THE NEWSLETTER OF THE BRITISH HYDROLOGICAL SOCIETY

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COME TO CARDIFF!

13th-16th September

There is still time to register (just) for daily attendance at BHS's 4th National Hydrology Symposium. The papers have been split into five main topic groups — Water resources, Environmental aspects, Information systems, Floods, and Modelling developments, preceded by a keynote address by Prof O Storosolszky of VITUKI, Hungary, *AND* there are the hydrological games .... how can you possibly *not* be there!

NB: Please pay your cheques to the University of Wales College of Cardiff.

The Science White Paper - abridged for hydrologists

Few readers will have the impulse to read the complete Science White Paper (*"Realising our potential: A Strategy for Science, Engineering and Technology"* HMSO (2250, May 1993, £9.65). The following summary may help to get the flavour. For the uninitiated, NERC stands for Natural Environment Research Council, SERC for Science and Engineering research Council, ACOS is the Advisory Committee on Science and Technology and OST is the Office of Science and Technology; WP is the White Paper. This document was put to the BHS Research Sub-committee on 5th July. It represents only a partial and personal view, so if in doubt refer to the full document.

NERC retains its identity and broadly its mode of operation. It is being given oversight of earth observation science.

SERC is to be split into two: the new Council of interest to hydrologists will be the Engineering and Physical Sciences Research Council (EPSRC).

The WP contains no direct reference to hydrology.

The Mission Statement for NERC (WP p.31) contains no reference to hydrology, presumably inferring that our discipline can be termed an earth science.

NERC has been given (WP p.31) the water, construction and forestry industries, amongst others, as its 'user community'. The EPSRC by contrast has been given the engineering, construction, information technology and other industries as users — but not the water industry.

The government will now look closely at the possibility of privatising its directly-owned research laboratories; the first announced for that process is the Transport Research Laboratory at Crowthorne, Berks: it used to be prominent in urban hydrology research but recently has not been involved in hydrology in any major way.

The research institutes of research councils look as if they will only be considered for privatisation at some later date.

There is to be a Technology Foresight Steering Group which will (WP p.19) 'draw up an agreed list of technology sectors each of which would be the subject of a foresight assessment overseen by a panel of experts'. 'Science-push' and 'demand-pull' will be evaluated.

There is a strong emphasis on wealth creation and partnership with

industry (such that the dampener of little funding for 'near-market' R&D may disappear, see WP p.16).

There is a blessing on one-year MSc courses prior to any individual moving on to a three-year PhD. (This can be interpreted as changing the balance of numbers undertaking research at different levels). The WP also implies (pp 60-61) that the nature of doctoral training in science and engineering must change.

Although the government recognises the need for large sums of public money being used for research, it values 'above all the generation of national prosperity and the improvement of the quality of life' (WP p.2). There is no clear recognition of a science such as hydrology which maintains the quality of life by quantifying, e.g. flood, drought and water quality risks.

The replacement of ACOST by a new Council for Science and Technology is unlikely to benefit (or harm) hydrology unless its membership reflects, say, the water industry.

WP p.7 promises that 'Government negotiating positions will be better co-ordinated across the range of European and international science and technology programmes'.

WP p.14 says the government will 'encourage universities as well as industrially-orientated research organisations to strengthen their links with local business communities'.

OST will now take a leading responsibility for the 32 LINK programmes (WP p.35) and the government's 50% grants. (Has hydrology become involved in any of these?).

General university research funds will continue (WP p.37) to go through the education departments and the Higher Education Funding Councils; but the new co-ordinating committee (WP p.38) will bring in the research charity voice.

There will be a Director-General over all Research Councils. One of his/her tasks will be to look at more funding of research fellows rather than of research projects (WP p.64).

F M Law
Institute of Hydrology

The Third Postgraduate Symposium

University of Lancaster
6-8 April 1993

Improbable maximum floods, the takeover of hydrology by modellers and an unexpected demonstration of sprinkler hydrology were among the many contributions to that total experience, the Society's Third Postgraduate Symposium, held on the University of Lancaster campus. Forty-one current, recent or aspiring postgraduate students attended, fifteen stimulating talks were presented and there was a lively discussion on the direction of hydrological research. As with the earlier symposia (at Loughborough in March 1990 and Edinburgh in April 1992), the aim was to enable postgraduates to gain experience in the presentation of research work and to discuss ideas and difficulties within their peer group in an informal setting.

Rainfall, Mires and Chemicals

As chairman of the opening session (afternoon of 6 April) I reminded the speakers that there would be a prize of a book "Channel Network Hydrology" (edited by K.J. Beven and M.J. Kirkby), kindly donated by our host, **Professor Keith Beven**, for the best presentation. **Jutta Thielen** (Institute of Environmental and Biological Sciences, University of Lancaster) then stepped up to talk about the influence of topography and upper air winds on the outbreak of convective storms in the Pennines. Initiation of convective storms over sunfacing slopes, the juxtaposition of different air masses from east and west of the main ridge, and the direction of steering level winds relative to the underlying topography were shown to be of major importance for storm development.

Barney Austin (Department of Civil Engineering, University of Salford) spoke next on using radar to predict the probable maximum precipitation/probable maximum flood (PMP/PMF) in the UK. Still at an early stage, this study will apply archived images from UK weather radars to selected river catchments, to estimate the PMP and also the PMF of a catchment, with particular emphasis on storm spatial structure. Discussion on the meaning of the PMF resulted in a new term, the Improbable Maximum Flood, being coined!

Rita Smit (Department of Biological Sciences, University of Dundee) went on to discuss the derivation of a seepage hydrograph for a Scottish raised mire (defined as a place where you need wellies). Water balance, hydrograph separation and mixing model (combined with tracer study) techniques are being tested as means of obtaining the hydrograph.

Pippa Chapman (Department of Civil Engineering, Imperial College) then discussed the hydrochemical response of stream water to storm events in a headwater catchment in mid-Wales (at Plynlimon). Her results suggest that natural episodic acidification of the stream water may be associated with an increase in acid neutralisation capacity (ANC) and therefore questions the present definition of an "episode" as a short-term depression in stream water ANC.

Mike Hutchins (Department of Civil Engineering, Imperial College) spoke about hydrogeochemical modelling at the same small moorland catchment. He described the development and application of a conceptual empirical model for the catchment hydrology and discussed how to incorporate a chemical (ANC) end-member mixing model into the simulation.

A short discussion period concentrated on data collection problems and, in particular, the use of radar to overcome the difficulty of knowing when to go out to sample rainfall, especially convective storms.

Tropical forest hydrology

Following a reception and dinner, **Dr Nick Chappell** (Institute of Environmental and Biological Sciences, University of Lancaster) gave an informative guest presentation on tropical forest hydrology, based on his

experiences in Borneo and illustrated with slides of idyllic rainforest settings. He began with a description of the impacts of commercial logging, which include increased sediment yield (1000 t km^{-2} $year^{-1}$ compared with 300 t km^{-2} $year^{-1}$ in undisturbed areas) causing channel siltation and flooding, and also affecting coral formation at sea. As the sediment comes from very localised sources, improvements in forest management will require understanding of the relevant processes at a fine scale, with subsequent scaling up for application. Nick therefore described a water balance study (which established that surface runoff, evaporation and subsurface flow each accounted for around 33% of the rainfall) and the development of a hillslope response model.

The latter showed that macropore flow is important in generating the observed rapid response of streamflow to rainfall and the large stormflows important in transporting the channel sediment load. Currently Nick is modelling the hydrology of logging tracks, which form a principal source of runoff and sediment in logged areas. Discussion of this and the rest of the day's talks continued at the bar!

Groundwater models, surface water models, macromodels and urban drainage models

With Professor Keith Beven in the chair, the first talk in the morning session (7 April) was by **Amjad Sami Aliewi** (Department of Civil Engineering, University of Newcastle upon Tyne) on numerical simulation of the behaviour of the fresh/saline water transition zone around a scavenger well. The study has provided a better understanding of the upconing movement of the transition zone and means of determining the maximum freshwater pumping rate and the freshwater recovery ratio.

Continuing the groundwater theme, **Uwadiale Eigbe** (Department of Civil Engineering, Imperial College) spoke on stochastic estimation of groundwater piezometric heads by Kalman filtering, using one-dimensional and two-dimensional simulations. Inclusion of the Kalman filter in modelling hypothetical but realistic aquifer flows under conditions of uncertainty showed improved results compared with simulations without the filter.

Ro Charlton (Department of Geography, University of Bristol) then discussed her work on modelling contributions to floodplain inundation from the adjacent hillslopes. She will be using a coupled hillslope hydrology-floodplain inundation model to identify the circumstances under which hillslope contributions are likely to be significant (Figure 1).

Jenny McArthur (Institute of Environmental and Biological Sciences, University of Lancaster) took us downstream to talk about extreme events in estuaries. Rapid erosion and redistribution of sediment by storm events in the Esk estuary, Cumbria, has been the signal for a field measurement campaign in the estuary and the development of a two-dimensional hydrodynamic/dispersion model for modelling storm events and their impacts.

Robert Lamb, also from the University of Lancaster, went upscale to present a talk on a conceptual approach to macroscale modelling, using TOPMODEL as a basis. The aim is to relax some of the restrictive assumptions of the present model in favour of more general concepts, especially for the saturated zone component, which will permit macroscale modelling.

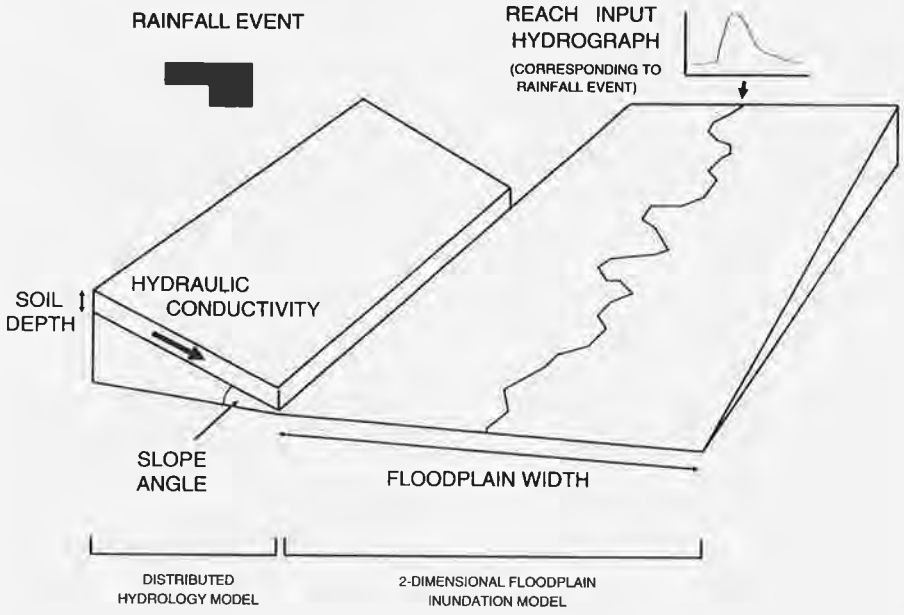


Figure 1 The input parameters for the coupled hillslope hydrology-floodplain inundation model. The parameters will be varied to represent a range of environments, from which the circumstances in which hillslope contributions affect floodplain inundation significantly will be identified.

Staying with the topic, **Tim Jolley** (Department of Civil Engineering, Imperial College) described his work on macromodelling of the River Severn. Using the Penman bucket model as an example, he showed how river discharge data (for the Severn) could be used to validate the hydrological component of global circulation models, noting, though, that data for a range of climates and environments are needed to validate all parts of the model.

In the final morning paper, **Richard Griffith** (Department of Civil Engineering, University of Salford) spoke on flow forecasting for real time control of urban drainage systems. In his system, rainfall forecasting, based on radar measurements, provides a distributed input to physically realisable transfer function models, which give flow forecasts at relatively large catchment scales, for example 180 km^2 for the test catchment in Manchester (Figure 2).

Pre-lunch discussion revolved round the problems of keeping models simple and not overparameterised.

Water resources and sediments

Dr Susan Walker (National Rivers Authority, Northwest Region, and the Society's President Elect) launched the afternoon session with a talk on starting a career in hydrology. She began with professional qualifications, noting that a number of routes to obtaining chartered status were opening up but that the relevant institutions would be looking for breadth of understanding and knowledge of managerial and financial affairs in applicants. She then moved to career openings including the water industry, the NRA and the Scottish RPBs, consultants, academia and research institutes and referred to the recent Society survey of its members' employment (Circulation, No. 35, August 1992). The water industry comprised both regulated and non-regulated components and Susan described the various regulatory authorities, especially the NRA. She also noted the forthcoming development of the UK environmental agency (ENVAGE?!) which will combine the NRA, Her Majesty's Inspectorate of Pollution and the waste regulation authorities. The talk was clearly of interest to the assembled postgraduates, standing at the threshold of their hydrological careers.

Susan then took over the chair for the three final papers. First up was **Sarah Douglas** (NRA, Southern Region) who spoke on the NRA Southern Region's water resources development strategy. The strategy shows that the region can remain self-sufficient in water resources for at least twenty years, provided that a programme of

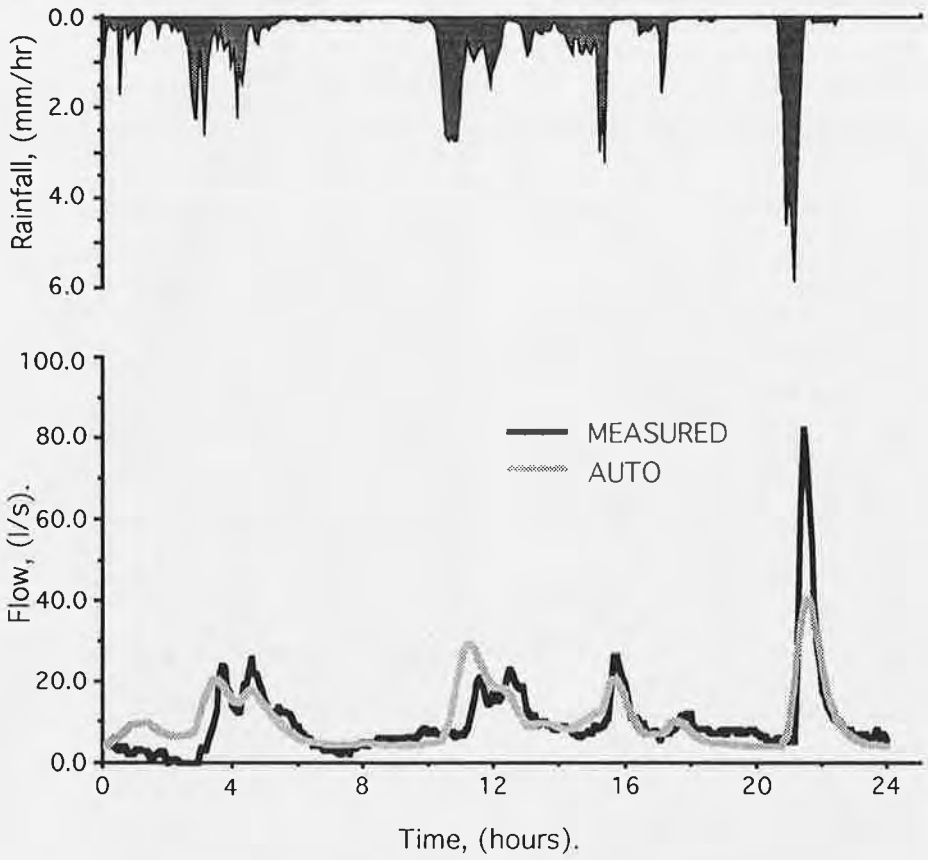


Figure 2 Comparison of the measured flow for the event of 14 June 1991 at the Davyhulme Urban Drainage Area, Sub-Area 10, Flow Monitor 39, with the flow simulated using radar rainfall data and a physically realisable transfer function model with automatically optimised parameters.

water conservation, including demand management, is introduced.

Next **Max Wheeler** (Department of Engineering, University of Aberdeen) described his research on streams with excessive bed load. A flume study (aimed at improving physical understanding as the basis for developing sediment transport equations) is showing the impact of imposed sediment loads on mixed grain size beds and the flow regime.

Lastly **Joe Pearce** (NRA, Southern Region) discussed sediment investigations on the River Test. Concern over detrimental increases in sediment loads, arising largely from the conversion from grassland to arable land over the last fifty years, has led to a study to define optimal channel sizes which will maintain channels in a sediment-free condition. An important component of the study will be a Chalkstream Management Handbook.

Prize speaker

The prize for the best talk was then presented by Susan to **Ro Charlton**. It had proved difficult to choose the best as all the presentations had been of a high standard. However, the judges felt that Ro had distinguished herself with a good introduction, clear and audible presentation, useful conclusions and good timekeeping!

Does hydrology equal modelling?

There followed a lively discussion about the role of modelling in hydrological research and whether it was becoming the dominant activity. Field studies are often more expensive than computer modelling studies and, because of the caprices of the natural environment, are less guaranteed to produce results in the time available. Consequently there is a temptation to concentrate on modelling research. However, there was clear concern at the meeting that modelling may be proposed for its own sake (rather than providing real insight into hydrological processes) and that inordinate time may be spent on coding rather than thinking about the science.

One suggestion was that research establishments should employ computer programmers to develop and correct the model coding (in accordance with the research student's ideas), leaving the student more time to concentrate on the science. It was recognised also that it was no longer sufficient just to develop a model to obtain a PhD. The model should also be tested and applied. However, this required field data, which brought us back to the expense of fieldwork. Combined field and modelling studies were seen as advantageous and it was suggested that these could best be carried out by small teams. As several students had raised the frustrations of working on their own, team studies could also provide the additional benefit of more supportive and fruitful working conditions.

Floodbusting in Namibia

Following supper **Paul Webster** (Department of Civil Engineering, University of Birmingham) entertained us with a fascinating and beautifully illustrated guest lecture on his earlier existence as a hydrologist in the Department of Water Affairs in Namibia, searching for and then gauging flash floods (*Circulation 10*, May 1986).

To monitor the higher flood flows important in establishing stage/discharge relationships, it was necessary for the gauging team to be on site before the arrival of the flood. In a flashflood environment, the only way that this could be managed was to form a rapid response team which could be mobilised when there was a strong expectation of a flood developing.

Thus was born the Flood Patrol. Although requiring a strong commitment of staff and equipment (not the least item being beer!), and despite inevitable wild goose chases, the Patrol was highly effective. It provided for improved monitoring, observation of flashflood processes (Paul's pictures of mud-laden torrents have to be seen to be believed!) and observation of the data collection systems in operation. Indeed Paul's principal recommendation concerned the understanding of hydrological processes which could be obtained from going out and observing in the field. At this stage, however, the symposium, feeling parched by Paul's stunning pictures of waterless scenery, could head only for the bar!

Contaminant-Tracing Facility

On the morning of 8 April there was an optional tour of laboratory and field plot tracer experiments being carried out by the Centre for Research on Environmental Systems, University of Lancaster, led by **Dr Nick Chappell**. In the laboratory a number of large soil cores (one with a small tree growing in it) were being used to study tracer and water flow in the presence of macropores. At the field site (at the University's Hazelrigg Field Station) an impressive facility has been installed to provide data for testing contaminant transport models and parameterisation methods.

In the first instance it is being used to validate the SHETRAN-UK contaminant migration modelling system of the Water Resource Systems Research Unit, University of Newcastle upon Tyne. Across the 30-m x 30-m plot, a three-dimensional network of instrumentation and samplers is measuring relevant soil moisture

conditions and tracer concentration, while regulated inputs of artificial rainfall from sprinklers constrain the uncertainty in the parameter identification procedures. Tracer tests, initially using sodium chloride, are providing data on subsurface contaminant migration. Symposium participants had to exhibit a smart piece of migration themselves as the sprinkler system came on automatically during the tour of the plot.

Conclusions

As in previous years, the enthusiastic and lively atmosphere of the symposium suggested that its professional aims had been achieved. The campus location and informal setting of the Senior Common Room lounge used for the presentations also contributed to an enjoyable social occasion. Overall the symposium indicated UK hydrological research to be wide ranging and in an impressively healthy state.

Finally many thanks to Professor Keith Beven and his team and to the University of Lancaster for hosting the meeting and for the local organisation of accommodation, meeting room and eating arrangements.

James C Bathurst
Department of Civil Engineering
University of Newcastle upon Tyne

Postgraduate Comment

The following participants kindly reported their views on the symposium:

Barney Austin (Department of Civil Engineering, University of Salford):

A good test of the success of a symposium is the ability of participants to stay awake in the very comfortable chairs provided (especially after a long previous night in the bar). Engineers at least are notorious for their short span of attention but, despite this, there was not a moment of inattentiveness for the whole two days.

The quality of the papers presented was outstanding and the discussions after each talk thought-provoking and enlightening. I sincerely hope that there will be similar symposium next year and encourage everyone to attend.

Pippa Chapman (Department of Civil Engineering, Imperial College):

As the field of hydrology is dispersed around a number of different University departments throughout Britain, students can often feel isolated in their work. This symposium gave an opportunity for people to meet and discuss their research, life as a postgraduate and generally socialise with others working in the field of hydrology. It was also an ideal opportunity to practise presenting a short talk to a group of people, given the informal atmosphere of the meeting. After the presentations a lively discussion ensued on the issue of how accurately hydrological models can represent physical, chemical and biological processes occurring in the field!

Sarah Douglas ((NRA, Southern Region):

Both myself and my colleague **Joseph Pearce** were impressed by the range of topics currently being investigated by postgraduate researchers in Britain. With studies ranging from the use of radar to predict maximum floods to the stochastic modelling of groundwater piezometric head variation, the enthusiasm and depth of knowledge of each of the speakers was striking.

The predominance of modelling in the studies presented was most noticeable and perhaps indicative of the continued expansion of computer models within hydrology. The development and application of models to aid the understanding of climatological and geochemical processes was of particular interest. The aptitude for modelling shown by the majority of the participants indicates there is considerable talent in this field within academic circles.

Overall the symposium incorporated a wide range of study areas with a diversity of approaches, all of which may help further our understanding of hydrological processes, most especially that of a small upland catchment in Wales that shall remain nameless!

Max Wheeler (Department of Engineering, University of Aberdeen):

'Well-presented topical papers, charged discussion and pubs' best sums up BHS's third highly-successful postgraduate symposium. Personally I learnt about time-keeping when giving my first presentation, but, more importantly, I was reassured to find many experiencing the same problems.

Hydrometry practitioners' workshop

Telford
14 & 15 April 1993

The "Hydrometry Practitioners' Workshop" was organised by Rod Hawnt and attended by over 100 delegates over the two days. The same programme was repeated on the second day, so that as many delegates as possible could attend. The programme of events was circulated in advance: it promised an interesting mixture of traditional and "state-of-the-art" hydrometry, combined with field visits to observe the practical application of both. This review is based on experiences of the first day of the workshop.

The day started at 0900 hours with a computer workshop session giving delegates the opportunity to get some "hands on" experience — for those who were brave enough at such an early hour! These sessions continued intermittently during breaks throughout the day, with practical exercises being provided on the GAUGEMAN current-meter gauging database and stage-discharge rating development package by Hydro-Logic Ltd, and two packages produced by Institute of Hydrology, the HYDATA hydrometric data processing system and SWIPS, a soil water information processing system.

Geoff Burrow of NRA Southern Region gave the first presentation entitled "A review of the NRA's future requirements for hydrometry". Geoff started by stressing the importance of hydrometric data to all core functions of the NRA and how attention was being focused on the need for standards, particularly as the environmental 'policing' role of the Authority was becoming more important.

Geoff then briefed the meeting on the current Water Resource R&D programme, with particular emphasis on topic B1 (Hydrometric Data) for which Geoff is project leader. Work completed, or substantially complete, at the time of the meeting included: Remote sensing of snow by satellite; A review of Hydrometric Data Processing Systems; A review of Hydrometric Field Techniques; Practical guidelines for choosing methods of abstraction measurement, and A review of low

velocity measurement techniques. It is not practical to summarise the findings of all these projects in *Circulation*, but if anyone has a particular area of interest they should first contact Geoff.

The two topics most closely related to the day's agenda were the "Practical guidelines for choosing methods of abstraction measurement of surface and groundwater flow" and the "Review of Hydrometric Field Techniques".

In 1992 the NRA undertook a benchmark review of hydrometry, carried out under contract by Hydro-Logic Ltd. It was the most comprehensive survey of hydrometry carried out in recent years. It identified a number of areas requiring attention, which were further endorsed by NRA staff attending a hydrometry seminar in October.

They included instrument evaluation procedures, forum for technical information exchange, requirement for standards and procedures throughout hydrometry, and specifications for instrument procurement.

As a result of these findings, the Water Resources Managers had recently approved the setting up of a National Hydrometric Group with representatives from each NRA Region. This group will act as a focus for hydrometry within the NRA for progress in the areas identified for action. They will also recommend future R&D work in hydrometry.

Geoff then brought the group up to date with current and planned R&D work, a great deal of which was recommended by the reviews carried out during 1992 and by staff attending the October seminar.

Ongoing hydrometric R&D projects and their project leaders are:
Calibration of Portable Electromagnetic current meter at low velocities - John Gill (Thames)
Enhancement of Ultrasonic River Flow Gauge - Simon Taylor (Southern)
Performance Assessment of Ultrasonic and Electromagnetic Gauges at low velocities - Peter Grange (Anglian)

Instrument Development

Geoff stressed the importance of R&D to the work on the ground. R&D needs are likely to become apparent at the operational end and it is essential that deficiencies are highlighted by those responsible for actually collecting and measuring. Field operatives must therefore be given the opportunity to feed this information back, and this workshop and the October seminar certainly provide a useful mechanism for this.

Geoff finished his presentation by whetting our appetites for things to come with the new impetus for hydrometry provided by "Climate Change". If the temperature rise predicted of up to 2 degrees Celsius over the next 40-50 years occurs, then this brings with it the possibility of long-term trend changes in rainfall, flow and groundwater levels.

This new priority must be added to the continuing requirement for accurate real-time hydrometric data on which to base operational decisions, for flood relief and warning schemes and for water transfer schemes.

During the discussion, **Terry Marsh** highlighted the issue that causes a major hydrometric problem in this country: three quarters of streams have Q95s less than 1 cumec, with corresponding shallow depths (20–30 mm) and/or low velocities. He added that the setting up of the national group should enable sensible bids to be made for R&D budget and ensure that the most important work is tackled first. Terry also confirmed the need for feedback from ground level to senior management and coordination with the requirements of the water resources engineer.

The second paper of the day was by **Tom Poodle** (Clyde River Purification Board), who is chairman of the British Standards working group on Hydrometric Instrumentation and Equipment.

Tom's presentation expanded on the area of standards, identified for action in Geoff Burrow's paper. With increasing importance placed on the 'policing' role of the NRA, the potential for challenges to the accuracy of flow measurement is increasing. It is therefore crucial that, wherever practical, flow measurement is carried out to recognised, defensible standards.

He went on to describe the British Standards Institution and its prime objective as an independent commercial enterprise: it must sell standards to survive. Tom then gave an insight into the production of "A Standard" pointing out that ultimately the committee producing the standard should be made up of people with experience in the relevant field. These people may be experienced individuals nominated by an appropriate institution, specialists on specific topics, or technical experts nominated by manufacturers' associations. BSI provides the secretariat.

In hydrometry the parent committee responsible for promoting standardisation is technical committee PCL 3 - "Flow Measurement of Surface and Groundwaters". This parent committee is served by six sub-committees created to ensure production of standards in the following fields:
PCL/3/1 - Methods of Measurement
PCL/3/2 - Weirs, Flumes and Structures
PCL/3/3 - Vocabulary and Symbols
PCL/3/4 - Dilution Methods
PCL/3/5 - Instrumentation and Equipment
PCL/3/6 - Sediment Transport

The principal British Standard for use in Hydrometry, BS 3680, has many constituent parts. The standards provide a definition of the essential vocabulary, specifications for recognised methods to produce optimum results, specifications for standard pre-calibrated structures and guidance to ensure that they are sensibly used, specification and guidance to ensure that equipment is appropriate to the expectation of the user.

Tom also detailed the relationship between British Standards and International Standards: many of them are identical in content, which reflects the UK's active role in developing International Standards. European Standards will come into force over the next two years, but present there are no European Standards for Hydrometry and so International Standards will be adopted. It is particularly important to iron out any differences between British Standards and International Standards, where they exist, because the new European Standards will take precedence over British Standards.

Tom then took us on a guided tour of BS 3680, highlighting specific problems that require attention. He finished with part 3Q: Safe Practice in Stream Gauging, a fitting place to emphasize what has become increasingly important over the last ten years: the health and safety implications of hydrometric installations and practice.

The final paper of the morning session was presented by **Richard Jones** (Warren Jones Engineering Ltd) on "Flow Gauging techniques for wastewater management". Richard introduced his company as specialists in critical flume design and the measurement of upstream head by "through-air" ultrasonics.

Richard started his presentation by giving us his two golden rules for dealing with "dirty" water:
1. Keep it moving!
2. Don't touch it!

The traditional approach to flow measurement using critical flumes (BS 3680 part 4C) and measurement of upstream head to calculate discharge is widely applied in the "dirty" water business. The latest R&D work at Warren Jones includes development of a "platform weir" and associated Ultrasonic depth measuring technology for this type of low head-loss device.

The main problem of using a single point measurement to determine the average velocity at a section is that it requires a detailed knowledge of the velocity distribution profile at that point/section. It is therefore important to control the velocity profile and with non-critical flow acceleration through a contraction reduce variations in the profile to a situation where a single point measurement may suffice.

The latest development in this area is the platform weir which has the appearance of one side of a rectangular flume lying on the bed of the channel. Hydraulics Research have tested such a device and identified a short section of the level platform over which a uniform velocity profile is generated. In

hydrostatic conditions the velocity can be calculated from a measurement of the head. Because the platform weir is a low head-loss device, it requires a high precision depth measurement system to achieve the required accuracy.

This precise depth measurement is achievable with through-air ultrasonics. Richard described the various problems associated with the use of ultrasonic transducers. Transmitters for measurement of small ranges <2 m have been developed using "single-hit" transmission mechanics. This produces 'neater' wave packets and reduces the effect of tail decay when picking up and timing the return echo. This is important as it allows the transducer to be located closed to the water surface which means temperature effects on time of flight are reduced.

Richard advised that resolutions of 0.4 mm through water, and 0.6 mm through air were achievable. The main problem occurs with the measurement of low velocity and low depths as only very small depressions in water surface are generated over the structure. Other design limitations are likely to allow measurement of flows ranging from dry weather flow (DWF) to five times DWF.

At this point delegates were ushered to the nearest exit and onto two mini coaches. Such was the timing of events that packed lunches were handed out for consumption in transit.

Our coach driver must have been related to Nigel Mansell and must have been briefed to make up time: I must confess to having difficulty drinking my can of coke until the bus stopped!

Severn Trent NRA hydrometric staff, ably assisted by **Rick Brassington**, gave guided tours of three sites altogether, providing an introduction to the two presentations that were to follow that afternoon. At Crudgington we were introduced to the problems and practicalities of installing and configuring an electromagnetic flow gauge. At Hodnet we were given details of one of the abstraction boreholes for the Shropshire Groundwater Scheme and shown a variety of hydrogeological sampling equipment. We were also shown the automatic weather monitoring station at the site, which provided essential data for monitoring aquifer recharge. Understanding of recharge was also enhanced by the ability to measure soil moisture by Neutron Probe (see Figure), which was demonstrated to us at a nearby site by **Roger Dutton** (Severn Trent NRA).

Returning to Meeting Point House for the afternoon session we were now behind schedule. The first presentation was by Rick Brassington (Southern Science Ltd) on "Some aspects of field hydrogeology".

Starting with groundwater hydrometry, Rick identified the predominant reasons for taking measurements: groundwater resource investigation, groundwater quality investigation, pollution problems (e.g. landfills) and groundwater control (e.g. new construction works).

Having identified *why* we measure, he continued by describing *what* we measure and *how*. He stressed that the most important piece of equipment was *THE BOREHOLE*.

Rick stressed the importance of long-term data for showing trends in groundwater work and highlighted the dangers of drawing straight lines between a limited number of data points. He also covered the variation of level and quality parameters within a borehole. It was pointed out that the rest water level in a borehole can change considerably as its depth is increased. This was illustrated with an example from Halewood on Merseyside where the level varied from -0.4 m to +0.5 m around the mean. The same is true of quality parameters and Rick detailed the use of packer tests to determine the variation of key parameters with depth.

Having detailed a typical production borehole (as found in BS 6316) we were then given an insight into the use of step tests and other longer-term tests for the determination of borehole and aquifer characteristics. It is important to obtain accurate measurement of discharge from the borehole: weir tanks are commonly used to achieve this. It may also be a requirement to determine the effect, if any, on surface water courses: to this end it is necessary to accurately measure stream flows. This is often best achieved by damming the watercourse and using a piped outflow to facilitate volumetric measurement (check with the NRA first!), particularly where the recurring problem of shallow depths and low velocities rules out current meter gauging. Quality samples can also help to determine where the water in a pumped borehole is being drawn from.

A question was raised at the end of Rick's presentation on the suitability of meters for the measurement of pump test discharges. It was considered that if meters were correctly installed according to the manufacturer's recommendations, and recently calibrated, then they were a reasonable compromise if a weir tank could not be used. A problem may arise where the discharge contains a high sediment load. This is often the case in sandstone and it may well be necessary to clean out the borehole before installing the meter.



The mysteries of soil moisture measurement being explained during a field session

The final paper of the day was a joint presentation by **Richard Iredale** and **Mick Jackson** of Severn Trent NRA. Richard began with the performance of ultrasonic flow gauges. Severn Trent region of the NRA installed their first ultrasonic gauge in 1982 at Bewdley on the River Severn. They now operate a total of 14 sites and have collected 78 station-years of flow data. The performance of ten of the ultrasonic gauges has been assessed against two criteria:

a) The quality of the data, i.e. the accuracy of the gauge
b) The quantity of the data, i.e. the percentage of time the gauge functions satisfactorily.

The other four stations had only a limited number of check gaugings and it was not considered sensible to undertake any statistical analysis.

As the technology was new it was considered sensible to assess accuracy and performance against known methods and standards. It had been decided that current meter gauging

would be used as the benchmark and since installation of the first gauge there had been a routine programme of current meter check gauging.

The data analysis involved producing a curve (or curves) of best fit based on the formula

$$Q_{us} = B(Q_{cmg} - A)C$$

where A, B and C are constants, Q_{us} = Ultrasonic measured flow and Q_{cmg} = Current-meter gauged flow.

Richard's presentation was based on a full report of the findings of the performance review. The main conclusions drawn were:

1. The accuracy of most sites have proved to be better and more consistent over a long period of record than originally anticipated. So much so that it has not been necessary to reprocess the data archive based on the fact that only a marginal improvement to the database would result.

2. The gauge calibration software does not require amending other than to update the mean bed level as a result of annual bed surveys.

3. Relationships defined by the curves of best fit remained fairly stable.

Richard also pointed out that the length of record associated with these installations was on the whole very good. Nine out the fourteen demonstrated a 100% record, with only two less than 95%.

Michael Jackson (no relation, he assured us!) reviewed the performance and calibration of electromagnetic flow gauges. Severn Trent Region of the NRA currently operate six electromagnetic flow gauges, which were installed in the early 1980s. They were installed in sections where weed growth was a problem and at three of the sites flooding implications ruled out any sort of structure. Details of the performance of the gauges are contained in a separate report. Four of the sites were shown to have greater that 10% error when compared with current meter check calibrations over the periods of record.

Michael then described how it was necessary to calibrate an electromagnetic gauge to ascertain four calibration constants which were then used to calculate flows within the gauge based on a measure of induced voltage.

An attempt was made to re-evaluate these constants to obtain a better correlation between electromagnetic and current meter gauged flows. Although this was achieved, the values obtained were not suitable for use in the existing gauge.

The gauge manufacturer had now proposed a new formula for calibration with five calibration constants: values were derived for these constants using two different methods in order to optimise gauge performance.

The table indicates the comparative improvements achieved with the proposed calibration.

Electro-magnetic Gauge Site	Average % difference between CMG and EM flows	Average % difference with proposed calibration
Blyth	15.8	10.4
Crudgington	11.6	6.7
Littlethrope	14.3	7.7
Mattersey	6.4	5.5
South Wigston	7.3	4.8
Syston	10.6	7.2

The meeting closed with a vote of thanks to all those responsible for an excellent day which was both enjoyable and informative.

Steve Mayall

The President's Piece

Farewell

By bringing forward the date of the AGM from December to coincide — biennially at least — with our National Symposium, my term of office (and that of the Treasurer and two retiring committee members) is truncated to a mere 21 months. If someone runs a hydrological version of Trivial Pursuit at the 21st Anniversary celebrations in 2004, then I at least will know the answer to 'Who served the shortest term of office as President?'. But that is not the only reason why time has flown: I really have enjoyed it.

Let me thank, therefore, all those committee members who have helped things go smoothly, and BHS members generally for being such a friendly and welcoming bunch of people. I would particularly like to acknowledge the contributions of my fellow retiring committee members.

Tony Lewis (Hon Treasurer) battled manfully against the sequence of anomalies and quirks, which inevitably arise from the use of computers, to organise our records of membership and subscriptions. (In fact, Tony is not retiring at all: he is continuing on the committee as the representative of the Pennines Section; he has also offered to help his successor as Treasurer to continue the struggle.)

James Bathurst has been quite outstanding in his contribution to Society affairs — at one stage it seemed as if he was organising all our scientific meetings single-handed! He pioneered the concept of the annual post-graduate symposium and has seen it through its first three years. He has also been a regular and witty contributor to *Circulation*. I am sure he will be back after a well-earned rest.

Ron Manley has ended his spell with a flourish, introducing the concept of a 'Hydrologist's Workbook' (see previous issue). He has promised to continue to steer it forward, despite being now able to spend more time with his family!

Jim Blackie's efforts have not quite finished. He was co-opted onto the committee as the Society's Convenor of the Cardiff symposium. However, I would like to take this opportunity of thanking both him and **Rob Drayton**, the Local Organiser, for all their hard work.

I wish my successor, **Susan Walker**, as much satisfaction and fun as I have had and also an equally cooperative and supportive committee.

Ties

The news you have all been waiting for: the BHS tie will be available at Cardiff! This, our first foray into such things, is a modestly-priced item of subtle distinction. You can have any colour you like as long as it's blue and a vast range of material with particular emphasis on deluxe polyester. If, as expected, it proves an irresistible buy, then we will be able to consider expansion into all manner of other such goodies. **Linda Aucott** has suggested we solve the problem of what to do for lady members (not enough of you to justify a scarf it seems) by opting for a stick pin which has many gender-free applications apart from being a decorative lapel item. Further thoughts to the Editor.

For those not coming to Cardiff, you can make amends by ordering the tie directly from **Louise Picton** at the ICE (address on back page) enclosing a cheque for £6.5,0 payable to the British Hydrological Society.

Ballot forms

You will already have received ballot forms to replace retiring committee members and to vote on changes to the statutes, which are recommended by your committee. May I please urge you all to use your vote. It is excellent for the Society to have four candidates for two vacant places as 'ordinary' committee members. They will be your representatives and deserve your considered vote.

There was not the same rush to be nominated as a candidate for Treasurer. Fortunately there was the necessary, yet sufficient, number of 1 and we can therefore announce that **Rod Hawnt** has been elected unopposed.

Regarding the proposed change to the statutes, we would be grateful for your considered approval of these minor changes. Although minor, they deserve some explanation.

Firstly, the change in the lower age limit for concessionary membership dues. The committee has long recognised the importance of attracting younger members to the Society and we have now accepted, through **Jennifer Taylor's** prompting, that some in the 21-25 age group might be deterred from paying the full rate. If you approve the change then, in future, those under 25 will benefit from the lower (50%) annual subscriptions, and from any other concessions which may be put to the AGM. As somebody said in committee, 25 is a good choice because you can pay the increased subscription out of savings on car insurance!

Secondly, the proposed change to statutes 5.1 and 5.3 (and deletion of 5.6). This is really to consolidate arrangements for the main committee, which have already evolved, and to clarify the statute wording. In particular, there is no longer any point in including reference to the situation during the first few years of the Society's existence.

Finally, the re-wording of Statute 6 is designed to reflect the intention of the changed date of the AGM. It is now possible for the AGM to vote on the proposed subscription rates for the following year, so it is sensible to give the meeting the power and requirement to do so.

Ten years old

I have spent some time going through the files from the time of the formation of the Society to try to decide the day in 1983 on which it was formed. The inaugural meeting was 1st November 1983 but the Society was already in existence (with 276 members having paid the initial £10 subscription by the end of September). To cut a long story short, it seems to me that September 15th at Cardiff is perfectly placed to be the occasion for celebrating our 10th Anniversary and we will treat ourselves to a reception before the Symposium Dinner on that Wednesday evening.

Value for money

Yes indeed, our initial subscription was £10. Now it is £19 (+90%, broadly in line with inflation). In the same ten years the ICE membership subscription has risen by 150% and the average salary for graduates joining the Water Industry by 97%. Of course it is true that there are now more charges for attending meetings, but this usually reflects the direct costs of hiring rooms (which used to be free) and does not illustrate any significant change in Society policy, which is to encourage attendance by keeping the cost as low as possible.

All in all, I submit, the Society provides very good value and, with satisfactory reserves and a developing programme of awards, promises to do even better in future. None of this would be possible without the continued support of the Institution of Civil Engineers (we pay for services but below the 'market' rate) and the Institute of Hydrology who provide generous amounts of staff time. Nor should we forget the efforts put in by many individuals either in their own time or by agreement with generous employers.

This rosy outlook must be counterbalanced with some words of caution. It is becoming increasingly difficult to keep a professional Society afloat in these days of close scrutiny by market-oriented bosses. Travel is restricted in all sectors and time spent attending meetings or otherwise supporting the Society often has to be 'stolen' from perhaps only feebly-related budgetary headings. At present, there are enough dedicated people around to make it all happen, but the warning signs are plain to see. If the trend towards internal markets continues we may be forced to pay commercial rates for services provided.

Despite these worries, if you were to ask me to guess the membership numbers in another 10 years I would say around 800. I think we have almost reached the natural level, but there is still scope for modest expansion in certain sectors. The challenge now is to retain existing members whilst achieving it. To do so, the Society has to remain in touch with its members and press forward with new initiatives to meet changing requirements, rather than slip into a complacent rut. I am confident that the BHS is so structured as to make the latter almost inconceivable: if any member thinks otherwise, then you know exactly what you must do about it!

Mike Lowing

Hydrology and Sustainable Development

BHS Southern Section / RGS
Royal Geographical Society, London
12 May 1993

About 80 delegates attended the meeting, which focussed on the hydrological aspects of Agenda 21, the agenda for action on environmental matters which arose from the United Nations Conference on Environment and Development (UNCED) at Rio de Janeiro.

In his opening remarks as Chairperson, **Dr Howard Wheater** (Imperial College), reminded the audience that a year had passed since the Rio Earth Summit. The preparatory work for UNCED had involved discussion between governments, non-governmental organisations (NGOs) and aid agencies. The International Conference on Water and the Environment, held in Dublin in January 1992, had produced the major input on freshwater problems to the Rio summit.

The UK's commitment to Agenda 21 required the preparation of a national plan for 'sustainable development'. Although this term might be generally well understood, it is sometimes difficult to define precisely. Today's meeting provided the opportunity for the several speakers to put their case on matters related to hydrology in the context of what they understood by

'sustainable development'. A Panel Discussion at the end of the day would enable members of the audience to raise issues with, and put questions to, the main speakers.

In his pre-meeting notes, the first speaker, **Professor Malcolm Newson** (Newcastle University) had drawn attention to the point that, while Agenda 21 makes no explicit calls upon the scientific basis of hydrology, it does nevertheless make heavy demands on applications of hydrological science in a working environment characterised by "data shortages and decision-support dilemmas" – a situation with which many of us in the hydrological community are familiar.

The seven programme areas of Chapter 18 of Agenda 21 are

- Integrated water resources development and management
- Water resources assessment
- Protection of water resources, water quality and aquatic ecosystems
- Drinking water supply and sanitation
- Water and sustainable urban development
- Water for sustainable food production and rural development
- Impacts of climate change on water resources

In addressing these, the most significant contribution the hydrologist might make, answering the call to apply integrated or holistic approaches, is to stress the importance of aspiring to attain human and natural resource balances within river or groundwater basin units.

In his address, Prof. Newson referred to the need to expand hydrology into areas of social responsibility such that the 'carrying capacity' of environmental systems (especially groundwater systems) were not exceeded.

Unfortunately the impact of changing land-use on some groundwaters, though covered in pre-Rio discussions, was not featured in Agenda 21. We were reminded also of the possibility of 'water wars' in some regions and the need for better international agreements than the Helsinki rules for management of international rivers. Five priority topics were proposed:

- hydrological carrying capacities
- transferability of results from small to larger scales
- incorporating research results into decision making
- technical support for innovative low energy or enhanced traditional structures
- land-ocean-atmosphere interactions, with a focus on climate change

The next speaker, **Mr Alan Simcock** (Water Resources and Marine Division, Department of the Environment) has responsibilties for the UK Sustainable Development Plan, and for the Government Report to be completed in 1993 (a commitment entered into by all the 'Group of 7' developed countries). He presented the meeting with essential background, insights and points of administrative interest concerning the Report. Agenda 21 presents more of a menu for choice rather than a set of firm commitments, he said.

Today's meeting was an interface between hydrology, other sciences and policy/legislation, but it was important to realise that Agenda 21 was negotiated simultaneously with other important 'Rio matters', such as transfer of resources and technology, and biodiversity. In some respects Agenda 21 may, therefore, appear to be rather provisional and a little "weasely". Mr Simcock reminded the meeting that while the UK enjoys a good integrated government, other administrations are more like fiefdoms, which sometimes precludes good relationships between Ministries (poorer still, probably, between central and regional offices).

'Water wars', triggered by difficulties in managing international water resources, may be a real concern in some regions of the world but not in the UK. We have no international rivers and are in a strong administrative position to resolve any minor internal political arguments over water resources. A conference had been held recently at Green College, Oxford to address questions such as "What does sustainable development mean in the UK?" and "What bearing does it /will it have on other countries?". There will be a Consultation Paper before final production of the UK Plan. Clearly, Mr Simcock said, activities such as agriculture, industry, energy, transport, land-use and overseas trade are all very important aspects of sustainable development in the UK. We have to manage our 'ecological footprint', i.e. our influence on the physical environment beyond our administrative boundaries.

In terms of our maritime 'footprint' there have already been reductions in lead and cadmium. We have some local problems with unsustainable relics from the past, such as lead in drainage water from Roman mines worked around 200 AD still reaching and polluting Welsh coastal waters, and the effluent from Cornish tin mines too. A contemporary problem is pollution of natural freshwaters from diffuse sources of pesticides and fertilisers. It was suggested that water resource development in the UK to 2121 (the current target date) is complicated by regional inconsistencies in estimates of growth and water demand (nowcast and forecast). In this context, domestic water supply metering is likely to be important for moving towards sustainable development in the UK.

Mr Koy Thompson (International Institute for Environment and Development) described the Rio Earth Summit as the opening of a political window of opportunity for NGOs in planning their future work. Post-Rio, he suggested, the Government had adopted the language of sustainable development, and there seemed to be a mood in which less confrontational debate could take place. There also seemed to be greater willingness to include science in the political debate.

Ecological footprints acknowledged that we import carrying capacity from outside our land-mass boundary. "How would it all turn out?" In his pre-meeting notes, Mr Thompson wondered whether it was "a real change, a passing fashion, or an apology to the status quo". We were advised that Agenda 21 is a good read — and that it is not legally binding or prescriptive. Indeed, NGOs will need to take the initiative, acting in the spirit of Agenda 21. In thought-provoking mode throughout, Mr Thompson spoke of the possible emergence of an international civil society to meet the challenges of global sustainable development, involving a (re)definition of environmental economics. Although the UK Plan will be finalised after a consultative phase, he wondered whether the business and banking sectors might dominate this process. Agenda 21 highlights the need to attract people from all sectors to the debate: he remarked that there were relatively few people representing non-technical interests at today's meeting.

After coffee, **Dr Ian Calder** (Institute of Hydrology) focussed more on the nuts and bolts, showing how a detailed hydrological field investigation could clarify some of the problems of ensuring that development is sustainable. He described work in southern India on the effects of tree plantations (Eucalyptus) on water resources and soil erosion, with a view towards improving water-use efficiency, for example by species selection. The results presented showed that water-use by Eucalyptus is about the same as that for indigenous tree species (e.g. teak), but about twice that of local agricultural crops. Although for a deep soil site (>0.8m) there was some evidence that transpiration exceeded rainfall, leading to 'mining' of soil water, there was no evidence to support an original concern: that direct effects might lead to lower groundwater levels regionally. Species selection could influence both water-use efficiency and soil erosion. Contrary to indications from previous work, drop size, and therefore impact erosion, was shown to be different beneath the canopies of different species of Eucalyptus. Suggestions for applying the results to improve the sustainability of plantation management practice included rotation of Eucalyptus with the local agricultural crop. The deeper-rooted trees would replenish the upper soil with nutrients drawn from lower levels. Depletion of soil water by trees could be made-up during periods of agricultural crop growth. A patchwork distribution, already used by many farmers in the region, reduces the risk of adversely affecting the soil water budget, and

irrigation could enable the same quantity of timber to be produced as if the whole area was afforested.

Professor Ian Douglas (University of Manchester) rounded off the morning with an overview of the consequences of logging and large-scale deforestation on streamflow and sediment yield, with particular reference to the humid tropics. Both activities reduce the amount of rainfall intercepted by the vegetation canopy and lead, therefore, to increases in streamflow. In small-stream catchments, changes in the routes taken by water as a consequence of removal of trees can lead to changes in runoff characteristics.

The magnitude of peak flows for small and medium-sized rainfall events can increase, and their timing after the start of rain can decrease. However, for high-rainfall events, which occur (on average) once every 25 years or more in the humid tropics, the presence or absence of trees is not such an important factor. During such storms, most or all of the catchment acts as a stormflow contributing area (we are talking *serious* rain here: e.g. 461mm in 3 days in the Babinda catchments, Queensland), so the runoff characteristics during the event are little affected by the type of vegetation. Changes in erosion related to logging/deforestation are far greater than changes in runoff. Much of the increased stream sediment load comes from a few restricted areas, particularly unsealed roads, roadside gullies and tracks along which tractors pull the logs to loading points. Downstream deposition of the increased sediment load can reduce the flood-carrying capacity of channels, with serious consequences. A low-cost method of reducing soil erosion, applied by the local community in Borneo, is to create earth banks across the logging tracks. On the question of whether deforestation can affect rainfall, Prof. Douglas distinguished between different geographical situations. In the Amazon basin, remote from open water sources of evaporation, it has been estimated that about half of the rainfall is water evaporated from the forest. Large-scale deforestation there would, therefore, be likely to cause a reduction in rainfall over the forest, and even changes in the global hydrological cycle and climate. On islands and peninsulas, where the coastline is never too distant, the rainfall is likely to be mostly water evaporated from the oceans, so even widespread deforestation would not greatly affect rainfall.

In the first afternoon session, **Dr Mike Hulme** (University of East Anglia) spoke about the resource implications of rainfall trends in Africa. The rainfall regimes of the continent are highly variable, both in time and space. Being strongly seasonal, they differ markedly from those of higher latitudes. Attention was focussed on the Sahel region of northern Africa, where unparalleled changes in mean seasonal rainfalls have occurred in recent decades. For example, the Sahel 1961-1990 average June to August rainfall is 20-40% less than the corresponding 1931-1960 average, while further south similar statistics indicate greater, rather than less, rainfall for the most recent 30-year 'standard period'. Autocorrelation plots for Sahel rainfall exhibit a degree of persistence not observed for other regions. While all of Africa is subject to droughts of varying lengths and intensities, it is only the Sahel region which has witnessed sustained rainfall depletion in recent decades. The surface area of Lake Chad has decreased notably over the past 20 years. Dr Hulme used excellent visual aids to convey the significance of contemporaneous changes in rainfall and socio-economic factors in Africa. A map illustrating how the Sudan 400 mm isohyet had shifted over the past 17,000 years was shown. Recent decades have seen many African countries becoming independent, and the population of Africa has doubled since 1960 (to 700 million). Regional stresses on agriculture, dryland degradation and water resources in times of rainfall deficiency -- and the repercussions of all of these factors on sustainable development -- are indeed matters of great concern. In the Sahel there has been an increase in the frequency of breaks in the traditional wet-season rainfall, impacting on agriculture. Increases in airborne dust related to dryland degradation have been noted. What are the forcing functions of such serious changes in rainfall regimes? Land-use change has been proposed, but Dr Hulme thought that this probably had only a minor impact on average rainfall. Shifts in global atmospheric circulation patterns are the most likely cause, brought about by natural variations in ocean circulation patterns and possibly by global warming resulting from increased atmospheric levels of 'greenhouse gases'. Global Circulation Models (GCMs) tend to suggest an increase in precipitation over equatorial Africa and decreases further south, but these projections are uncertain. Dr Hulme's presentation made it very clear that sustainable development in many regions of the African continent was severely constrained by the vagaries of the basic commodity, rainfall, exacerbated by the uncertainties which surround predictions of global and regional climate change.

The next speaker, **Dr Robin Herbert** (British Geological Survey), described a programme of work funded by the Overseas Development Administration (ODA). For many arid and semi-arid regions it may never be economically viable to provide piped water supplies to dispersed village communities, but more efficient abstraction of any groundwater which is available locally can assist greatly in developing sustainable systems. Most of the available water in such regions is in the weathered layer above the crystalline basement rocks, and it moves from topographic highs to lows. Slim, deep boreholes can be sunk, in the hope that they will hit fissures in the bedrock. The sustainable yield from successful boreholes is typically 0.1 to 0.3 ls^{-1}, while dug wells in the weathered zone (about 2 m in diameter) typically have yields about three times as great. Work in Zimbabwe, Sri Lanka, Malaysia, Botswana and Malawi has demonstrated that a dug well can be extended to become a collector well by drilling 30 m adits horizontally from its base, giving yields about 10 times as great as from slim boreholes.

Clearly, the siting of dug/collector wells is very important. Simple, automated equipment for shallow seismic surveying is available for identifying sites where the thickness of the weathered zone is greatest, or where fissures are water-filled. About one third of the thousands of slim boreholes being drilled by UNICEF are dry or have very low yield. Hydraulic fracturing of such boreholes, by forcing water down the borehole under high pressure, can open up fissures and increase the sustainable yield. Of 12 in Zimbabwe where this technique was applied, the average improvement in yield was 80% (in the range 10% to 240%).

Dr Herbert stressed the need for such technical improvements to be coordinated with other prerequisites for sustainable development: e.g. the impact of better water supplies can be negated if sanitary facilities are inadequate. Clearly, the way in which the water is used is also important for sustainable development. ODA-funded trials are underway in Zimbabwe by a BGS/IH group to assess and demonstrate the potential for supporting micro-irrigation using water from collector wells.

The final scheduled presentation of the day, by **Dr Alan Jenkins** (Institute of Hydrology), dealt mainly with surface water quality issues in the Middle Hills of Nepal, one of the world's poorest countries. In this region there is a pressing need to increase food production to support the rapidly growing population (mainly in Kathmandu). Rice, the staple in Nepal, has already replaced significant areas of hardwood forest. It is cultivated in terraces and sown twice a year (April and July/August). Heavy dressings of mineral and organic fertiliser ensure rapid crop growth, but can lead to blooms of filamentous green algae downstream. Soil erosion from the rice terraces is evident. The terraces are flooded (rice uses the reduced form of nitrogen as a nutrient) for 10-14 weeks, with flowing water to control temperature. There is a local view that abstractions for terrace irrigation are causing a decrease in the flow of the Vishnumati

(a tributary of the Bagmati) through Kathmandu. The ODA is funding a multi-catchment study in an area of the Middle Hills some 4 or 5 hours walk from the nearest road. Streamflow is measured by dilution gauging techniques. Local scientists run solid-state recording devices for stream pH, dissolved oxygen, turbidity and hydrometeorological variables. Grab samples of stream, soil and rain water are taken regularly for analysis. Initial results show that streamwater sulphate concentrations are high in intensively cultivated catchments (all 40 farmers surveyed were using high-sulphate fertiliser, but the official view on this point was somewhat different). A component of the streamwater sulphate will be from atmospheric deposition and from oxidation of sulphur compounds in the soil and rock, but it seems clear that the main source is the fertiliser. Chloride, a 'conservative' constituent (i.e. essentially unreactive either chemically or biologically within the catchment) is also present in relatively high concentrations in intensively cultivated catchments. This results from the relatively high rates of evaporation and transpiration losses from open water and rice vegetation surfaces. Nitrate and phosphate streamwater concentrations also tend to be relatively high in the cultivated areas but decrease downstream because of nutrient uptake by algae.

There is some concern that the biology of the streams and riparian areas is changing. Although there is a much higher fish biomass in the cultivated areas, the diversity of species there is lower. The project only began in 1991 but has already gathered useful data from the instrumented catchments and from a regional stream chemistry and biology survey involving some 300 sites. Ultimately, it is intended that catchment-scale mathematical models will be developed to assist with setting policy for future land-use management in the region, and perhaps in other regions with similar topography, hydrology and agriculture.

Mr Alan Reed (Oxfam) remarked during a mini-presentation that technical assessment of water resources in many rural areas of the world was often hindered by lack of data. On their departure, colonialists had often taken with them valuable records which subsequently became dispersed and difficult to track down. He suggested that just as there is the *RedR* network of engineers there should be a similar source of hydrologists who have knowledge of where we might look for these missing records. **Mr Frank Law** (Institute of Hydrology), opened the Panel Discussion "Meeting the needs of the NGO sector". In response to Mr Reed's point, he said that there was, for example, a Somalian hydrometric database at IH.

A very wide-ranging, fairly free-format but skillfully steered, discussion of several issues took place. Amongst the very many important points raised in this session, two quite different ones stuck in the mind of your rapporteurs.

Dr Ted Hollis (University College, London) related the tale of how some hydrometric charts had been used for packing peanuts (some of us may know of similar deeds nearer to home).

Sir Charles Pereira reminded us of the likely grave consequences of uncontrolled human population growth, particularly in some tropical countries. Without some modification, nothing we can do will meet the needs of some regions within a sustainable framework. All references to birth control in drafts of Agenda 21, he said, had been excised at the behest of influential groups who hold unwavering convictions on this sensitive issue.

Dr Mike Lowing (President, BHS) wound up the meeting, giving a clear, personalised summary of the main speakers' contributions and thanking them all for a truly absorbing day. Thanks were also expressed to Frank Law for chairing the Panel Discussion, to Howard Wheater for acting as Chairperson and to the Royal Geographical Society for providing the venue. It was, indeed, a most interesting day.

Ian Littlewood
Natasha Fellowes

Pennines Hydrological Group

Annual General Meeting and presentation of papers on Leakage Control 19 May 1993

The AGM ratified the decision of the extraordinary AGM in October for the Pennines Hydrological Group to become a Regional Section of BHS. The revised constitution, which had the support of the PHG caretaker committee, the Local Associations of ICE and the IWEM Branches, was unanimously agreed. Sue Walker, as BHS President-elect, then formally welcomed the Pennines Group as a BHS Regional Section.

After the AGM, there was a lively technical meeting on leakage control issues. **John Suter** (Haiste Ltd) started the day by giving us an interesting introduction to the implementation of leakage control strategies. The paper gave an instructive first view of the complex field of leakage control to many of us who are new to the subject. Perhaps many in the audience had not realised how difficult leakage control is — the needle in the haystack is extremely small! John showed us how the major advances made in the last few years in network modelling have obvious benefits to the water companies in assessing different leakage control strategies. It was interesting to hear that the newer members of the EC will soon overtake the UK in the leakage control field! The paper provoked a wide ranging and stimulating discussion, something the newly re-invigorated PHG is keen to encourage.

Allan Lambert's paper was entitled "BABE - Accounting for Losses". Allan gave us a thoroughly entertaining and thought provoking paper, adding quantitative information to a lot of the concepts introduced by John Suter this morning. He very clearly brought out the multi-causal nature of leakage problems and the need for a conceptual model to bring together previous studies and analysis of the problem. BABE provides a methodology to aid practitioners in the identification of areas where there may be undetected leakage. It provides the opportunity to develop *economic* leakage control policies and demand management strategies. This approach should provide interesting food for thought for OFWAT. A lively and interesting discussion followed which continued well into the tea break!

The day ended with **Gordon Halliday** from Reten Acoustics giving a paper on physical surveys for leakage detection. Gordon's presentation gave us an insight into the practical side of leakage detection and consumption analysis. The presentation illustrated the actual equipment used in leakage detection and network flow monitoring. I didn't realise that listening sticks were still in use!

The state-of-the-art technology now used in leakage detection was

discussed. We heard some interesting case-studies of leak detection for metered clients of water companies, illustrating the large savings that can be made, for both customer and company. Another example showed how high pressure can cause customers problems (as Allan's paper also indicated).

As water costs increase and public institutions become ever more cost conscious, we are likely to see the type of service provided by Reten becoming more widespread. This was another thought-provoking presentation followed by useful and interesting discussion.

We hope that this lively meeting will set the style for an active future for the Pennines Group, newly rejuvenated under the BHS banner.

Katherine Howard
Warrington

Envage update

Newspaper reports in May indicated that the Government plans for the new Environment Agency have been "on hold". The Agency, which is to combine the activities of the NRA, HMIP and Waste Regulation Authorities, was scheduled to be formed on 1 April 1995 (see timetable in *Circulation 36*). Indications are that the legislation will not form part of this Autumn's Queen's Speech, so the formation would be delayed by at least 12 months. There must be questions about the ultimate outcome, since by then the possibility of a General Election will be looming.

Sue Walker

Information transfer using HOMS

The Hydrological Operational Multi-purpose Subprogramme (HOMS) of the WMO is an international network for transferring packages of proven hydrological know-how. It is particularly aimed at helping developing countries. Components include instruments and equipment, computer software and technical and general guidance manuals.

A free booklet describing the HOMS scheme and listing the available components and the national centres is available from Dr Howard Oliver at the Institute of Hydrology, Wallingford, OX10 8BB (Tel. 0491 838800, Fax 0491 832256).

New Members

We welcome the following members to the Society. The membership stands at 637.

Butcher, D.P. ..... Dept of Geography, University of Huddersfield
Channon, J.M. ..... Twickenham, Middx
Chappell, S.A. ..... Solihull, West Midlands
Charlton, R.A. ..... Dept of Geography, University of Bristol
Craxford, S.J. ..... Panteg, Gwent
Howard, K. ..... Brighton, East Sussex
Hyndman, M. ..... Belhaven Press, London
Jepps, J.E. ..... NRA, Thames Region, Reading
Jose, P. ..... Royal Society for the Protection of Birds, Sandy, Beds
Lindfield, D. ..... Sutton, Surrey
Loh, R. ..... Dynamco Ltd, Haywards Heath, West Sussex
Midgley, I.D. ..... Mott Macdonald Group, Cambridge
Mosley, P. ..... Wellington, New Zealand
Murrell, K.N. ..... WRc, Swindon, Wiltshire
Nott, M.R. ..... Brighton, East Sussex
Perryman, M. ..... Wells-next-the-Sea, Norfolk
Scott, M.G. ..... Thelwall, Cheshire
Steinitz, A.R. ..... Ladbroke Grove, London
Tindall, C.I. ..... Institute of Hydrology, Wallingford
Younger, P.L. ..... Dept of Civil Engineering, University of Newcastle upon Tyne

Land-use change impacts

BHS National Meeting
University of Sheffield
14 December 1992

Seventy-three people came to Sheffield for a touch of northern exposure and heard seven papers reviewing the impacts of land use change on river basin hydrology, water quality and soil erosion. Experiences in UK and other climatic environments were contrasted, modelling techniques were examined and means of minimizing unwanted impacts were proposed. The participants were welcomed to the Department of Geography, University of Sheffield, by *Professor Rob Ferguson*, who apologised for not being able to arrange an exciting flood such as that which had marked conditions at the December meeting the previous year!

In the keynote paper **Clem Davies** (NRA, Exeter) considered the impact of land use, especially agriculture, on the aquatic environment. Noting the current UK and EC pollution prevention programmes, Clem summarized several developments which would help their implementation, using the acronymic abstract in Figure 1. A practical manual reviewing up-to-date means of reducing impacts would contribute to a campaign of Publicity, Education and Persuasion (*PEP*) aimed at keeping land owners aware of impact problems and ensuring that they adopt the Best Land Use Practices (*BLUP*). Clear land use *targets* were needed to help planning but would probably have to wait for the formation of the UK Environmental Protection Agency in 1995. Finally the

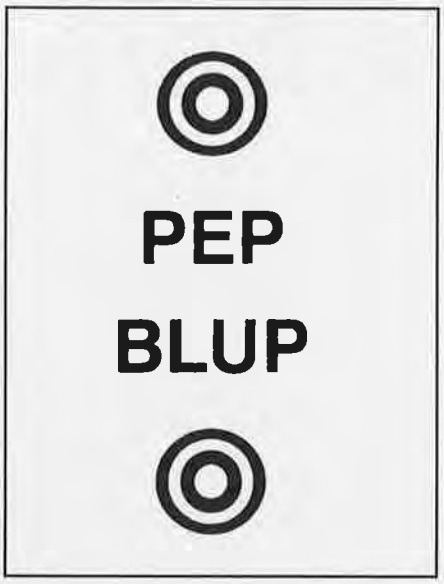


*Figure 1 Summary of means for achieving land use **targets** by encouraging landowners to adopt Best Land Use Practices (BLUP), including a campaign of Publicity, Education and Persuasion (PEP) and **integration** of programmes*

currently uncoordinated UK programmes need to be *integrated*, for example with integrated catchment management. Clem noted with approval New Zealand's forward looking and powerful legislation for dealing with conflict between water and land use issues. In discussion the manual on remedial actions generated considerable interest and suggestions for a joint BHS and NRA production.

Professor Malcolm Newson (University of Newcastle upon Tyne) then examined UK land use change scenarios and river basin management options. He began by warning that, in view of the potential effects of land use policies on farmers' livelihoods and industrial companies' continued existence, we must be sure that our understanding of land-use change impacts is correct before basing laws on it. He noted that the past emphasis on planning towns, rather than countryside, means that data on the hydrological characteristics of different land uses are lacking.

Additional complexity is also being introduced through increasing diversification (including bison and ostrich reserves!), merging of rural and land-use aims (e.g. golf and health clubs) and the impacts of set aside and Common Agricultural Policy reforms. To minimize impacts, Malcolm suggested the introduction of catchment maps indicating high and low risk areas and a greater consideration of within catchment variations. Lime treatment and nitrate controls, for example, could then be limited to relevant parts of a catchment, rather than introduced everywhere.

Warming to the theme of land-use changes in the tropics, **Professor Ian Douglas** (University of Manchester) paid particular attention to conversion of forest lands. Such land-use changes may typically increase runoff by 5-20% whereas sediment supply is increased by several hundreds per cent. Regrowth or plantation after logging subsequently reduces the impact on runoff but the impact on sediment supply continues for much longer, causing siltation of rivers and flooding.

The greatest success in controlling impacts has been achieved with properly managed plantations; the biggest failures are where land abandoned after logging is taken over by settlers. Prediction of land-use change impacts requires information on terrain stability, canopy density, soil characteristics, climatic seasonality and total volume of precipitation.

In discussion Ian commented that erosion and biological recovery proceed faster in the tropics than in temperate lands. He also called for support of the local institutions in tropical countries to improve their confidence in tackling problems.

Professor John Thornes (King's College, London) then spoke on desertification and land use in a changing climate. He concentrated on Mediterranean Europe, long subject to soil degradation, where there is concern over worsening soil erosion and flooding, and the possible impacts of climate change. Plant cover reacts sensitively to the large interannual variations in rainfall and soil moisture typical of the area, and in turn exercises a powerful influence on hydrological and erosion response. With periods of drought expected to increase, models are required to predict the variation in vegetation gradients in response to climate change and the impact on hydrology and erosion.

John described the features of a crop yield model which incorporated climate, soil moisture and soil depth dependencies but cautioned that nonlinearities in vegetation response make such modelling very difficult. Asked if increasing carbon dioxide levels could offset the reduction in crop growth caused by increasing drought, he replied that the impact for the Mediterranean area was unknown but likely to be significant.

The modelling theme was further pursued by **Professor Jim O'Callaghan** (University of Newcastle upon Tyne) in his talk on the NERC/ESRC Land Use Programme at the University of Newcastle upon Tyne, which is developing a decision support system for addressing "what-if" questions concerning the impacts of proposed land use changes at the basin scale. The system combines an economics model (accounting for land productivity, economic constraints and policy), an ecology model (accounting for species composition as a function of land use) and a hydrological/water quality model (SHETRAN-UK, a development of the Système Hydrologique Européen, with a nitrogen transport component).

Spatially distributed land-use data are drawn from a range of sources and organized for model use by an information system (Figure 3). Jim illustrated the use of the system in predicting the effect of deintensification of agriculture

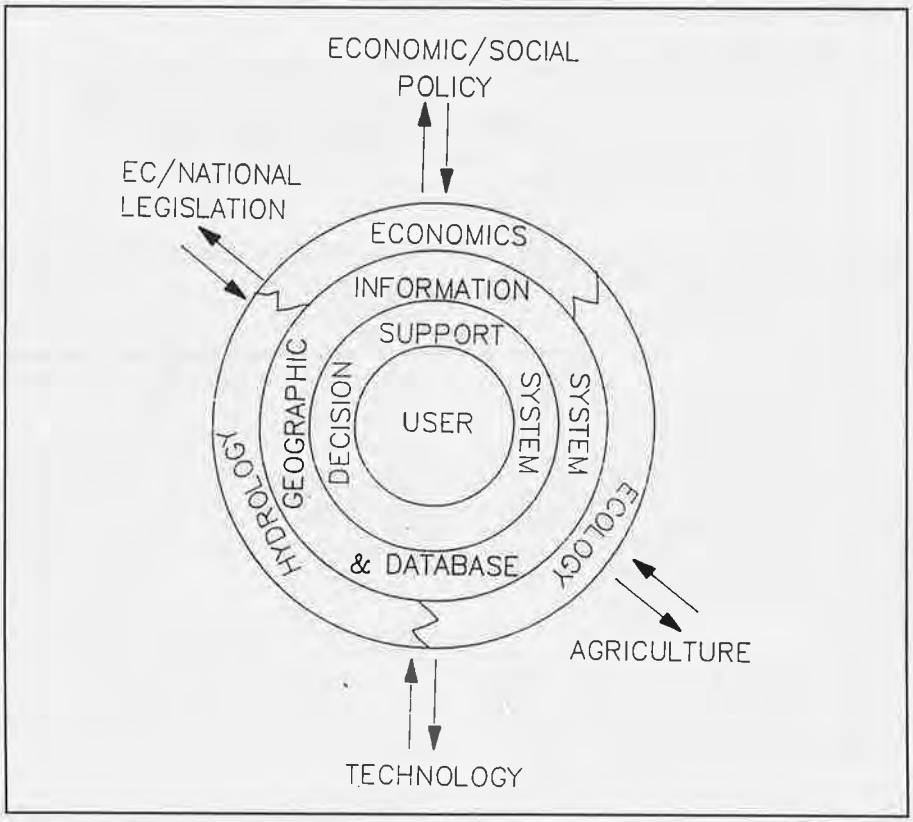


Figure 3 The NERC/ESRC Land Use Programme information environment

in the Tyne basin on the probable distribution of a particular bird, the Gooseander. In discussion he emphasised the considerable advance which the system represented in bringing together available data and understanding.

A joint paper by **Dr Steve Trudgill** and **Dr Louise Heathwaite** (University of Sheffield) on agricultural pollution and rural land use change impact was presented by Steve. He described an export coefficient model for predicting the nitrate loadings caused by diffuse pollution in agricultural catchments. This incorporates sources for different land uses, deliveries and transformation of nitrate loadings, to produce an overall nitrate budget.

Steve illustrated its use in connection with studies of the deteriorating ecology of Slapton Ley in Devon. He discussed the use of the model for distinguishing the relative importance of hydrological control (transport rate) and dissolution rate (transfer from the semisolid to the liquid phase) for solute losses and thence the introduction of techniques for managing water quality, and showed that hydrological change can have a greater effect than solute transfer. Steve also noted that realistic simulation of basin response requires mixing models which can combine old soil water containing large solute loads with recently arrived or new water containing low solute loads.

In the final paper, **Robert Smission** (Hydro Research and Development Ltd, Clevedon) considered integrated catchment planning and source control in urban areas. Urban development has a significant impact on rates and volumes of stormflow, pollutant levels, aquifer recharge and wetlands preservation. Source control uses principles of infiltration, percolation and attenuation to minimise the impacts and support sustainable development.

Robert described a variety of control methods, illustrated by examples from Scandinavia, such as grass swales, detention basins, ponds and permeable pavements (which trap pollutants for subsequent vacuuming!) Many of these methods have low maintenance costs and can act as wildlife sanctuaries. Best results are achieved by integrating several methods and by matching methods with site characteristics. He stressed that early inclusion of environmental considerations in an integrated development plan avoids the later appearance of environmental problems which have to be cleared up at the expense of development profits. In discussion he noted the need for simple catchment plans indicating whether or not discharges can be made, which can be consulted by developers during short planning periods.

The final half hour of discussion was wide ranging, with contributions from many participants. Ideas were mooted for the manual on means of reducing land use change impacts (for example, concentrating on proven local successes) although noone actually volunteered to take it in hand! Response timescales were contrasted: pressures in developing countries leave no time for forest or fallow lands to recover after use; conversely the thirty-year period of the nitrogen cycle in the UK means that certain long-lived effects of land-use changes may not become apparent except over a similar period.

On the modelling side, warnings were issued about using models as surrogates for data, given that the calculation capacity of models currently outstrips the capacity to provide data. The lively debate kept most of the participants at the meeting until its close, an excellent comment on an interesting and stimulating day. A good turnout from the universities and the NRA/RPBs was recorded, leavened by a selection of research institute staff and a handful of consultants.

Thanks are due to Professor Rob Ferguson and the University of Sheffield for hosting the meeting, to **Dr Rick Cryer** who did most of the local organisation in Sheffield, and to **Dr Howard Wheater** (Imperial College) and Rob, who, along with me, chaired the sessions.

James Bathurst
University of Newcastle upon Tyne

RAINFALL-RUNOFF MODELLING

BHS National Meeting
Imperial College, London
23 June 1993

A popular topic drew over 85 participants to this meeting, with more turned away because of lack of space. More than 30 came from the NRA regions, together with representatives of a dozen consultancies, a score of university researchers, a contingent from the Institute of Hydrology and other interested members. The veteran of the proceedings, and a lively contributor to the discussions, was *Victor Appleby*, whose first contributions to the subject were published in the 1930s.

The meeting was in four sessions. **Brian Wilkinson**, Director of the Institute of Hydrology, chaired the morning sessions. He opened the proceedings by thanking Howard Wheater for organising the meeting, and introduced him as the first speaker.

INTRODUCTION

Commenting that it had been several years since a BHS meeting addressed the topic of rainfall-runoff models, **Dr Howard Wheater** (Imperial College) explained that the purpose of his introductory talk *What use are models?* was to set the scene by defining generic model types, reviewing their strengths and weaknesses, and hence discussing appropriate strategies for a range of modelling tasks. He identified three generic types: black box, conceptual and physics-based (or alternatively, metric, parametric and mechanical), for which Sherman's unit hydrograph theory, the Stanford Watershed Model, and the early work of Alan Freeze provide the historical archetypes. This ordering is characterised by increases in the amount of information encapsulated by the models, their data requirements, their use of computer time and (at least in principle) the range of scenarios to which a given model can be applied, but not necessarily by any increase in accuracy or "scientific advancement".

Metric models allow "the data to decide" through an arbitrary separation into components which are usually amenable to linear analysis. Approaches to identification include least-squares, the Nash cascade, and time-series analysis techniques such as the extended Kalman filter and instrumental variable methods. Model parameters are able to be well identified, allowing for regional analysis and study of the effects of catchment change.

Conceptual models take an assumed form whose parameters are meaningful but not, in general, directly measurable, and are therefore identified through optimisation, be it subjective (trial and error, experience) or objective (through minimisation of an error function in some large n-dimensional space). However, problems arising from the structure of the response surface, and the fact that different optimisation methods may identify different parameter sets, suggest that models of even moderate complexity (six or more parameters) are unidentifiable. This indeterminacy in the optimum parameter set leads to the failure of regional analysis.

Physics-based models appear to rely on quantities which are, in principle, measurable. However, important questions remain concerning the choice of scale at which to aggregate grid elements to reproduce a response, whether the right physics is represented, and whether effective parameters exist at the model scale (and if so, how to identify them). In practice optimisation is required, with its resulting indeterminacy, and hence physics-based models are non-identifiable (at least in the subsurface).

Thus physics-based models can provide a powerful summary of processes, conceptual models, although non-identifiable, provide a useful framework for the modeller and are appropriate for many applications, and metric models, although limited by their simplicity, provide the only unique identification of catchment response. In terms of modelling tasks, the problem of an existing catchment with input/output data can be addressed by all models, although only metric ones are unambiguous.

For the problem of an ungauged catchment, only metric models are practicable, whilst the problem of catchment change can be tackled through a "what if?" approach using physics-based models. Appropriate use of models will seek to exploit strengths and minimise weaknesses, for example through hybrid modelling approaches.

Opening the discussion, **Keith Beven** (University of Lancaster) pointed out that a two-component metric model was still ambiguous: much depended on the choice of filtering algorithm. Howard Wheater noted that with one component identification was possible, but agreed on the two-component point.

James Bathurst (University of Newcastle-Upon-Tyne) contended that the accuracy of physics-based models was less relevant than their ability to look at change and uncertainty. Howard concurred, but said that simple models still often give the required accuracy.

Kegang Wu (King's College, London) suggested that modern optimisation techniques (genetic algorithms, simulated annealing, neural networks) meant that the global optimisation problem was in fact solvable. Howard replied that there was a blurred distinction between metric, identifiable models and conceptual models: even if parameters could be identified, model structure was still ambiguous.

Brian Wilkinson then introduced **Dr Ian Littlewood** (Institute of Hydrology) who talked about the metric model *IHACRES*, a "grey box" model comprising a non-linear conversion of rainfall into rainfall excess, followed by a combination of linear elements (usually a fast and a slow path) to convert rainfall excess into streamflow. It takes unit hydrograph theory, which is most commonly applied to direct runoff during individual events using an arbitrary definition of rainfall excess, and extends it to unbroken time-series and total streamflow using a varying catchment wetness index and separation of the hydrograph into quick and slow components.

This separation identifies a catchment slow flow index which may be more useful than the baseflow index in current use. The 6.5 parameters of the model can be uniquely identified, together with confidence limits on their values, for use in regional analysis.

Keith Beven remarked that a similar model used at Lancaster, but based on a non-linear method, gave similar accuracy but a different separation of the hydrograph: because of this uncertainty, regionalisation based on such results required care — Ian concurred.

OPERATIONAL FORECASTING

In his talk on *Real-time forecasting using Weather Radar*, **Professor Ian Cluckie** (University of Salford) described the activities of the Salford Weather Radar Research Group.

Work for the NRA in Wessex is focused on the development of a radar-based forecasting system (WRIP). This approach is characterised by the indirect, noisy nature of the measurements, requiring rainfall-runoff models to match, and the large amounts of data to be handled in real-time. The latter comprise 2km or 5km grid data, usually every 15 minutes but possibly going down to <5 min, to be merged with telemetry and other data. These data may go into many types of rainfall-runoff model, but grid-based models have failed and the operational models are metric (transfer function) models of lumped sub-catchments. He emphasised the need for careful choice of model structure. Work is also under way to characterise the pattern and movement of precipitation for forecasting between 1 and 6 hours ahead, and to improve the use of telemetry to monitor gauges and update models. He pointed out that an important feature of the system is that it retains expertise, and that there is great potential for the development of purpose-built expert systems in this field.

Work on urban drainage at the city scale (100s of km²) is in progress in the Manchester area, aimed at the real-time control of around 40 underground storages and major pumps to minimise spillage from sewers into rivers. The scale is rather different from conventional urban hydrology, with only big pipes (~1 m diameter) of interest. Such control is not possible using raingauges, as spatial data is needed to feed into pipe network models. A resolution of approximately 500 m is desired, and work with McGill University should result in a non-scanning C-band radar with a resolution of 250 m and two minutes, at a tenth of the cost of a conventional radar.

Conventional radars have measurement problems if the beam is looking above the precipitation or in the region where the precipitation is melting (the "bright band"). Vertically-pointing radars (VPRs) can be used to determine what is being seen by the conventional radar, and thus calibrate the measurements and remove bright band. A mobile X-band VPR has been developed with a 7.5 m bin height and 2 seconds measurement interval. This will be deployed in the Brue catchment in Somerset during the forthcoming HYdrological Radar EXperiment (HYREX), instigated by NERC under its Special Topic Programme.

Mike Karle (NRA Severn-Trent) asked whether gauges would be needed to distinguish types of precipitation. Ian replied that the experiment would involve a wide variety of meteorological measurements, possibly including radiosonde ascents.

Brian Wilkinson asked whether more raingauges would be required to complement a radar with a resolution of 500m. Raingauges would not be used in dense urban areas where gauge measurements are likely to be poor, and they hoped to calibrate using vertically-pointing radar. The work in Wessex did not use raingauges.

Mike Thoms (Knight Piesold & Partners) asked why the grid-based modelling approach had failed. Ian replied that such models are conceptually good, but no satisfactory method exists for updating them in real time.

Under the title *Integrated Systems for Hydrometeorological Forecasting of Floods*,

Bob Moore (Institute of Hydrology) described work carried out at IH under the headings of Radar Calibration and Forecasting, Flow Forecasting and Control, and Opportunities for the Future, interspersed with slides of notable British floods to remind everyone of the purpose of this work.

The performance of rainfall-runoff models had been limited by sparse raingauge data: this had stimulated research at IH on weather radar calibration and radar rainfall forecasting. The local radar calibration scheme, developed at the Institute on behalf of NRA Thames, aims to combine the spatial resolution of radar with the accuracy of gauge measurements. Coincident radar/gauge ratios from a network of gauges are used to fit a calibration surface which varies smoothly in space and is updated every 15 minutes. The local forecasting scheme infers storm velocity from a comparison of radar images 15 minutes apart, and uses this to advect the precipitation field forward in time, smoothing towards the field-average with increasing lead time. Getting the rainfall pattern right up to one hour ahead is a reasonable expectation, and the speed and 2 km resolution of this local scheme usefully complement the slower and coarser (5 km) national scheme, FRONTIERS. The calibration and forecasting schemes are being integrated with reception, database and display software to make up the HYRAD package.

The River Flow Forecasting System (RFFS), initially developed for the 13500 km² NRA Yorkshire Region, is a flexible generic system which can be reconfigured for any river network using a modular system of data files. The operational problem addressed by this system is much bigger than usual research problems, encompassing metric (kinematic wave, ARMA), conceptual (snowmelt, runoff) and physics-based (hydraulic) models, as well as operating rules and fallback options, running automatically in real time. At the heart of the system is the Information Control Algorithm, which organises the flow of execution by working through a modular tree structure in which each Forecast Requirement is met by a Model Component, which may employ a number of Model Algorithms, and may in turn require forecasts from further up the tree. The system is served by a database which receives data from telemetry (and HYRAD), stores sets of forecast values, and can be interrogated by display and decision systems.

Research into rainfall-runoff modelling for operational applications focuses on distributed radar data in combination with data from digital terrain models. Thus a radar grid-square model is being developed in which height, slope and path information are used to define parameters for travel time to the catchment outlet, combined with a runoff production function for each square, which might also make use of LandSat land-use data.

(The full paper is available from Bob Moore at the Institute of Hydrology.)

Cliff Dobson (NRA Severn-Trent) suggested that the speaker tended to be preoccupied with direct use of radar, and that a combination of raingauge, DTM and radar data might improve modelling. Bob commented that calibration was one way in which this might be achieved. Height had not proved useful as an explanatory variable in the local calibration scheme over London, but it might elsewhere. The optimal combination of radar and gauge data would be addressed in HYREX using a dense raingauge network (53 gauges over 140 km²) in the Brue catchment.

Jim Tricker (NRA Severn-Trent) asked whether flow channels derived from DTM data might help in modelling ungauged lateral inflows. The channel routing algorithm used within the RFFS incorporates lateral inflows, and ungauged inflows are estimated using adjacent gauged catchments with optimised weights or other simple empirical results, which might include DTM data.

In the last talk of this session, *Forecasting Severn Flows*, Cliff Dobson (NRA Severn-Trent) described the system used for flood forecasting in the Severn and Trent basins, which aims to achieve a four-hour forecast on major rivers of the exceedence of three warning levels. He emphasised that the aim was not to match forecast and observed hydrographs, but to forecast thresholds, and that researchers needed to address this problem.

He was looking to rainfall forecasting to extend lead-times in the headwaters, although the dendritic structure of the network meant that forecasts for the major rivers were not heavily dependent on rainfall-runoff models. Radar data were not used because it was felt that they were too noisy and the raingauge data were of good quality, but he would like to be able to use radar for convective storms.

He briefly described the lumped conceptual rainfall-runoff model used: it employs some 26 parameters, of which about 10 control most of the response. The model is applied to 65 sub-catchments in the Severn basin and 48 in the Trent. Parameters are derived by optimisation for the 40% of catchments which are gauged, and for the remainder by a regionalisation based on the regression of model parameters against measurable catchment characteristics. A second conceptual model is used for flow routing. Error predictors are used to refine the forecast flows based on the differences between observed and hindcast flows. The primary considerations in the design of the system were that the models should be simple, flexible, stable, robust, resilient to data loss, rapid in execution and maintainable.

The prototype system was calibrated in 1982; subsequent developments have concentrated on upgrading data gathering, processing and dissemination. A combination of DTS loggers, fast PSTN lines and a DEC MicroVAX have reduced data interrogation time to 16 minutes, and model execution time to 3 minutes per basin, with automatic alarm raising and forecast generation facilities. Data and forecasts can be downloaded over standard telephone lines for display on portable computers in the homes of duty officers. The models in use have remained substantially unaltered since 1982 and recalibration, now under way, is a high priority.

Cliff divided sources of forecasting error into three categories: input data errors, model formulation errors, and parameter calibration inadequacy. The problem for the forecaster is to recognise and understand the significance of these errors, and to make allowances for them in real time. For gauged catchments, current work aims to modify the performance of two key storages and two timing parameters by applying factors whose values are optimised in real time as the hydrograph develops.

Frank Law (Institute of Hydrology) pointed out that the Met. Office had been able to demonstrate improvements in forecast accuracy over time, and asked if the same could be said of the Severn-Trent system. Cliff replied that this was not possible at present, but that they were looking into the collection of statistics for quality control. He believed that improved data collection had resulted in improved performance, although this had been let down through lack of model development.

Ian Cluckie suggested that the rainfall-runoff model had far too many parameters, and that "minimal" models, which were good for automatic updating, were more stable and able to use radar data. Cliff did not disagree, pointing out that only 10 parameters were effectively used.

Victor Appleby questioned whether the updating procedure could take account of the different types of error (amplitude and recession rate) evident in the forecast hydrograph. It was not possible to do everything: the pragmatic approach was to combine the complementary approaches of updating and error prediction to achieve the best result.

SIMULATION FOR DESIGN

The first afternoon session addressed the application of rainfall-runoff models to engineering design. All models presented were of the conceptual type, in Howard Wheater's classification,

reflecting the nature of models currently used by consultants.

Rod Hawnt (Hydro-Logic) presented an application of *RORB, a distributed model for flood design*. RORB was developed for the Burroughs mainframe computer in 1975 and is now available as a PC version. It has become a standard model in Australasia and Pacific Asia and was adopted in the UK by Thames Water (now NRA Thames) to assess the impact of urban developments.

The model represents a catchment as a number of subareas linked by a channel network, comprising a number of channel lengths. Storage features such as reservoirs and balancing ponds are defined explicitly within the channel network. For each storm event to be modelled, rainfall series and discharge series are needed at selected calibration points. Antecedent catchment wetness conditions can be defined in terms of soil moisture deficits (SMD), antecedent precipitation index (API) or a catchment wetness index (CWI). For calibration only three or four parameters need to be considered.

Rod used the study of urbanisation in the Stort catchment to demonstrate the model's ability to represent a catchment with varied characteristics in a distributed way. The study began in 1980 with an MSc project at Imperial College: this considered the modification of river channels as a result of urbanisation. In 1988 the model was applied to the whole Stort catchment as a planning tool to enable Thames Water to determine whether or not balancing ponds would be needed for new developments. In order to be a useful tool the model had to be able to represent the existing response of the river throughout the system. In 1991 the model was modified to provide the tributary inflows to the main channels to be modelled using the ONDA hydraulic model.

Rod presented some excellent fits for single-peak events and reasonable fits for multi-peaked events. The model results were used to classify river reaches as green, amber or red, depending on the need for additional off-line storage upon urbanisation.

He concluded that the application of RORB to the Stort had been successful and was an important aid in assessing the impacts of catchment land-use change. However, local knowledge needed to be incorporated when developing and operating distributed models.

Keith Beven informed the audience that the use of RORB and any necessary modifications were to be discussed at an imminent meeting of the Association of Australian Engineers.

Frank Law added that regionalisation of the model parameters has been successful in the past, and that RORB is now accepted in Malaysia as well.

Mike Thoms had applied RORB with a fair degree of success to a 3000 km^2 catchment in Kenya with sparse data, confirming the model's flexibility.

Brian Adams of Flynn and Rothwell, the consultants responsible for the 1991 study of the Stort, gave the audience more detail of the use of RORB with the ONDA model. Independent calibration of the two models had not been possible: a successful calibration was only possible by considering the model in a coupled way.

Robin Wardlaw (Edinburgh University) then took over to convince the audience that after 25 years the *Stanford Watershed Model* (SWM) is still very much alive.

There can be little doubt that the publication of the SWM technical report in 1966 was a significant landmark in hydrological modelling: it encouraged modellers to associate stream flow with the physical processes that occur in a catchment. The original flow chart still provides an excellent description of the water cycle and elucidates the processes included in SWM, and consequently identifies those which are not by their absence.

Robin focused on the representation of the infiltration process. The infiltration function adopted is based on the Philips equation and accounts for spatial variability of soil properties. The interflow function is similar to the infiltration function but is empirically based. So, although the SWM conceptualises the hydrologic cycle as a system of nonlinear stores it has a basis in hydrological theory.

In keeping with Rod's example, he presented several examples of catchments where the SWM gave excellent estimates of storm runoff, but it did not work well in every case: the simulated flows for a Chinese catchment were poor despite a reasonable raingauge network — analysis of the raingauge data showed that even this network was insufficient to represent the spatial distribution of rainfall.

Robin moved on to recent developments in the SWM. Kinematic routing based on Manning's equation is now used, soil erosion and sediment transport are an added option, the snowmelt routines have been updated and the model has been linked with a finite difference groundwater model as an integrated catchment model. This latter development allows the use of groundwater levels as well as stream flows for model calibration.

He concluded by saying that with greater modularity and friendlier user-model interfaces there is a future for distributed modelling, which is a logical progression from lumped parameter modelling.

Mike Thoms wanted more details on the snowmelt model. A water balance had been carried out on the snow pack and Robin could give fuller details on request.

Howard Wheater enquired about the level of success with using SWM on ungauged catchments. Although the model has 30 to 32 parameters in its full version, only four are needed for a reasonable calibration. These parameters control infiltration and interflow. With regard to ungauged catchments, in theory the parameters are identifiable from catchment characteristics, but in practice this had not been possible and stream flow data and experience are needed for calibration. Professor George Fleming had attempted to regionalise the model parameters for use with ungauged catchments, but the study had proved inconclusive.

Brian Wilkinson asked whether the inclusion of a finite difference groundwater model was an inefficient use of computer resources, given that groundwater systems generally have response times orders of magnitude less than surface processes. Robin agreed that this might be true in some catchments, but that a modular approach to integrated catchment modelling allowed components to be brought in as required.

The last presentation in this session, *A less complex package (HYRROM) for the rapid modelling of runoff time series*, was given by Tania Jones and Frank Law (Institute of Hydrology).

HYRROM was described by Tania as a lumped conceptual model for daily flows: it is now available as a simple to use, menu-driven PC package. The model has nine calibration parameters and is driven by rainfall and evaporation input series. Possible applications of the model were infilling missing discharge data, quality control of data, extending historical flow records and generating synthetic flow series. Evidently models have other uses than just transforming rainfall into runoff.

The model comprises conceptual reservoirs representing interception, surface retention, soil water, groundwater and channel storage. The nine calibration parameters were listed, with their possible ranges of values.

HYRROM is a part of the Institute's data processing package HYDATA. Within this package the user can use the Rosenbrok automated optimisation algorithm to calibrate the model using the mean of the residuals squared as an objective function. Tania recommended that no more than four parameters should be optimised at a time using this technique, so that the modeller can ensure that all parameters lie within their accepted ranges.

Frank Law then presented an example of applying HYRROM to a catchment in the Cameroon. The Institute of Hydrology was to provide inputs for a hydraulic model, HEC5, prepared by another consultant. Using 15 to 20 years of flow data, much of it affected by subsequent dam construc-

tion, and reasonable data from 25 rain-gauges, Frank was able to demonstrate the flexibility of the model and the speed at which an inexperienced user can obtain reasonable results.

Mike Thoms wanted to know how many parameters could be identified *a priori* from the data. Frank replied that all parameters have to be identified by optimisation: attempts at *a priori* identification have not been successful so far.

Peter Baur had used HYRROM for stream flow estimation at dam sites in Guinea where data availability was very poor: his experience confirmed that there was no alternative to parameter optimisation.

Cliff Dobson, commenting on the use of the Rosenbrok algorithm and choice of objective function, recommended the use of a variety of objective functions. Frank cited the American Association of Civil Engineers guidelines on watershed modelling as one source of information on objective functions, optimisation algorithms and measures of model performance.

Tania demonstrated a model calibration on a laptop PC. This exercise demonstrated that modern computer technology cannot always be relied upon to work when required (!) and, more importantly, that recent developments in menu-driven interfaces reduces the user's contact with the model to a minimum, a development that not all would see as desirable.

PHYSICS-BASED MODELS

James Bathurst of the University of Newcastle-upon-Tyne, speaking on behalf of co-authors **John Ewen, Chris Kilsby** and **Geoff Parkin**, began the final session of the day with a quick overview of the physical basis to *the SHE model*, which has been renamed SHETRAN-UK since the introduction of a sediment transport capability. James emphasised that the physical basis of the model made SHE much more than a rainfall-runoff model: it could 'reach the parts that other models could not reach'. In addition to runoff prediction, SHE could also be used to predict the impacts of land-use and climate change.

In the past SHE has been validated using the established split sample testing procedure where one half of the data series is used to calibrate the model parameters and the other half is used to validate the model. The Newcastle group are currently establishing the principles of blind testing. Blind testing involves firstly defining a set of criteria which the model predictions must satisfy, secondly the model parameters are identified from field evidence alone with no reference to the observed stream flows or other model output and finally the model is run and its performance is compared to the initial criteria necessary for an acceptable model.

James used some results from SHE modelling of the Rimbauld catchment in Southern France to demonstrate blind testing. SHE was set up based on a 50 m grid, soil samples were used to identify soil parameters (e.g. hydraulic conductivities) and hydrometeorological inputs for the period 1968 to 1970 were used. Four criteria were established for the blind test:

i) Continuous discharges should fall within an acceptable range either side of the observed discharges.

ii) An acceptable proportion of all peak discharges should fall within an acceptable range either side of the observed peak discharges.

iii) A specified number of monthly discharges should fall within an acceptable range either side of the observed monthly discharges for wet months.

iv) The total volume of runoff during the simulation period should lie within an acceptable range either side of the observed value.

Initial results showed that the model failed to satisfy criteria i) and ii). However, James was not despondent: the blind test is extremely severe and in the light of these initial trials the Newcastle group will be reconsidering the criteria for future blind tests.

He then turned his attention to the choice of grid scale and parameter identification at the grid scale. Newcastle are addressing the issue of scaling up plot scale measurements of parameters to grid scale parameter values. A range of scales are being investigated ranging from 167 m^2 plots to 32 ha sub-catchments up to the 600 km^2 Cobres catchment in Portugal. James reported that using plot scale measurements to identify parameters for 50 m grid squares has been successful, but further scaling up to a 2 km grid for the Cobres catchment has required some calibration work: in general the results are promising.

James cautioned against the general use of plot scale parameters at large scales. It might be reasonable for surface processes, but the subsurface boundary conditions are poorly defined. For example, it is generally reasonable to define effective parameters at large scales when runoff is generated by the infiltration excess mechanism (Horton runoff), but is not generally possible for the representation of the saturation excess runoff generating mechanism.

Howard Wheater led off the questioning by asking for a comment on David Woolhiser's observations in 1971 that physics-based models are useful for surface processes but have difficulties with subsurface processes. James said that SHE had successfully modelled runoff from small and large storms in the Rimbauld catchment and had therefore implicitly been able to represent both surface and subsurface processes, despite the possibility that not all the active physical processes are represented explicitly in SHE.

Victor Appleby enquired whether a non-linear relationship had been observed between peak runoff and rainfall intensity. This had not been looked at and James had insufficient results with him today to test this hypothesis. He added that the SHE calibrations for the Rimbauld catchment had been agreed at group meetings of all hydrologists involved in the project and had survived the rigorous inspection of several experienced hydrologists.

Ian Littlewood responded, on behalf of the metric modelling camp, to some of James's earlier remarks on the capabilities of physics-based models: IHACRES was being used to predict the impacts of land-use and climate change on gauged catchments and metric models should not be under-estimated.

Professor Keith Beven concluded the presentations with a discussion on *Uncertainty estimation for rainfall-runoff models — a justification for more field work?* He introduced the audience to the problem of equifinality in hydrological modelling: how can the discipline of rainfall-runoff modelling progress while current models have multiple optimal solutions to a single problem? Keith suggested that modellers should put aside the concept that a unique model can be identified for a given system and instead recognise the uncertainties in the modelling procedure by using measures of belief to evaluate the risk of false prophecy.

Enter the *Generalised Likelihood Uncertainty Estimation Procedure* (GLUE). This uses a Bayesian procedure to update an *a priori* estimate of the probability of a particular parameter set being the true set, so that in a well-posed problem some parameter sets become more likely than others. Keith presented results from a study of the Gwy catchment in mid-Wales using a finite element hillslope model. However, the general adoption of GLUE is currently limited as it uses a computationally intensive technique to establish optimal parameter sets and likelihood functions.

In a modelling study of the Mai Mai catchment in Spain, single site water table data was introduced into the optimisation problem. The new data significantly reduced the feasible area of the objective function, but Keith pointed out that this may be because only single site data was used.

On the value of data Keith emphasised the need to have data at appropriate scales; point observations are not necessarily useful for the estimation of model scale parameters. New measurement techniques are needed to produce data that is commensurate with the model scale. This was demonstrated for storm centre data by illustrating how two measures of uncertainty, entropy 'H' and uncertainty 'U', significantly decreased when additional rainfall data was introduced.

Keith concluded by challenging modellers to address equifinality: it is no longer acceptable to assume that there is always a single optimal parameter set.

Howard Wheater asked Keith for his views on the practice of prior conditioning of conceptual models based on the modeller's perception of the hydrological processes. Keith agreed that this was valid: in fact it was a Bayesian approach, as it attached a likelihood to an *a priori* model structure. However in practice modellers do not then update this likelihood on the basis of data.

Howard wondered if the dominant processes in upland catchments would ever be sufficiently understood to do this. Keith responded that in this case modellers should use a rejection likelihood measure rather than an acceptance likelihood measure.

Brian Wilkinson commented that too much doom and gloom about the future of modelling was not useful: what was needed was the identification of those components of the hydrological cycle which can be modelled sufficiently well to allow resources to be focused on areas of poor knowledge. He proposed the description of vertical transfers of water and energy between the surface and atmosphere as one area where models performed well, where as the groundwater component suffers from a lack of data, the real problem is the unsaturated phase. Soils could be treated as homogeneous.

Keith agreed with the use of data to constrain model uncertainties where knowledge is least available, but he did not agree that soils could be treated as homogeneous: in his experience soil parameters are highly heterogeneous, perhaps indicating that parameters such as Darcy's K are the wrong descriptors of soil parameters at large scales?

Charles Eeles asked why the Gwy catchment had been used, given its complexity, its exposed rock surfaces, old mine workings, variable soil depths and highly variable transmissivities. Keith said that physics-based models have always been applied to complex catchments: perhaps the poor results obtained point to the folly of trying to find physically-based parameters for such catchments.

Victor Appleby reminded the audience always to have regard for what is reality. One of the originators of hydrological modelling, Sherman, recognised the complexity of hydrological systems when he separated stream flow into a linear storm runoff component and a nonlinear base flow component: it is the non-linear base flow component that needs addressing.

Howard Wheater thanked all the speakers for their valuable contributions and the audience for attending and participating in what had been a useful and challenging meeting.

Roger Austin & Tim Jolley

News from Members

Members on the Move

Our congratulations go to **Howard Wheater** on his appointment to a personal Chair in Hydrology at Imperial College, London. [Is *this the first UK Professor of Hydrology? - Ed*] Congratulations too to **Geoff Petts** who has been appointed to a challenging dual role at the University of Birmingham. His appointment, which takes effect from 1 January 1994, is to the Chair of Physical Geography and also to the post of Director of Environmental Research and Management (ERM). Paul Webster, writing in on behalf of the BHS Midlands Group, tells us that this is a campus-wide initiative at Birmingham for coordinating strategic research in environmental issues, with stewardship provided largely by the Faculty of Science. We wish Geoff a smooth transition from Loughborough to Birmingham; Paul and other stalwarts of the Midlands Group are looking forward to Geoff's continued involvement in BHS affairs. **Prof Ian Reid** from Birkbeck College, University of London, moves to replace Geoff as Professor of Physical Geography at Loughborough.

Gary Moys has worked for HR Wallingford in many guises since taking his PhD at Southampton in 1986. He set up a joint venture and HR subsidiary in Yorkshire, as well as another HR joint venture, Nereis, in Italy.

Now he is going to work in France for SOGREAH Ingénieurie, where his duties will include modelling the central Paris urban drainage system, possibly the single largest study of its kind in Europe.

The Tison award goes to IH scientist for the second time

Pam Naden (Institute of Hydrology) has received the prestigious Tison award for her paper entitled "Spatial variability in flood estimation for large catchments" published in the international *Hydrological Sciences Journal**. Pam received her prize at the IAHS Assembly in Yokohama, Japan, last month.



Pam Naden receiving the Tison Award from Dr Uri Shamir, President of the IAHS.

The paper reports on research on flood defence carried out at IH and funded by MAFF. The significance of the paper is that it develops a methodology for extending the unit hydrograph approach to rainfall-runoff modelling so that spatial variations in either the rainfall input or the soil response may be incorporated.

The key to this lies in the separation of the catchment response into hillslope and network components, and the use of a linear convective-diffusion model and observed network width function to define the channel routing element. The method is particularly appropriate for large catchments — the example discussed in the paper is that of the River Thames at Cookham (7000 km^2).

The Tison Prize is given annually for an outstanding paper published by a person under 41 years of age in one of the many publications of the International Association of Hydrological Sciences. It was awarded two years ago to Bob Moore, also at IH, and now Pam Naden is the first woman to receive the award.

**Hydrological Sciences Journal, 35 (1992)*

Two new IH Reports

The Institute of Hydrology has just published *Report No. 120*, "Methods of hydrological basin comparison", ISBN 0 948540 48 6, 197 pp, £30 net.

It contains 20 papers from western and central Europe, covering a range of hydrologic comparisons and using a wide variety of methodologies. The papers were all presented at the 4th conference of the European Network of Experimental and Representative Basins, held in Oxford last year.

IH Report No. 121, "Optimum control of pump operations", by Duncan Reed, (ISBN 0 948540 48 6, 34 pp, £10 net) is the result of a study of the operational control of land-drainage pumping stations.

The OCOPO methodology is presented and applied to a specific pumping station in the fens. Wider applications are also discussed.

These reports may be ordered from the Librarian, Institute of Hydrology, Crowmarsh Gifford, Wallingford, Oxon, OX10 8BB.

Travel grants

As previously announced (*Circulation 38*), travel grants in the range £75-£100 are available to help members attend meetings. The scheme will be open to anyone, but is intended principally to help students or younger members whose travelling expenses are not met by an employer.

Applications should be sent to the Hon Secretary (**Richard Harpin**) and should include details of the meeting, whether or not a paper or discussion is to be presented, the total costs and benefits of attendance, brief details of your financial situation, your background and aspirations in hydrology. A brief supporting letter from a supervisor is also required.

Successful applicants are expected to produce a short report of their experiences in attending the meeting.

Disks please!

Contributions to *Circulation* are always most welcome, especially if they are submitted on a computer disk, saving the Editor's typing fingers and minimising the introduction of new errors.

Our IBM system can read most common word processing formats, e.g. WordPerfect, Word, Wordstar, but plain ASCII text is almost as good.

BHS Midlands Section News

The representatives of the Midlands Section, namely **Richard Douglas, David Mitchell, Richard Cross, Geoff Petts** and **Paul Webster**, met in late June to arrange an interesting programme for the next 12 months or so (details to be announced in *Circulation*).

Reviewing the previous year's meetings, they felt that the frequency of about four per year was about right. The afternoon format had worked well, as had the trend to promote joint meetings with other societies.

They also looked at wider issues, particularly the constitution of the Midlands Section. There was little support for modifying the existing informal arrangements, unless prompted by dissatisfied Midlands members or the need for financial control. Any Midlands member with strong views on this or other issues is invited to contact any of the Section representatives.

Water Grids, Inter-Basin Transfers or Self Sufficiency?

BHS and RGS Midlands Sections Joint Meeting
Derby
9 June 1993

Over 40 members attended this joint meeting at Severn Trent's offices in Derby. The chairman *Richard Douglas* (Severn Trent Water) introduced the speakers to the expectant audience on a topic which has attracted a lot of interest recently.

The first paper was presented by **Jerry Sherriff**, Water Resources Manager at NRA headquarters in Bristol, who outlined the water resources development strategy currently proposed by the NRA and developments since the discussion document was published in March 1992.

Water resources planning is now a high profile occupation with recent initiatives on leakage control and "*Using water wisely*" (DoE) accompanied by four years of drought conditions in the south-east.

Forecasting demands for the year 2021 is not easy and the current public water supply estimates range from 18,000 to 22,000 Mld^{-1} with a baseline of 20,500 Mld^{-1}. Demand forecasts vary regionally, with large increases expected in Wessex (45%), Anglian (42%) and Thames (26%) regions, while demand in North West is expected to fall (-10%). When these estimates are compared with present resources, deficits in reliable yields emerge, with shortfalls of 951 Mld^{-1} in Thames, 421 Mld^{-1} in Anglian and 636 Mld^{-1} in Southern, Wessex and South West Regions combined. Even if all the available schemes identified in plans produced in accordance with Section 143 of the Water Act 1989 were constructed, there would still be a 4% shortfall in Anglian and only very small surpluses in Wessex, Thames and Southern. However not all the schemes are being considered, and some existing yield will be lost in solving low flow problems. Attention must therefore be directed to areas of greatest need, the east and south-east, where there are the least available resources, the highest demand and greatest use of existing resources and the most significant low flow problems.

To meet these rising demands a wide range of options has been put forward. The most unlikely — transfers by ship and icebergs — have, unfortunately, been the most talked about. The more likely options are demand management, groundwater development, direct river abstraction and indirect effluent re-use. Other more expensive options have been reservoir

schemes, inter-regional transfer three options have emerged: firstly, the use of Mid-Cambrian sources transferred down the Severn to the Thames; secondly using the Trent to supply East Anglia through a Trent-Witham, Ely Ouse-Essex transfer, and thirdly to extend the Kielder-Yorkshire link to the Ouse.

Since the publication of the discussion document, yields of the "Section 143 schemes" and the inter-basin transfers have been re-evaluated. Options have been costed, marginal demand centres defined, demand projections revised and environmental implications examined. In order to address the proposals a basin linkage modelling strategy for England and Wales has been developed. RESPLAN has been used to simulate and optimise the costs of transfer capacities between future demand centres and yield from a variety of sources.

The paper on Details and Options has just been sent to the water companies to comment on demand projections and a further consultation on Options will take place in October 1993, with the final strategy due to be published in October 1994.

Jerry stressed the need for an open, integrated strategy, involving the water undertakings, which is sufficiently flexible to accommodate the uncertainty about future demands.

In response to a question from **Gordon Davies** (NRA) about funding, Jerry said that it was the NRA's role to promote schemes to the water companies for development: at present there was no public money for resources development.

David Mitchell (University of Wolverhampton) asked if land-use change and afforestation had been taken into account in yield projections, but was told that these aspects have not been considered yet.

Mike Lowing inquired about the standardisation of yield estimates. Some schemes had been designed on the wrong drought period with reduced groundwater yields.

Cliff Dobson (NRA) asked if the strategy was for public supply only. What about agricultural and industrial demands? Jerry said that discussions with relevant bodies had taken place. Thames, Anglian and Severn-Trent were the key regions in the national strategy, with Southern Region being self-sufficient.

Will Bradford (Severn Trent Water) wondered whether leakage control had been built into the forecasts: guidelines on this were currently emerging.

The second paper was by **Tim Turner** of Sir William Halcrow and Partners, who are acting as consultants to the NRA on aspects of water resource planning. As regional water demand forecasts for 2021 for the 1 in 50 year drought suggest possible deficits of up to 1443 Mld^{-1} (Thames Region 775 Mld^{-1}), there is a need to plan for these scenarios. The impact of demand growth can be limited by metering, leakage control and drought restrictions, however as developing additional storage in a region is constrained, the transfer of water between regions become an option.

The Water Resources Board considered three schemes in 1974, an extension of the Kielder-Tyne-Tees transfer, a Thames-Severn scheme using Craig Goch and Shropshire groundwater and the Wash barrage-Essex rivers transfer via the Ely-Ouse. The present proposal is for transfer schemes linking the Severn, Trent & Thames basins in a ring. With Kielder supplying demands in the north-east and the full development of Vyrnwy, Craig Goch, Shropshire groundwater and possibly Trent abstractions, an available yield of 1855 Mld^{-1} for 2021 would be available to meet the deficits.

The river may benefit from additional water to dilute sewage treatment effluent and minimise low-flow problems. Hydrologically there would be yield gains and losses through river transfers. Different critical periods of the contributing rivers would effectively increase the overall yield of a transfer scheme.

Timing losses would occur depending on the length of the transfer and the severity and duration of the drought. A trigger point at an inlet above the minimum flow would be needed to initiate a transfer as it may take days for the water to reach it destination. In this time rainfall may occur deeming the transfer worthless unless there is downstream storage provision.

Transmission losses (10-20%) would take the form of evaporation, transpiration and seepage to aquifers and although aggravated by illegal abstractions and spray irrigators these are not considered as important as the timing loss.

Chemically, changes could occur in pH, conductivity, nutrient concentrations and hardness. Physically, transfers may affect water temperature, flow velocity and pattern, erosion and deposition, bank stability and channel morphology. Biologically there could be a washout of biota, a loss of weed growth, and cause changes in species composition through the introduction of disease of predators. From an engineering viewpoint pipeline routes, length, static lifts, tunnelling, intake and discharge points together with storage requirements to minimise timing losses will all have to be considered.

While local schemes incur high capital costs, operating costs are lower whereas with transfer schemes the reverse is true, with lower capital costs and higher operating costs. The time periods and duration of operation in relation to droughts and peak demands need to be additionally considered.

A water grid ring supplying raw water by pipeline between Bristol, London, Peterborough and Birmingham, with feeders from Kielder and Craig Goch reservoirs, has also been compared with river transfers. Capital costs and operating costs would be greater but, as illustrated by the Yorkshire grid, there can be improved response to peak demands, improved security and the potential to mix waters from different sources. There would be no adverse environmental impacts on rivers but no contribution to solving low flow problems could be made.

A balance is needed between the cost of local resource exploitation and the environmental benefits of water importation.

David Mitchell asked about the economic implications and costs of the schemes. The political sensitivities between water companies would have to be overcome.

Paul Webster (University of Birmingham) inquired about the present Yorkshire scheme. Tim thought that the grid was 80% integrated and had the potential for increased conjunctive use. However with a grid, high retention time leas to inherent water quality problems.

Asked about using Great Bradley reservoir in a transfer system, Tim said that the strategy is in addition to the use of local resource and that Great Bradley and Broad Oak could be used to boost the system. It was also pointed out that 70 Mld^{-1} of Shropshire groundwater is presently used within the Severn basin.

A personal view of self sufficiency was expressed in the final presentation by **Dave Cook**, Water Resource Manager with Thames water Utilities. With an effective rainfall equivalent to 8200 Mld^{-1} and abstraction of 4500 Mld^{-1} the Thames basin is one of the most heavily used systems in the world. At present 75% of this supply comes from surface resources, chiefly the supply reservoir groups at Farmoor, Thames Valley and Lee Valley.

Water companies have a statutory objective to secure and duty to supply water to defined standards of service. Water companies have no powers to act as planning authorities. Privatisation has brought additional pressures of sometimes conflicting demands from the NRA over environmental implications, OFWAT over water charging, the government with its 'Using water wisely' initiative and from a whole range of interest groups. Furthermore the public dislike drought orders and hosepipe bans, wanting to use as much water as they want, when they want, but without paying for it!

Demand management measures are one way of tackling future resource needs. Thames Water are considering compulsory water metering but are sceptical whether savings in reality would match those seen initially in the Isle of Wight trials. Leakage control can

yield good returns, but as leakage is tackled the area of diminishing returns is reached. Thames are also promoting use of water-efficient domestic appliances and toilets. There remains a general need to educate the public on water use and bye-laws and to dispel myths of direct Sewage Treatment Works to Water Treatment Works pipelines.

Additional resources may have to be secured by developing artificial recharge schemes using effluent, local groundwater schemes, additional reservoir storage, inter-basin transfers or by water reuse.

Having considered the range of options, Thames Water aim to meet their future water requirements by constructing the southwest Oxfordshire reservoir near Abingdon. At this strategic location the reservoir (150 x 10^6 m^3 capacity) could be used for river regulation, local supply or as terminal storage.

The increase in future demands will affect resource strategies. At the lower end of projections, demand management involving leakage control, metering, efficiency and education would be most cost effective. Development of local reservoir storage is the cheapest option to meet actual forecast demands, while Dave Cook did not believe that major inter-basin transfers would be an economic option in his lifetime.

Roger James, NRA Anglian region, inquired as to whether Thames Water had considered working with other water undertakers on future resource projects. Dave Cook replied that Thames cooperates with other water companies in the Thames area, but that these were not showing any financial interest in developments and that Thames Water could not justify to its customers and shareholders building a reservoir in Wales, for example.

In response to **Roger Goodhew** (NRA Severn-Trent Region), Dave Cook commented that in future there would be more conjunctive use schemes.

Before the close of the meeting **Mike Halford** of the Inland Waterways Association spoke briefly about the potential for using canals for water transfer. While the costs of building new canals would exceed those of a pipelines, the former would maximise potential recreational and environmental benefits, capture the public's imagination and be a 'sexy' solution to the problem!

Paul Webster then thanked the speakers on behalf of the BHS and RGS for their interesting and thought-provoking presentations.

Richard Davis
University of Birmingham

New radar committee reports

The old NERC Steering Committee on the Hydrological Application of Weather Radar has been replaced by an Interagency Research Committee on the Hydrological Use of Weather Radar (*title's just as long - Ed*) who have just produced their first report*. Set up to create a forum for the exchange of ideas between research, applications and commercial exploitation of weather radar, the Committee membership embraces representatives from the Meteorological Office, MAFF, NRA, NERC, SERC, the Scottish Office and the Water Services Association.

A major component of the report is the section on HYREX (HYdrological Radar EXperiment), a new programme of fundamental research in two main areas: the science of weather radar as a remote sensing device, and investigation of the precipitation process and its link with runoff response. HYREX has attracted Special Topic funding from NERC with a provisional allocation of £750,000 over three years. Details of the awards made so far are listed.

Other important components of the report are the classification of research proposals according to priority and whether they are deemed to be basic or applied research, depending on whether new knowledge is sought of the fundamental aspects of weather radar phenomena or directed primarily towards practical aims.

Also included is an inventory of UK capabilities in weather radar, listing interested groups, their expertise and their equipment.

** copies available from Roger Austin, Institute of Hydrology.*

BOOKS

Won't somebody listen?

Land, Water and Development, Malcolm Newson. Routledge, 1992, 350 pp, ISBN 0 415 08031 2. Hardback or softback.

Professor Malcolm Newson has long been ardent in his advocacy of the need both to understand and respect the natural forces which shape river basin systems and to manage human affairs in sympathy with such forces. As might be expected therefore, this book contains many insights into the mind of a geographer striving to communicate the ideals of sympathetic river basin management to politicians and planners with rather different perspectives and agenda.

To briefly describe the content, the book opens with an interesting account of the history of river basin management. The next two chapters teach us about the processes of sediment transfer and water transfer respectively (the author recommends that non-hydrologists read the third chapter first). The fourth chapter comprises a collection of miscellaneous extracts from river basin management reports emanating from the USA, Canada and New Zealand. Various figures and tables are included, not to form a coherent technical presentation but to illustrate the kind of management issues that have been raised elsewhere. For example, a map of New Zealand Catchment Authorities is presumably not meant to be of any relevance in itself but it does help to show the extent of administrative sub-division which New Zealand found sensible to adopt.

Chapter 5 looks at the developing world and includes some fascinating dissections of why certain major schemes have been recorded as failures. The final three chapters cover the more specifically technical and institutional issues of river basin management.

It must be a problem for authors to decide how much information to spell out in their own text and how much can be referred to that of others. This book has an 18-page reference list and must provide an invaluable starting point for someone starting out on a research programme. The reader with less time to follow every twist and turn of the arguments may find the frequent attributions counter-productive and occasionally irritating. For example, I thought I would try to use the book to check up on sediment transport concepts and prediction formulae. Chapter 2 (Natural river basins - transfer systems) was the place to start.

I found that a quick skim through provided a useful refresher in the basic concepts and reinforced my instinctive feeling that it was just too complicated a subject for any formulae to be trusted. Nevertheless, I needed some numbers so I read it more carefully. This time I actually seemed to understand less. I got involved with the author's language and syntax to the point where I had to admit that I did not understand exactly what point he was trying to make. This is where I found that the references and quotations were tripping me up rather than guiding me along. I longed for him to be less 'pure' in crediting all those who had helped to fashion his beliefs and arguments and to present his perception of transfer systems in a more succinct and forceful way. I found mention of transport formulae in

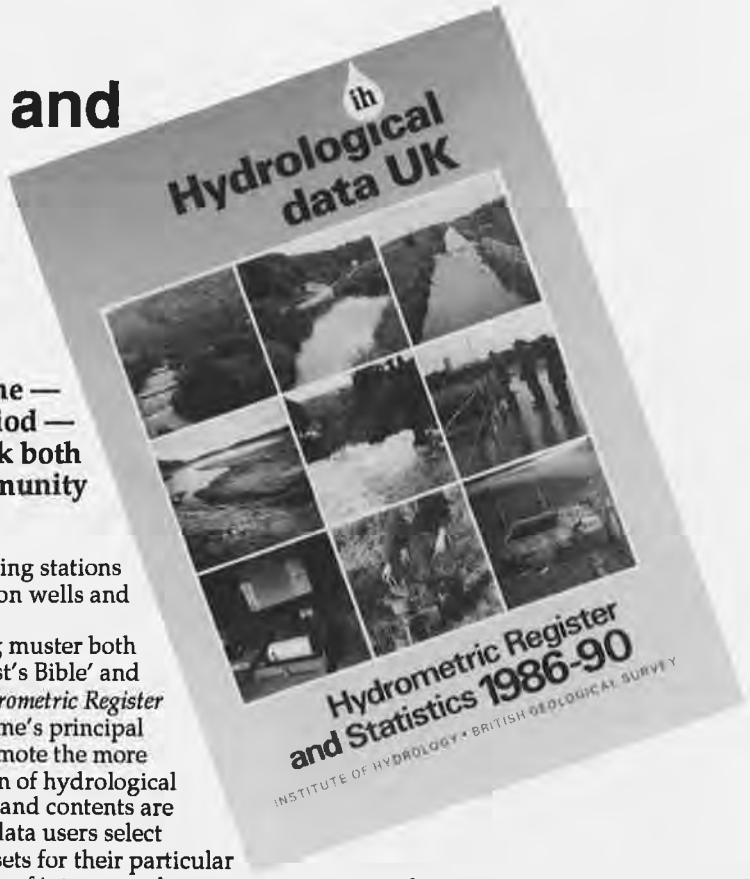
reference to a review by others and their recommendation of a 'best buy' — Bagnold's 1977 paper in Water Resources Research. However, the formulae themselves were not given and I realised that this was not going to be the 'cookbook' work of reference that I had been half hoping for. Rather, it is a set of essays where the author more than adequately demonstrates that he has a powerful grasp of the way in which water shapes both the form of the land and the society of man.

The book is not an 'easy read', nor is it a comfortable one, especially not for an engineer who prefers to solve problems rather than to admit the possibility that the best 'solution' (for the planet and the total well-being of present and future populations) might sometimes be to go away and leave things alone. The author succeeds in his aim of making the reader think hard about the total situation we human beings find ourselves in. His purpose is broadly educational and, if the book is treated as a mine of challenging and thoughtful ideas to be explored at leisure, it might come to be regarded as one of the most influential compositions ever penned by a hydrologist.

Mike Lowing

Hydrometric Register and Statistics 1986-90

The *Hydrometric Register and Statistics 1986-90* has recently been published by the Institute of Hydrology. Prepared in collaboration with the British Geological Survey and published in the *Hydrological data UK* series, this reference volume — like its predecessor which covered the 1981-5 period — is expected to become an indispensable handbook both for the practising hydrologist and the wider community of hydrometric data users.



Compiled with the help of the NRA, the River Purification Boards and other measuring authorities, the 1986-90 volume is a comprehensive source of data and information relating to gauging stations and observation boreholes in the national network. Variations in surface and groundwater resources during an especially volatile period are documented and the retrieval facilities associated with the National River Flow and Groundwater Level Archives are described.

For each major measuring authority region a map shows the national network gauging stations. Details of their location appear in the accompanying Hydrometric Register, together with a number of important hydrological descriptors, e.g. the monthly minimum flow and the mean annual flood. The Statistics section includes data for each of the five featured years and, for comparison, the average and extreme values for the preceding period of record. The data are complemented by concise descriptions of the gauging stations and the catchments they command. Typically, these descriptions embrace the hydrometric characteristics of the monitoring site, a brief geographical sketch of the catchment and an outline appraisal of the net impact of artificial influences on the natural flow regime. The Well Register contains reference details for monitoring wells and bore-holes, together with assessments of annual recharge — expressed as a percentage of the long-term average — for 1985/86 to 1989/90. Combined figures are also given for the major aquifer unit. Details are given of around 1300 gauging stations and 200 observation wells and boreholes.

Whilst passing muster both as the 'Hydrologist's Bible' and 'Wisden', the *Hydrometric Register and Statistics* volume's principal objective is to promote the more effective utilisation of hydrological data. Its structure and contents are designed to help data users select appropriate data sets for their particular application or area of interest and — crucially — to guide the interpretation of analyses based on such data. The need for such information has been well documented in the UK during the last few years which have been remarkable in hydrological terms. Persistently high runoff rates have characterised much of Scotland whilst an extremely protracted drought in the English lowlands underlined our continuing vulnerability to exceptional climate patterns.

However, flows and groundwater levels reflect more than just the incidence of rainfall and the magnitude of evaporation losses. Catchment geology and land use influence river runoff and aquifer recharge and the natural variations of each are often substantially disturbed by the complex and evolving pattern of water utilisation. Consequently a considerable range of ancillary information is commonly required to exploit basic hydrological data fully.

Hydrometric Register and Statistics 1986-90 costs £20 and is available through the National Water Archive Office — contact Shirley Black (0491 838800 Ext. 2201).

Recent IAHS Publications

The variety of hydrophysical conditions exhibited in karst aquifers is very large and ~25% of the world's population depend on them for water supplies. *Hydrological Processes in Karst Terranes*, IAHS Publ. No. **207** contains 37 papers presented at an International Symposium in Turkey. The price is $60 (US) and the ISBN is 0 947571 28 0.

The proceedings of *HydroGIS '93*, the Vienna conference on *Application of Geographical Information Systems in Hydrology and Water Resources Management* has recently been published as IAHS Publ. No. 211, price $80 (US), ISBN 0947571 48 5.

They may be ordered from IAHS Press at the Institute of Hydrology.

Hydrogeology of Wetlands

BHS / Hydrogeological Group joint meeting
Birmingham University
13 June 1993

This meeting, sponsored jointly by the Hydrogeological Group of the Geological Society and the British Hydrological Society, comprised three sessions chaired by *David Lerner* (Birmingham University), *Harriet Nash* (Blackett-Ord and Nash) and *Susan Walker* (NRA). About 150 people attended and heard papers on a wide variety of wetland research topics.

The first session concerned the assessment and management of Wetlands in the UK. **J R Wright** (English Nature) described the particular problem of wetland SSSIs suffering from dewatering problems because of nearby sand and gravel extraction workings. he also discussed how impermeable bunds and recharge trenches can be used to maintain water levels in such cases.

A point made by Richard about the NRA developing protection zones around wetlands similar to the protection zones around supply boreholes was neatly picked up by the next speaker, **David Burgess** (NRA Anglian Region). He briefly described his interpretation of NRA wetlands policy and took us through the evaluation of case site at Chippenham Fen where the needs of ground water and ecology were balanced by artificially creating springs.

The next wetland considered was very different. Baffins Pond is in an urban area (Portsmouth): it is highly polluted, of little ecological significance and contains water that closely resembles pea soup. **N G R Walton** (University of Portsmouth) described how the only solution in this case was to flush out the existing water of the pond using a specially drilled borehole penetrating the underlying chalk aquifer.

The final talk of this session was given by **M Harding** (Suffolk Wildlife Trust) about Redgrave and Lopham fens. He described how even a small change in head can produce a large change in water chemistry and thus adversely affect the ecology of the fen. This triggered a lively discussion about whether a few centimetres of head change can affect ecology. It was generally agreed that not enough research has been done in this area.

After two hours of talks, lunch provided a welcome break to make new contacts. The second session concerned case studies from the UK and began with **Kostos Paptolios** (Birmingham University) outlining how studies of a small corridor wetland in Devon have shown that this particular wetland is robust enough to survive attempts to drain it. This was in stark contrast to some of the other wetlands described at the conference.

Paul Younger (University of Newcastle upon Tyne) then tried to described how sedimentological, pedological and radiocarbon techniques had been applied to a wetland on the chalk in East Yorkshire to date head changes. He was thwarted by projector problems: it jammed in mid-talk so he had to resort to the whiteboard. He claimed this made him feel more like Tony Hart than a lecturer. Remote-sensing research then made an appearance with **David Gilvear** (University of Stirling), who outlined an approach to use multi-spectral imagery to determine water table depths in the Insh Marches, Scotland.

After tea the session on overseas wetland studies began with **E P Wright** (Consultant) who described the Geology and Hydrogeology of the Okavango delta. This fan is an inland system which covers a huge area of land (22,000 km^2) intimately controlled by tectonic forces.

The last paper of the day by **G E Hollis** (UCL) explored not only the interaction of ecology and hydrology on wetlands but also the political and socio-economic effects. he described how human population pressure, finance and corruption have indirectly lead to the derogation of Mediterranean wetlands.

The conference was well attended by representatives from national bodies, such as the NRA, English Nature, BGS and IH, as well as consultants and academics. The conference was particularly commendable for the wide range of wetland topics covered.

Richard Treves

Some more NERC research grants in hydrology

Semi-distributed physically-based modelling of glacier hydrology (Dr K S Richards/Dr M Sharp/Dr I C Willis, Cambridge)

Predictive uncertainty in distributed models: likelihood functions, the value of calibration data and visualisation techniques (Prof K J Beven, Lancaster)

Sediment-transport competence of interill overland flow (Dr J A Parsons, Keele)

Effects of extreme climatic events on land form change in Southern France (Dr J Wainwright, Southampton)

The oxygen content of snow and ice melt; hydrological implications (Dr M Tranter, Bristol/Dr G H Brown, Cambridge/Dr T D Davies, UEA/Dr M J Sharp, Cambridge)

FORTHCOMING EVENTS

Meetings

ICE / IWEM
WATER ENVIRONMENT '94
Westminster, London
9-10 March 1994

This event joins ICE's World Water conference series with IWEM's annual conference and comprises two one-day seminars linked by a central theme.

Day 1: concerns the strategic, economic and ethical implications arising for the implementation of the Urban Wastewater Treatment Directive thoughout Europe and of Statutory Water Quality Objectives in England and Wales.

Day 2: concentrates on specific case studies of works now under construction, or at the detailed planning stage, to satisfy the current requirements. The presentations will consider the reasons why particular solutions were adopted, their technical implementation and the environmental enhancement or impact.

Further information: Carol Chin, Thomas Telford Services Ltd., Conference Office, (Tel: 071 839 9803)

ASCE
2nd International Symposium on
ARTIFICIAL RECHARGE OF GROUND WATER
Orlando, Florida
17-22 July 1994

Scope: Design, construction and operation of wells, spreading basins and other recharge facilities, and recharge with various qualities of potable water, surface water and reclaimed wastewater into consolidated and unconsolidated, confined and unconfined aquifers. Hydraulic and water quality changes occurring during recharge, including soil-aquifer treatment processes.

Abstracts (3 copies, <300 words) will be accepted until 15 November 1993.*Further details*: Ivan Johnson, 7474 Upham Court, Arvada, Co 80003, USA *Tel/FAX:* 303-425 5610

IHE - Delft
1st International Conference on
HYDROINFORMATICS
Delft, The Netherlands
19-23 September 1994

A meeting point for users and developers of software for the support of consultancy, research and education in the areas of hydraulics, hydrology and environmental engineering. The organisation of this event breaks new ground by moving away from the traditional concentration on paper presentations to focuss on exhibitions, special demonstrations and round-table discussions.

Papers are invited (full text, 6-8 pages incl. figs), to be submitted by 31 January 1994.

Further details: Organising Committe HYDROINFORMATICS Conference, IHE, PO Box 3015, 2601 DA Delft, The Netherlands.

Diary

13th-16th September 1993
4th BHS National Symposium
Venue: Cardiff
Contact: Rob Drayton *(Tel. 0222 704321)*

14th September 1993
Welsh Hydrological Group
AGM: "Regional water transfer schemes"
Venue: Cardiff
Time: 6.30 p.m.
Contact: Linda Aucott, NRA Wessex Region, Bridgwater *(Tel.: 0278 457333, Fax: 0278 662153)*

13th-15th October 1993
2nd International FRIEND Conference (Flow Regimes from International Experimental and Network Data)
Venue: Braunschweig, Germany
Contact: Prof. Dr A. Herrmann *(Tel: +49 531 391 5607, Fax: +49 531 391 4577)*

13th-15th October 1993
IDNDR Conference
"Protecting vulnerable communities"
Venue: The Royal Society, London
Contact: Rachel Coninx, ICE Conference Office, 1-7 Great George Street, London SW1P 3AA *(Tel: 071 839 9807, Fax: 071 233 1743)*

15th October 1993
Welsh Hydrological Group
"Effect of mine closure on water quality"
Venue: University College, Swansea
Contact: Linda Aucott *(address above)*

20th October 1993
BHS Southern Section Meeting
"Low flows and their environmental impact": *Environmentally acceptable flows on the Darent* (Simon Taylor); *Estimating ecologically-acceptable flows* (Ian Johnson).
Venue: Civil Eng Dept, Imperial College
Time: 5.30 p.m. (tea at 5 p.m.)
Contact: Dr Nigel Arnell, Institute of Hydrology, Wallingford, OX10 8BB *(Tel. 0491 838800; Fax: 0491 832256)*

3 November 1993
BHS Pennines Section
"Groundwater protection"
Venue: University of Newcastle
Contact: Tony Lewis (Tel: 061 833 9111 ext 2197)

17th November 1993
ICE/BHS/IAHR/NRA Seminar
"Sustainable development of water resources"
Venue: Institution of Civil Engineers
Contact: ICE Conference Office, 1-7 Great George Street, London SW1P 3AA *(Tel: 071 839 9807, Fax: 071 233 1743)*

Nov (date to be confirmed)
BHS Midlands Section
"The nitrate problem"
Venue: Derby or Nottingham
Contact: Paul Webster, Dept of Civ. Engg, University of Birmingham, Birmingham B15 2TT (Tel: 021 414 5055, Fax: 021 414 3675)

9 December 1993
BHS Southern Section
"Routes to chartered status"
Venue: Civil Eng Dept, Imperial College
Time: 5.30 p.m. (tea at 5 p.m.)
Contact: Heward Wheater, Dept. of Civ. Engg, Imperial College, London SW7 2BU (Tel: 071 589 5111 ext 4736/4720)

Copy Deadline for Issue No. 40 8th October 1993

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