	6.803	21.843	-15.143	-4.170	-6.657	-7.827	-6.145	-3.926
Ouse1 - D	-37.690	-30.152	10.942	-13.374	-3.666	-5.268	4.369	5.433
Ouse1 - E	-25.258	-15.346	0.515	-12.371	-10.530	-8.076	-1.657	3.768
Ouse1 - F	-7.951	-11.889	-4.082	-6.017	-8.738	-5.372	1.361	4.100
Ouse1 - G	-5.770	-15.135	12.590	3.410	-0.019	6.470	3.186	-0.330
Ouse1 - H	-0.570	-7.472	7.597	3.513	-2.178	4.874	0.739	-1.327
Ouse1 - I	11.240	1.738	4.103	7.672	0.531	6.482	1.053	-3.360
Ouse1 - J	6.769	2.498	-0.807	2.981	-2.358	1.718	0.000	-1.987
Ouse1 - K	-0.251	-2.974	3.331	1.540	-2.071	2.137	0.390	-1.467
Ouse1 - L	-5.285	-0.522	0.444	-2.421	-4.554	-1.466	-1.828	-1.356
Ouse1 - M	1.441	-2.368	-1.512	-0.036	-3.930	-0.528	0.681	-0.063
Ouse1 - N	2.867	-0.015	-1.746	0.560	-3.713	-0.209	0.066	-0.802
Ouse1 - O	1.074	0.831	0.792	0.933	-2.679	0.886	-0.622	-1.941
Ouse1 - P	5.647	3.082	4.027	4.837	-0.644	4.567	-0.825	-3.801
Ouse1 - Q	7.722	10.811	-2.979	2.372	-2.583	0.588	-2.795	-4.150
Ouse1 - R	12.322	9.019	-0.301	6.010	-0.509	3.906	-1.098	-4.420
Ouse1 - S	3.750	10.439	2.954	3.352	-0.313	3.220	-3.501	-5.998
Ouse1 - T	12.704	5.239	-0.963	5.870	0.151	3.593	1.176	-2.887
Ouse1 - U	5.822	4.048	-5.672	0.075	-3.811	-1.841	-0.087	-0.904
Ouse1 - V	6.578	3.114	0.749	3.664	-0.192	2.692	0.649	-2.720
Ouse1 - W	-2.831	-4.055	4.342	0.756	-1.808	1.951	0.421	-1.428
Ouse1 - X	13.208	12.106	-1.836	5.686	-2.575	3.179	-3.162	-4.980
Ouse1 - Y	13.717	8.563	-0.782	6.467	-1.639	4.051	-1.362	-4.102
Ouse1 - Z	0.818	-0.957	1.738	1.278	-3.701	1.431	-0.900	-1.636
Ouse1 - AA	5.978	4.436	-3.153	1.413	-2.856	-0.109	-0.437	-1.878
Ouse1 - AB	0.677	5.552	-1.825	-0.574	-4.416	-0.991	-2.914	-2.708
Ouse1 - AC	-0.552	3.425	-5.060	-2.806	-6.034	-3.557	-2.152	-0.892

Table H.3 cont Error in mean velocity using the methods outlined in Table 2.3 (%)

Reference	Method number 1	2	3	4	5	6	8	9
Ouse1 - AD	0.654	6.532	-5.637	-2.491	-4.806	-3.540	-2.315	-1.778
Ouse1 - AE	-22.610	-0.941	-0.986	-11.798	-4.173	-8.194	-2.656	-0.733
Ouse2 - A	-39.119	1.969	1.036	-19.041	-10.039	-12.349	-10.104	-2.418
Ouse2 - B	-10.360	-3.718	-17.708	-14.034	-13.887	-15.258	-1.176	5.805
Ouse2 - C	-14.126	4.841	-15.059	-14.592	-10.952	-14.748	-4.045	1.950
Ouse2 - D	12.205	16.312	-0.030	6.088	0.254	4.049	-3.730	-7.043
Ouse2 - E	12.225	8.243	-3.430	4.398	-0.712	1.788	0.123	-3.108
Ouse2 - F	12.559	15.308	-12.596	-0.018	-6.121	-4.211	-3.338	-2.505
Ouse2 - G	10.159	7.809	-0.312	4.924	-0.584	3.178	-0.857	-3.997
Ouse2 - H	3.580	6.886	-4.319	-0.369	-3.809	-1.686	-1.944	-2.340
Ouse2 - I	0.510	3.799	5.395	2.953	0.356	3.767	-1.426	-4.506
Ouse2 - J	-1.891	1.141	-0.267	-1.079	-4.135	-0.808	-1.666	-1.696
Ouse2 - K	3.170	1.228	1.613	2.392	-2.084	2.132	-0.455	-2.353
Ouse2 - L	4.375	4.803	-0.248	2.064	-2.680	1.293	-1.601	-2.974
Ouse2 - M	6.442	2.401	2.213	4.328	-1.035	3.623	-0.117	-2.960
Ouse2 - N	4.916	6.559	-1.115	1.901	-3.467	0.895	-2.514	-3.294
Ouse2 - O	8.499	6.546	4.543	6.521	1.096	5.862	-0.995	-5.176
Ouse2 - P	21.345	22.122	-7.109	7.118	1.182	2.376	-2.259	-6.701
Ouse2 - Q	-10.037	-4.481	10.480	0.222	0.087	3.641	-0.905	-3.326
Ouse2 - R	5.873	15.062	2.477	4.175	0.679	3.609	-4.395	-7.444
Ouse2 - S	5.938	-7.192	-4.513	0.713	-2.162	-1.029	5.321	2.613
Ouse2 - T	-1.762	8.943	-0.745	-1.253	-2.710	-1.084	-3.794	-4.246
Ouse2 - U	-3.482	-17.019	6.292	1.405	3.543	3.034	8.674	2.423
Ouse2 - V	-6.960	-2.242	5.861	-0.549	0.293	1.587	0.147	-2.564
Ouse2 - W	-7.463	7.463	-4.478	-5.970	-3.433	-5.473	-2.985	-2.488
Ouse3 - A	-19.571	6.810	-12.869	-16.220	-6.166	-15.103	-2.949	0.536
Ouse3 - B	18.329	11.369	-18.794	-0.232	0.464	-6.419	5.336	0.928
Ouse3 - C	7.544	5.554	-3.692	1.926	-3.451	0.054	-0.963	-2.087
Ouse3 - D	5.332	-2.003	0.780	3.056	-0.845	2.297	2.211	-0.954
Ouse3 - E	7.872	7.055	1.312	4.592	-0.364	3.499	-1.166	-4.276
Ouse3 - F	8.516	8.791	2.335	5.426	2.885	4.396	-0.000	-5.220

Table H.3 cont Error in mean velocity using the methods outlined in Table 2.3 (%)

Reference	Method number							
	1	2	3	4	5	6	8	9
Ouse3 - G	2.151	7.097	0.134	1.142	-0.538	0.806	-1.478	-3.898
Ouse3 - H	-2.878	-1.583	0.120	-1.379	-3.717	-0.879	-0.480	-0.879
Ouse3 - I	0.484	0.533	-0.121	0.182	-3.027	0.081	-0.484	-1.533
Ouse3 - J	-8.213	-4.928	2.053	-3.080	-4.589	-1.369	-0.845	-0.362
Ouse3 - K	2.273	-1.818	-2.841	-0.284	-4.205	-1.136	0.795	0.189
Ouse3 - L	-8.982	-6.874	-2.994	-5.988	-6.766	-4.990	0.120	1.996
Ouse3 - M	-4.598	-4.552	0.000	-2.299	-4.138	-1.533	0.345	0.192
Ouse3 - N	-15.094	-8.302	4.953	-5.071	-4.009	-1.730	-0.708	-0.157
Ouse3 - O	5.263	2.201	-4.306	0.478	-4.426	-1.116	-0.239	-0.718
Ouse3 - P	5.909	1.672	-1.895	2.007	-4.125	0.706	-0.557	-1.338
Ouse3 - Q	8.861	-1.570	5.063	6.962	-0.380	6.329	1.266	-2.532
Ouse3 - R	11.524	-1.264	0.372	5.948	-1.673	4.089	2.107	-1.074
Ouse3 - S	14.374	13.509	0.464	7.419	-2.009	5.100	-4.019	-6.234
Ouse3 - T	57.051	29.231	-32.692	12.179	-19.231	-2.778	-6.731	-0.641
Rother1 -A	5.965	-12.967	20.487	13.226	2.276	15.646	2.355	-3.715
Rother1 -B	56.026	36.728	-12.165	21.930	5.742	10.565	-0.151	-10.087
Rother1 -C	1.485	-0.235	3.268	2.377	0.404	2.674	1.093	-2.397
Rother1 -D	8.316	5.398	7.750	8.033	4.453	7.939	0.634	-5.846
Rother1 -E	4.147	3.558	-3.149	0.499	-3.706	-0.717	-0.822	-1.575
Rother1 -F	3.006	4.278	-1.080	0.963	-2.218	0.282	-0.934	-2.514
Rother1 -G	4.083	6.453	1.003	2.543	-0.233	2.030	-1.103	-3.964
Rother1 -H	7.980	6.531	-0.990	3.495	-1.213	2.000	-0.735	-3.327
Rother1 -I	10.970	12.784	2.192	6.581	1.271	5.118	-2.447	-6.559
Rother1 -J	11.928	8.333	3.614	7.771	1.702	6.385	-0.683	-5.487
Rother1 -K	14.110	12.175	-0.655	6.728	1.744	4.267	-0.615	-5.398
Rother2 -A	44.900	32.127	-5.979	19.461	4.021	10.981	-2.556	-10.551
Rother2 -B	9.175	6.012	-5.149	2.013	-3.069	-0.374	-0.251	-1.760
Rother2 -C	0.380	5.493	3.146	1.763	0.582	2.224	-1.245	-4.345
Rother2 -D	5.672	4.447	-0.045	2.814	-0.581	1.861	0.009	-2.918
Rother2 -E	-0.683	-1.751	1.096	0.206	-3.211	0.503	-0.178	-1.146
Rother2 -F	-7.545	-5.029	3.064	-2.241	-2.968	-0.472	0.008	-0.664

Table H.3 cont **Error in mean velocity using the methods outlined in Table 2.3 (%)**

Reference	Method number							
	1	2	3	4	5	6	8	9
Rother2 -G	-3.703	-2.346	-0.592	-2.148	-4.219	-1.629	-0.341	-0.377
Rother2 -H	5.624	1.604	-2.465	1.579	-4.357	0.231	-0.522	-1.124
Rother2 -I	12.730	13.380	-0.849	5.941	0.898	3.678	-1.754	-5.752
Rother3 -A	-23.462	-13.610	3.962	-9.750	-3.848	-5.179	1.105	2.016
Rother3 -B	-9.051	-1.363	3.523	-2.764	-3.041	-0.668	-1.872	-2.090
Rother3 -C	-40.016	-23.566	9.071	-15.472	-7.073	-7.291	-0.255	3.770
Rother3 -D	-10.866	-5.713	0.707	-5.080	-5.654	-3.151	-1.045	0.359
Rother3 -E	2.998	-3.178	1.672	2.335	-1.887	2.114	1.475	-0.843
Rother3 -F	-0.909	-1.032	-3.149	-2.029	-6.609	-2.403	-1.351	0.019
Rother3 -G	-0.256	-2.925	0.588	0.166	-4.671	0.306	-0.450	-0.569
Rother3 -H	3.418	-2.605	-0.667	1.375	-4.507	0.694	0.312	-0.262
Rother3 -I	13.654	3.909	-4.181	4.737	-1.368	1.764	1.885	-1.353
Rother3 -J	2.611	1.299	-0.516	1.047	-3.745	0.526	-0.938	-1.668
Rother3 -K	0.105	4.782	-1.630	-0.762	-4.395	-1.052	-2.702	-2.506
Sheppey-A	-13.632	1.000	5.115	-4.258	1.580	-1.134	-0.765	-3.441
Sheppey-B	2.286	3.803	-3.461	-0.587	-2.211	-1.545	-0.010	-1.556
Sheppey-C	30.873	25.638	-17.464	6.704	1.304	-1.352	0.762	-4.470
Sheppey-D	4.142	3.294	6.084	5.113	3.067	5.437	0.725	-4.561
Sheppey-E	-2.193	1.478	-1.849	-2.021	-3.340	-1.964	-0.778	-1.286
Sheppey-F	1.728	0.716	-0.804	0.462	-2.145	0.040	0.379	-1.370
Sheppey-G	-4.615	-2.046	1.431	-1.592	-1.831	-0.584	0.360	-1.156
Sheppey-H	2.140	0.667	-1.111	0.515	-2.307	-0.027	0.435	-1.250
Sheppey-I	-0.344	1.897	-1.331	-0.837	-4.024	-1.002	-1.397	-1.604
Sheppey-J	1.765	-0.369	-0.746	0.509	-2.611	0.091	0.505	-1.012
Sheppey-K	-3.110	1.190	-0.990	-2.050	-4.020	-1.697	-1.490	-1.472
Sheppey-L	-6.921	-2.235	0.742	-3.090	-3.964	-1.813	-0.984	-0.860
Sheppey-M	-0.364	0.182	-1.487	-0.926	-2.671	-1.113	0.270	-0.956
Sheppey-N	9.613	10.282	-6.143	1.735	-0.587	-0.891	0.000	-2.911
Sheppey-O	2.901	10.089	0.417	1.659	0.605	1.245	-1.983	-5.031
Sheppey-P	45.032	36.291	-22.966	11.033	0.083	-0.300	-1.241	-6.334
Swale1 - A	-16.118	11.316	1.151	-7.484	-7.730	-4.605	-10.197	-5.702

Table H.3 cont Error in mean velocity using the methods outlined in Table 2.3 (%)

Reference	Method number							
	1	2	3	4	5	6	8	9
Swale1 - B	-52.134	-32.180	-1.672	-26.903	-11.995	-18.493	2.422	10.342
Swale1 - C	20.422	12.260	-0.036	10.193	2.698	6.783	0.411	-5.634
Swale1 - D	3.925	9.452	-0.444	1.741	-2.713	1.012	-3.539	-4.523
Swale1 - E	-2.517	-3.619	0.849	-0.834	-2.686	-0.273	0.849	-0.415
Swale1 - F	0.685	-1.479	-0.869	-0.092	-3.182	-0.351	0.519	-0.586
Swale1 - G	-1.073	-1.851	-0.252	-0.662	-3.083	-0.525	0.359	-0.662
Swale1 - H	-1.233	-3.520	2.531	0.649	-2.217	1.276	0.688	-1.010
Swale1 - I	-0.577	-0.830	-0.551	-0.564	-3.621	-0.560	-0.276	-0.917
Swale1 - J	10.350	6.749	1.694	6.022	-1.053	4.580	-1.378	-4.297
Swale1 - K	-4.905	-4.305	2.858	-1.023	-4.614	0.271	-1.059	-0.847
Swale1 - L	9.620	10.890	5.366	7.493	3.387	6.784	-1.440	-6.959
Swale1 - M	-4.403	8.679	-4.717	-4.560	-2.075	-4.612	-2.201	-2.830
Swale1 - N	-53.560	-3.406	2.941	-25.310	-9.056	-15.893	-9.288	-1.187
Swale2 - A	13.177	6.128	1.859	7.518	2.526	5.632	1.496	-4.136
Swale2 - B	3.974	8.276	-0.359	1.808	-1.554	1.086	-2.301	-4.143
Swale2 - C	0.203	5.561	-1.321	-0.559	-2.795	-0.813	-2.053	-2.879
Swale2 - D	1.474	3.899	-1.697	-0.111	-4.444	-0.640	-2.207	-2.177
Swale2 - E	3.514	1.684	-2.551	0.481	-5.090	-0.529	-1.227	-1.123
Swale2 - F	3.021	-1.050	-0.760	1.131	-4.057	0.501	-0.045	-0.771
Swale2 - G	-5.632	-2.534	-0.576	-3.104	-5.001	-2.262	-0.983	-0.317
Swale2 - H	-1.761	-1.398	-2.054	-1.907	-4.554	-1.956	-0.279	-0.219
Swale2 - I	0.404	-1.655	-1.000	-0.298	-3.299	-0.532	0.531	-0.481
Swale2 - J	2.893	0.114	-1.805	0.544	-4.317	-0.239	-0.368	-0.827
Swale2 - K	12.352	8.720	1.210	6.781	-0.486	4.924	-1.459	-4.820
Swale2 - L	26.656	24.115	-3.012	11.822	3.502	6.877	-2.377	-8.758
Swale2 - M	-20.474	1.523	-2.284	-11.379	-5.838	-8.347	-4.146	-1.156
Ure1 - A	11.905	30.286	-19.048	-3.571	-13.452	-8.730	-12.381	-5.556
Ure1 - B	-15.082	-25.779	6.464	-4.309	-1.331	-0.718	7.858	5.408
Ure1 - C	-5.442	-14.790	8.608	1.583	2.810	3.925	6.289	0.877
Ure1 - D	0.985	3.777	2.080	1.533	-2.121	1.715	-1.916	-3.394
Ure1 - E	1.826	1.227	2.895	2.361	-0.214	2.539	0.230	-2.780

Table H.3 cont Error in mean velocity using the methods outlined in Table 2.3 (%)

Reference	Method number						
	1	2	3	4	5	6	8	9
Ure1 - F	-3.689	0.608	2.408	-0.641	-0.687	0.376	-0.216	-2.403
Ure1 - G	-4.430	-2.041	0.050	-2.190	-3.571	-1.444	-0.324	-0.697
Ure1 - H	-7.076	-4.287	1.654	-2.711	-2.774	-1.256	0.345	-0.452
Ure1 - I	2.970	2.979	-1.674	0.648	-2.488	-0.126	-0.378	-1.865
Ure1 - J	8.651	1.496	-4.792	1.929	-4.120	-0.311	0.759	-0.311
Ure1 - K	25.591	16.658	4.440	15.016	4.007	11.491	-1.524	-8.653
Ure1 - L	13.867	21.025	5.531	9.699	1.322	8.310	-6.669	-10.533
Ure1 - M	-22.870	-7.444	4.484	-9.193	-8.610	-4.634	-4.753	-0.299
Ure2 - A	3.187	9.718	-2.038	0.575	-5.408	-0.296	-4.990	-4.084
Ure2 - B	9.258	7.556	-3.464	2.897	-3.849	0.777	-1.967	-2.858
Ure2 - C	-2.037	2.990	0.231	-0.903	-3.204	-0.525	-1.996	-2.504
Ure2 - D	-7.502	-2.609	-0.084	-3.793	-4.353	-2.556	-0.871	-0.455
Ure2 - E	-1.821	0.824	0.155	-0.833	-3.878	-0.503	-1.496	-1.727
Ure2 - F	17.577	9.761	-3.029	7.274	-2.457	3.840	-1.271	-3.768
Ure2 - G	10.917	5.306	-2.365	4.276	-3.402	2.062	-0.932	-2.443
Ure2 - H	24.815	16.669	-2.628	11.093	-0.583	6.520	-2.310	-6.301
Ure2 - I	1.563	-10.625	-10.156	-4.297	-3.711	-6.250	7.161	5.686
Ure2 - J	-100.00	-13.366	2.439	-48.780	-18.049	-31.707	-15.610	2.439
Ure3 - A	-30.670	-12.009	2.820	-13.925	-4.700	-8.343	-0.470	1.841
Ure3 - B	-24.342	-11.579	18.969	-2.686	1.919	4.532	-0.987	-3.692
Ure3 - C	14.795	-9.647	17.112	15.954	1.337	16.340	2.353	-3.743
Ure3 - D	37.444	15.453	-4.625	16.410	-0.882	9.398	-0.074	-5.213
Ure3 - E	24.670	17.096	-4.232	10.219	-0.728	5.402	-2.064	-5.914
Ure3 - F	-0.490	-0.580	3.421	1.465	-1.743	2.117	-0.443	-2.328
Ure3 - G	7.879	-0.998	0.443	4.161	-2.039	2.921	1.364	-1.190
Ure3 - H	11.167	9.756	-7.297	1.935	-5.103	-1.142	-2.251	-2.344
Ure3 - I	7.809	7.549	-2.216	2.797	-1.769	1.126	-1.139	-3.272
Ure3 - J	7.024	1.373	-2.932	2.046	-2.541	0.386	1.081	-0.888
Ure3 - K	5.005	-2.894	1.044	3.025	-2.874	2.365	1.109	-0.732
Ure3 - L	14.809	8.243	-1.292	6.758	-1.507	4.075	-0.861	-3.820
Ure3 - M	10.580	4.568	-5.848	2.366	-6.252	-0.372	-1.398	-1.026

Table H.3 cont Error in mean velocity using the methods outlined in Table 2.3 (%)

Reference	Method number							
	1	2	3	4	5	6	8	9
Ure3 - N	21.633	11.438	-5.224	8.204	-2.090	3.728	-0.588	-3.619
Ure3 - O	24.948	0.931	3.249	14.099	3.700	10.482	5.157	-2.795
Ure3 - P	26.793	0.504	4.692	15.743	3.529	12.059	4.924	-3.128
Wharfe - A	9.927	7.178	-1.149	4.389	-1.960	2.543	-1.256	-3.498
Wharfe - B	7.001	6.676	-0.346	3.328	-1.530	2.103	-1.320	-3.592
Wharfe - C	3.715	2.172	0.581	2.148	-1.769	1.626	-0.240	-2.337
Wharfe - D	0.343	0.610	1.641	0.992	-1.769	1.209	-0.279	-2.148
Wharfe - E	6.664	3.906	0.142	3.403	-0.907	2.316	0.053	-2.793
Wharfe - F	0.561	-0.279	3.475	2.018	-0.636	2.504	0.257	-2.450
Wharfe - G	-2.400	-1.065	1.176	-0.612	-2.408	-0.016	-0.127	-1.411
Wharfe - H	-0.750	-0.456	1.587	0.418	-1.556	0.808	0.216	-1.759
Wharfe - I	-0.160	2.102	-0.160	-0.160	-2.256	-0.160	-0.676	-2.065
Wharfe - J	0.974	3.763	-0.016	0.479	-1.052	0.314	-0.500	-2.690
Wharfe - K	-2.118	0.766	0.364	-0.877	-2.963	-0.463	-0.961	-1.776
Wharfe - L	6.956	5.123	1.115	4.035	-0.548	3.062	-0.510	-3.540

Table H.4 Percentage error in velocity with reduced points in vertical for individual verticals

Method type	95%limit	67% limit
Method 1	30.998	8.132
Method 2	21.899	6.057
Method 3	12.597	3.151
Method 4	14.677	3.787
Method 5	7.377	3.799
Method 6	9.821	3.081
Method 8	5.455	1.373
Method 9	6.308	2.787

Table H.5 Percentage error in velocity with reduced points in vertical for whole rivers

Method type	95%limit	67% limit
Method 1	7.219	1.896
Method 2	4.496	1.855
Method 3	1.750	0.812
Method 4	3.332	1.378
Method 5	3.970	2.857
Method 6	2.036	1.198
Method 8	1.207	0.510
Method 9	3.181	1.918

Table H.6 Error in velocity with reduced points in vertical and reduced number of verticals for the whole river (%)

Method Number	Full verticals		Ten verticals		Seven verticals		Five verticals	
	95%	67%	95%	67%	95%	67%	95%	67%
1	7.068	2.081	7.679	5.651	12.591	5.787	16.284	8.423
2	5.262	1.826	7.690	5.628	12.912	6.297	16.942	9.284
3	1.814	1.011	8.067	4.721	12.579	7.108	20.011	8.904
4	3.724	1.551	6.993	4.131	11.050	6.380	18.091	9.554
5	4.172	2.872	10.392	6.938	15.052	8.915	21.456	11.710
6	1.932	1.236	7.236	4.588	10.617	6.496	19.301	9.114
8	1.308	0.454	9.200	5.724	12.498	8.250	20.078	10.011
9	3.101	1.753	10.953	6.303	14.226	8.632	20.744	12.024
10	0.000	0.000	8.975	5.088	12.542	7.521	18.539	9.578

Table H.7 Error in discharge using a single surface velocity value

Surface Velocity Constant	Percentage error 95%ile	Percentage error 67%ile	Surface Velocity Constant	Percentage error 95%ile	Percentage error 67%ile
0.500	47.105	41.285	0.750	25.921	13.776
0.510	46.047	40.111	0.760	25.160	12.794
0.520	44.989	38.937	0.770	24.176	11.646
0.530	43.931	37.762	0.780	23.490	11.510
0.540	42.873	36.588	0.790	23.791	11.150
0.550	41.815	35.414	0.800	24.092	10.347
0.560	40.757	34.239	0.810	24.974	11.039
0.570	39.699	33.065	0.820	26.517	12.410
0.580	38.642	31.891	0.830	28.060	13.781
0.590	37.584	30.716	0.840	29.603	15.021
0.600	36.526	29.542	0.850	31.146	15.471
0.610	35.468	28.368	0.860	32.689	16.810
0.620	34.410	27.194	0.870	34.232	17.771
0.630	33.352	26.019	0.880	35.774	19.124
0.640	32.294	24.845	0.890	37.317	20.478
0.650	31.236	23.671	0.900	38.860	21.832
0.660	30.178	22.496	0.910	40.403	23.185
0.670	29.120	21.322	0.920	41.946	24.539
0.680	28.063	20.148	0.930	43.489	25.893
0.690	27.005	18.974	0.940	45.032	27.247
0.700	25.947	17.910	0.950	46.575	28.600
0.710	24.889	16.738	0.960	48.118	29.954
0.720	24.885	15.565	0.970	49.660	31.308
0.730	25.115	15.227	0.980	51.203	32.661
0.740	25.576	14.066	0.990	52.746	34.015
0.750	25.921	13.776	1.000	54.289	35.369

APPENDIX I Error analysis data (Rapidly varying flow)

Table I.1 Combined error from reduced number of verticals with reduced points in vertical for individual verticals for 200 second exposure time error from flume data (%)

Method Number	Number of verticals								
	20	15	10	7	5	4	3	2	1
1	7.089	8.953	11.526	15.042	18.400	24.146	33.853	41.333	75.708
2	5.117	6.933	9.205	12.550	15.566	21.510	31.394	38.312	72.459
3	3.185	5.165	7.255	10.567	13.346	19.557	29.641	36.157	70.210
4	3.603	5.519	7.636	10.944	13.765	19.916	29.958	36.547	70.613
5	2.220	4.441	6.497	9.837	12.541	18.879	29.049	35.429	69.464
6	2.652	4.746	6.813	10.138	12.872	19.155	29.289	35.724	69.766
8	1.923	4.252	6.305	9.657	12.343	18.715	28.907	35.255	69.286
9	2.049	4.330	6.384	9.731	12.424	18.782	28.965	35.326	69.358
10	1.486	4.012	6.064	9.434	12.099	18.515	28.735	35.043	69.071

Table I.2 Combined error from reduced number of verticals with reduced points in vertical for individual verticals for 100 second exposure time error from flume data (%)

Method Number	Number of verticals								
	20	15	10	7	5	4	3	2	1
1	7.119	8.985	11.564	15.083	18.446	24.190	33.895	41.385	75.764
2	5.159	6.974	9.251	12.599	15.621	21.560	31.439	38.368	72.518
3	3.218	5.192	7.285	10.596	13.378	19.584	29.665	36.187	70.241
4	3.622	5.536	7.655	10.963	13.785	19.934	29.974	36.567	70.633
5	2.252	4.463	6.519	9.858	12.563	18.898	29.065	35.449	69.484
6	2.678	4.766	6.834	10.158	12.894	19.174	29.305	35.744	69.786
8	1.941	4.263	6.316	9.667	12.354	18.724	28.915	35.265	69.296
9	2.066	4.341	6.395	9.741	12.435	18.791	28.973	35.336	69.369
10	1.510	4.024	6.076	9.445	12.111	18.525	28.743	35.053	69.081

Table I.3 Combined error from reduced number of verticals with reduced points in vertical for individual verticals for 50 second exposure time error from flume data (%)

Method Number	Number of verticals								
	20	15	10	7	5	4	3	2	1
1	7.119	8.985	11.563	15.083	18.446	24.190	33.895	41.385	75.764
2	5.159	6.974	9.251	12.599	15.621	21.560	31.439	38.368	72.518
3	3.218	5.192	7.285	10.596	13.378	19.584	29.665	36.187	70.241
4	3.622	5.536	7.655	10.963	13.785	19.934	29.974	36.567	70.633
5	2.252	4.463	6.519	9.858	12.563	18.898	29.065	35.449	69.484
6	2.678	4.766	6.834	10.158	12.894	19.174	29.305	35.744	69.786
8	1.941	4.263	6.316	9.667	12.354	18.724	28.915	35.265	69.296
9	2.066	4.341	6.395	9.741	12.435	18.791	28.973	35.336	69.369
10	1.510	4.024	6.076	9.445	12.111	18.525	28.743	35.053	69.081

Table I.4 Combined error from reduced number of verticals with reduced points in vertical for individual verticals for 30 second exposure time error from flume data (%)

Method Number	Number of verticals								
	20	15	10	7	5	4	3	2	1
1	7.180	9.049	11.638	15.165	18.540	24.280	33.980	41.490	75.879
2	5.242	7.057	9.345	12.697	15.732	21.661	31.531	38.481	72.638
3	3.285	5.248	7.344	10.655	13.443	19.640	29.714	36.247	70.303
4	3.662	5.571	7.693	11.000	13.827	19.970	30.006	36.607	70.674
5	2.315	4.506	6.563	9.900	12.609	18.936	29.098	35.490	69.526
6	2.732	4.807	6.876	10.199	12.939	19.211	29.338	35.785	69.828
8	1.978	4.286	6.339	9.689	12.377	18.744	28.932	35.285	69.317
9	2.101	4.363	6.417	9.762	12.458	18.810	28.990	35.356	69.390
10	1.557	4.048	6.100	9.467	12.135	18.544	28.760	35.074	69.102

Table I.5 **Combined error from reduced number of verticals with reduced points in vertical for individual verticals for 20 second exposure time error from flume data (%)**

Method Number	Number of verticals 20	15	10	7	5	4	3	2	1
1	7.154	9.022	11.607	15.130	18.501	24.242	33.944	41.446	75.831
2	5.207	7.022	9.305	12.656	15.685	21.618	31.492	38.433	72.588
3	3.257	5.225	7.319	10.630	13.416	19.616	29.693	36.222	70.277
4	3.645	5.556	7.677	10.985	13.810	19.955	29.993	36.590	70.657
5	2.289	4.488	6.545	9.882	12.590	18.920	29.085	35.473	69.509
6	2.709	4.790	6.858	10.182	12.920	19.196	29.324	35.768	69.810
8	1.962	4.276	6.329	9.680	12.368	18.736	28.925	35.277	69.308
9	2.086	4.354	6.408	9.753	12.448	18.802	28.983	35.348	69.381
10	1.537	4.038	6.090	9.457	12.125	18.536	28.753	35.065	69.093

Table I.6 **Combined error from reduced number of verticals with reduced points in vertical for individual verticals for 10 second exposure time error from flume data (%)**

Method Number	Number of verticals 20	15	10	7	5	4	3	2	1
1	7.289	9.165	11.774	15.314	18.711	24.443	34.135	41.681	76.088
2	5.392	7.205	9.513	12.874	15.932	21.843	31.698	38.686	72.856
3	3.404	5.348	7.451	10.761	13.561	19.740	29.803	36.356	70.415
4	3.734	5.634	7.761	11.069	13.904	20.037	30.065	36.679	70.749
5	2.427	4.583	6.644	9.976	12.693	19.006	29.159	35.565	69.602
6	2.827	4.879	6.953	10.273	13.020	19.280	29.398	35.859	69.903
8	2.044	4.327	6.380	9.728	12.420	18.779	28.962	35.323	69.355
9	2.163	4.403	6.459	9.801	12.501	18.846	29.020	35.394	69.428
10	1.640	4.091	6.143	9.506	12.178	18.580	28.791	35.112	69.141

Table I.7 **Combined error from reduced number of verticals with reduced points in vertical for individual verticals for 5 second exposure time error from flume data (%)**

Method Number	Number of verticals 20	15	10	7	5	4	3	2	1
1	7.459	9.345	11.985	15.545	18.976	24.697	34.379	41.980	76.416
2	5.619	7.433	9.772	13.149	16.243	22.128	31.960	39.008	73.199
3	3.583	5.501	7.618	10.925	13.744	19.898	29.942	36.528	70.593
4	3.844	5.732	7.868	11.176	14.023	20.140	30.157	36.792	70.867
5	2.593	4.703	6.768	10.095	12.824	19.115	29.254	35.682	69.722
6	2.971	4.992	7.072	10.388	13.148	19.388	29.493	35.975	70.023
8	2.143	4.391	6.445	9.789	12.487	18.834	29.010	35.382	69.416
9	2.257	4.466	6.523	9.862	12.567	18.901	29.068	35.453	69.488
10	1.762	4.158	6.210	9.569	12.246	18.636	28.839	35.171	69.201

Table I.8 **Combined error from reduced number of verticals with reduced points in vertical for whole rivers for 200 second exposure time error from flume data (%)**

Method Number	Number of verticals 20	15	10	7	5	4	3	2	1
1	2.194	4.424	6.479	9.821	12.522	18.864	29.036	35.413	69.447
2	1.794	4.177	6.228	9.586	12.265	18.651	28.852	35.187	69.217
3	1.537	4.037	6.089	9.457	12.124	18.536	28.753	35.065	69.093
4	1.662	4.103	6.155	9.518	12.190	18.590	28.799	35.122	69.151
5	1.731	4.141	6.193	9.553	12.229	18.621	28.826	35.155	69.185
6	1.554	4.046	6.098	9.465	12.133	18.543	28.759	35.073	69.101
8	1.510	4.024	6.076	9.445	12.111	18.525	28.743	35.053	69.082
9	1.647	4.095	6.147	9.510	12.182	18.583	28.794	35.115	69.144
10	1.486	4.012	6.064	9.434	12.099	18.515	28.735	35.043	69.071

Table I.9 Combined error from reduced number of verticals with reduced points in vertical for whole rivers for 100 second exposure time error from flume data (%)

Method Number	Number of verticals								
	20	15	10	7	5	4	3	2	1
1	2.289	4.488	6.545	9.883	12.590	18.920	29.085	35.473	69.509
2	1.910	4.244	6.297	9.649	12.334	18.708	28.901	35.248	69.279
3	1.605	4.073	6.124	9.489	12.160	18.564	28.778	35.095	69.124
4	1.705	4.126	6.178	9.539	12.214	18.609	28.816	35.142	69.172
5	1.772	4.164	6.216	9.574	12.252	18.640	28.843	35.176	69.206
6	1.599	4.070	6.121	9.487	12.157	18.562	28.776	35.093	69.122
8	1.534	4.036	6.088	9.456	12.123	18.534	28.752	35.064	69.092
9	1.669	4.107	6.158	9.521	12.194	18.593	28.802	35.125	69.155
10	1.510	4.024	6.076	9.445	12.111	18.525	28.743	35.053	69.081

Table I.10 Combined error from reduced number of verticals with reduced points in vertical for whole rivers for 50 second exposure time error from flume data (%)

Method Number	Number of verticals								
	20	15	10	7	5	4	3	2	1
1	2.289	4.488	6.545	9.883	12.590	18.920	29.085	35.473	69.509
2	1.909	4.244	6.297	9.649	12.334	18.708	28.901	35.248	69.279
3	1.605	4.072	6.124	9.489	12.159	18.564	28.778	35.095	69.124
4	1.705	4.126	6.178	9.539	12.214	18.609	28.816	35.142	69.172
5	1.772	4.164	6.216	9.574	12.252	18.640	28.843	35.176	69.206
6	1.599	4.070	6.121	9.487	12.157	18.562	28.776	35.093	69.122
8	1.534	4.036	6.088	9.456	12.123	18.534	28.752	35.064	69.092
9	1.669	4.107	6.158	9.521	12.194	18.593	28.802	35.125	69.155
10	1.510	4.024	6.076	9.445	12.111	18.525	28.743	35.053	69.081

Table I.11 Combined error from reduced number of verticals with reduced points in vertical for whole rivers for 30 second exposure time error from flume data (%)

Method Number	Number of verticals 20	15	10	7	5	4	3	2	1
1	2.472	4.615	6.677	10.007	12.728	19.035	29.184	35.595	69.634
2	2.125	4.379	6.433	9.777	12.475	18.824	29.001	35.371	69.404
3	1.735	4.143	6.195	9.555	12.231	18.623	28.828	35.157	69.187
4	1.788	4.173	6.225	9.582	12.261	18.648	28.849	35.184	69.214
5	1.852	4.210	6.262	9.617	12.299	18.679	28.876	35.217	69.247
6	1.687	4.117	6.169	9.530	12.204	18.601	28.809	35.134	69.164
8	1.580	4.060	6.111	9.478	12.147	18.554	28.769	35.084	69.113
9	1.712	4.130	6.182	9.543	12.218	18.612	28.819	35.146	69.175
10	1.557	4.048	6.100	9.467	12.135	18.544	28.760	35.074	69.102

Table I.12 Combined error from reduced number of verticals with reduced points in vertical for whole rivers for 20 second exposure time error from flume data (%)

Method Number	Number of verticals 20	15	10	7	5	4	3	2	1
1	2.397	4.562	6.622	9.955	12.670	18.987	29.142	35.544	69.581
2	2.037	4.323	6.376	9.724	12.416	18.775	28.959	35.319	69.352
3	1.681	4.114	6.165	9.527	12.201	18.598	28.807	35.131	69.161
4	1.753	4.153	6.205	9.564	12.241	18.632	28.835	35.166	69.196
5	1.818	4.191	6.243	9.599	12.279	18.663	28.862	35.199	69.230
6	1.651	4.097	6.149	9.512	12.184	18.585	28.795	35.117	69.146
8	1.561	4.050	6.102	9.468	12.137	18.546	28.761	35.076	69.104
9	1.694	4.120	6.172	9.534	12.208	18.604	28.812	35.137	69.167
10	1.537	4.038	6.090	9.457	12.125	18.536	28.753	35.065	69.093

Table I.13 Combined error from reduced number of verticals with reduced points in vertical for whole rivers for 10 second exposure time error from flume data (%)

Method Number	Number of verticals 20	15	10	7	5	4	3	2	1
1	2.774	4.839	6.910	10.232	12.975	19.242	29.365	35.818	69.861
2	2.470	4.614	6.675	10.006	12.726	19.034	29.183	35.594	69.633
3	1.950	4.269	6.322	9.672	12.360	18.729	28.919	35.270	69.302
4	1.930	4.257	6.309	9.661	12.347	18.719	28.910	35.259	69.290
5	1.989	4.293	6.346	9.695	12.385	18.750	28.937	35.292	69.324
6	1.838	4.202	6.254	9.609	12.291	18.672	28.870	35.209	69.240
8	1.662	4.103	6.155	9.517	12.190	18.590	28.799	35.122	69.151
9	1.787	4.173	6.225	9.582	12.261	18.648	28.849	35.183	69.214
10	1.640	4.091	6.143	9.506	12.178	18.580	28.791	35.112	69.141

Table I.14 Combined error from reduced number of verticals with reduced points in vertical for whole rivers for 5 second exposure time error from flume data (%)

Method Number	Number of verticals 20	15	10	7	5	4	3	2	1
1	3.194	5.172	7.263	10.575	13.355	19.564	29.648	36.165	70.219
2	2.933	4.962	7.040	10.357	13.114	19.359	29.468	35.944	69.991
3	2.248	4.460	6.516	9.856	12.561	18.895	29.063	35.447	69.482
4	2.135	4.385	6.440	9.783	12.482	18.830	29.006	35.377	69.410
5	2.189	4.420	6.476	9.817	12.519	18.861	29.033	35.410	69.444
6	2.052	4.332	6.386	9.733	12.426	18.783	28.966	35.328	69.360
8	1.783	4.170	6.222	9.580	12.258	18.646	28.847	35.181	69.211
9	1.900	4.239	6.291	9.644	12.329	18.704	28.897	35.243	69.274
10	1.762	4.158	6.210	9.569	12.246	18.636	28.839	35.171	69.201

Table I.15 Combined error from reduced number of verticals with reduced points in vertical for individual verticals for 200 second exposure time error from field data (%)

Method Number	Number of verticals								
	20	15	10	7	5	4	3	2	1
1	7.089	8.953	11.526	15.042	18.400	24.146	33.853	41.333	75.708
2	5.117	6.933	9.205	12.550	15.566	21.510	31.394	38.312	72.459
3	3.185	5.165	7.255	10.567	13.346	19.557	29.641	36.157	70.210
4	3.603	5.519	7.636	10.944	13.765	19.916	29.958	36.547	70.613
5	2.220	4.441	6.497	9.837	12.541	18.879	29.049	35.429	69.464
6	2.652	4.746	6.813	10.138	12.872	19.155	29.289	35.724	69.766
8	1.923	4.252	6.305	9.657	12.343	18.715	28.907	35.255	69.286
9	2.049	4.330	6.384	9.731	12.424	18.782	28.965	35.326	69.358
10	1.486	4.012	6.064	9.434	12.099	18.515	28.735	35.043	69.071

Table I.16 Combined error from reduced number of verticals with reduced points in vertical for individual verticals for 100 second exposure time error from field data (%)

Method Number	Number of verticals								
	20	15	10	7	5	4	3	2	1
1	7.971	9.893	12.627	16.256	19.792	25.485	35.137	42.911	77.444
2	6.283	8.111	10.551	13.982	17.189	23.003	32.775	40.009	74.271
3	4.097	5.961	8.120	11.431	14.308	20.389	30.379	37.065	71.151
4	4.173	6.030	8.196	11.508	14.394	20.465	30.447	37.149	71.238
5	3.059	5.063	7.147	10.461	13.229	19.457	29.553	36.049	70.099
6	3.386	5.332	7.435	10.744	13.543	19.725	29.789	36.339	70.398
8	2.431	4.586	6.647	9.979	12.696	19.008	29.161	35.567	69.605
9	2.532	4.659	6.722	10.051	12.775	19.074	29.219	35.638	69.677
10	2.103	4.365	6.419	9.764	12.460	18.812	28.991	35.358	69.391

Table I.17 Combined error from reduced number of verticals with reduced points in vertical for individual verticals for 50 second exposure time error from field data (%)

Method Number	Number of verticals								
	20	15	10	7	5	4	3	2	1
1	7.422	9.306	11.939	15.495	18.919	24.642	34.326	41.915	76.344
2	5.570	7.384	9.716	13.090	16.176	22.066	31.903	38.938	73.124
3	3.544	5.468	7.582	10.890	13.704	19.864	29.912	36.490	70.554
4	3.820	5.710	7.845	11.153	13.997	20.118	30.137	36.768	70.841
5	2.558	4.677	6.741	10.069	12.795	19.091	29.233	35.656	69.696
6	2.94	4.968	7.0458	10.363	13.12	19.365	29.472	35.95	69.997
8	2.122	4.377	6.4312	9.7753	12.473	18.822	29	35.369	69.402
9	2.237	4.452	6.5088	9.8483	12.553	18.889	29.058	35.44	69.475
10	1.736	4.144	6.1956	9.5554	12.232	18.624	28.828	35.158	69.188

Table I.18 Combined error from reduced number of verticals with reduced points in vertical for individual verticals for 10 second exposure time error from field data (%)

Method Number	Number of verticals								
	20	15	10	7	5	4	3	2	1
1	8.504	10.467	13.303	17.009	20.659	26.331	35.959	43.921	78.567
2	6.946	8.802	11.351	14.850	18.181	23.937	33.654	41.090	75.442
3	4.601	6.433	8.643	11.966	14.908	20.919	30.856	37.652	71.764
4	4.509	6.345	8.545	11.865	14.795	20.819	30.766	37.540	71.647
5	3.505	5.434	7.545	10.853	13.663	19.829	29.881	36.452	70.514
6	3.793	5.686	7.818	11.126	13.967	20.092	30.114	36.739	70.812
8	2.715	4.794	6.863	10.186	12.925	19.200	29.328	35.772	69.815
9	2.806	4.863	6.936	10.256	13.002	19.265	29.385	35.842	69.886
10	2.426	4.582	6.643	9.975	12.692	19.005	29.158	35.564	69.601

Table I.19 Combined error from reduced number of verticals with reduced points in vertical for individual verticals for 5 second exposure time error from field data (%)

Method Number	Number of verticals 20	15	10	7	5	4	3	2	1
1	11.029	13.241	16.602	20.742	24.982	30.659	40.273	49.217	84.613
2	9.878	11.969	15.083	19.012	22.975	28.629	38.229	46.708	81.719
3	6.770	8.618	11.137	14.617	17.914	23.684	33.415	40.796	75.122
4	6.064	7.886	10.291	13.703	16.872	22.708	32.498	39.670	73.906
5	5.360	7.173	9.477	12.836	15.889	21.803	31.662	38.642	72.809
6	5.552	7.366	9.696	13.068	16.151	22.043	31.882	38.913	73.097
8	3.949	5.826	7.971	11.280	14.140	20.242	30.248	36.903	70.982
9	4.012	5.883	8.034	11.344	14.210	20.304	30.303	36.971	71.053
10	3.756	5.653	7.782	11.090	13.928	20.057	30.084	36.701	70.773

Table I.20 Combined error from reduced number of verticals with reduced points in vertical for whole rivers for 200 second exposure time error from field data (%)

Method Number	Number of verticals 20	15	10	7	5	4	3	2	1
1	2.194	4.424	6.479	9.821	12.522	18.864	29.036	35.413	69.447
2	1.794	4.177	6.228	9.586	12.265	18.651	28.852	35.187	69.217
3	1.537	4.037	6.089	9.457	12.124	18.536	28.753	35.065	69.093
4	1.662	4.103	6.155	9.518	12.190	18.590	28.799	35.122	69.151
5	1.731	4.141	6.193	9.553	12.229	18.621	28.826	35.155	69.185
6	1.554	4.046	6.098	9.465	12.133	18.543	28.759	35.073	69.101
8	1.510	4.024	6.076	9.445	12.111	18.525	28.743	35.053	69.082
9	1.647	4.095	6.147	9.510	12.182	18.583	28.794	35.115	69.144
10	1.486	4.012	6.064	9.434	12.099	18.515	28.735	35.043	69.070

Table I.21 Combined error from reduced number of verticals with reduced points in vertical for whole rivers for 100 second exposure time error from field data (%)

Method Number	Number of verticals 20	15	10	7	5	4	3	2	1
1	4.255	6.107	8.281	11.594	14.491	20.550	30.524	37.242	71.336
2	4.063	5.930	8.086	11.396	14.269	20.355	30.349	37.028	71.112
3	3.001	5.016	7.097	10.413	13.175	19.411	29.513	36.000	70.049
4	2.682	4.769	6.837	10.161	12.897	19.176	29.308	35.747	69.789
5	2.725	4.802	6.871	10.194	12.933	19.207	29.334	35.780	69.823
6	2.617	4.720	6.786	10.112	12.843	19.131	29.268	35.699	69.739
8	2.120	4.376	6.430	9.774	12.472	18.821	28.999	35.368	69.402
9	2.220	4.441	6.497	9.837	12.541	18.879	29.049	35.429	69.464
10	2.103	4.365	6.419	9.764	12.460	18.812	28.991	35.358	69.391

Table I.22 Combined error from reduced number of verticals with reduced points in vertical for whole rivers for 50 second exposure time error from field data (%)

Method Number	Number of verticals 20	15	10	7	5	4	3	2	1
1	3.107	5.101	7.188	10.501	13.273	19.494	29.586	36.090	70.141
2	2.839	4.888	6.962	10.282	13.030	19.289	29.406	35.868	69.913
3	2.187	4.419	6.474	9.816	12.517	18.859	29.032	35.408	69.442
4	2.092	4.357	6.412	9.757	12.452	18.805	28.985	35.351	69.384
5	2.147	4.393	6.448	9.791	12.490	18.836	29.012	35.384	69.418
6	2.007	4.304	6.357	9.706	12.396	18.759	28.945	35.302	69.334
8	1.757	4.156	6.207	9.566	12.244	18.633	28.837	35.168	69.198
9	1.876	4.224	6.277	9.631	12.314	18.691	28.887	35.230	69.261
10	1.736	4.144	6.196	9.555	12.232	18.624	28.828	35.158	69.188

Table I.23 Combined error from reduced number of verticals with reduced points in vertical for whole rivers for 10 second exposure time error from field data (%)

Method Number	Number of verticals								
	20	15	10	7	5	4	3	2	1
1	5.184	6.999	9.279	12.628	15.654	21.590	31.466	38.401	72.554
2	5.028	6.845	9.106	12.446	15.449	21.404	31.297	38.193	72.334
3	3.659	5.568	7.690	10.998	13.824	19.968	30.004	36.604	70.671
4	3.181	5.161	7.252	10.564	13.342	19.554	29.638	36.154	70.207
5	3.217	5.191	7.284	10.595	13.377	19.583	29.664	36.186	70.240
6	3.125	5.116	7.204	10.517	13.290	19.509	29.599	36.106	70.157
8	2.441	4.593	6.654	9.986	12.704	19.015	29.167	35.574	69.612
9	2.528	4.655	6.718	10.047	12.772	19.071	29.216	35.635	69.674
10	2.426	4.582	6.643	9.975	12.692	19.005	29.158	35.564	69.601

Table I.24 Combined error from reduced number of verticals with reduced points in vertical for whole rivers for 5 second exposure time error from field data (%)

Method Number	Number of verticals								
	20	15	10	7	5	4	3	2	1
1	8.729	10.712	13.592	17.332	21.032	26.698	36.318	44.361	79.061
2	8.637	10.612	13.475	17.200	20.880	26.548	36.171	44.181	78.859
3	6.169	7.993	10.415	13.835	17.023	22.848	32.629	39.831	74.079
4	5.153	6.969	9.245	12.593	15.614	21.554	31.433	38.360	72.511
5	5.176	6.991	9.270	12.619	15.643	21.581	31.458	38.391	72.543
6	5.120	6.935	9.207	12.553	15.569	21.513	31.396	38.315	72.463
8	3.765	5.662	7.792	11.100	13.938	20.066	30.092	36.711	70.783
9	3.823	5.713	7.847	11.155	14.000	20.120	30.140	36.770	70.844
10	3.756	5.653	7.782	11.090	13.928	20.057	30.084	36.701	70.773

APPENDIX J: GAUGING TIMES

Table J.1 Summary of data used to calculate time of gauging

Agency Region	River	Gauging Station	River Discharge (m^3s^{-1})	Width of River (m)	Gauging Time (secs)	Number of verticals	Exposure time (secs)	Number of points in vertical	Method of metering	Time for moving the current meter (secs)
Severn Trent	Amber	Wingfield Park	0.780	5.00	2100	12	50	1	Waded	125.000
Severn Trent	Arrow	Studley	0.220	5.60	2100	17	50	1	Waded	73.529
Severn Trent	Avon	Lilbourne	4.410	7.80	3000	16	100	1	Cableway	87.500
Severn Trent	Blythe	Castle Farm	0.770	10.76	2640	20	100	1	Waded	32.000
Severn Trent	Blythe	Castle Farm	0.910	11.29	3360	22	100	1	Cableway	52.727
Severn Trent	Derwent	Chatsworth	2.730	27.40	5100	26	100	1	Cableway	96.154
Severn Trent	Derwent	Chatsworth	2.730	23.00	8700	21	100	2	Cableway	214.286
Severn Trent	Manifold	Ilam	1.840	12.50	2640	22	100	1	Waded	20.000
Severn Trent	Manifold	Ilam	3.800	13.10	2880	22	100	1	Waded	30.909
Severn Trent	Mease	Stones Br.	0.590	6.80	2100	20	100	1	Waded	16.667
Severn Trent	Rea	Calthorpe Park	0.550	9.10	2700	18	100	1	Waded	42.105
Severn Trent	Rea	Calthorpe Park	3.560	9.20	3000	16	100	1	Cableway	66.667
Severn Trent	Severn	Saxon's Lode	47.500	59.20	7200	17	50	2	Cableway	323.529
Severn Trent	Stour	Shipston	0.679	9.00	2700	15	100	1	Waded	58.824
Severn Trent	Tanat	Llanyblodwell	0.700	17.65	4200	17	100	1	Waded	147.059
Severn Trent	Tanat	Llanyblodwell	1.180	16.00	2400	14	100	1	Waded	71.429
Severn Trent	Teme	Tenbury	6.070	17.00	2700	16	50	2	Cableway	68.750

Table J.1 cont **Summary of data used to calculate time of gauging**

Agency Region	River	Gauging Station	River Discharge (m^3s^{-1})	Width of River (m)	Gauging Time (secs)	Number of verticals	Exposure time (secs)	Number of points in vertical	Method of metering	Time for moving the current meter (secs)
Severn Trent	Trent	Stoke	3.230	7.20	1860	15	100	1	Cableway	24.000
South West	Avon	Fordingbridge	65.140	39.00	3300	18	50	1	Cableway	133.333
South West	Brue	Lovington	7.530	9.27	900	9	60	1	Cableway	40.000
South West	Brue	Lovington	32.900	12.60	1500	11	60	1	Cableway	76.364
South West	Camel	Denby	22.080	11.15	2400	14	60	1	Cableway	111.429
South West	Dart	Austin's Br.	145.440	33.40	2400	19	60	1	Cableway	66.316
South West	Doniford	Swill Br.	1.950	5.55	1800	12	60	1	Waded	90.000
South West	Doniford	Swill Br.	7.730	5.50	1200	12	60	1	Waded	40.000
South West	Exe	Thorverton	49.780	32.50	2100	17	50	1	Cableway	73.529
South West	Inny	Beal's Mill	29.050	13.01	1200	8	50	1	Cableway	100.000
South West	Nadder	Ct St Br.	8.380	10.20	2160	15	50	1	Cableway	94.000
South West	Okement	Jacobstone	38.860	15.75	1380	12	50	1	Cableway	65.000
South West	Ottery	Werrington	37.020	22.20	1800	18	50	1	Cableway	50.000
South West	Piddle	Bagg's Mill	7.610	6.80	2460	15	50	1	Cableway	139.231
South West	Stour	Blackwater Br.	115.430	55.00	4140	28	50	2	Cableway	47.857
South West	Stour	Blackwater Br.	125.620	60.00	4800	24	50	2	Cableway	100.000
South West	Tamar	Gunnislake	283.690	32.24	2220	17	50	1	Cableway	80.588

Table J.1 cont Summary of data used to calculate time of gauging

Agency Region	River	Gauging Station	River Discharge (m^3s^{-1})	Width of River (m)	Gauging Time (secs)	Number of verticals	Exposure time (secs)	Number of points in vertical	Method of metering	Time for moving the current meter (secs)
South West	Tavy	Ludbrook	83.970	22.65	1380	13	50	1	Cableway	56.154
South West	Till	Ct St Br.	0.261	5.23	1500	13	50	1	Waded	65.385
South West	Tone	Bishop's Hull	11.480	12.00	3300	11	60	1	Cableway	240.000
South West	Tone	Bishop's Hull	27.390	12.00	1500	7	60	1	Cableway	154.286
South West	Torridge	Torrington	214.850	28.40	1500	15	50	1	Cableway	50.000
South West	Wolf	Roadford	3.047	8.25	1200	15	50	1	Cableway	30.000
South West	Wolf	Roadford	7.460	8.25	1500	9	50	1	Cableway	116.667
South West	Yeo	Pen Mill	15.410	14.80	2820	12	60	1	Cableway	175.000
South West	Yeo	Pen Mill	46.080	18.85	5400	23	60	1	Cableway	174.783
South West	Yeo	Pen Mill	52.450	17.70	1740	10	60	1	Cableway	114.000
Southern	Arlington	Cuckmere	9.440	19.00	3000	18	50	2	Cableway	66.667
Southern	Arlington	Cuckmere	9.490	19.00	3000	20	50	1	Cableway	116.667
Southern	Arlington	Cuckmere	9.750	19.00	5400	18	50	5	Cableway	50.000
Southern	Arlington	Cuckmere	10.440	19.90	3000	19	50	2	Cableway	57.895
Southern	Blackwater	Ower	7.730	6.00	1200	9	100	1	Waded	71.429
Southern	Gt Stour	Hoston	13.890	12.50	2700	12	50	2	Cableway	125.000

Table J.1 cont **Summary of data used to calculate time of gauging**

Agency Region	River	Gauging Station	River Discharge (m^3s^{-1})	Width of River (m)	Gauging Time (secs)	Number of verticals	Exposure time (secs)	Number of points in vertical	Method of metering	Time for moving the current meter (secs)
Southern	Gt Stour	Wye	11.050	12.30	3900	13	50	2	Cableway	200.000
Southern	Gt Stour	Wye	11.420	12.25	2100	12	50	1	Cableway	125.000
Southern	Ouse	Goldbridge	16.810	14.00	5400	16	50	2	Cableway	237.500
Southern	Ouse	Goldbridge	25.000	16.20	2100	16	50	2	Waded	31.250
Southern	Tanyard Fish Farm		0.360	16.00	4380	15	50	1	Waded	242.000
Thames	New RIver	New Gauge	1.220	7.51	5400	10	60	6	Waded	180.000
Thames	New RIver	New Gauge	1.250	7.51	5400	10	60	1	Waded	480.000
Welsh	Conwy	Conwy	22.850	34.98	9600	17	50	6	Cableway	264.706
Welsh	Dee	IronBr.	101.670	41.20	7200	20	100	2	Cableway	160.000
Welsh	Dee	Bala	30.000	24.50	5100	25	100	2	Cableway	4.000
Welsh	Dee	Bala	52.870	26.30	6900	26	100	2	Cableway	65.385
Welsh	Dee	Ironbridge	140.000	42.20	7200	19	100	2	Cableway	178.947
Welsh	Elwy	Pont-y-Gwyddel	10.160	17.23	3000	17	100	1	Cableway	76.471
Welsh	Elwy	Pont-y-Gwyddel	12.780	17.73	3300	17	100	1	Cableway	94.118
Welsh	Dyfi	Dyfi	59.210	33.06	10800	9	50	6	Cableway	900.000
Welsh	Tawe	Ynystanglws	40.370	27.83	1500	13	50	1	Cableway	65.385
Welsh	Tawe	Ynystanglws	82.680	29.40	2100	14	50	1	Cableway	100.000

Table J.1 cont **Summary of data used to calculate time of gauging**

Agency Region	River	Gauging Station	River Discharge (m^3s^{-1})	Width of River (m)	Gauging Time (secs)	Number of verticals	Exposure time (secs)	Number of points in vertical	Method of metering	Time for moving the current meter (secs)
Yorkshire	Aire	Armley	67.270	20.50	12000	13	100	5	Cableway	423.077
Yorkshire	Aire	Armley	108.880	22.50	9000	13	100	5	Cableway	192.308
Yorkshire	Aire	Kildwick	21.730	14.00	2100	13	100	1	Cableway	61.538
Yorkshire	Aire	Kildwick	41.030	17.80	6600	10	100	5	Cableway	160.000
Yorkshire	Calder	Mytholmroyd	49.740	16.00	2400	15	100	1	Cableway	60.000
Yorkshire	Don	Doncaster	51.041	24.50	3000	16	100	1	Cableway	87.500
Yorkshire	Rother	Whittington	19.070	9.00	11400	8	200	5	Cableway	425.000
Yorkshire	Rother	Whittington	21.670	9.50	1800	9	100	1	Cableway	100.000
Yorkshire	Ure	Kilgram Br.	146.465	33.00	7500	9	100	5	Cableway	333.333

Table J.2 Combined percentage error using whole river and flume data errors with total time taken to complete a gauging

Number of verticals	Meter position	Exposure time (secs)	Percentage Error	Total time for gauging (secs)	Totatl time for gauging (mins)
20	0.5	200	1.794	5800	96.667
20	0.5	100	1.91	3800	63.333
20	0.5	50	1.909	2800	46.667
20	0.5	30	2.125	2400	40.000
20	0.5	20	2.037	2200	36.667
20	0.5	10	2.47	2000	33.333
15	0.5	200	4.177	4350	72.500
15	0.5	100	4.244	2850	47.500
15	0.5	50	4.244	2100	35.000
15	0.5	30	4.379	1800	30.000
15	0.5	20	4.323	1650	27.500
15	0.5	10	4.614	1500	25.000
10	0.5	200	6.228	2900	48.333
10	0.5	100	6.297	1900	31.667
10	0.5	50	6.297	1400	23.333
10	0.5	30	6.433	1200	20.000
10	0.5	20	6.376	1100	18.333
10	0.5	10	6.675	1000	16.667
7	0.5	200	9.586	2030	33.833
7	0.5	100	9.649	1330	22.167
7	0.5	50	9.649	980	16.333
7	0.5	30	9.777	840	14.000
7	0.5	20	9.724	770	12.833
7	0.5	10	10.006	700	11.667
5	0.5	200	12.265	1450	24.167
5	0.5	100	12.334	950	15.833
5	0.5	50	12.334	700	11.667
5	0.5	30	12.475	600	10.000

Table J.2 cont **Combined percentage error using whole river and flume data errors with total time taken to complete a gauging**

Number of verticals	Meter position	Exposure time (secs)	Percentage Error	Total time for gauging (secs)	Totatl time for gauging (mins)
5	0.5	20	12.416	550	9.167
5	0.5	10	12.726	500	8.333
20	0.6	200	2.194	5800	96.667
20	0.6	100	2.289	3800	63.333
20	0.6	50	2.289	2800	46.667
20	0.6	30	2.472	2400	40.000
20	0.6	20	2.397	2200	36.667
20	0.6	10	2.774	2000	33.333
15	0.6	200	4.424	4350	72.500
15	0.6	100	4.488	2850	47.500
15	0.6	50	4.488	2100	35.000
15	0.6	30	4.615	1800	30.000
15	0.6	20	4.562	1650	27.500
15	0.6	10	4.839	1500	25.000
10	0.6	200	6.479	2900	48.333
10	0.6	100	6.545	1900	31.667
10	0.6	50	6.545	1400	23.333
10	0.6	30	6.677	1200	20.000
10	0.6	20	6.622	1100	18.333
10	0.6	10	6.91	1000	16.667
7	0.6	200	9.821	2030	33.833
7	0.6	100	9.883	1330	22.167
7	0.6	50	9.883	980	16.333
7	0.6	30	10.007	840	14.000
7	0.6	20	9.955	770	12.833
7	0.6	10	10.232	700	11.667
5	0.6	200	12.522	1450	24.167
5	0.6	100	12.59	950	15.833
5	0.6	50	12.59	700	11.667

Table J.2 cont **Combined percentage error using whole river and flume data errors with total time taken to complete a gauging**

Number of verticals	Meter position	Exposure time (secs)	Percentage Error	Total time for gauging (secs)	Totatl time for gauging (mins)
5	0.6	30	12.728	600	10.000
5	0.6	20	12.67	550	9.167
5	0.6	10	12.975	500	8.333
20	0.8 + 0.2	200	1.537	11200	186.667
20	0.8 + 0.2	100	1.605	7200	120.000
20	0.8 + 0.2	50	1.605	5200	86.667
20	0.8 + 0.2	30	1.735	4400	73.333
20	0.8 + 0.2	20	1.681	4000	66.667
20	0.8 + 0.2	10	1.95	3600	60.000
15	0.8 + 0.2	200	4.037	8400	140.000
15	0.8 + 0.2	100	4.073	5400	90.000
15	0.8 + 0.2	50	4.072	3900	65.000
15	0.8 + 0.2	30	4.173	3300	55.000
15	0.8 + 0.2	20	4.114	3000	50.000
15	0.8 + 0.2	10	4.269	2700	45.000
10	0.8 + 0.2	200	6.089	5600	93.333
10	0.8 + 0.2	100	6.124	3600	60.000
10	0.8 + 0.2	50	6.124	2600	43.333
10	0.8 + 0.2	30	6.195	2200	36.667
10	0.8 + 0.2	20	6.165	2000	33.333
10	0.8 + 0.2	10	6.322	1800	30.000
7	0.8 + 0.2	200	9.457	3920	65.333
7	0.8 + 0.2	100	9.489	2520	42.000
7	0.8 + 0.2	50	9.489	1820	30.333
7	0.8 + 0.2	30	9.555	1540	25.667
7	0.8 + 0.2	20	9.527	1400	23.333
7	0.8 + 0.2	10	9.672	1260	21.000

Table J.2 cont **Combined percentage error using whole river and flume data errors with total time taken to complete a gauging**

Number of verticals	Meter position	Exposure time (secs)	Percentage Error	Total time for gauging (secs)	Totatl time for gauging (mins)
5	0.8 + 0.2	200	12.124	2800	46.667
5	0.8 + 0.2	100	12.16	1800	30.000
5	0.8 + 0.2	50	12.159	1300	21.667
5	0.8 + 0.2	30	12.321	1100	18.333
5	0.8 + 0.2	20	12.201	1000	16.667
5	0.8 + 0.2	10	12.36	900	15.000

APPENDIX K CALCULATION PROCEDURE WHERE DEPTH CHANGES BY MORE THAN 5% DURING GAUGING

9.4 Determination of discharge for variations of water-level

If the fluctuation of water-level during the period of velocity measurement is less than 5 % of the mean depth, the mean value shall be adopted for the computation of the discharge. If the fluctuation is more than this amount, then this discharge shall be computed as shown in 9.4.1. and the mean water-level corresponding to this discharge computed as shown in 9.4.2.

If the independant vertical method described in 8.1.4.4-f has been used, the computation of discharge is given in 9.4.3.

9.4.1 Computation of discharge

The water level is flotted separately for each segment to form a serie of steps as shown in Fig.4. Alternatively, the level can be joined by a smooth curve. A curve of mean water surface line ; the area enclosed representating the total discharge.

Corrected water level

Gauge datum

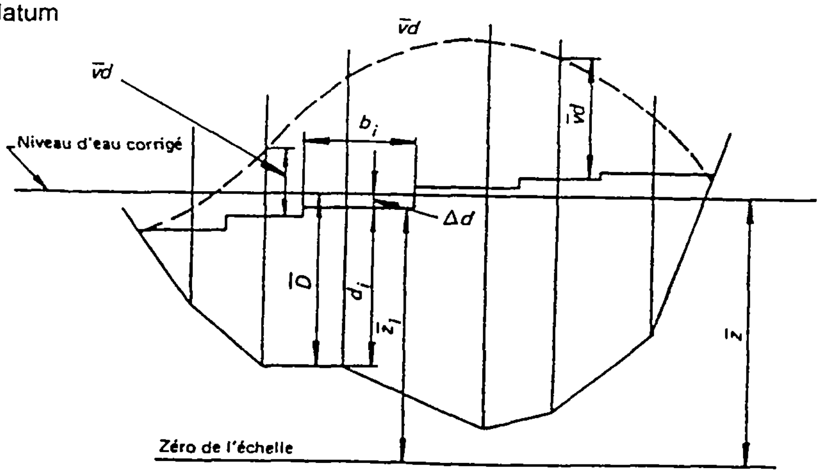


Figure 4 - Computation of discharge and mean water-level for variations of water-level

9.4.2 Computation of mean water-level

The mean water-level representative of the discharge measurement shall be computed from the equations :

$$\bar{z} = \frac{\sum q_i \bar{z}_i}{Q}$$

$$q_i = b_i d_i \bar{v}_i$$

where

- $\bar{z}$ is the mean water-level above the gauge datum ;
- q_i is the partial discharge in the ith segment ;
- $\bar{z}_i$ is the mean water-level corresponding to the partial discharge q_i ;
- Q is the total discharge and equal to the sum of the partial discharge $\sum q_i$;
- b_i is the width of the ith segment ;
- d_i is the depth of the ith segment ;
- $\bar{v}_i$ is the mean velocity in the ith segment.

The method is indicated in figure 4.

9.4.3 Computation of discharge for independent vertical method

By employing this gauging technique over a period of time, if a sufficiently large range in flow has been covered, it will be possible to derive a relationship between level and unit-width discharge for each vertical. A family of curves can then be constructed, each curve representating an independant stage/discharge relationship for the corresponding segment of channel width. This assumes of course that the channel geometry remains constant and that no change occurs in the position of a vertical relative to the zero reference point.

Then, for a given value of river stage, total flow in the cross section is obtained with an arithmetical method by summation of all segment discharges (Fig.5a) ; or with a graphical method (Fig.5b) by plotting the unit width discharge for all verticals and determining the area under this curve.

Total flow in the cross section for any given value of stage (Fig.5c) can be obtained by either of these methods.

APPENDIX L: LABORATORY RESULTS (SMALL STREAMS)

Table L.1 Summary of flume data. Ott C2 rotating element meter with Type 6 impeller. 100 seconds exposure time.

Chan. type	Chan. top width (m)	Flow depth (m)	Weir flow (m^3/s)	Number of verticals									
				20	15	14	12	10	7	5	3	2	1
				Metered discharge (m^3/s)[1]									
Rect.	0.500	0.050	0.01296							0.01249		0.01323	0.01325
		0.100	0.03626							0.03753		0.03822	0.03855
		0.250	0.03626							0.03886		0.04012	0.04148
Rect.	0.915	0.050	0.01751					0.01735		0.01778		0.01791	0.01805
		0.100	0.04315					0.04440		0.04437		0.04512	0.04569
		0.250	0.05910					0.06155		0.06272		0.06245	0.06500
Rect.	1.500	0.050	0.02656		0.02624			0.02688		0.02685		0.02768	0.02791
		0.100	0.05790		0.05988			0.06018		0.06219		0.06072	0.06279
		0.250	0.09073		0.09249			0.09297		0.09391		0.09344	0.10210
Rect.	2.000	0.050	0.03123	0.03177				0.03175		0.03189		0.03146	0.03013
		0.100	0.05595	0.05711				0.05749		0.05814		0.06014	0.05922
		0.250	0.11176	0.11227				0.11503		0.11476		0.11797	0.11618
Trap.	2.000	0.050	0.01907				0.01939		0.01940		0.01960		0.01977
1:2 side slopes		0.100	0.06196			0.06466			0.06388		0.05975		0.05952
		0.250	0.10438	0.11006					0.10862		0.10222		0.10056

Note : [1] Metered discharge calculated using velocity-area method.

Table L.2 Summary of flume data. Ott C2 rotating element meter with Type 6 impeller. 100 seconds exposure time. Statistical analysis of deviation of metered discharge from weir discharge (%)

Chan. type	Chan. top width (m)	Flow depth (m)	Weir flow (m^3/s)	Number of verticals									
				20	15	14	12	10	7	5	3	2	1
				Deviation of metered discharge[1] from weir discharge (%)									
Rect.	0.500	0.050	0.01296							-3.64		2.05	2.24
		0.100	0.03626							3.51		5.40	6.31
		0.250	0.03626							7.18		10.64	14.40
Rect.	0.915	0.050	0.01751					-0.92		1.56		2.26	3.08
		0.100	0.04315					2.90		2.84		4.57	5.89
		0.250	0.05910					4.15		6.12		5.67	9.98
Rect.	1.500	0.050	0.02656		-1.20			1.60		1.47		4.62	5.48
		0.100	0.05790		3.43			3.94		5.85		4.87	8.44
		0.250	0.09073		1.95			2.47		3.51		2.99	12.55
Rect.	2.000	0.050	0.03123	1.73				1.65		2.11		0.75	-3.52
		0.100	0.05595	2.08				2.76		3.91		7.49	5.85
		0.250	0.11176	0.45				2.93		2.69		5.55	3.96
Trap.	2.000	0.050	0.01907				1.69		1.73		2.76		3.70
		0.100	0.06196			4.35			3.11		-3.57		-3.90
		0.250	0.10438	5.44					4.06		-2.07		-3.70
				Statistical analysis									
Average				2.42	1.29			2.39	2.97	3.09	-0.96	4.74	4.72
Standard Deviation				1.84	2.07			1.43	0.96	2.68	2.70	2.53	5.33
Deviation about the average - min				0.58	-0.78			0.96	2.01	0.41	-3.40	2.21	-0.61
Deviation about the average - max				4.26	3.36			3.82	3.93	5.77	1.74	7.27	10.05

Note : [1] Metered discharge calculated using velocity-area method.

Table L.3 Summary of flume data. Aqua Data - Sensa RV1 electromagnetic flowmeter. 60 seconds exposure time.

Chan. type	Chan. top width (m)	Flow depth (m)	Weir flow (m^3/s)	Number of verticals									
				20	15	14	12	10	7	5	3	2	1
				Metered discharge (m^3/s)[1]									
Rect.	0.500	0.050	0.01296							0.01186		0.01255	0.01267
		0.100	0.03626							0.03638		0.03697	0.03741
		0.250	0.03626							0.03653		0.03758	0.03978
Rect.	0.915	0.050	0.01751										
		0.100	0.04315										
		0.250	0.05910										
Rect.	1.500	0.050	0.02656										
		0.100	0.05790										
		0.250	0.09073										
Rect.	2.000	0.050	0.03123	0.02934				0.03015		0.03097		0.03167	0.03162
		0.100	0.05595	0.05329				0.05577		0.05668		0.06038	0.05903
		0.250	0.11176	0.11034				0.10698		0.11199		0.11399	0.11503
Trap.	2.000	0.050	0.01907										
1:2 side slopes		0.100	0.06196										
		0.250	0.10438										

Note : [1] Metered discharge calculated using velocity-area method.

Table L.4 Summary of flume data. Aqua Data - Sensa RV1 electromagnetic flowmeter. 10 and 60 seconds exposure time. Statistical analysis of deviation of metered discharge from weir discharge (%)

Chan. type	Chan. top width (m)	Flow depth (m)	Timing period (secs)	Weir flow (m^3/s)	Number of verticals									
					20	15	14	12	10	7	5	3	2	1
					Deviation of metered discharge from weir discharge (%)									
Rect.	0.500	0.050	10	0.01296							-8.30		-2.50	-2.20
		0.100		0.03626							-0.26		1.46	3.17
		0.250		0.03626							-1.14		5.50	7.00
Rect.	0.915	0.050		0.01751										
		0.100		0.04315										
		0.250		0.05910										
Rect.	1.500	0.050		0.02656										
		0.100		0.05790										
		0.250		0.09073										
Rect.	2.000	0.050		0.03123					-1.06		-0.60		-0.50	1.00
		0.100		0.05595	0.90				-1.84		0.10		6.50	6.50
		0.250		0.11176	-1.50				-1.74		0.20		3.60	-4.60
Trap.	2.000	0.050		0.01907										
		0.100		0.06196										
		0.250		0.10438										
Rect.	0.500	0.050	60	0.01296							-8.50		-3.20	-2.20
		0.100		0.03626							0.30		1.95	3.17
		0.250		0.03626							0.75		3.60	9.70
Rect.	0.915	0.050		0.01751										
		0.100		0.04315										
		0.250		0.05910										
Rect.	1.500	0.050		0.02656										
		0.100		0.05790										
		0.250		0.09073										
Rect.	2.000	0.050		0.03123	-6.06				-3.45		-0.80		1.42	1.26
		0.100		0.05595	-4.75				-0.30		1.30		7.90	5.50
		0.250		0.11176	-1.27				-4.27		0.20		2.00	2.90
Trap.	2.000	0.050		0.01907										
		0.100		0.06196										
		0.250		0.10438										
Statistical analysis														
Average					-1.58				-0.70		-0.70		1.16	1.04
Standard Deviation					2.34				1.27		2.37		2.56	2.86
Deviation about the average - min					-3.92				-1.97		-3.07		-1.40	-1.82
Deviation about the average - max					0.75				0.57		1.67		3.72	3.90

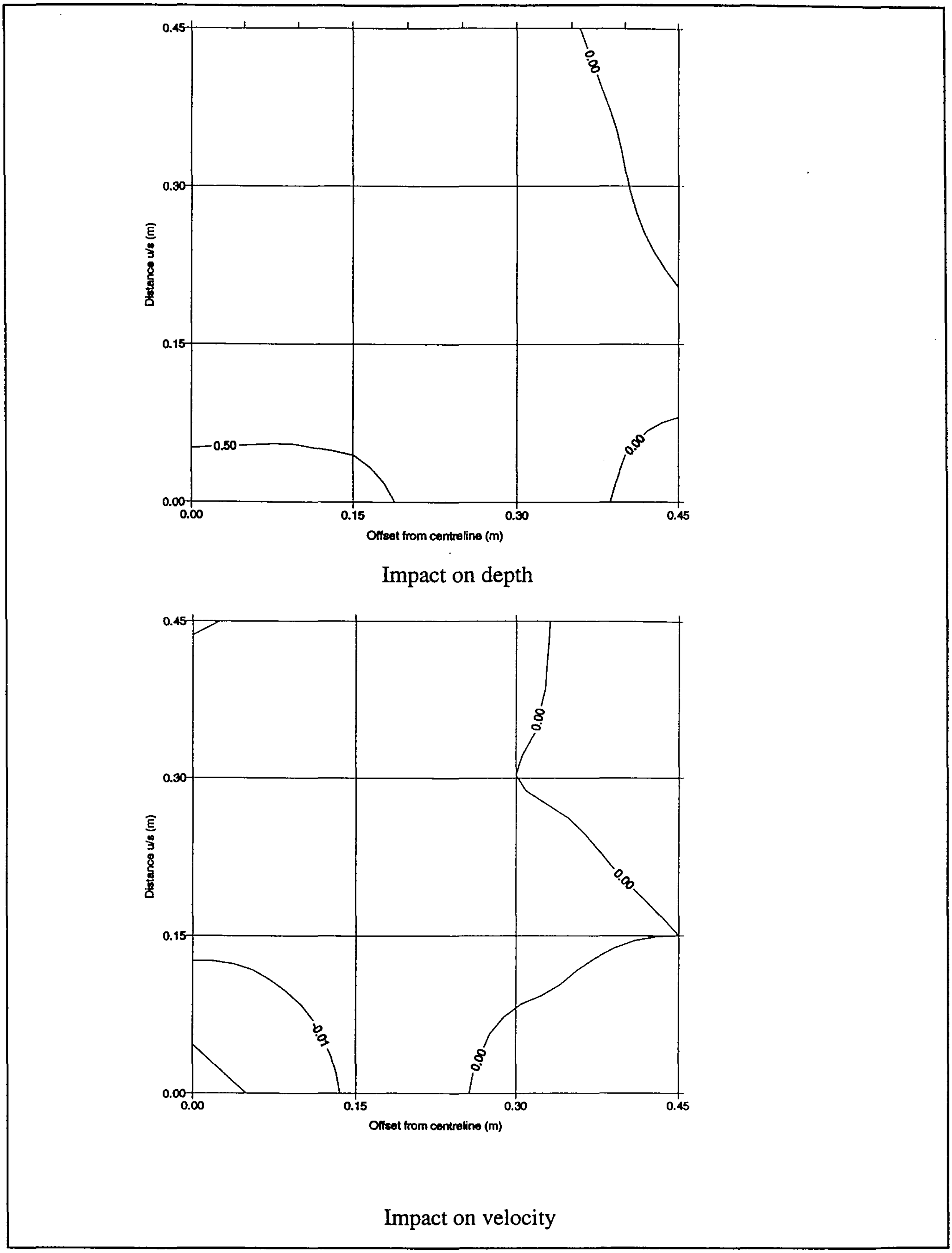
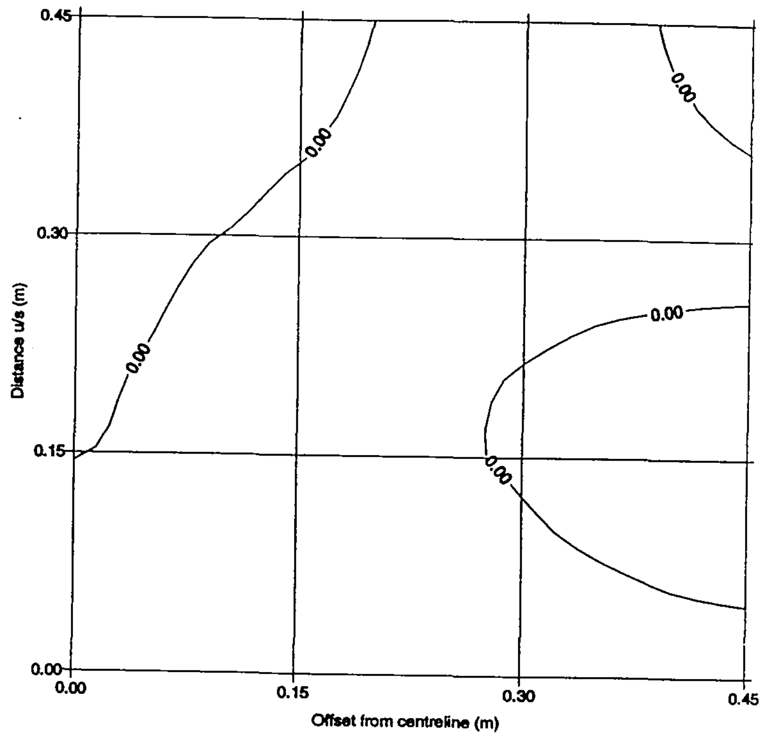
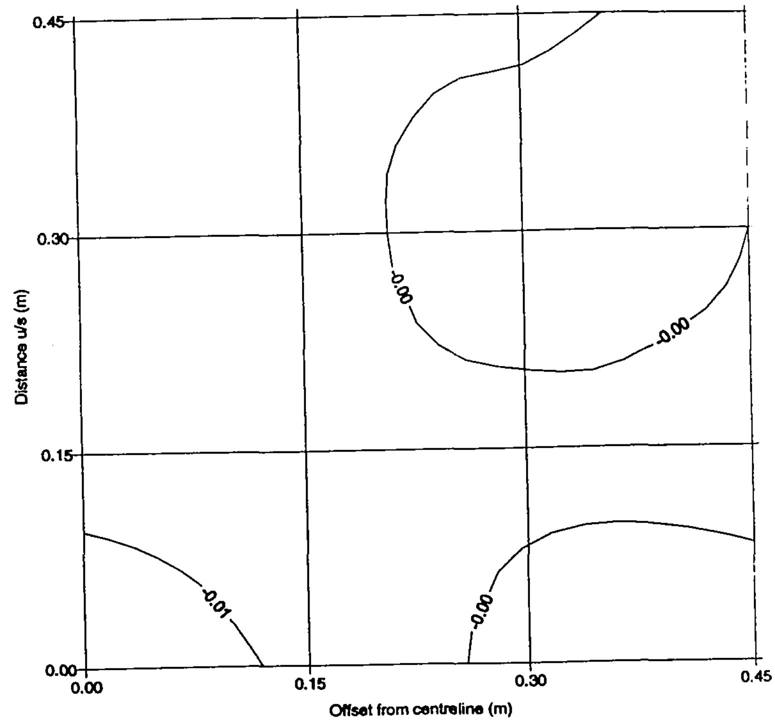


Figure N.30 Impact of wading on flow measurement - Boots apart
Channel depth = 0.25 m Channel velocity = 0.10 m/s

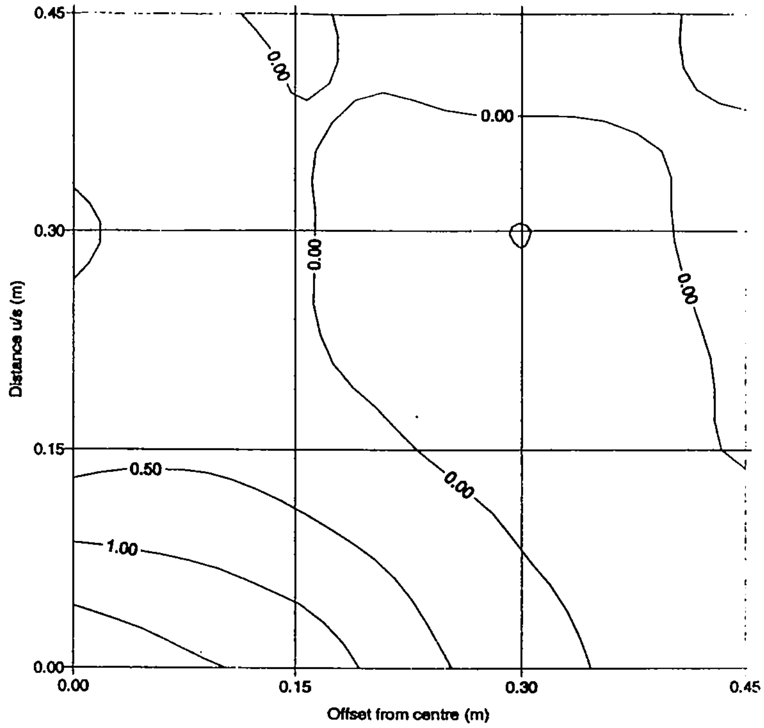


Impact on depth

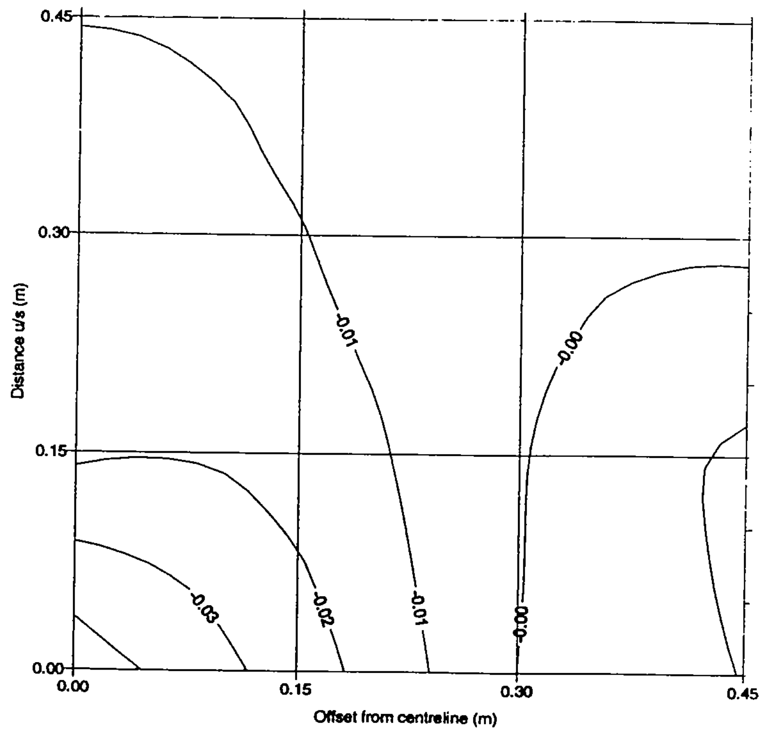


Impact on velocity

Figure N.31 Impact of wading on flow measurement - Boots together
Channel depth = 0.25m Channel velocity = 0.10 m/s

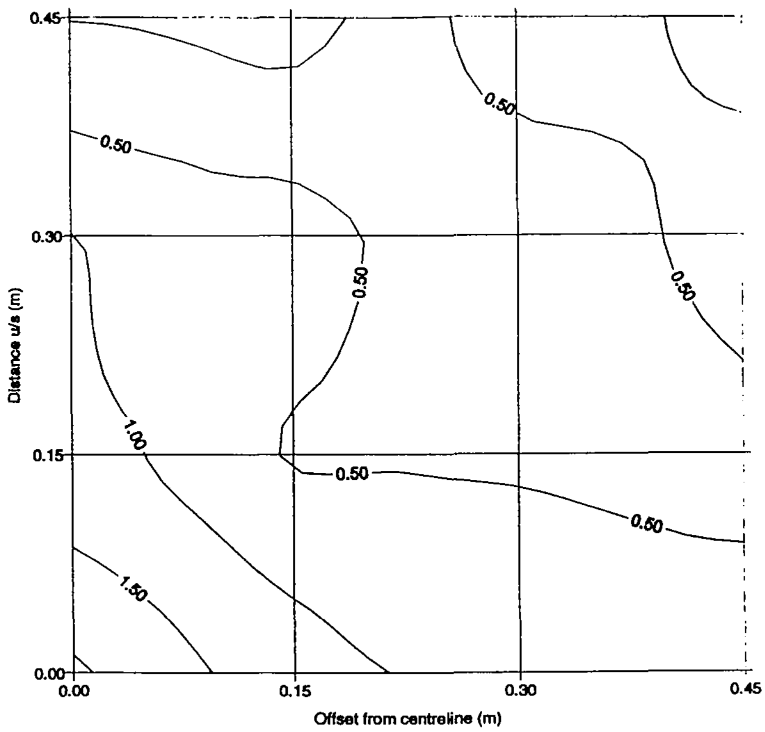


Impact on depth

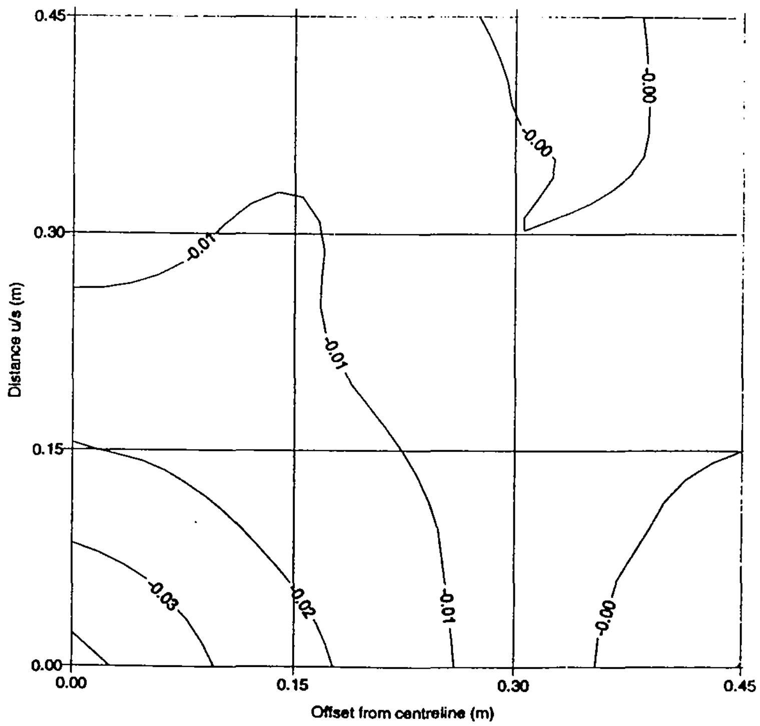


Impact on velocity

Figure N.33 Impact of wading on flow measurement - Boots perpendicular
Channel depth = 0.25 m Channel velocity = 0.24 m/s

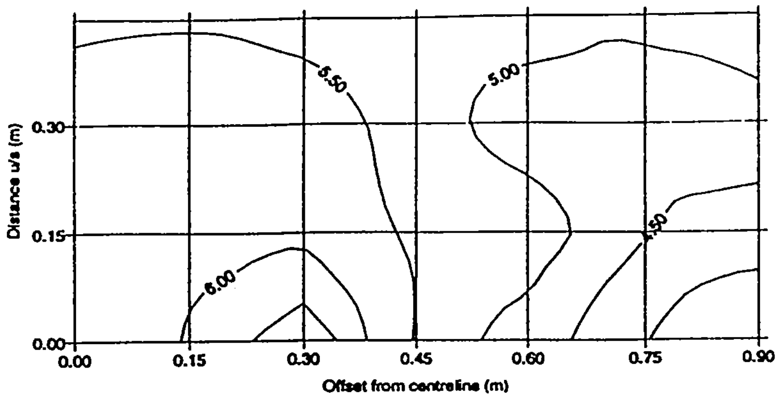


Impact on depth

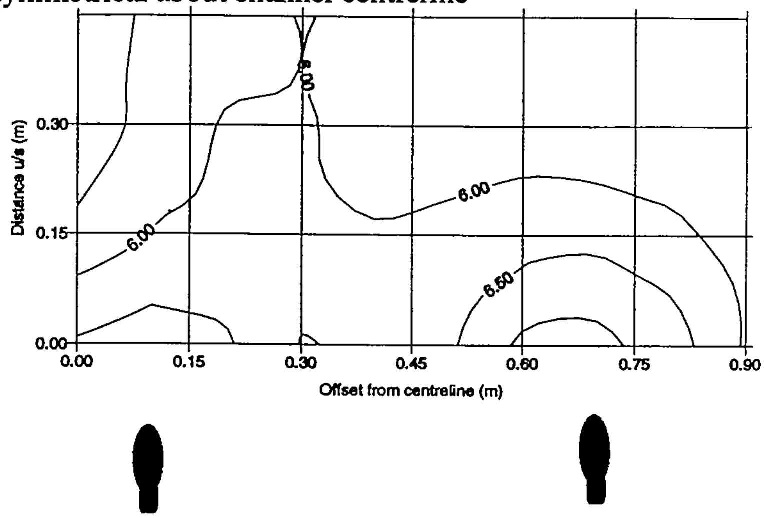


Impact on velocity

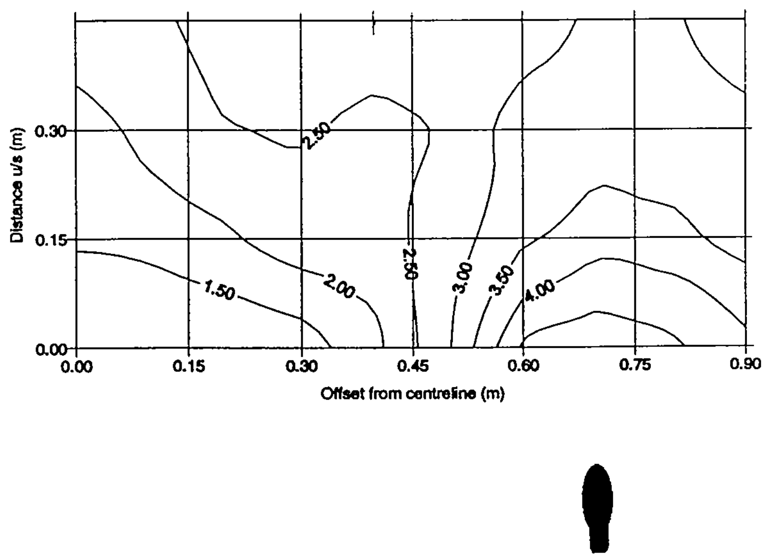
Figure N.34 Impact of wading on flow measurement - Boots together
Channel depth = 0.25m Channel velocity = 0.24 m/s



Boots symmetrical about channel centreline

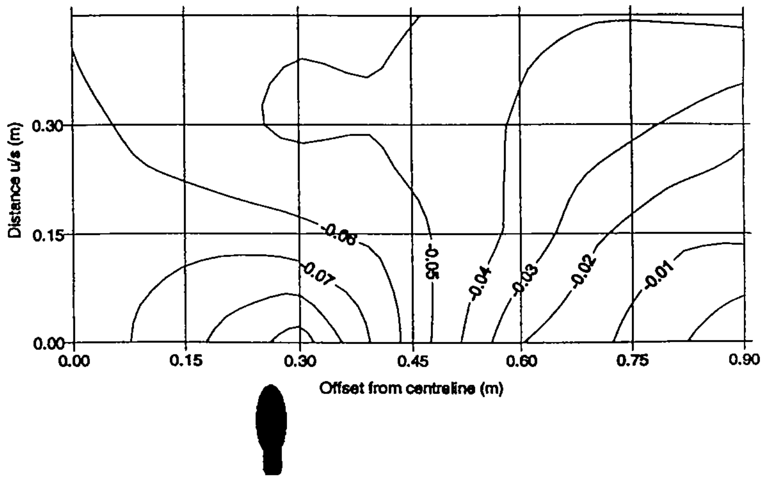


Boots offset by 0.2m towards left bank

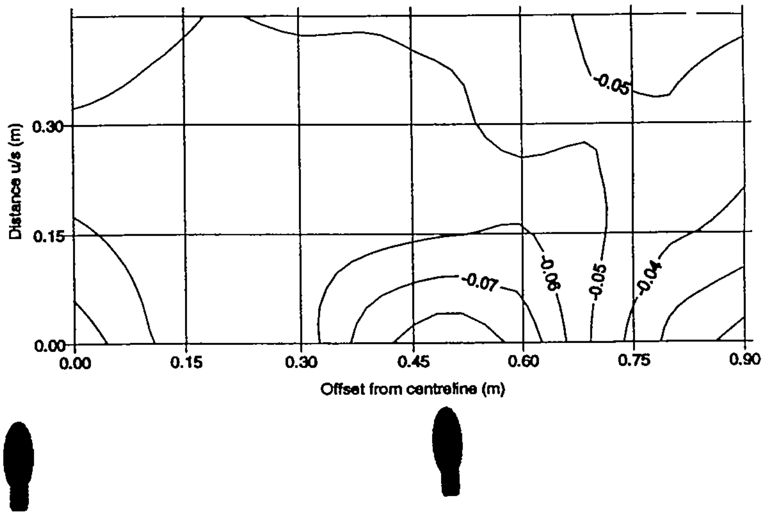


Boots offset by 0.4m towards left bank

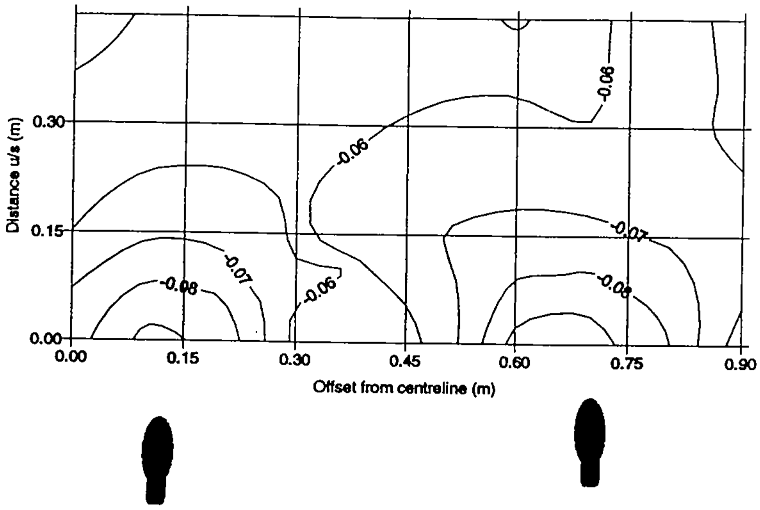
Figure N.36 Impact of wading, relative to the bank, on flow measurement Variation in flow depth



Boots symmetrical about channel centreline

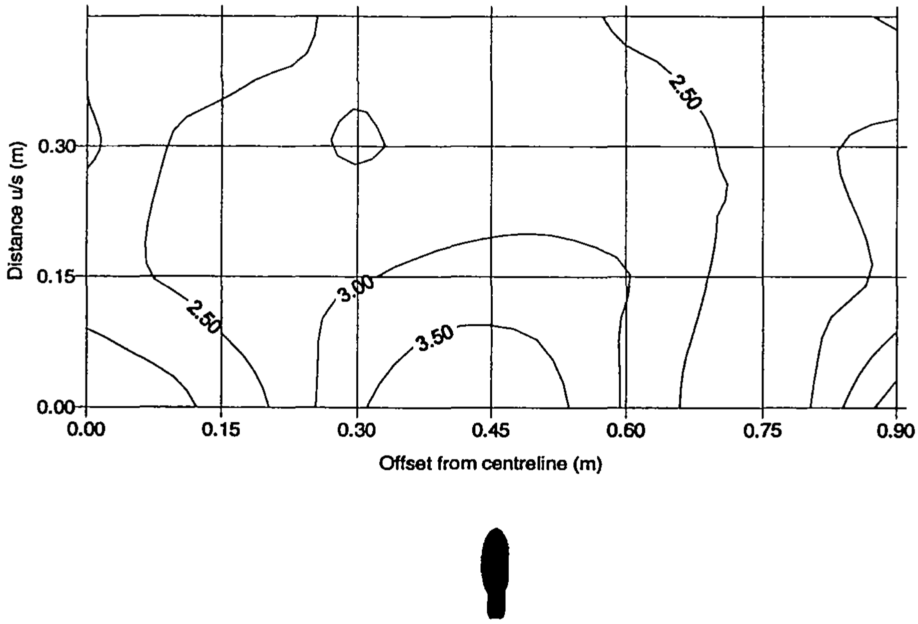


Boots offset by 0.2m towards left bank

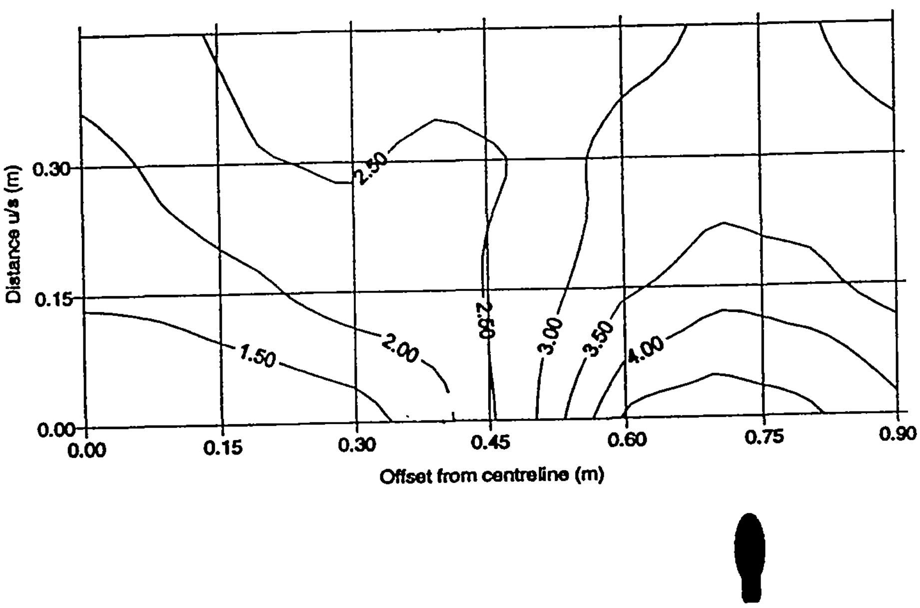


Boots offset by 0.4m towards left bank

Figure N.37 Impact of wading, relative to the bank, on flow measurement Variation in flow velocity

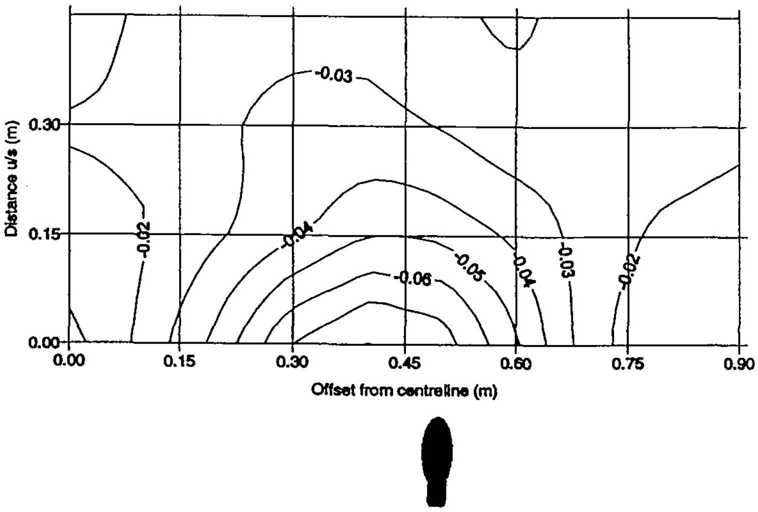


Boots offset by 0.2m towards left bank
Left boot in right boot position

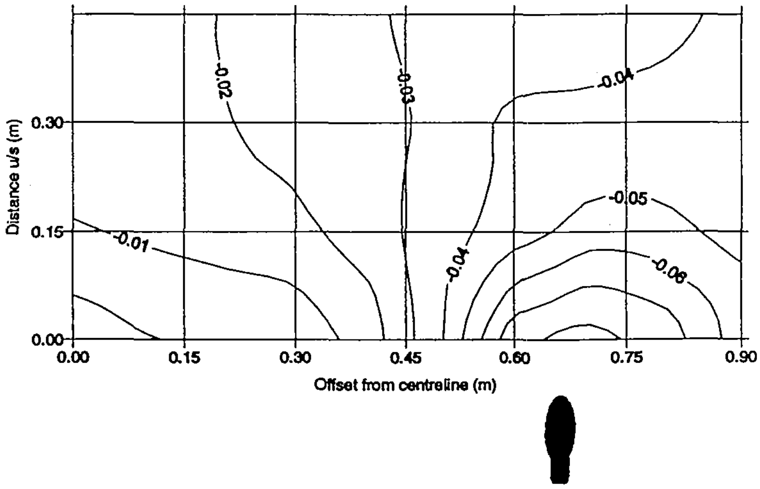


Boots offset by 0.4m towards left bank
Left boot in right boot position

Figure N.38 Impact of wading, relative to the bank, on flow measuremnet
One boot only - variation in flow depth



Boots offset by 0.2m towards left bank
Left boot in right boot position



Boots offset by 0.4m towards left bank
Left boot in right boot position

Figure N.39 Impact of wading, relative to the bank, on flow measuremnet
One boot only - variation in flow depth