The Evaluation of Acoustic Doppler Current Profiler Equipment

Hydro-Logic Ltd.

R&D Technical Report W71

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The Evaluation of Acoustic Doppler Current Profiler Equipment

A Study of the Use of the Equipment on U.K. Rivers

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Statement of use
This report is a technical report of the research evaluation carried out on the Acoustic Doppler Current Profiler. The aim of the project was to assess whether the ADCP equipment is of use as an efficient and cost effective method for measuring discharge in U.K. rivers. No similar study on the use of the equipment on small rivers has been completed by any other users.

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APPENDICES

The Evaluation of Acoustic Doppler Current Profiler Equipment

EXECUTIVE SUMMARY

An Acoustic Doppler Current Profiler (ADCP) is a device for measuring the current velocity profile through the water column, in an efficient and non-intrusive manner. In addition, when moved across the river, the instrument simultaneously measures an accurate cross-section of the channel bed and combines this with the velocity measurements to calculate discharge. This R&D report assesses the feasibility of using an ADCP for discharge measurement in UK rivers. The report describes the limitations of its use in extending and improving the Environment Agency's flow measurement capacity and includes a recommended standard practice.

The ADCP technique, originally used for oceanographic research, was only recently developed for use in rivers. The Environment Agency commissioned Hydro-Logic Ltd to undertake a full field evaluation of the device in the fluvial environment. The evaluation work considered the instrument's performance in a variety of physical conditions and channel characteristics and the accuracy and repeatability of measurements. Logistical requirements such as different deployment methods, manning levels and time required, and the cost benefit of the equipment's use were also examined. To make use of a wider field of experience in the use of ADCP technology, a literature and user review was performed.

Execution of the project required a considerable amount of field work. ADCP trials were carried out at gauging station sites to allow comparison of the ADCP measured flows with known data. The evaluation sites used were selected to reflect a wide range of physical conditions in order to test the ADCP equipment in most of the environments found in UK rivers.

During the evaluation work a total of 25 field visits have been made to 21 sites. These field visits have been vital in establishing the operational limits of the ADCP and have helped to pinpoint any logistical and measurement problems. Generally the ADCP performed well. However, occasionally the instrument systematically underestimated the flow. In the majority of these occasions a satisfactory explanation for this was found.

KEY WORDS

Acoustic Doppler Current Profiler; ADCP; Flow measurement; Gauging; Velocity profiles; Bed profiles; Recommended practice.

1. INTRODUCTION

All unusual and technical terms - related to the Acoustic Doppler Current Profiler - used in this report are explained in the glossary (section 11). Further information can be obtained from the Project Record for this project or references given in the bibliography (section 10).

1.1 About ADCP Technology

An Acoustic Doppler Current Profiler (ADCP) is a device for measuring the current velocity profile through the water column, in an efficient and non-intrusive manner. In addition, when moved across the river, the instrument simultaneously measures an accurate cross-section of the channel bed and combines this with the velocity measurements to calculate discharge.

An ADCP consists of an array of four ultrasonic transducers mounted onto a cylindrical metal case. The case houses the electronics to operate the system, an initial data processing and storage unit, a compass and a battery power supply. Photographs of the unit appear in appendix 1. In operation, the transducers "look" down through the water column at a slight angle to the vertical and at right angles to each other. In addition to the ADCP, a "deck box" is required for communication with a PC. The PC is used to both configure the instrument and to download and further process the data.

The instrument can be thought of as working rather like a police radar gun. In simple terms it measures the relative velocities between itself, the river bed (bottom track) and suspended particles in the water column. The ultrasonic transducers emit a pulse of sound (a ping) into the water column. Suspended particles in the column reflect some of the sound back while the channel bed reflects the strongest return signal. The velocity of the particles is assumed to be the velocity of the current, the channel bed is assumed to be stationary.

Various operating modes and configuration parameters can be selected to optimise the ADCP's performance under different conditions. These are explained later in this document.

1.2 This Project

This R&D report assesses the feasibility of using ADCP equipment for discharge measurement in UK rivers and the physical limitations of its use in extending and improving the Environment Agency's flow measurement capacity.

The ADCP technique, originally used for oceanographic research, was recently developed for use in coastal areas, estuaries and rivers. In the past the equipment has been used in the fluvial environment in North America, Europe and Asia. The Environment Agency commissioned Hydro-Logic Ltd to undertake a full evaluation of the device. The detailed evaluation included the following:

- Field tests of the equipment under a wide range of physical conditions e.g. depth, velocity, weeds and skewed flow to assess limitations of use, reliability, accuracy and repeatability;
- Evaluation of different deployment methods;
- Development of a best field practice including Health and Safety implications;
- Development of criteria for selecting sites suitable for gauging using ADCP technology;
- Literature and user review and assessment of experience in other parts of the world;
- Cost Benefit analysis.

The instrument selected for use in this project was a 600kHz Broadband ADCP manufactured by RD Instruments (RDI).

This report summarises the results and conclusions of the field work and research undertaken. The equipment was tested in all Environment Agency regions and problems with different methods of deployment or general operation found. Costs of deployment and the limitations of the instrument have also been ascertained.

Throughout the duration of the project regular meetings and discussions were held between the Environment Agency and Hydro- Logic Ltd.

2. EVALUATION SITE SELECTION

The evaluation sites were selected to reflect a wide range of physical conditions *in* order to test the ADCP equipment in most of the environments found in UK rivers. Most of the sites had reliable gauging stations providing a control discharge measurement for comparison with the ADCP results. The technology was tested at locations with the following physical characteristics:

- Narrow Channel;
- Wide Channel;
- Deep Channel;
- Shallow Channel;
- Low Current Velocities;
- Controlled River;
- Skewed Flow;
- Irregular Velocity Distribution;
- Simultaneous Bi-directional Flow;
- Turbulence;
- Artificial Channel;
- Low Suspended Solids;
- High Suspended Solids;
- Rapid Artificial Flow Changes;
- Variety of bed materials;
- Channel subject to weed growth;

At least one evaluation site was selected in each region to permit demonstration of the equipment to hydrometric staff.

A list of sites finally selected as test sites for the ADCP are given in Appendix 2. with the field visit results. Appendix 1.1 of the Project Record for this report gives more information about these sites.

3. EVALUATION PROCEDURES

3.1 Field Work

The evaluation trials were dependant on the site characteristics and the facilities available at each location. Blank field sheets appear in Appendix 1.2 of the Project Record for this report. Evaluation trials consisted of combinations of the following:

- Deployment Methods: different techniques for propelling the ADCP across the river.
- Operational Characteristics: varied set up characteristics and profiling modes, traversing speed and traverse paths.
- Comparisons of ADCP results with: gauging station, current meter, other ADCP and survey results

During the trials assessment was also made of the following points:

a) Minimum staffing requirements;
b) Health and safety considerations for various deployment methods and site conditions;
c) Time required for flow measurement including set-up and download time.

3.2. Data Gathering and Processing Methods

The ADCP was deployed and the data retrieved using the ADCP software. A preliminary analysis of the data was then undertaken on site. The results were further analysed in the office. In the main the data gathered was processed using the ADCP software. Some further analysis was carried out by exporting the data as an ASCII file and importing into an excel spreadsheet.

Some data was also sent to RDI to have the processed results verified.

For the purpose of this investigation several river traverses were performed during each deployment and the results plotted individually. From the user review it seems that generally most ADCP users take the average discharge from four traverses. As each traverse takes only two or three minutes, even on a wide river, this is easily achieved.

4. DEPLOYMENT METHODS

4.1 Carrying/Deployment Assembly and Raft/Floatation Collar

A framework was built which supports the ADCP and allows it to be carried safely, mounted on different deployment fixings and transported in a vehicle. A raft/floatation collar was constructed from two small surf (body) boards which are fixed by mounting brackets to the ADCP assembly. Design drawings and photographs of this framework and collar are included in Appendix 2.1 of the Project Record for this report.

There are three fixing positions for the floatation collar on the framework. They allow the ADCP transducer depth to be set and maintained at 0.1, 0.2 or 0.3m.

In general the ADCP was always deployed in the framework and floatation collar.

4.2 Propulsion Methods

The ADCP was successfully deployed from the Consultant's gauging boat using its floatation collar, both pushing it in front of the boat and holding it on the side. Tests were also undertaken with the ADCP deployed from a cableway. At many sites the ADCP was successfully towed manually from bank to bank while mounted on its floatation collar.

A remote control craft was designed and constructed for the ADCP. This consisted of a platform that bolted onto the ADCP frame. The craft is driven by two motors powered by two 12 volt batteries. Several successful deployments were performed using this craft.

For further information, photographs showing all ADCP deployment methods are given in Appendix 2.2 of the accompanying Project Record.

4.3 Self Contained versus Real Time Deployment

ADCP equipment can be deployed in two data retrieval modes; "self contained" and "real time". During self contained deployment the data is stored internally then downloaded after a number of traverses. During real time deployment the ADCP is permanently connected to the deck box and computer, and the gauging results displayed as the measurements are taken.

4.4 Deployment Modes and Operating Setup

Various operating modes and configuration parameters can be selected to optimise the ADCP's performance under different conditions.

The operating modes define both the type and pattern of sound pulses emitted by the transducers, and the method of processing the reflected signals. There are four modes (1, 4, 5 and 8) suitable for use on UK rivers. The differences between these modes are given in sections 5.2 (Findings) and 8 (Recommended Practice). More detail about deployment modes can be found in literature accompanying the ADCP and listed in the Bibliography (section 10).

Two other major deployment parameters must be set. The "bin size" is the size of each depth cell in the velocity profile, eg. a bin size of 20cm will give an average velocity for every 20cm through the water column. The "blanking distance" allows for a time delay between the emission of the signal and the transducer being able to receive reflected signals. This is needed to avoid interference. More details about these parameters are again given in sections 5.2 and 8.

5. EVALUATION WORK

As well as assessing the operational limitations of the ADCP in the site conditions given in section 3 some evaluation work was directed towards finding the cause of errors in some discharge measurements. This included a two day field test with the ADCP suppliers representative present.

5.1 Field Visits

A list of the sites visited during preparation of this report, including summary results and reasons for selecting each site, appears in Appendix 2.

5.2 Findings

One of the aims of this project was to define the operational limitations of the ADCP and derive recommended standard practice for its use. The recommended standard practice is in section 8. The general project findings and operational limitations follow. Detailed information on individual field visits and the conclusions drawn from each visit are given in the Project Record associated with this report.

5.2.1 Methods of Deployment

All the methods of deployment outlined in section 4 were evaluated. Important points for each method were noted and are outlined in the table below.

Deployment Method	Remarks
From a cableway	The floatation collar should be used.
From a boat	The boat hull should not be directly upstream of the instrument. If the transducers are close to the surface the boat must be manoeuvred slowly to avoid turbulence.
On a tow rope	Account must be taken of river width, current velocity and amount of river traffic. The tow ropes should be attatched symetrically to improve stability.
By remote control	A light line should be attached
From a gauging 'A' Frame on a bridge.	The floatation collar **must** be used.

The floatation collar is needed to maintain the ADCP transducers at constant depth.

Although towing the ADCP across a section can be the easiest and most efficient deployment method, in a wide, fast flowing, navigable river it can be impractical and cumbersome. Traverses may have to be interrupted or even abandoned when a boat passes. Due to the time it takes to perform a traverse in this manner, interruption is very common on a busy river. Also the amount of rope or cable needed to cross a wide river is heavy and could cause health and safety problems in high velocity streams.

If an 'A' Frame is used to lower the ADCP into the water it must be able to take the weight of the ADCP and its cage (46kg) and remain stable. Ropes should be attached to the ADCP before it is launched so these, not the 'A' frame, can be used to tow the ADCP across the river.

Certain constraints are imposed by channel conditions when setting the transducer depth.

- Under turbulent flow, air entrainment may prevent measurements being taken. Therefore the transducers should be set more than 0.2m below the surface.
- In shallow channels best results are obtained when the transducers are set at the minimum depth below the surface (0.1m).
- **In high current velocities the assembly is prone to capsize if the transducers are set at 0.1m.** When using towing ropes symetrical attachment low down on the cage can be used to prevent this. During boat deployment a bracing rope attached to the top of the ADCP and the boat fulfils a similar role.

The speed at which the ADCP traverses the channel does not have a significant effect on the results produced.

5.2.2 Limits of Operation and Operating Modes

The ADCP is subject to the following limits of operation.

Channel depth.

i) The minimum depth of deployment in mode 8, has been found to be about 0.8m.
ii) The minimum depth of deployment in mode 5 is about 1.25m.
iii) The minimum depth of deployment in mode 4 is about 3m.
iv) The maximum depth of deployment was not exceeded. (As would be expected in UK rivers.)

Current velocity

v) In mode 8 the ADCP could measure water velocities down to 0.06m/s.
vi) In mode 5 the ADCP could gauge current velocities as low as 0.04m/s. An assessment below this could not be made as no comparison methods were available.
vii) The maximum water velocity was not exceeded in this project. Other users have reported successful use of the ADCP in velocities of 3.5m/s. The maximum velocity is dependent on the mode used.

Other Considerations

viii) The width of the channel has no effect on the ADCP results.
ix) The ADCP functions well in river sections with High Suspended Solids.
x) The ADCP works in sections with low suspended solids provided some reflectors are present.

General Findings

i) The ADCP will usually underestimate the true flow if a blanking distance as low as 0.1m is used. Erroneous velocities are recorded for the top bin.

ii) Mode 5 generaly gives more reliable results than mode 8 so should be used when possible.

iii) Mode 8 tends to overestimate in low velocities.

5.2.3 Advantages in Using the ADCP

i) In a reasonably wide river passing boats and wind disturbance of the water surface do not seem to have a significant affect on the ADCP readings.

ii) The actual data collection time is very short so "instantaneous" flow gaugings can be performed.

iii) The machine is only in the top layer of the water column so does not itself distort the flows being measured.

iv) In many situations the technique does not require hydrometric personnel to get into or onto the water. If a boat is used staff do not have to lean over the side holding unwieldy equipment.

v) Total gauging time is much less than that required by bridge, boat or cableway gauging.

vi) A far more detailed bed and velocity profile is obtained than with conventional gauging.

5.2.4 Disadvantages in Using the ADCP

i) The collected data should be downloaded between each deployment. If several sites are to be visited during the day a computer with a reliable power source must be available.

ii) In a minority of cases the ADCP seems to underestimate the true flow for no apparent reason.

iii) Despite the fact that the ADCP is easier to carry in its mounting/carrying assembly it is still very difficult to manhandle, particularly in difficult field conditions. Three technicians are required.

iv) For wide rivers like the Severn at Bewdley (40m wide) the data takes as long to download as it takes to collect on continuous recording.

v) The ADCP unit makes large demands on battery power. A battery with 80% power will not independently power the unit.

Many of the errors in field measurements were due to the use of the ADCP at or beyond the operational limits of the equipment. This was expected as one of the aims of the project was to define these limits. Explanations of these errors appear in the table in Appendix 2. They have been used to define the recommended standard practice (section 8).

There are a few cases where the error in discharge measurement remains unexplained. A possible source of error is in the extrapolation of velocities up to the water surface. The ADCP does not measure the velocities at the water surface. It cannot measure flow velocities above the transducer levels and velocities just below the transducer are ignored as the signals are prone to interference. The velocities in this missing section of the water column are estimated by the ADCP software in one of two ways;

i) Constant velocity to the surface is assumed,
ii) A power law is applied based on the measured velocities.

If the true surface velocities do not follow either of these patterns these assumptions may well cause underestimation of flow in shallow rivers. (All UK rivers are shallow by world standards.)

6. LITERATURE AND USER REVIEWS

Full details of the literature and user reviews appear in the Project Record accompanying this report. Not much could be gleaned from the literature review. Most of the ADCP work done in the past was on the ocean or on rivers considerably larger than those found in the UK. On these larger rivers the equipment can be used on the manufacturer's recommended settings and many of the problems identified during this study do not appear to arise.

Only the company that manufactures the instrument seems to have performed extensive studies on its use and accuracy. These tests have all been in large rivers. If any other studies have been carried out the results have not been presented in a formal report. A full list of papers found on the ADCP appears in Appendix 4.1 of the accompanying Project Record.

Eighteen canvassing letters were sent out to organisations that own and use ADCP equipment. The letters enquired about general use of the equipment, any problems found and any assessments that had been carried out. Five replies were received, these are in Appendix 4.2 of the accompanying Project Record. Further contact was made by fax and telephone, providing useful information.

None of the ADCP users contacted had experience using the instrument in watercourses as shallow as most UK rivers. Despite this some suggestions were forthcoming as to possible causes of any measurement errors. These suggestions were examined and either disproved or accounted for in the project findings.

General information on the use of the ADCP was also forthcoming. Most users take an average of four traverses when gauging using the ADCP. Although there was not an opportunity to test the equipment in high flow conditions in Britain during this project, a German user has recorded water velocities up to 3.5m/s.

7. COST BENEFIT ANALYSIS

The technical analysis showed that due to the minimum depth limitations the ADCP will not replace conventional current meter gauging by wading as a means of measuring flows on smaller rivers. However, on larger deeper rivers it could have a role to play as a replacement for boat or cableway and possibly bridge gauging. In addition it could provide a means of gauging rivers where current meter gauging is unsuitable. Flood peaks could be gauged in a shorter time and low current velocities could be gauged more accurately. The ADCP produces a velocity profile so can be considered the equivalent of a multipoint gauging.

7.1 Economic Analysis

Details of the economic analysis appear in the project record for this report. Summary sheets appear in appendix 4 of this document.

The number of gaugings made in a region in an average year was calculated by taking the average total number of gaugings in a year and dividing this by the number of regions. Average figures are also used for the proportion of cableway, bridge and boat gaugings. For boat gaugings it was assumed that equal numbers were at navigable and non-navigable sections. The number and proportion of gaugings may vary greatly between regions, so the analysis can only give a rough idea.

Two comparisons of the manpower cost of gauging have been performed; one based on an assumed number of gaugings per day and one based on the time taken for each gauging.

A table showing the results of the cost benefit analysis follows. The key information is in bold. The costs have been discounted using an annual rate of 6%.

Table 7.1 Results of Cost Benefit Analysis

Gauging Method Item	Boat (£)	Bridge (£)	Cableway (£)	ADCP (£)
Capital Cost	8000	4500	20000	38484
Discounted Annual Cost	741	610	1744	3962
Ancillary Equipment (optional) Boat				4500
Remote Control				1150
Discounted Annual Cost				boat 392 rem. control 118
Manpower (development per person)	200			300
Discounted Annual Cost	17			31
Consumables (year)	Excluding petrol 10	10	10	300
Maintenance (annual)	Current Meter only 350	Current Meter only 350	550	1627
Minimum annual running cost, not including gauging*	Excluding petrol **1109**	**960**	**2304**	**6313**
Manpower (per gauging) Based on gauging time	non-navigable 134 navigable 201	127	62	29
Manpower (annual[a]) Based on gauging time	3 440	15 486	13 159	10 145
Total manpower(based on time)			**32 084**	**10 145**
Manpower (gauging) Based on gauging /day†	non-navigable 141 navigable 212	141	71	four 106 five 85
Manpower (annual[a]) Based on gauging /day	3 636	17 179	14 963	four 37 510 five 30 008
Total manpower (based on days)			**35 778**	four **37 510** five **30 008**
Annual gauging costs for average region based on time taken	4 548	15 486 17 179	13 159 14 963	16 457
Total (based on time)			**36 457**	**16 457**
Annual gauging costs for average region based on gaugings per day	4 744	17 179	14 963	four 43 823 five 36 321
Total (based on days)			**40 150**	four **43 823** five **36 321**

*Assuming 20 years of life for conventional equipment, 15 for the ADCP and a technician passing on their skill.
[a] Based on number of gaugings performed by the "average" region.
†Assuming 4 or 5 ADCP gaugings per day and 2 of each of the others.

Summary

	Conventional Gauging (£)	ADCP (£)
Annual Cost based on time taken	**36 457**	**16 457**
Annual Cost based on gaugings per day	**40 150**	four **43 823** five **36 321**

If the ADCP was to be used to avoid the necessity of building a cableway it would be cheaper to run an ADCP instead of building three cableways. The cost of performing a gauging using the ADCP is much less than the cost of any other method.

Spreadsheets used during the economic analysis appear in appendix 5 of the Project Record for this report. Summary sheets appear in appendix 4 of this document. The analysis assumes that all equipment for each gauging method would have to be purchased and all gaugings currently carried out using cableway, bridge and boat gauging methods can be carried out using the ADCP.

7.2 Intangible Costs and Benefits

There are various intangible benefits intrinsic to each gauging method which have not been included in the economic analysis. These include Health and Safety, environmental and practical benefits and the degree of confidence in the method. A table giving these costs and benefits follows.

Table Showing Intangible Costs and Benefits of Different Gauging Methods

	Gauging Method	Cableway	Bridge	Boat	ADCP
Cost	Personnel on or in the water			x	Sometimes
	Personnel leaning over water			x	
	Chance of equipment overbalancing into water		x		Sometimes
	Bulky equipment to manhandle		x	x	x
	Road traffic danger to operators		Sometimes		
	Cable impeding navigation			x	Sometimes
	Boat launching site required			x	Sometimes
	Bridge required on site		x		Sometimes
	Permanent intrusive structure required	x			
	Length of time required for one gauging	x	x	x	
	No complete velocity profile produced	x	x	x	
	Cannot gauge in shallow water				x
	Cannot gauge velocities Ω 0.04m/s	x	x	x	
	Wet line correction required in high velocities	x	x	x	
	Does not record Bi-directional flow	x	x	x	
	Occasional systematic error				x
Benefit	No personnel on or in the water	✔	✔		Sometimes
	No leaning over water	✔			✔
	Equipment stable	✔		✔	✔
	No manhandling of bulky equipment	✔			
	No road traffic danger to operators	✔	Sometimes	✔	✔
	No obstruction to navigation	✔	✔		Sometimes
	No boat launching site required	✔	✔		Sometimes
	No need for bridge	✔		✔	Sometimes
	No intrusive permanent structure		✔	✔	✔
	Gauges flow quickly if "instantaneous" value is needed				✔
	Complete velocity profile produced				✔
	Can gauge in shallow water	✔	✔	✔	
	Can gauge velocities < 0.04m/s				✔
	No wet line correction required in high velocities				✔
	Records Bi-directional flow				✔
	Rare systematic error	✔	✔	✔	

The major intangible benefit of the ADCP is its flexibility. The deployment method can be selected according to the site to be visited using what is available at the site and taking account of any problems relating to the site. If the site is subject to heavy river traffic use a deployment method that does not involve stretching a cable across the river. If there is no bridge deploy the equipment using a boat or cableway or find another means of getting across the river with the end of a rope. There are also some intangible technical benefits to gauging difficult sites with the ADCP and obtaining full velocity profiles.

The main intangible cost with using the ADCP is the systematic error which occurs at some sites, although this error is less than 10% (the accuracy of most other gauging methods).

8. RECOMMENDED STANDARD PRACTICE

During the evaluation of the ADCP equipment for use in UK rivers it was possible to ascertain the best practice for use of the equipment. The type of sites suitable for ADCP use, and limitations to its use and accuracy, have been found. Safe and efficient deployment methods and working practices have been determined. Operation and maintenance requirements have been pinpointed and data handling and analysis methods put into practice. A description of recommended practice follows and flow charts appear in appendix 3 along with some notes on ADCP deployment.

8.1 Type of Site

The major site constraint on ADCP use is the channel depth.

- Operating mode 4 only functions in depths greater than 3m.
- Operating mode 5 only functions in depths greater than 1.25m
- Operating mode 8 only functions in depths greater than 0.8m

Channels are usually shallower near the banks than in the main part of the channel. To avoid losing too much of the flow the following rules should be applied:

i) When using mode 8 the gauging section should be at least 1m deep.
ii) When using mode 5 the gauging section should be at least 1.5m deep.
iii) When using mode 4 the gauging section should be at least 3m deep.

Another major consideration with site selection is the minimum flow velocity.

- Mode 4 is not suitable for gauging flow velocities less than 0.5m/s[1].
- Mode 5 can accurately measure flow velocities lower than 0.04m/s.
- Mode 8 can only accurately measure flow velocities greater than 0.06m/s.

These considerations need to be combined with the section depth constraints.

<u>Guidance Table for selecting ADCP Operating Mode</u>

	Velocity (m/s)				
Depth (m)	>1	1>v>0.5	0.5>v>0.06	0.06>v>0.04	<0.04
<1	none	none	none	none	none
1<d<1.5	none	mode 8	mode 8	none*	none*
1.5<d<3	mode 1[1]	mode 5	mode 5	mode 5	#
>3	mode 4[1]	mode 4	mode 5	mode 5	#

*In a <u>rectangular</u> channel over 1.25m deep it may be possible to use mode 5.
#The minimum water velocity detectable in mode 5 has not been ascertained.

[1]Information taken from ADCP River Discharge Measurement Manual

The ADCP can be deployed and produce results in channels with high and low suspended solids.

Finally there is one practical consideration, the ADCP equipment is bulky. The site must be accessible with this equipment.

8.2 Deployment Methods

The ADCP should always be deployed in its support cage and floatation collar. This ensures the transducers are always a constant depth below the water surface.

The ADCP can be deployed in several different ways. Here they are listed in order of preference.

- On a tow rope.
- From a cableway
- On a remote control craft.
- From a boat.

Four traverses of the river section should be performed and an average result taken when using the ADCP for discharge measurement.

8.2.1 On a Tow Rope

Use of a tow rope is the simplest and most efficient method for deploying the equipment at most gauging sites. The equipment needed is simple, two ropes that will stretch across the section. One operator has to be able to cross the river with the end of a rope.

The method would obstruct boats so is not recommended for sections subject to a great deal of passing traffic. If there is no option but to use this method at such a site then one of the ropes should be substituted with a cable which can be sunk to allow a boat to pass. One of the operators should have a megaphone so that they can warn river traffic about the rope and inform them which side of the equipment to pass.

In a wide river with high current velocities - particularly if a cable is being used - the drag on the equipment may endanger the operators and this deployment method should not be used. The width of river that can be safely gauged using this method depends on the current velocities and whether a rope or cable is used. The ADCP can be safely towed on a rope across a river over 50m wide with velocities of 0.1m/s. It may be dangerous to use a cable at a similar site although a cable could be used at a site of over 30m width with the same water velocities.

8.2.2 From a Cableway

There are a limited number of sites where this method can be applied. At these sites it is an effective and efficient deployment method. No additional equipment is needed.

If this method is used the suspension cable should be slack enough to ensure the floatation collar is resting on the water surface.

8.2.3 On a Remote Control Craft

Deployment of the ADCP on a remote control platform allows maximum control of the equipment's path across the section. This is ideal if the ADCP is being used to produce bed and velocity profiles of the section. It is prefered where there is no cableway and no means of crossing the river.

For this deployment method additional equipment must be purchased at a cost of £1150. As the ADCP is a valuable piece of equipment it is advisable that a light line is attached to the cage in case of failure of the motors or control device. The remote control used in the trials had a range of 0.5km and could perform in flow velocities of up to 1m/s but this is not recommended as the motor platform might flood. The remote control could conservatively perform in velocities up to 0.5m/s.

When deploying the ADCP on a remote control craft one of the operators should have a megaphone so that they can warn river traffic about the safety line and inform them which side of the equipment to pass.

8.2.4 From a Boat

The ADCP can be deployed from a boat if there is no cableway and no means of crossing the river. A boat can cope with high current velocities and wide sections and does not impede river traffic. If the ADCP is to be deployed in real time mode it must be deployed from a boat (unless the section is narrow enough for the connecting cable to stretch across).

A suitable boat might cost £4500 and the operator must have a boat handling certificate. In addition there must be a suitable place to launch a boat near the site. The boat hull should not be upstream of the ADCP.

8.3 Operating Set-up

On arrival at site the depth of the ADCP transducer array must be selected. This can be 0.1, 0.2 or 0.3m, for the assembly used in the evaluation, and is set while attaching the floatation collar to the ADCP cage. Guidance on transducer depth selection is given in the table appearing later in this section.

When the ADCP is in the river the operating mode must be selected based on the tables in section 8.1 and this section. For most UK rivers modes 5 and 8 are appropriate. Mode 5 is more precise and in general more accurate than mode 8 so it is better to use this if possible. However, mode 8 can operate at sites too *shallow for* mode 5. Certain deployment parameters can be set within each operating mode.

- Bin size (size of each depth band in the velocity profile)
- Blanking distance (parameter indicating which reflected signals to ignore to avoid interference)
- ADCP depth (depth of transducers below the surface)

Although the ADCP depth is set physically when the ADCP cage is bolted onto the floats, the depth must be included in the deployment command file.

The parameter values are set in whole decimetres. The bin, blanking distance and transducer depth selected depend on the water depth and channel conditions. No data is collected less than one bin from the bottom. No data is collected less than the sum of all three parameters from the water surface[2]. Water velocities are estimated in these two regions. The literature supplied with the ADCP states that a minimum of two depth cells must produce good velocity data to give accurate flow measurements. Recommended settings can be deduced from this information.

<u>**Recommended Settings for ADCP Deployment**</u>

Channel Conditions	Mode	Bin (m)	Blank (m)	Transducer Depth (m)
Very Deep Channels	4	0.5	0.5	0.3
Deep Channels (manufacturer's recommendation)	5	0.2	0.3	0.3
Shallow Channels	8	0.1	0.2	0.1
Low Velocity Shallow Channels	5	0.1	0.2	0.1
High Velocity Channels v<1m/s	5	0.1	0.2	0.2 or 0.3
High Velocity Deep Channels v>1m/s,	4	0.3	0.3	0.3
High Velocity Shallow Channels 2>v>1m/s,	8	0.1	0.2	0.2 or 0.3
High Velocity Shallow Channels v>2m/s,	1	0.1	0.2	0.2 or 0.3
General Deployment	5	0.1	0.2	0.1

As errors are introduced in the estimation of the surface velocities it is best to minimise the depth over which the velocities need to be estimated. Thus it is best to use the last setting if possible.

It is a good idea to set up some library configuration and command files including the various combinations of operating parameters. The file can then be selected when needed.

There are important rules to note:

[2] From ADCP River Discharge Measurement Manual.

i) Always ensure the depth specified in the deployment file is the depth at which the transducers are set.
ii) Never use Blank<0.2m. Erroneous velocities will be recorded in the top bin.
iii) In turbulent or high velocity flow increase the transducer depth to 0.3m to increase stability and prevent air entrainment interfering with the signal.
iv) When reading the data make sure the configuration file has the same parameter values as the deployment file.

There is another parameter that can be set within the operating mode which can be used to reduce the time required to download the deployment. This is the number of bins (depth cells) to be recorded. Obviously limiting the number of bins also limits the depth gauged so this number must be chosen carefully. The expected maximum depth of the section should be divided by the bin size selected. Extra bins should then be added to this number to allow a safety margin (a few extra seconds downloading is better than failing to measure the entire flow).

8.4 General

The average results from four traverses should be taken as the discharge measurement.

A note should be made of the width of channel between the end of the ADCP traverse and the bank. If it is large it can be used to adjust the calculated flow.

When several traverses are performed during the same deployment care must be taken to note the time, distance and discharge values at either end of each transect. These values can be used to calculate the true distance and discharge covered by each transect. It is helpful for the ADCP to be synchronised with the timing device used to record the traverse start and finish time.

8.5 Maintenance

The manufacturers recommend the ADCP is serviced every three years. Few of their clients do this but on average an ADCP seems to need minor repairs every three years anyway.

There are diagnostic checks that can be run on the ADCP using the instrumentation software. The programme checks that all the ADCP systems are responding. It is recommended that these are performed at the beginning of each field day. Key checks are the battery condition (80% full power is essential) and available memory.

9. CONCLUSIONS

This R&D report was initiated to assess the feasibility of using an Acoustic Doppler Current Profiler (ADCP) for discharge measurement in UK rivers. The aim was to describe the limitations of its use in extending and improving the Environment Agency's flow measurement capacity and to derive a recommended standard practice.

Execution of the project involved a considerable amount of field work. During the evaluation work a total of 25 field visits have been made to 21 sites. These field visits have been vital in establishing the operational limits of the ADCP and have helped to pinpoint any logistical and measurement problems. ADCP trials were carried out at gauging station sites to allow comparison of the ADCP measured flows with proven data. The evaluation sites used were selected to reflect a wide range of physical conditions in order to test the ADCP equipment in most of the environments found in UK rivers. Generally the ADCP performed well.

The ADCP can be deployed in several different ways on UK rivers over 1m deep.

- On a tow rope.
- From a cableway
- On a remote control craft.
- From a boat.

The instrument can cope with various difficult site conditions.

- Water surface disturbance (by wind or passing boats)
- Low water velocities
- Irregular flow
- Bi-directional flow
- High suspended solids
- Low suspended solids
- Weed growth

There are various advantages in using an ADCP. The actual data collection time is very short so "instantaneous" flow gaugings can be performed. As the instrument is only in the top layer of the water column it does not distort the flows being measured. In many situations the technique does not require hydrometric personnel to get into or onto the water. If a boat is used staff do not have to lean over the side holding unwieldy equipment. A far more detailed bed and velocity profile is obtained with the ADCP than with conventional gauging.

As with all methodologies there are also disadvantages. If several sites are to be visited during the day a computer with a reliable power source must be available. Despite the fact that the ADCP was mounted in its carrying assembly it is still very difficult to manhandle, particularly in difficult field conditions. Three technicians are required. Following a deployment in self contained mode it can take several minutes to download data for one deployment, as long as the deployment itself. On a few occasions the ADCP underestimated the flow for no apparent reason. The problem in some instances may be with the measurement methods used for comparison. Further operational experience with the use of the equipment may lead to the resolution of this problem.

10. BIBLIOGRAPHY

A list of relevant papers for further reading appears in Appendix 4.1 of the accompanying Project Record. Other literature referred to during the preparation of this report is listed below.

British Standards Institute; BS 3680: Part 3A, Methods of Measurement of Liquid Flow in Open Channels: Part 3. Stream Flow Measurement: Part 3A. Velocity-area Methods.

RD Instruments; Acoustic Doppler Current Profilers, Principles of Operation: A Practical Primer. (1 January 1989).

RD Instruments; User's Manual for the RD Instruments Transect Program (for use with Broadband ADCP). P/N 951-6004-02 (July 1994).

RD Instruments; User's Manual for the RD Instruments Playback Program (for use with Broadband ADCP). P/N 951-6047-00 (February 1995).

RD Instruments; Direct Reading and Self-contained Broadband Acoustic Doppler Current Profiler Technical Manual. P/N 951-6046-00 (August 1995).

RD Instruments; ADCP River Discharge Measurement Manual. P/N 951-6068-00 (November 1995).

11. GLOSSARY

Acoustic	pertaining to sound.
ADCP	Acoustic Doppler Current Profiler, the main equipment being used.
ADCP Depth	see Depth, Transducer.
BBSC	programme in the ADCP software suite used for deploying the ADCP and retrieving data.
BBTEST	programme in the ADCP software suite used for checking the ADCP is in working order.
Bin	depth cell
Blank	blanking distance, ~ after transmit, delay between transmitting a sound pulse and being able to receive. The delay is written in terms of a sound travel distance.
Blanking Distance	see Blank.
Cage	support framework.
Carrying Assembly	deployment assembly, mounting assembly, framework constructed to support the ADCP during transportation and deployment.
Command file	*.cmd file usedto send the ADCP operating commands.
Communication cable	heavy black cable connecting the ADCP to the deck box during initialisation and downloading.
Configuration file	*.cfg file used to read retrieved data in TRANSECT.
Data Retrieval Modes	two different modes, self contained and real time, in which the ADCP can retrieve data.
Deck Box	unit linking the ADCP to its computer during real time deployment, initialisation of self contained deployment and downloading of data.
Deploy	initialise the ADCP to collect data then propel the instrument across the section to record data. A deployment can last for several river traverses. Derived words: deployment, deployed, etc.
Deployment Assembly	see Carrying Assembly.
Deployment Fixings	items attached to the ADCP and required for deployment, e.g. cableway cable, ropes.
Deployment Method	technique for propelling the ADCP across the river, e.g. towing.
Deployment Mode	mode, water mode, operating mode, profiling mode, defines the type and pattern of sound pulses emitted by the transducers and the way they are processed; e.g. mode 5, mode 8.
Depth, Transducer	the depth of the ADCP transducers below the water surface during deployment.
Doppler Effect/Shift	change in an observed sound frequency caused by the relative velocity between a sound source and an observer.
Download	retrieval of data from the ADCP using the ADCP computer.
Floatation Collar	raft, device attached to the carrying assembly to support the ADCP on the water surface.
Mounting Assembly	see Carrying Assembly.

Operating Mode	see Deployment Mode.
Pass	see Traverse
Ping	sound pulse emitted by the ADCP.
PLAYBACK	programme in the TRANSECT section of ADCP software suite used for viewing results.
Profiling Mode	see Deployment Mode.
RDI	RDInstruments, suppliers of ADCPs.
Real Time (Mode)	data retrieval mode in which the ADCP relays information to the operating computer as it gathers it. The ADCP and computer are connected throughout the deployment.
Receive Signal	reflected ultrasonic pulse received by a transducer.
Self Contained (Mode)	data retrieval mode in which the ADCP stores the information it gathers. This data is then downloaded to the computer after the deployment.
TP	time between pings, time between two successive ping emitted by the ADCP.
Transducer	device for transforming one form of energy into another, in this case electronic energy into ultrasonic sound energy and back.
Transducer Depth	see Depth, Transducer.
TRANSECT	programme in the ADCP software suite used for deploying the ADCP and retrieving and viewing data.
Traverse	pass, one sweep across a river during an ADCP deployment. In self contained mode a deployment can consist of any number of traverses. In real time mode a deployment consists of one traverse.
Water Mode	see Deployment Mode.

ENVIRONMENT AGENCY R&D TECHNICAL REPORT W71

THE EVALUATION OF ACOUSTIC DOPPLER CURRENT PROFILER EQUIPMENT

APPENDIX 1

PHOTOGRAPH OF ADCP

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THE EVALUATION OF ACOUSTIC DOPPLER CURRENT PROFILER EQUIPMENT

APPENDIX 2

TABLE GIVING SITE LIST, FIELD VISIT DETAILS AND RESULTS

Table giving Results of ADCP Field Tests

Key to Table

Deplyt.	Deployment number.
Trans. Depth	Transducer depth
Ave. Vel.	Average water velocity
Water depth	Average depth of water in channel.
Site Attributes	Reason for visiting the site.
Deployt. Method	Deployment method
Values in italics	Taken from the ADCP data files so not independently verified, they are the right order of magnitude.
Matched Control Readings	Showing no systematic error. Scattered around the control result, usually within 5% but 10% was acceptable.
EA	Environment Agency
NWEA	North West Region.
5EA	Using Environment Agency's older ADCP.
H-L floats	Floatation collar.
TP000025	TP = 0.25s, time between pings in hundredths of a second (In Real Time TP = 000009).

PART I: SUCCESSFUL DEPLOYMENTS

Site	Deplyt.	Bin (m)	Blank (m)	Mode	Trans. Depth (m)	Section Width (m)	Ave. Vel. (m/s)	Water Depth (m)	Site Attributes	Deployt. Method	Test Results	Remarks
Severn at Saxons Lode (1st visit) 19/4/96	1	0.2	0.3	4	0.3	59	0.4	4.4	Large, wide, deep navigable river, with tidal influence.	Cableway	Matched control results	
Severn at Bewdley 1/5/96	1	0.2	0.3	4	0.3	*45*	*0.51*	*2*	Large, wide	Cableway	Matched control readings	
	2	0.2	0.3	5	0.3				Large, wide	Cableway	Matched control readings	
	3	0.2	0.3	8	0.3				navigable river.	Cableway	Matched control readings	
	4	0.2	0.3	8	0.3					Boat	Matched control readings	
Kennet at Newbury 4/6/96	2	0.1	0.2	8	0.1	8.5	0.4	1.7	Narrow, medium to high velocities.	Towing	Matched control readings	
	3	0.1	0.3	8	0.1				Moderate depth.	Towing	Matched control readings	
	4	0.1	0.3	8	0.1					Boat	Matched control readings	
Thames at Sutton Courtenay 6/6/96	2	0.1	0.2	8	0.1	37	*0.15*	1.605	Larger river with sheet piling on	Towing	Matched Control Readings	
	3	0.1	0.2	8	0.1				both banks, and close proximity	Towing	Matched Control Readings	
	5	0.1	0.2	8	0.1				of powerlines.	Boat	Generally matched control readings	Errors occurred in the 2 traverses under the powerlines
	6	0.1	0.2	8	0.2					Towing	Matched Control readings	
	7	0.1	0.2	8	0.2					Boat	Matched Control Readings	

Site	Deplyt.	Bin (m)	Blank (m)	Mode	Trans. Depth (m)	Section Width (m)	Ave. Vel. (m/s)	Water Depth (m)	Site Attributes	Deployt. Method	Test Results	Remarks
Nene at Wansford 18/7/96	5	0.2	0.2	5	0.1	35	0.04	3.5	Wide channel, low velocities, navigable.		Matched Control Readings	
Yorkshire Ouse at Skelton 25/7/96	5	0.1	0.2	8	0.1	33.8	*0.08*	5.21	Deep, wide and navigable river.	Cableway	Matched Control Readings	
Severn at Saxons Lode (3rd visit) 21/8/96	3	0.2	0.3	5	0.3	*54*	*0.07*	*4.2*	Large, wide, deep navigable river, with tidal influence.	NWEA catamaran, boat	Match Control Readings	Run off deck box battery
	4	0.2	0.3	5	0.3					H-L floats, boat	Match Control Readings	Run off deck box battery
Mersey at Westy (2nd visit) 30/11/96	5EA	0.2	0.3	5	0.3	48	0.18	4	Convenient location, slight tidal influence.	Real time	Matched Control Readings	EA ADCP,
Thames at Caversham 18/12/96	1	0.1	0.2	5	0.2	55	0.08	3.5	Low velocity site	Towing	Matched Control Readings	
	2	0.1	0.2	5	0.2					Towing	Matched Control Readings	
	3	0.1	0.2	5	0.2					Towing	Matched Control Readings	
	4	0.1	0.2	5	0.2					Towing	Matched Control Readings	
	5	0.1	0.2	5	0.2					Towing	Matched Control Readings	
	6	0.1	0.2	5	0.2					Towing	Matched Control Readings	
	7	0.1	0.2	5	0.2					Towing	Matched Control Readings	

Site	Deplyt.	Bin (m)	Blank (m)	Mode	Trans. Depth (m)	Section Width (m)	Ave. Vel. (m/s)	Water Depth (m)	Site Attributes	Deployt. Method	Test Results	Remarks
Itchen at Riverside 17/3/97	2	0.1	0.2	8	0.1	10	0.3	1.5	River with low suspended solids content.	Towing	Matched Control Readings	
	3	0.1	0.2	8	0.1					Towing	Matched Control Readings	
	4	0.1	0.2	8	0.1					Towing	Matched Control Readings	
	5	0.1	0.2	5	0.1					Towing	Matched Control Readings	
	6	0.1	0.2	5	0.1					Towing	Matched Control Readings	
Parrett at Bridgewater 13/5/97	1	0.1	0.2	0.2	5	varied	varied	varied	Tidal site with	Towing	No control	Verified incoming tide
	2	0.1	0.2	0.2	5				High Suspended	Towing	Matched Control Readings	Falling tide produced variation in discharge, velocities matched
	3	0.1	0.2	0.2	5				Solids	Suspended from 'A' frame	Matched Control Readings	Stationary Profile ADCP functions in high suspended solids
Thames at Kingston 20/6/97	1	0.1	0.2	5	0.1	70		4	Very low current velocities	Boat	Matched Peek, underestimate Accusonic 66%	Very low velocities on site. Erratic readings typical of all measurement methods. Throughout the visit, the Peek ultrasonic readings and ADCP measurements were closer to each other than either were to the Accusonic. The ADCP seems to be as good as any other current metering method in such low velocities.
	3	0.1	0.2	5	0.1					Boat	Matched Peek, underestimate Accusonic 23%	

PART II: DEPLOYMENTS DEFINING THE OPERATIONAL LIMITS OF THE INSTRUMENT

Site	Deplyt.	Bin (m)	Blank (m)	Mode	Trans. Depth (m)	Section Width (m)	Ave. Vel. (m/s)	Water Depth (m)	Site Attributes	Deployt. Method	Test Results	Remarks
Severn at Bewdley 1/5/96	5	0.2	0.3	8	0.1	*45*	*0.51*	2	navigable river.	Boat	Underestimate 35%	Traverses included loops and moved downstream. This may have missed some of the flow and caused error in the analysis of the results.
Wye at Redbrook 15/5/96	1	0.2	0.3	5	0.3	53.22	*0.7*	0.6 - 1.4	Large section with wide range	Cableway	Underestimate 50%	Half the channel was too shallow for mode 5
	2	0.2	0.3	8	0.3				of flows, cobbled bed. Shoal on right bank.	Cableway	Underestimate 33%	1 third the channel was too shallow for mode 8
Tern at Walcot 22/5/96	1	0.1	0.1	5	0.1	*15*	*0.22*	1.1	Middle range site	Towing	Underestimate 14%	Blank of 0.1m causes underestimation.
	2	0.1	0.1	5	0.1				with possibility to	Towing	Underestimate 12%	As above
	3	0.1	0.1	5	0.1				work in hydraulic	Towing	Underestimate 25%	As above
	4	0.1	0.1	5	0.1				jump.	Towing	Underestimate 6%	As above
	5	0.1	0.1	8	0.1					Towing	Underestimate 14%	As above
	6	0.1	0.1	5	0.1					Towing	No results	Flow too turbulent for 0.1 depth
Kennet at Newbury 4/6/96	1	0.1	0.1	8	0.1	8.5	*0.4*	1.7	Narrow, medium	Towing	Underestimate 10%	Blank of 0.1m causes underestimation.
	5	0.1	0.2	8	0.2				to high velocities. Moderate depth.	Towing	Underestimate 10%	Transducer depth too great.
Lambourn at Shaw 4/6/96	1	0.1	0.2	8	0.2	13.7	*0.2*	0.85	Shallow, clean flowing river.	Towing	Underestimate 40%	Transducer depth too great for shallow channel
	2	0.1	0.2	8	0.1				Affected by summer weed	Towing	Underestimate 20%	Edges of channel not gauged as too shallow.
	3	0.1	0.2	8	0.1				growth	Towing	Underestimate 20%	As above
	4	0.1	0.1	8	0.1				Convenient location.	Towing	Underestimate 40%	Blank of 0.1m causes underestimation.

Site	Deplyt.	Bin (m)	Blank (m)	Mode	Trans. Depth (m)	Section Width (m)	Ave. Vel. (m/s)	Water Depth (m)	Site Attributes	Deployt. Method	Test Results	Remarks
Thames at Sutton Courtenay 6/6/96	1	0.2	0.2	8	0.1	37	*0.15*	1.605	Larger river with sheet piling on both banks, and close proximity of powerlines.	Towing	Underestimate 50%	Sludge layer, Channel has silty bed.
	4	0.1	0.2	8	0.1					Towing	Underestimate 10%	Powerlines
Avon at Great Somerford 5/7/96	1	0.2	0.3	5	0.1	*8*	0.03	*1.1*	Shallow with. low velocities	Towed	No results	Too shallow for mode 5.
	2	0.1	0.2	8	0.1					Towed	No results	Too slow for mode 8
Nene at Wansford 18/7/96	1	0.2	0.3	8	0.1	35	0.04	3.5	Wide channel, ,. low velocities navigable	Cableway and Towing	Overestimate 20%	Too slow for mode 8
	2	0.2	0.3	8	0.1						Overestimate 20%	Too slow for mode 8
	3	0.2	0.3	8	0.1						Overestimate 20%	Too slow for mode 8
	4	0.2	0.2	8	0.1						Overestimate 40%	Too slow for mode 8
King's Dyke, Stanground 19/7/96	1	0.2	0.2	8	0.1	11	0.06	2.5	Narrow channel with low. velocities	Towing	Overestimate 50%	Too slow for mode 8,
	2	0.2	0.2	8	0.2						Overestimate 50%	Too slow for mode 8,
	3	0.2	0.2	5	0.2					Towing	Underestimate 35%	Underestimating depth
Thames at Kingston 20/6/97	2	0.1	0.2	5	0.1	70		4		Boat	Underestimate 17%	Very low velocities on site. Erratic readings typical of all measurement methods. Generally,
	4	0.1	0.2	5	0.1					Boat	Overestimate Peek 15%, underestimate Accusonic 5%	throughout the visit, the Peek ultrasonic readings and ADCP measurements were closer to each other than either were to the Accusonic. The ADCP seems to be as good as any other current metering method in such low velocities.

PART III: DEPLOYMENTS PRODUCING UNEXPLAINED ERRORS IN THE RESULTS

Site	Deplyt.	Bin (m)	Blank (m)	Mode	Trans. Depth (m)	Section Width (m)	Ave. Vel. (m/s)	Water Depth (m)	Site Attributes	Deployt. Method	Test Results	Remarks
Severn at Saxons Lode (1st visit) 19/4/96	2	0.2	0.3	4	0.3	59	0.4	4.4	Large, wide, deep navigable river,	Cableway	Underestimate 8%	
	3	0.2	0.3	4	0.3				with tidal influence.	Boat	Underestimate 8%	
Mole at Castlė Mills 14/6/96	1	0.1	0.2	8	0.1	15	*0.23*	1.0	Shallow river, affected by weed growth.	Towing	Overestimate 10%	
Severn at Saxons Lode (2nd visit) 20/6/96	1	0.1	0.2	5	0.1	*54*	*0.09*	*3.8*	Large, wide, deep	Boat	Underestimate 15%	
	2	0.1	0.2	8	0.1				navigable river,	Boat	Underestimate 15%	
	3	0.1	0.2	8	0.2				with tidal	Boat	Underestimate 8%	
	4	0.1	0.2	8	0.2				influence.	Towing	Underestimate 6%	
Yorkshire Ouse at Skelton 25/7/96	1	0.2	0.2	8	0.2	33.8	*0.08*	5.21	Deep, wide and	Cableway	Underestimate 10%	
	2	0.2	0.2	5	0.2				navigable river.	Cableway	Underestimate 10%	
	3	0.1	0.2	5	0.2					Cableway	Underestimate 10%	
	4	0.1	0.2	5	0.1					Cableway	Underestimate 4%	
	6	0.1	0.2	5	0.3					Boat	Underestimate 10%	
	7	0.1	0.2	8	0.3					Boat	Underestimate 10%	
Aire at Lemonroyd 26/7/96	1	0.1	0.2	5	0.3	25	0.06	3.4	Low velocity site	Towed	Underestimate 10%	
	2	0.1	0.2	5	0.3				with accurate	Towed	No data	Memory full
	3	0.2	0.2	5	0.3				crump weir.	Towed	Underestimate 16%	
	4	0.1	0.2	5	0.1					Towed	Underestimate 20%	
	5	0.1	0.2	5	0.1					Towed	Underestimate 12%	
Severn at Saxons Lode (4th visit) 20/9/96	1	0.2	0.3	5	0.3	*41*	0.08	*4.2*	Large, wide, deep	Towed	Underestimate 15%	
	2	0.2	0.3	5	0.3				navigable river,	Boat	Underestimate 10%	
	3	0.2	0.3	5	0.3				with tidal	Boat	Underestimate 10%	TP000025
	4	0.2	0.3	5	0.3				influence.	Boat	Underestimate 10%	Run off deck box battery
	5	0.2	0.3	5	0.3					Boat	Underestimate 10%	Run off deck box battery, TP000025

Site	Deplyt.	Bin (m)	Blank (m)	Mode	Trans. Depth (m)	Section Width (m)	Ave. Vel. (m/s)	Water Depth (m)	Site Attributes	Deployt. Method	Test Results	Remarks
Mersey at	1	0.2	0.3	5	0.3	48	0.19	4	Convenient	Real time	Underestimate 13%	single traverse,
Westy	2	0.2	0.3	5	0.3				location, slight	Real time	Overestimate 8%	single traverse,
(1st visit)	3	0.2	0.3	5	0.3				tidal influence.	Real time	Overestimate 15%	single traverse,
29/11/96	4	0.2	0.3	5	0.3					Real time	Underestimate 6%	single traverse,
	5	0.1	0.2	5	0.3					Real time	Underestimate 5%	single traverse,
	6	0.1	0.2	5	0.3					Real time	Underestimate 9%	single traverse,
	7	0.1	0.2	5	0.3					Real time	Underestimate 13%	single traverse,
	8	0.2	0.3	5	0.3					Boat	Underestimate 13%	
	9	0.1	0.2	5	0.3					Boat	Underestimate 10%	
Mersey at	1	0.2	0.3	5	0.3	48	0.18	4	Convenient	Boat	Underestimate 6%	
Westy	2	0.2	0.3	5	0.3				location, slight	Remote	Underestimate 7%	
(2nd visit)	3	0.1	0.2	5	0.3				tidal influence.	Remote	Underestimate 9%	
30/11/96	6	0.2	0.3	5	0.3					Remote	Underestimate 6%	
	6EA	0.2	0.3	5	0.3					Real time	Underestimate 8.5%	
	7	0.2	0.3	5	0.3					Remote	Underestimate 5%	TP000025s
	7EA	0.2	0.3	5	0.3					Real time	Underestimate 7.5%	Single traverse,
	8	0.2	0.3	5	0.3					Real time	Underestimate 2%	Single traverse,
	9	0.2	0.3	5	0.3					Real time	Underestimate 2%	Single traverse,
	10	0.2	0.3	5	0.3					Real time	Underestimate 4%	Single traverse,
	11	0.2	0.3	5	0.3					Real time	Underestimate 5%	Single traverse,
	12	0.2	0.3	5	0.3					Catamaran	Overestimate 4.5%	
	13	0.2	0.3	5	0.3					Real time	Overestimate 10%	Stationary Profile,
	14	0.2	0.3	5	0.3					Real Time	Overestimate 10%	Stationary Profile,
	15	0.2	0.3	5	0.3					Real time	Underestimate 2%	
Itchen at Riverside 17/3/97	1	0.1	0.2	8	0.1	10	0.3	1.5	River with low suspended solids content.	Towing	Overestimate 13%	

ENVIRONMENT AGENCY R&D TECHNICAL REPORT W71

THE EVALUATION OF ACOUSTIC DOPPLER CURRENT PROFILER EQUIPMENT

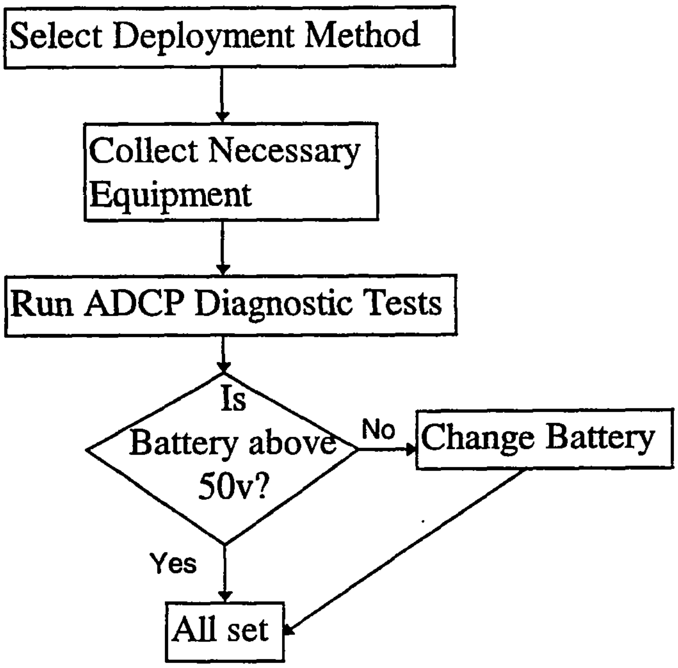
APPENDIX 3

FLOW CHARTS AND NOTES FOR RECOMMENDED STANDARD PRACTICE

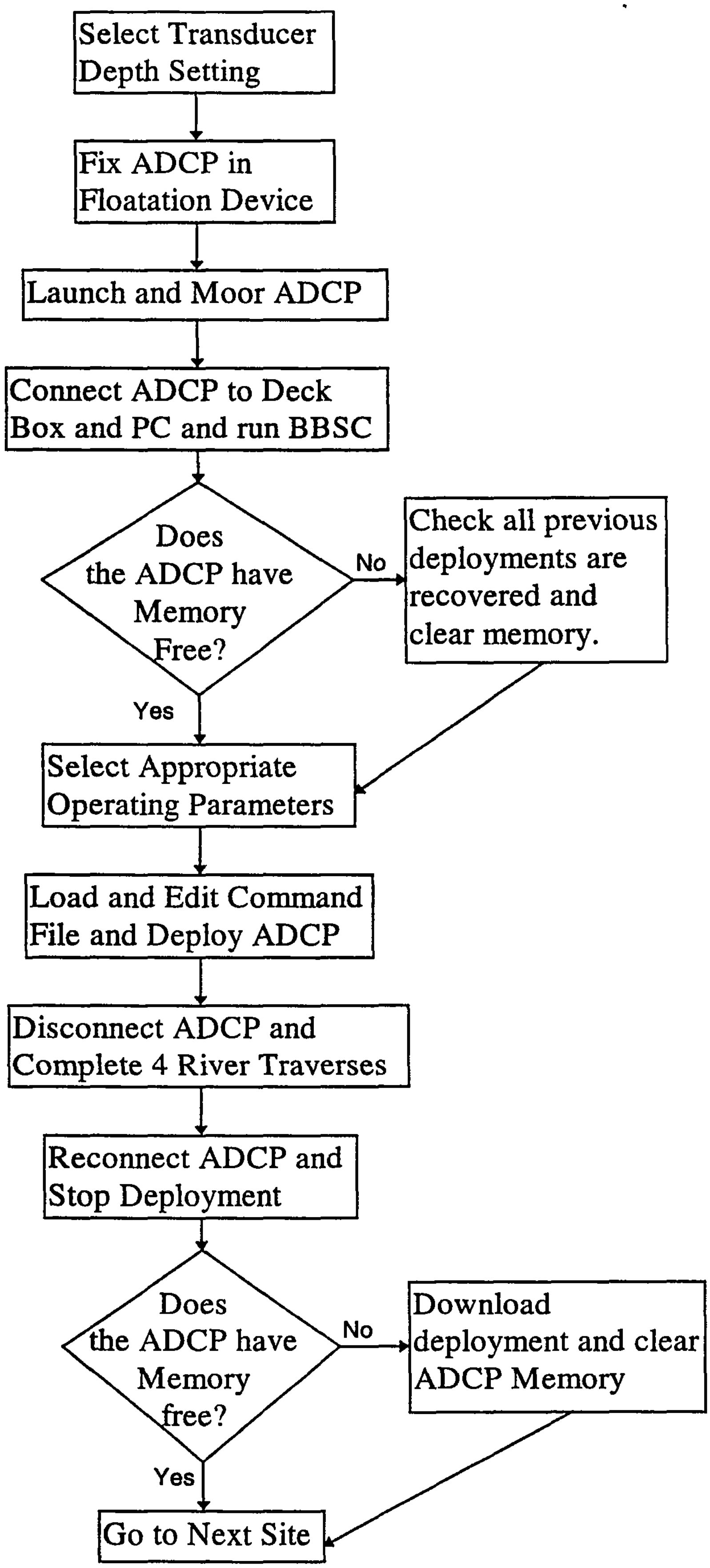
Flow Charts for ADCP Deployment

Recommended Practice

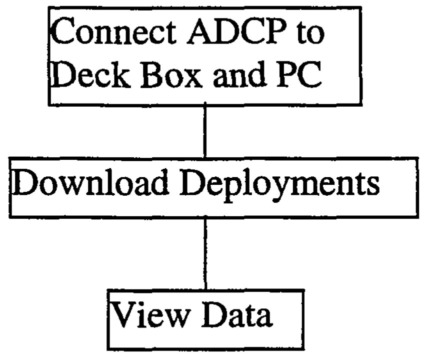
Before Leaving the Office



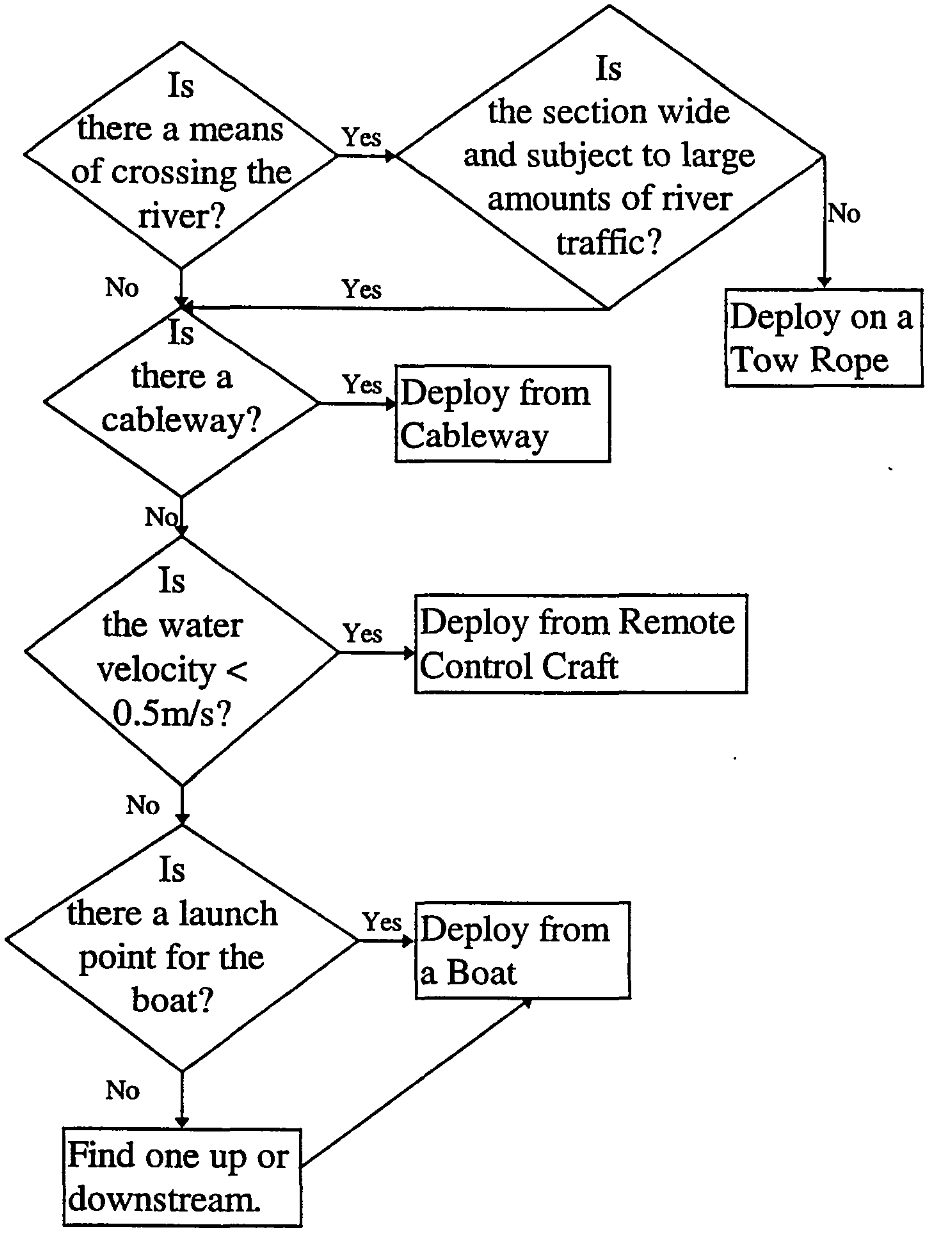
On Site


Select Transducer Depth Setting
Fix ADCP in Floatation Device
Launch and Moor ADCP
Connect ADCP to Deck Box and PC and run BBSC
Does the ADCP have Memory Free?
No
Check all previous deployments are recovered and clear memory.
Yes
Select Appropriate Operating Parameters
Load and Edit Command File and Deploy ADCP
Disconnect ADCP and Complete 4 River Traverses
Reconnect ADCP and Stop Deployment
Does the ADCP have Memory free?
No
Download deployment and clear ADCP Memory
Yes
Go to Next Site

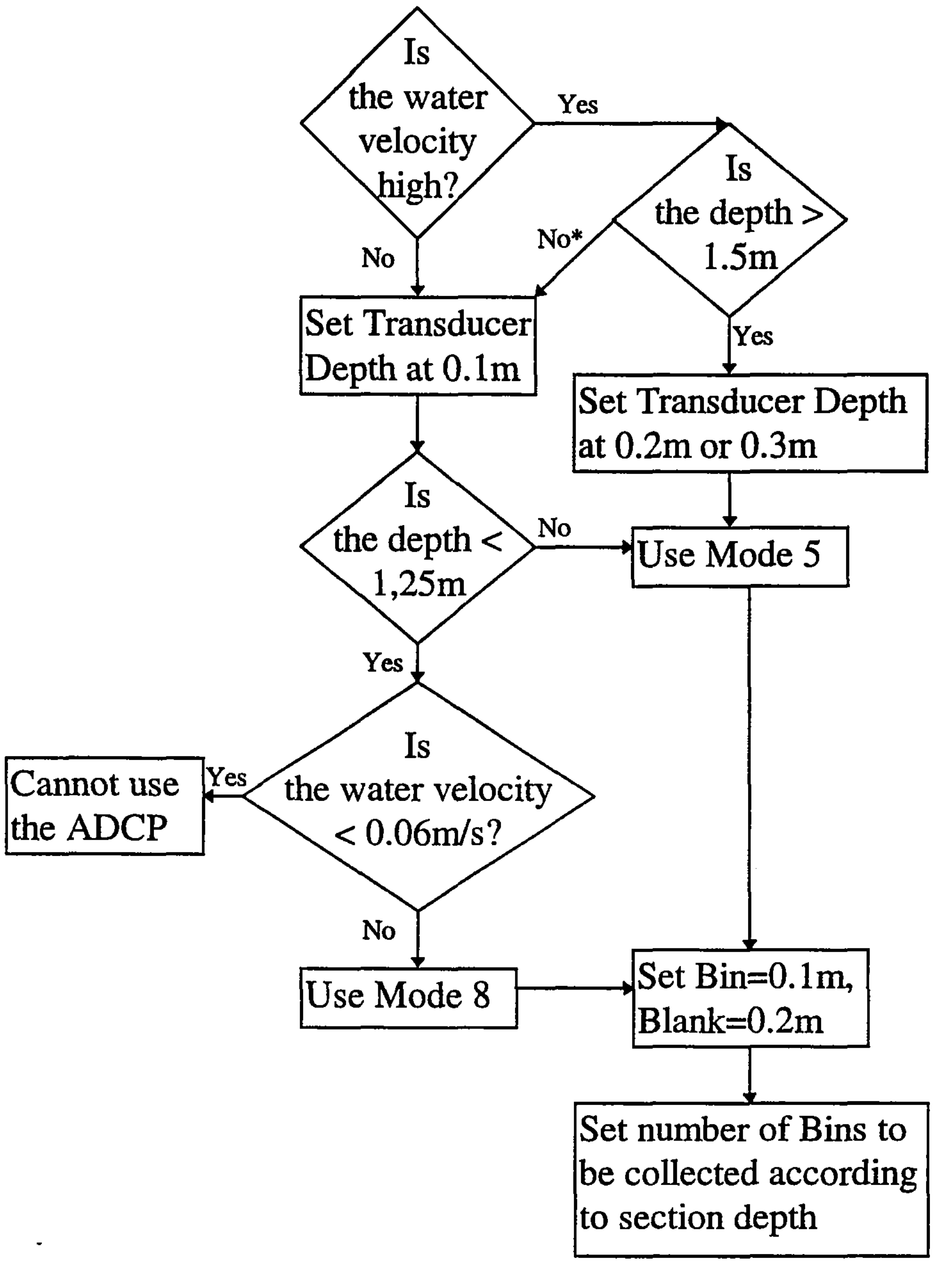
After Return to Office



Selecting Deployment Method



Selecting Transducer Depth and Deployment Parameters



*Take measures to stabilize equipment to prevent capsizing.

Notes on Testing and Deployment of ADCP

These notes assume the ADCP is already connected to the deck box and PC.

Self-Diagnostic Tests

1. Go to DOS directory c:\adcp
2. Run BBTEST
3. Select "Auto tests"
4. When tests are complete select "Exit"

Deployment

1. Go to directory c:\adcp
2. Run BBSC
3. Select "Recorder" to check available memory
4. A window will appear giving the available memory to the nearest MB. Check enough[3] is available and select "Cancel"
5. Select "Deployment"
6. At the next window select "load"
7. You will be promted for a filename. Enter a file from your library with the form *.cmd.
8. The command list for the file will appear. Tab until the cursor is in the editting screen to check the parameter values are correct:
   WF - Blanking distance in cms
   WS - Bin size in cms
   ED - Transducer depth in dms
   WN - Number of depth cells to be measured
9. Make any changes necessary, tab to the"Save" button and select.
10. Select "Deploy"
11. The message "Recorder not empty. continue?" may appear,select Yes.
12. The message operation successful should be displayed.
13. Select "File"
14. At the promt enter the log-file name for the deployment.
15. Select "Cancel" from successive menus.
16. At BBSC main menu pres ALT-X to exit.

Downloading

1. Run BBSC
2. Select "Recorder"
3. Select "Recover"
4. A new window will appear. Enter the name you intend to give your data file in the top field.
5. Enter the number of the deployment you intend to retrieve in the next field. The deployments stored in the ADCP memory will be numbered in chronological order.
6. Select "Recover".
7. Once the download is complete the message "Deployment recovered" is displayed. Select "OK"

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[3] If there is insufficient memory ensure all data has been downloaded then select "Erase".

8. If further deployments are to be downloaded repeat items 4 to 7 until all the data is retrieved.
9. Select "Cancel" from successive menus.
10. At BBSC main menu press ALT-X to exit.

Displaying Results

1. Go to directory c:\adcp
2. Run TRANSECT
3. Select "Playback"
4. Press F3 to load files
5. Select "Configuration"
6. Press "Enter", you will be given a list of available files.
7. Load the appropriate (*.cfg) file from your library.
8. Press F3
9. Select "Raw data file"
10. Press "Enter", you will be given a list of available files.
11. Load the appropriate data (*.000) file.
12. View the data in the form you require using the menus for guidence. ALT-W rewinds a data file to the beginning.

ENVIRONMENT AGENCY R&D TECHNICAL REPORT W71

THE EVALUATION OF ACOUSTIC DOPPLER CURRENT PROFILER EQUIPMENT

APPENDIX 4

SUMMARY OF THE ECONOMIC ANALYSIS

Key to Spreadsheets

ADCP	Acoustic Doppler Current Profiler.
All 3	Costs when a combination of cableway, bridge and boat gaugings are used for gauging. The assumed combination is based on an assessment of the country-wide distribution of gauging methods.
i	Discounting value Value to represent the annual interest rates. Used to calculate the true value of a sum of money in the future if invested rather than spent, or conversely to determine the investment required to generate a certain sum in the future. Thus it facilitates the comparison of long and short term costs at a fixed point in time.

ECONOMIC ANALYSIS OF ADCP - SUMMARY

Based on time per gauging

	EQUIVALENT ANNUAL COST OF EQUIPMENT ETC.	COST OF GAUGINGS IN AN AVERAGE YEAR	TOTAL COST
CABLEWAY	2304	13159	15463
BRIDGE	960	15486	16446
BOAT*	1109	3440	4548
ALL 3	**4372**	**32084**	**36457**
ADCP	**6313**	**10145**	**16457**

PERCENTAGE DIFFERENCE OF COST OF USING ADCP FROM COST OF EXISTING METHODS	**-54.86**

AVERAGE SAVING PER YEAR (for each region) IF ADCP WERE USED FOR ALL PREVIOUS CABLEWAY, BRIDGE AND BOAT GAUGINGS (£)	**20000**
(SAVING PER GAUGING(£))	**56**

*For boat gaugings it was assumed that there are an equal number of navigable and non-navigable sections.

NB. The Economic analysis assumes that all gaugings currently carried out using cableway, bridge and boat gauging methods can be carried out using the ADCP.

The analysis assumes that all equipment for each method would have to purchased.

The number of gaugings made in a region in an average year is calculated by taking the average total number of gaugings in a year and dividing this by the number of regions. Average figures are also used for the proportion of cableway, bridge and boat gaugings. However, both the number and proportion vary greatly between regions, so the analysis can only give a rough idea.

AVERAGE TOTAL NO. OF GAUGINGS PER YEAR			18356
AVERAGE NO. OF GAUGINGS PER YEAR (PER REGION)			2294.5
CABLEWAY	BRIDGE	BOAT	ADCP
0.0925	0.0531	0.00899	(if replacing all 3)
212	122	21	355

A value of i = 6% has been assumed.

ECONOMIC ANALYSIS OF ADCP - SUMMARY

Based on five ADCP gaugings per day

	EQUIVALENT ANNUAL COST OF EQUIPMENT ETC.	COST OF GAUGINGS IN AN AVERAGE YEAR	TOTAL COST
CABLEWAY	2304	14963	17267
BRIDGE	960	17179	18139
BOAT*	1109	3636	4744
ALL 3	**4372**	**35778**	**40150**
ADCP	**6313**	**30008**	**36321**

PERCENTAGE DIFFERENCE OF COST OF USING ADCP FROM COST OF EXISTING METHODS	**-9.54**

AVERAGE SAVING PER YEAR (for each region) IF ADCP WERE USED FOR ALL PREVIOUS CABLEWAY, BRIDGE AND BOAT GAUGINGS (£)	**3830**
(SAVING PER GAUGING(£))	**11**

*For boat gaugings it was assumed that there are an equal number of navigable and non-navigable sections.

NB. The Economic analysis assumes that all gaugings currently carried out using cableway, bridge and boat gauging methods can be carried out using the ADCP.

The analysis assumes that all equipment for each method would have to purchased.

The number of gaugings made in a region in an average year is calculated by taking the average total number of gaugings in a year and dividing this by the number of regions. Average figures are also used for the proportion of cableway, bridge and boat gaugings. However, both the number and proportion vary greatly between regions, so the analysis can only give a rough idea.

AVERAGE TOTAL NO. OF GAUGINGS PER YEAR			18356
AVERAGE NO. OF GAUGINGS PER YEAR (PER REGION)			2294.5
CABLEWAY	BRIDGE	BOAT	ADCP
0.0925	0.0531	0.00899	(if replacing all 3)
212	122	21	355

A value of i = 6% has been assumed.

ECONOMIC ANALYSIS OF ADCP - SUMMARY

Based on four ADCP gaugings per day

	EQUIVALENT ANNUAL COST OF EQUIPMENT ETC.	COST OF GAUGINGS IN AN AVERAGE YEAR	TOTAL COST
CABLEWAY	2304	14963	17267
BRIDGE	960	17179	18139
BOAT*	1109	3636	4744
ALL 3	**4372**	**35778**	**40150**
ADCP	**6313**	**37510**	**43823**

PERCENTAGE DIFFERENCE OF COST OF USING ADCP FROM COST OF EXISTING METHODS	**9.15**

AVERAGE SAVING PER YEAR (for each region) IF ADCP WERE USED FOR ALL PREVIOUS CABLEWAY, BRIDGE AND BOAT GAUGINGS (£)	**-3673**
(SAVING PER GAUGING(£))	**-10**

*For boat gaugings it was assumed that there are an equal number of navigable and non-navigable sections.

NB. The Economic analysis assumes that all gaugings currently carried out using cableway, bridge and boat gauging methods can be carried out using the ADCP.

The analysis assumes that all equipment for each method would have to purchased.

The number of gaugings made in a region in an average year is calculated by taking the average total number of gaugings in a year and dividing this by the number of regions. Average figures are also used for the proportion of cableway, bridge and boat gaugings. However, both the number and proportion vary greatly between regions, so the analysis can only give a rough idea.

AVERAGE TOTAL NO. OF GAUGINGS PER YEAR			18356
AVERAGE NO. OF GAUGINGS PER YEAR (PER REGION)			2294.5
CABLEWAY	BRIDGE	BOAT	ADCP
0.0925	0.0531	0.00899	(if replacing all 3)
212	122	21	355

A value of i = 6% has been assumed.